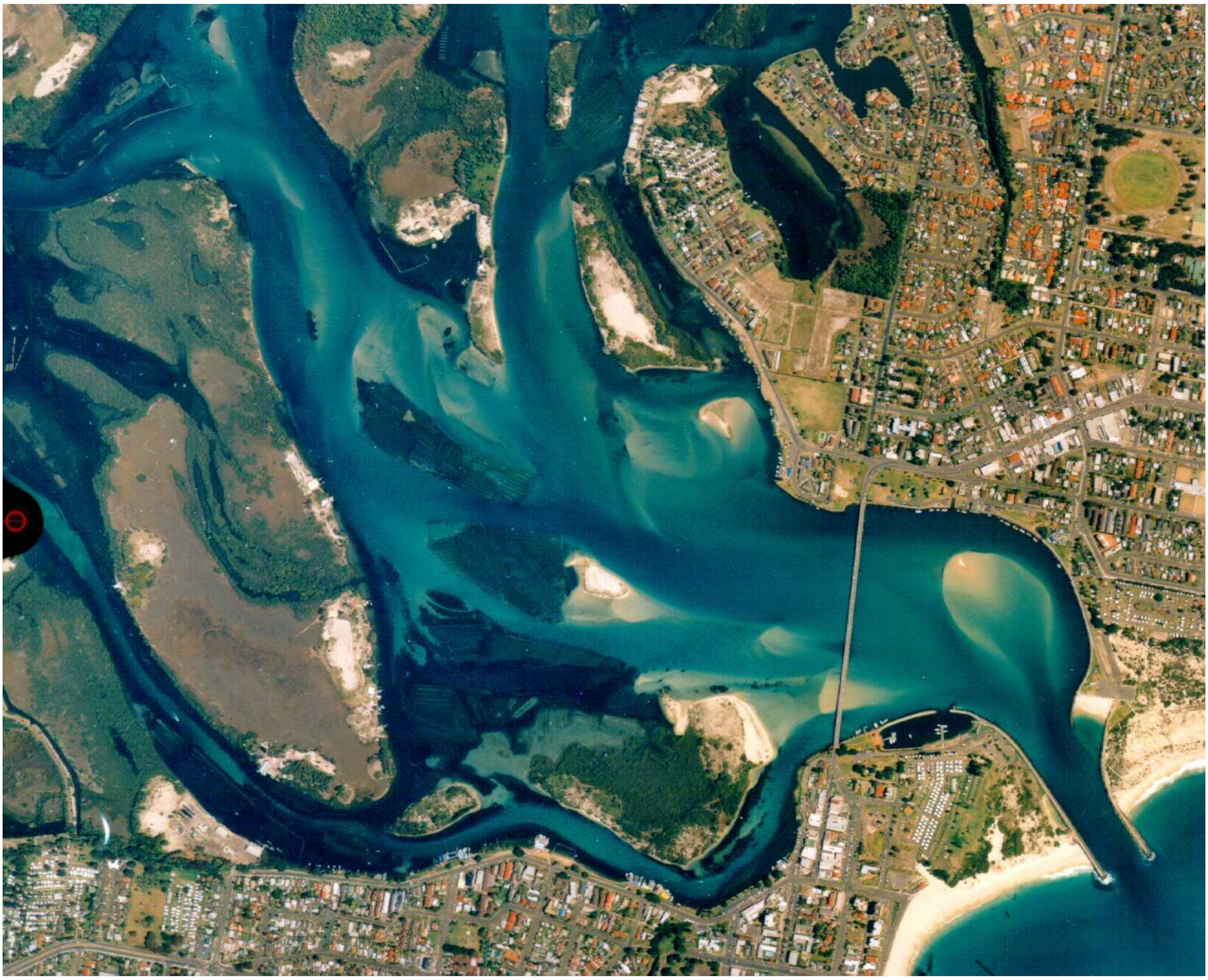
WALLIS LAKE FORESHORE (FLOODPLAIN) RISK MANAGEMENT STUDY AND PLAN



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WALLIS LAKE FORESHORE (FLOODPLAIN) RISK MANAGEMENT STUDY AND PLAN

JANUARY, 2014

Project Wallis Lake Foreshore (Floodplain) Risk Management Study and Plan	**Project Number** **24021**
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- Hazard mapping (100 year and PMF) in the Year 2010, 2060 and 2100.

for Tuncurry CBD, Pacific Palms, Green Point, Forster Keys, Forster CBD and Coomba Park.

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AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning
BOM	Bureau of Meteorology
CFERP	Community Flood Emergency Response Plan
DA	Development Application
DECCW	Department of Environment, Climate Change and Water (now OEH)
FPL	Flood Planning Level
GIS	Geographic Information System
CSIRO	Commonwealth Scientific and Industrial Research Organisation
IPCC	Intergovernmental Panel on Climate Change
LGA	Local Government Area
m	metre
m^3/s	cubic metres per second
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
RFS	Rural Fire Service
SES	State Emergency Service
SOBEK	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software program (hydraulic computer model)
SWW	Severe Weather Warning
WBNM	Watershed Bounded Network Model (hydrologic computer model)
1D	One Dimensional hydraulic computer model
2D	Two Dimensional hydraulic computer model

1. FOREWORD

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

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

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

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

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

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

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

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

The Wallis Lake Foreshore (Floodplain) Risk Management Study and Plan constitutes the second and third stages of the management process for Wallis Lake. It builds on the existing Floodplain Management Study and Plan for Forster and Tuncurry and encompasses all of the Wallis Lake foreshore. It has been developed by Great Lakes Council and prepared by WMAwater for the future management of flood liable lands surrounding Wallis Lake.

2. INTRODUCTION

2.1. Background

Wallis Lake lies approximately 250 kilometres north of Sydney in the Great Lakes region of the mid-north coast of NSW. It is bounded on the south by the Smith Lake and Myall Lake catchments, on the west and north by the Manning River catchment and in the north-east by the Khappinghat Creek catchment. The lake is a relatively large body (85 km^2) with moderate depths (average depth of approximately 2 m) and is approximately trapezoidal in shape, 40 km in the north-south direction, and 30 km to 40 km in the east-west region (Figures 1, 2 and 3).

The present rock breakwater entrance to the Pacific Ocean is in the north-east corner separating the townships of Forster and Tuncurry. However, breakouts to the ocean will have undoubtedly occurred in the past along the narrow strip adjacent to Seven Mile Beach near Tiona (Figure 1).

Great Lakes Council engaged WMAwater to prepare a Foreshore (Floodplain) Risk Management Study and Plan for Wallis Lake. The objectives of the project are to:

- identify the nature and extent of the flood problem,
- determine the social and economic effects of inundation,
- assess the full range of management measures to mitigate the effects of inundation on existing and future developments and identify measures suitable for implementation,
- review Council's current flood policy provisions and examine the implications to planning of adhering to or amending the policy,
- examine the environmental and social impact of any proposed works,
- assess the impacts of a human induced climate change increase in ocean levels and rainfall intensity increase,
- develop a Floodplain Risk Management Plan including details of priority, implementation and funding.

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

2.2. Floodplain Risk Management Process

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

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

This study constitutes the second and third stages of the process and is concerned with the immediate foreshore area of Wallis Lake. It is referred to as a "foreshore" rather than a "floodplain" management study to reflect the fact that the study area surrounds a tidal lake system rather than a river and incorporates some aspects of the coastal/estuarine interface not usually considered in the floodplain management process. However, the study and plan have been administered under the framework of the Floodplain Risk Management Process.

The Flood Study (Stage 1) was completed in 1989 with publication of the Forster/Tuncurry Flood Study (Reference 2). Due to the significant lapse in time since it was completed, a review of the Flood Study (Reference 3) was undertaken as part of this current management study. As a result, the hydraulic modelling of Wallis Lake was updated so as to reflect current best practice and make best use of the available data (both hydrosurvey, airborne laser scanning (ALS) survey and rainfall data).

This Foreshore (Floodplain) Risk Management Study and Plan are the second and third stages in the management process. A previous Floodplain Management Study and Plan was undertaken for Forster and Tuncurry in 1998 (References 4 and 5). These studies were reviewed and the outcomes incorporated into the current project. The management study seeks to fully identify the flood problem and canvass various measures to mitigate the effects of flooding and wave action, and to prevent future flood damages. The ultimate product of the process is the Foreshore (Floodplain) Management Plan (Stage 3), which describes how the affected lands are to be managed in the future. Both the Study and the Plan require community interaction to ensure that the measures are fully supported. The fourth and final stage is implementation of the Plan.

An additional study (Reference 6) undertook an assessment of the wind wave effects at 33 locations along the foreshore of Wallis Lake. This study indicated that at the majority of sites the 100 year ARI wind wave level exceeded the 100 year ARI stillwater level (resulting from the combination of the 100 year ARI design rainfall over the catchment combined with an elevated ocean level), thus the critical 100 year ARI water level for many areas is that from wind wave action rather than the stillwater level.

2.3. History of Development and Flooding

In the past agricultural enterprises have dominated the Wallis Lake catchment's economy; dairy, beef cattle, timber, fishing and the oyster industry provided a steady income for many of the catchments' residents. In more recent years however, tourism and lifestyle services have become the dominant industry. The growth in tourism and lifestyle industries has been associated with the population growth that has occurred throughout coastal Australia. In the Wallis Lake catchment, this has resulted in expansion of the Forster-Tuncurry urban area and led to a growth in village/rural living.

Since the construction of the road bridge at Forster-Tuncurry in 1959 and improved access to the Pacific Highway, the area experienced rapid growth from the tourism and retirement industries which now dominate the local economy.

Flooding on the main tributaries has occurred several times in recent years. However flooding of Wallis Lake, to the extent that it causes damage to property, has occurred very infrequently. The largest recorded flood occurred on 15th - 17th April 1927. Peak levels of up to 2.27 mAHD were recorded in Tuncurry although lower levels (to 0.92 mAHD) were recorded elsewhere. Since 1927 the highest water level recorded in the lake has been 1.1 mAHD in 1978.

There are three automatic water level recorders located within the lake at Tuncurry, Forster and Tiona (Figure 1). The Forster gauge is largely influenced by tidal processes in the outlet channel and does not reflect the water level in the lake itself, whilst the Tuncurry gauge reflects water levels on the Wallamba River upstream of the lake. Thus the Tiona gauge is more reflective of the water level in the majority of the lake. The entire records for Forster and Tiona are reproduced as Figure 4.

2.4. Scope of Floodplain Risk Management Study

This Foreshore (Floodplain) Risk Management Study is primarily concerned with above floor inundation of buildings (mainly residential) as a result of elevated lake levels or due to wave runup.

External damages to yards, boat ramps and sheds have not been included, primarily because these features either have to be within the floodplain (boat ramps), residents choose to locate them in this location (sheds), or they are part of the floodplain (yards). Some damages will occur to these features during floods but it is not proposed to develop management measures to mitigate them.

Inundation of foreshore properties can occur either from the lake (raised water levels or wave action) or as a result of local catchment runoff trying to enter the lake. This study is solely concerned with raised water levels due to runoff entering from the main tributaries and wave runup from the lake, not from local catchment runoff. Note, it may well be that higher flood levels at some foreshore properties will result from local catchment runoff. This problem, if it occurs, would be the subject of site specific local flooding investigations by Council.

Wave runup produces two broad effects, inundation which is the subject of this study and foreshore erosion which is not the subject of this study. Erosion has only been considered in this study as it is a foreshore hazard and needs to be addressed as part of Council's development control procedures, along with inundation. However this study is not concerned with quantifying the effect of erosion or providing management measures to address the issue.

Inadequate road drainage has also not been considered within this study. Again, this is a local issue which should be addressed by Council on a site specific basis.

Of increasing importance in floodplain management is consideration of the effects of human induced climate change, resulting in increased rainfalls and/or increased ocean levels. This study has therefore quantified the likely impacts for a range of climate change scenarios. Of particular importance is the effect of ocean level rise which will result in a rise in design flood levels and consequent impact on flood damages to buildings. The estimates of a climate change increase in design rainfall intensities is considered less reliable than a ocean level rise but if it eventuates will also produce significant increases in flood damages.

2.5. Evolvement during the Course of the Study

The scope of the project has evolved since commencement in 2004. This has occurred for a number of reasons including, to gain a better appreciation of the flood problem, the addition of more updated data (ALS) and advancements in our understanding of climate change issues. The main changes in the scope are summarised below.

2.5.1. To Gain a Better Understanding of the Flood Problem

Since completion of the Forster/Tuncurry Flood Study (Reference 2) in 1989 there have been significant advancements in hydraulic modelling as well as the availability of historical water level, ocean, survey and rainfall data and changes to the approach for design flood estimation in coastal lakes systems. An update of the Flood Study was therefore undertaken as described in Reference 3.

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

- the use of a two Dimensional (2D) hydraulic model which allowed greater definition of the floodplain than the 1D hydraulic model used in Reference 2,
- availability of detailed bathymetric data to better describe the bed of Wallis Lake rather than the use of cross sections,
- a more detailed appraisal of design ocean level conditions based on tidal records collected since 1989,
- the incorporation of an envelope approach based on the maximum of an ocean dominated event (design ocean event plus a 5 year ARI rainfall event) and a runoff dominated event (design runoff event in conjunction with an elevated ocean event termed the Modified Normal Tide) rather than the use of the previously adopted design runoff event in conjunction with the similar magnitude design ocean event,
- a rigorous review of the available historical flood level data was undertaken to explain the reasons for the relatively high recorded levels for the April 1927 event compared to those recorded in the last 25 years.

For the above reasons a SOBEK 2D hydraulic model was established, calibrated to historical data and adopted for design flood estimation.

2.5.2. Availability of Airborne Laser Scanning Survey

The 2D model was initially setup using the available bathymetric data which provided levels to approximately 0.5 mAHD and thus did not define the floodplain which was determined from 1:25,000 topographic maps.

Airborne Laser Scanning (ALS) survey was undertaken in 2009 and a validation assessment of this dataset was undertaken which concluded that the ALS dataset should be lowered by 0.1m to correct for the difference between the field surveyed levels and the ALS. This correction was applied for use in this study.

The incorporation of ALS into the 2D hydraulic model produced an approximately 0.2m reduction in the design flood levels estimated in the absence of the ALS. This difference in level is explained by the significant low lying area between 0.5 mAHD and up to 3 mAHD that was not identified using the 1:25,000 topographic maps.

2.5.3. Assessment of Climate Change

During the course of the study the Intergovernmental Panel on Climate Change (IPCC) issued their Fourth Assessment Report "Climate Change 2007" in 2007. This document, together with more recent climate change reports issued by the Australian and NSW governments, concludes that there is a high likelihood that ocean levels will rise as a result of climate change. The hydraulic model established for the Flood Study was then used to assess the effects of a climate change induced ocean level rise and rainfall increase.

The present floodplain risk management study was also expanded to include possible climate change adaptation measures.

2.6. Flood Planning Levels

2.6.1. Year 2011 Design Flood Levels

Flood levels in Wallis Lake are affected by runoff from the upper catchment into the lake as well as inflows from the Pacific Ocean due to elevated ocean levels. However these two flooding mechanisms, whilst associated with each other, it is incorrect to assume that a (say) 100 year ARI (Average Recurrence Interval) ocean event will occur in conjunction with a 100 year ARI rainfall event. Such an event would have an ARI of greater than 100 year (say 500 year ARI).

Elevated ocean levels occur due to a combination of tides (the high tide varies from approximately 0.5 m to 1.1 mAHD during the year) and what are known as ocean anomalies. The main components of ocean anomalies (difference between the predicted and the recorded tide) are storm surge and wave setup at the entrance to Wallis Lake. The storm surge component is the increase in ocean water level that occurs during storms as a result of inverse barometric pressure and wind stress. Barometric pressure causes a localised rise in ocean water levels of about 0.1 m for each 10hPA drop in pressure and strong onshore winds produce surface currents that cause a build up of water against the coastline.

The oceanographic component of the tidal anomaly covers a range of other factors that can affect ocean water levels. The most important of these are the shelf waves generated by large storms remote from the NSW coast.

Together these components can raise ocean levels by up to 1m. As part of this study ocean anomalies were investigated and two runoff/ocean scenarios were adopted to determine design flood levels in Wallis Lake. A modified normal tide (peak level of 1 mAHD) was adopted in conjunction with the design rainfall event (termed a rainfall dominated event) and the design ocean level in conjunction with a 5 year ARI event (termed an ocean dominated event).

The following conditions were adopted for the design flood analysis:

- 0 mAHD initial water level in Wallis Lake,
- 36 hour critical rainfall storm duration inflows in conjunction with a modified normal tide (peak at 1 mAHD),
- design ocean levels based on the design levels in Fort Denison/Sydney harbour plus a wave setup component of 0.35 m in the 100 year ARI reducing to 0.25 m in the 5 year ARI in conjunction with the 5 year ARI 36 hour critical rainfall storm duration inflows.

The results from this envelope approach indicated that downstream of the bridge the ocean dominated event generally produces the higher level but upstream the runoff dominated event produces the higher level. The adopted design flood levels in Wallis Lake are provided in Table 1.

Table 1: Design Flood Levels in Wallis Lake upstream of the Bridge (levels in m AHD)

Event (ARI)	Year 2012 with NO ocean level rise	Year 2060 with 0.5m ocean level rise	Year 2100 with 0.9m ocean level rise
PMF	4.4	4.5	4.6
200 year	2.2	2.6	2.9
100 year	2.0	2.4	2.7
50 year	1.8	2.2	2.5
20 year	1.5	2.0*	2.4*
10 year	1.5*	1.9*	2.3*
5 year	1.4*	1.8*	2.2*

*** Peak level due to design ocean tide in combination with a low inflow**

Table 2 provides a summary of key flood related levels for Wallis Lake (upstream of the bridge).

Table 2: Wallis Lake Water Levels Relating to Sea Level Rise

Level	Measure	Basis of Calculation	Planning & Development Conditions
0.1 mAHD	Year 2012 lake mean still water level	Approx 25+ years lake tide gauge average (Figure 4)	
< =1.0 mAHD	Below Year 2100 lake mean still water level	Hazard to land use, infrastructure, buildings, and services from progressive rise in permanent lake levels to Year 2100	High hazard permanent lake inundation area and high hazard lake flood area
1.0 mAHD	Year 2100 lake mean still water level	Year 2011 lake level + 0.9 m sea level rise	
1.5 mAHD	Year 2012 20 ARI year flood	Flood Study – Reference 3	
< =2.0 mAHD	Below Year 2012 100 year ARI flood	Assessment of depth/velocity of Year 2100 100 year ARI flood and other hazard factors	High hazard lake foreshore area in Year 2100

2.0 mAHD	Year 2012 100 year ARI flood	Flood Study – Reference 3	
2.0 mAHD	Year 2060 20 year ARI flood level	Flood Study – Reference 3	
2.4 mAHD	Year 2060 100 year ARI flood level	Flood Study – Reference 3 – includes 0.5 m sea level rise	
2.4 mAHD	Year 2100 20 year ARI flood level	Flood Study – Reference 3 – includes 0.9 m sea level rise	
2.5 mAHD	Year 2012 Flood Planning Level	Year 2012 100 year ARI flood level + 0.5m freeboard	Year 2012 Flood Planning Level
2.7 mAHD	Year 2100 100 year ARI flood level	Flood Study – Reference 3 – includes 0.9 m sea level rise	
2.9 mAHD	Year 2060 Flood Planning Level	Year 2060 100 year ARI flood level + 0.5 m freeboard	Flood planning level for habitable buildings with Year 2060 asset life
3.2 mAHD	Year 2100 Flood Planning Level	Year 2100 100 year ARI flood level + 0.5 m freeboard	Flood planning level for habitable buildings with Year 2100 asset life
4.4 mAHD	Year 2012 PMF	Flood Study – Reference 3	
4.5 mAHD	Year 2060 PMF	Flood Study – Reference 3 – includes 0.5 m sea level rise	
4.6 mAHD	Year 2100 PMF	Flood Study – Reference 3 – includes 0.9 m sea level rise	Flood planning level for Year 2100 for “sensitive development” such as hospitals, aged-care facilities

2.6.2. Year 2060 and Year 2100 Design Flood Levels

Design flood levels for the year 2060 and year 2100 have been modelled in the current 2012 Wallis Lake Flood Study Review (Reference 3) and are provided in Table 1. The criteria for establishing these are:

- The NSW Government’s benchmarks in the 2010 Flood Risk Management Guide (Reference 7) for sea level rise by the year 2050 (+0.4 m – Great Lakes assumes a 50 year planning horizon to the year 2060 and thus an increase of 0.5m was adopted) and the year 2100 (+0.9 m) were adopted and included in the hydraulic modelling undertaken in the 2012 Flood Study Review (Reference 3).
- The 2012 Flood Study Review (Reference 3) undertook an assessment of a 10%, 20% and 30% potential climate change increase in design rainfall intensities. However no increase in rainfall intensity has been included at this time as there is no certainty that such an increase will occur. The Bureau of Meteorology is undertaking on-going research in this field and once definitive advice is provided this should be considered with a view to amending the year 2060 and year 2100 design flood levels (either upwards or downwards). The results from the 2012 Flood Study Review (Reference 3) indicate that a 10% increase in rainfall raises the peak water level by approximately 0.1m at the 5

year ARI and up to 0.2m at the 100 year ARI. A 10% increase in design rainfalls exactly represents the increase from a 100 year ARI to a 200 year ARI event. Thus a 10% increase in design rainfall would increase the 100 year ARI lake level from 1.94 mAHD to 2.15 mAHD (approximately a 0.2m increase). It is also noted that the increase in rainfall from a 50 year ARI to 100 year ARI event is 10% and this also represents approximately a 0.2 m increase in lake level. Recent literature indicates that rainfall increases of up to 30% may occur. This increase in rainfall may increase the 100 year ARI lake level by up to 0.6 m.

- Climate change may also increase the ocean storm surge and wave setup components incorporated in establishing the design ocean levels adopted in the 2012 Flood Study Review (Reference 3). These issues have also been investigated in that study and conclude that ocean storm surge, wave setup and associated factors may increase design flood levels in Wallis Lake. This potential increase in design flood levels has not been included in estimation of the year 2060 or year 2100 design flood level estimation as there is no certainty that such an increase will occur.
- Wind setup on Wallis Lake (the effect of wind pushing water into a bay) may raise water levels in a local area. Wind setup has not been included in establishing design flood levels for year 2012, year 2060 or year 2100 conditions as it is a local condition, of relatively small magnitude and will affect (if it occurs during the design event) only a small percentage of the foreshore area.
- Wave runup (waves break and runup the foreshore reaching a higher level than the static water level) was investigated in the 2001 Foreshore Flooding Assessment (Reference 6). Wave runup is a very localised effect that is highly influenced by the local topography and will likely not extend beyond 50 m from the foreshore. It can be relatively easily mitigated by a formal structure (mound or wall) or vegetation (mangroves or trees). There are no reported occurrences of wave runup causing damage to property or risk to life.
- The 0.5 m freeboard above the 100 year ARI design flood level that is used to establish the minimum floor level of a residential building caters for uncertainty in design flood estimation and the effects of climate change, wind and wave action and local hydraulic effects. The effect of sea level rise cannot be included within this freeboard as it has been established with a reasonable degree of certainty that it will occur (2010 Flood Risk Management Guide - Reference 7).
- An overriding consideration in establishing the year 2060 and year 2100 design flood levels is that the assumed sea level rise has not yet occurred, thus there is some additional freeboard allowance in the years leading up to the year 2060 and 2100 should the 100 year ARI flood (or any other large event) occur prior to these dates.

2.6.3. 0.5 m Freeboard

A freeboard allowance above the design standard (generally the 100 year ARI flood level) is to provide reasonable certainty that other hydraulic effects do not compromise the adopted standard. There is no technical reason that a 0.5 m freeboard and not some other value (lower or higher) are applicable for Wallis Lake. A review of the hydraulic effects included in the freeboard indicates:

- Uncertainties in design flood levels: Whilst there is always uncertainty in design flood estimation the magnitude of any error for Wallis Lake is relatively small compared to river systems (say a maximum of ±0.3 m) due to the small height difference between a 100 year and say a 20 year ARI event (on river systems there is a much greater range),
- the effect of local hydraulics (say flow between buildings raising levels) is not a factor at Wallis Lake due to the relatively slow rate of rise of the floodwaters,
- wave action (causing wave runup) will generally be 0.5 m or less and there is no evidence that it has actually occurred. In the majority of the foreshore areas the existing and proposed developments are outside the potential 50 m impact zone of wave runup,
- Climate change: Sea level rise has been considered separately (not within the freeboard) as it has been established with a reasonable degree of certainty that it will occur as stated in the 2010 Flood Risk Management Guide (Reference 7). Other possible climate change effects are assumed to be included within the freeboard as there is no certainty that they will occur and possibly some may reduce flood levels (decrease in rainfall intensities may occur),
- the very large area of the lake (85 km^2) means that future development in the catchment or filling of the floodplain will produce no significant increase in the design flood levels and this component can effectively be ignored for Wallis Lake.

On the basis of the above assessment a freeboard of 0.5 m is reasonable.

3. STUDY AREA

3.1. Description

The total catchment area of the Wallis Lake catchment to the Pacific Ocean is approximately 1300 km^2. There are four main tributaries (Figure 2), namely:

- the Wallamba River - 437km^2 (34% of the total catchment),
- the Wang Wauk River - 207km^2 (16% of the total catchment),
- the Wallingat River - 182km^2 (14% of the total catchment),
- the Coolongolook River - 172km^2 (13% of the total catchment).

The remainder of the catchment (approximately 300 km^2 or 23%) comprises the lake itself and its immediate contributing catchment.

The study area comprises the foreshores of Wallis Lake and adjoining areas which are affected by flooding/inundation. This includes the townships of Forster, Forster Keys, Tuncurry, Coomba, Whoota, Green Point, Tiona and Booti Booti (Figure 1) which are affected by flooding to various degrees. This occurs as a combination of inflows from the tributaries, wind wave action on the lake and inflows from the ocean.

The lake is relatively shallow with depths varying from 1 m up to 9 m (Figure 3) with the percentage of area at given depths as follows:

- depth <1 m - 29%,
- depth 1 m to 2 m - 37%,
- depth 2 m to 5 m - 32%,
- depth >5 m - 2%.

3.2. Land Use Activities and Key Features

Today the most valuable industries in the catchment are tourism, oyster aquaculture, fishing and agriculture. Agricultural activities - primarily beef and dairy cattle - are the dominant land use in the catchment. Other major land uses include forestry, conservation and urban development. Urban areas are concentrated on the coastal fringe, particularly around the townships of Forster and Tuncurry.

Approximately 5% of the catchment area has been developed for urban and rural residential uses, including the associated industrial, commercial and infrastructure needs. Of the catchment population of 24,000, 75% is concentrated around the foreshores of Wallis Lake, with the majority in Forster and Tuncurry at the northern end of the lake.

3.3. Previous Studies

3.3.1. Forster/Tuncurry Flood Study - September 1989 (Reference 2)

This study established the one-dimensional Wallingford hydraulic model to determine design flood levels with a WBNM hydrologic model used to determine hydrologic inputs. Initially a comprehensive survey and flood data collection exercise was undertaken. The study indicated that the only large flood on record is the April 1927 event which was recorded at several locations. Model calibration was very limited due to the lack of available flood data and only the March 1978 flood and June 1987 tidal data were used.

The hydraulic modelling and estimation of design flood levels took account of design inflows as well as design ocean hydrographs.

3.3.2. Wallis Lake Foreshore (Floodplain) Risk Management Study - Flood Study Review (Reference 3)

Due to the significant time since completion of the Flood Study (Reference 2) a review was undertaken as part of this Management Study. As a result of this review it was determined that some approaches used in the original modelling of the Wallis Lake catchment were outdated, and coupled with better data available, a more rigorous hydraulic modelling approach was required. However the hydrologic modelling approach using a WBNM model was not changed.

Further details of the approach are provided in Section 4 of this present report.

3.3.3. Forster/Tuncurry Floodplain Management Study - April 1998 (Reference 4)

In this study the Wallingford hydraulic model set up in Reference 2 was upgraded to a MIKE-11 model with additional branches included. The design flood levels were generally in good agreement with the flood levels obtained in Reference 2.

The study undertook a review of the planning instruments and concluded that Council's documentation could be improved to centralise the flood provisions into one document.

A range of floodplain management measures were investigated including:

- **levees** - these were rejected due to high costs and low economic benefits as well as possible adverse impacts on flood levels,
- **landfill** - as the area of any proposed fill is a very small component of the total floodplain storage capacity the fill would have little impact upon flood levels unless located in a floodway (Point Road, Tuncurry),
- **flood warning scheme** - high capital cost and a feasibility study was recommended,
- **evacuation planning** - preparation of a Plan was proposed,
- **public information and education** - supported,
- **voluntary house raising** - supported,
- **voluntary house purchase scheme** - not warranted,
- **planning and development controls** - proposed a flood specific Development Control Plan (DCP) and to review the freeboard to take account of possible climate change and wind wave effects.

The study undertook a comprehensive community consultation program with distribution of 2500 resident surveys (773 returned) and 96 residents attended workshops.

The main outcomes were:

Forster Keys

- concern about stormwater issues, particularly the impact of increased stormwater runoff as the area continues to develop,
- stormwater drainage control and water quality had higher priority than flooding,
- residents did not generally favour structural options (levees) for managing flooding impacts. Residents differed on whether Council should permit fill to above the designated flood level in developed areas. In general, building to the designated flood level was supported.

Point Road, Tuncurry

- residents were strongly opposed to full levees as a means of mitigating flood impacts. Opinion was divided on the use of partial levees, there was concern about the height of a levee but some residents accepted that partial levees could be beneficial,
- residents did not support landfill in developed areas. Their concern was that land filled to higher than flood levels would encroach on the privacy of, and cause drainage problems in, adjoining properties.

Central Forster/Tuncurry

- residents did not support structural options such as levees to mitigate flooding impacts,
- residents were concerned about new development being filled up to the designated flood level and the impact that this would have on the privacy of neighbouring properties.

The Committee, having regard to the key outcomes of the survey and community workshops, decided to:

- investigate the effectiveness of partial levees in high hazard areas,
- promote emergency planning and communication during times of flood,
- investigate the effect on flooding of wind and wave action in Wallis Lake, and
- abandon the idea of full levees as a solution to flooding problems.

Residents' concerns over drainage and privacy problems associated with filling to the designated flood level were acknowledged. However, the report considered that appropriate planning and design measures would address these concerns, and that the requirement to fill land to the designated flood level should not be abandoned. Such planning and design measures should be included in a flood-specific DCP.

3.3.4. Forster/Tuncurry Floodplain Management Plan - April 1998 (Reference 5)

The Plan rejected levees, dredging and a deflector levee due to high costs and likely adverse reaction from the local community.

Of the five development (landfill) options analysed only the Point Road site at Tuncurry would produce adverse hydraulic impacts.

The following property/response modification measures were proposed:

- **flood warning, evacuation planning and public awareness/public education** - initially a feasibility study should be undertaken,
- **voluntary house raising** - an inventory and specific rules/conditions for applicants were proposed,
- **planning and development controls** - a review of Council's planning instruments was proposed as well as an updating of flooding on the Section 149 Certificates.

3.3.5. Wallis Lake Floodplain Management Study Foreshore Flooding Assessment - August 2001 (Reference 6)

The aim of the study was to determine the maximum water levels at 33 sites around the foreshore of Wallis Lake (Figure 3). The determination took into account the stillwater level, wave runup and wave setup from local wind waves, the bathymetry of Wallis Lake and the presence of any foreshore structures.

The 100 year and 20 year ARI wind elevated flood levels were calculated using the cross-sections adopted as representative of each site. It was noted that in time the cross-sections may change due to natural or man-made actions. The wind wave results from this study are discussed in Section 5.3.3 of this present report.

3.4. Planning

3.4.1. General

As part of the preparation of the Foreshore (Floodplain) Management Study, there is a requirement that the existing planning controls be reviewed, and suggestions made regarding the means by which the controls could be amended and/or supplemented with regard to land potentially impacted by floodwaters.

Table 3 lists the main planning documents considered during the course of the study.

Table 3: Main Planning Documents Considered During the Course of the Study

Document	Comment
Local Environmental Plans (LEPs):	
Great Lakes LEP, 1996	The Great Lakes LEP 1996 was gazetted on 13th December 1996 and is the main planning instrument used by Great Lakes Council to manage land use. It is currently being updated as part of a directive from the State Government.
Development Control Plans (DCPs):	
Great Lakes Subdivision DCP	Provides guidelines relating to subdivision.
DCP No. 28	Relates to Exempt and Complying development.
Residential DCP for Urban Areas	Provides guidelines relating to residential development.
Policies:	
Great Lakes Flood Policy	Seeks to control development in flood liable land within the Local Government Area.
Certificates:	
Section 149 Planning Certificates	Council notifies flood liable land on Section 149 Planning Certificates.

3.4.2. Interim Flood Policy

Great Lakes Council first adopted a flood policy in December 1985 with the 100 year ARI event as the flood standard. A 100 year ARI level of 2.28 mAHD for the foreshore areas of Wallis Lake has been adopted since completion of the Flood Study (Reference 2) in 1989. Great Lakes Council has adopted a substantial document titled "*Policy: Flood Management*". The aims and objectives of the policy are to:

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

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

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

In order to achieve the above aims and objectives, the Policy contains a number of development control requirements. For the foreshore area surrounding the lake, minimum floor levels were adopted as 0.5 m freeboard above the 100 year ARI level of 2.28 mAHD (level of 2.78 mAHD).

Council is currently (2010) undertaking a review of their flood policy and has implemented a climate change policy.

Section 149 Planning Certificates

Great Lakes Council currently has a notation which it places on Section 149 Planning Certificates which alerts the purchaser of that certificate that the subject land is affected by flooding. The wording is:

> *"Council considers that the land subject to this certificate is below the 2100 1% AEP flood planning level and therefore subject to flood-related development controls.*
>
> *Current Council information indicates that the estimated 2100 1% AEP flood planning level is ……. m AHD in the vicinity of the subject land."*

3.5. Environmental

A preliminary review of the flora, fauna and archaeological qualities of the area indicates that the lake and estuary supports abundant and diverse flora/fauna communities and significant Aboriginal heritage items (Reference 8). Flood management measures which may affect any of these qualities will require a detailed assessment.

3.6. Estuarine and Coastal Issues

This present study has been undertaken in accordance with the NSW Flood Policy. However, the NSW Government has other policies, specifically the NSW Estuary Management Policy and the NSW Coastal Policy, which are also relevant to the Wallis Lake foreshore area.

The primary goal of the NSW Estuary Management Policy (1992) is "*to encourage the integrated, balanced, responsible, and ecologically sustainable use of the State's estuaries*". The Estuary Management Manual contains guidelines and principles for better estuary management and defines the major steps in developing an Estuary Management Plan.

The estuary management process for Wallis Lake has included publication of:

- a Data Compilation Study (1996),
- an Estuary Processes Study (1999) (Reference 8),
- a Draft Estuary Management Study (2004), and
- a Draft Estuary Management Plan (2004) (Reference 9).

Further details of these studies are provided in Reference 9.

The NSW Coastal Policy 1997 covers the coastal zone including land within one kilometre of the foreshore around bays and estuaries such as Wallis Lake. This Policy has nine goals to:

- protect, rehabilitate and improve the natural environment,
- recognise and accommodate natural processes and climate change,
- protect and enhance the aesthetic qualities,
- protect and conserve cultural heritage,
- promote ecologically sustainable development and use of resources,
- promote ecologically sustainable human settlement,
- provide appropriate public access and use,
- provide information to enable effective management,
- provide for integrated planning and management.

At this time Great Lakes Council has not prepared coastal studies in accordance with the NSW Coastal Policy, nor approved DCPs or policies relating to coastal issues. The Estuary Management Plan addressed some of the issues in the NSW Coastal Policy but did not undertake a coastal (hazard assessment) study for the foreshore. This present Foreshore (Floodplain) Management Study has considered the goals of the NSW Coastal Policy in the formulation and evaluation of management measures, particularly in relation to ecological sustainability.

3.7. Public Consultation

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

- follow up telephone calls to key respondents;
- floodplain management committee meetings;
- workshops /site inspection and interviews;
- public exhibition of the Draft study in May 2011. During the exhibition period Council staff produced press releases, newspaper advertisements and provided a television interview (NBN) and phone interview to ABC regional radio. These opportunities were used to promote two community information sessions on the Wallis Lake project. These were held at 10th and 11th May 2011 at the Council Chambers and Pacific Palms Community Centre respectively. Low turnouts at both information sessions indicate that further targeted methods were needed to inform and engage people around the information that is available. It was felt that the reporting of the 2100 Flood Planning Level (FPL) on Section 149 (2) Certificates would begin to make people aware of the implications of sea level rise within Wallis Lake. Committee members suggested engagement with community groups as well as the Forster/Tuncurry Chamber of Commerce. A meeting was also suggested with real estate agents who have an interest in finding out about Section 149 (2) reporting and sea level rise in particular and speaking to service groups such as Probus, and the use of the Landcare and Dunecare networks. Committee members were generally comfortable with further engagement being undertaken as part of the final risk management plan development process.

4. EXISTING FLOOD ENVIRONMENT

4.1. Flood Behaviour

Flooding within Wallis Lake may occur has a result of a combination of factors including:

- an elevated ocean level due to ocean storm surge, wave setup at the entrance and/or a high astronomic tide,
- rainfall over the lake and the rivers entering Wallis Lake,
- wind wave action within the lake itself. This mechanism was not evaluated as part of this present study as it was analyzed in the Wallis Lake Floodplain Management Study - Foreshore Flooding Assessment (Reference 6).

One of the key considerations in modelling coastal systems is the probability of occurrence of an ocean and a rainfall event and the relative magnitude of both. An envelope approach was adopted in the Flood Study Review (Reference 3) which resulted in the design flood levels given in Table 1 and Table 4. Two areas are given, from the entrance to the bridge, where levels are dominated by ocean events and upstream of the bridge, where rainfall over the contributing catchment is the dominant process.

Table 4: Design Flood Levels (mAHD) with NO Climate Change

Event (ARI)	Seaward limit of Breakwater to Bridge	Upstream of Bridge within Lake
PMF	4.2	4.4
200 year	2.1	2.2
100 year	1.9	2.0
50 year	1.7	1.8
20 year	1.5	1.5
10 year	1.4	1.5*
5 year	1.3	1.4*

*** Peak level due to design ocean tide in combination with a low inflow**

4.2. Hydraulic Categorisation

The Floodplain Development Manual (Reference 1) defines three hydraulic categories which can be applied to areas of the floodplain.

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

> "*Flood storage* areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood

attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas."

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

The delineation of these categories is generally based on depth and velocity data from a hydraulic model containing detailed survey data.

For all areas south of Forster the foreshore lands are Flood Fringe in all design flood events. These areas are not considered Flood Storage due to the relatively shallow depths of inundation (say maximum of 1m in the 100 year ARI) and due to the relative size of the lake. Thus filling on any part of the foreshore will have minimal impact on flood levels.

The Forster/Tuncurry Floodplain Management Study (Reference 4) classified the Point Road peninsula as Floodway. This classification has been investigated in this study and it is concluded that the land is more accurately described as Flood Fringe. This is because the majority of the land has now either been occupied by buildings which "block" the overland flow path or the vacant land filled for building lots. Thus there is only a small effective flow path across the peninsula. This land has ground levels at 1.3 mAHD or above, thus in a 100 year ARI event the maximum depth of flow is 0.7m with average velocities less than 0.5 m/s. Hydraulic modelling into the effect of filling this vacant low lying land indicated that there would be less than 0.02m impact in the 100 year ARI event. On this basis the Point Road peninsula could not be classified as Floodway.

The effects of climate change on the hydraulic categorisation have been investigated in Section 6.1.

4.3. Flood Hazard Classification

4.3.1. General

Flood hazard is a measure of the overall adverse impacts of inundation from floodwaters. It incorporates the threat to life, the danger and difficulty in evacuating people and possessions, and the potential for damage, social disruption and loss of production. Primarily this study is concerned with stillwater inundation and foreshore wave runup impacts on land above the mean high water level. Inundation as a result of local catchment runoff, blocked drains, ponding in low lying areas or similar are not considered in this assessment.

Tsunami (tidal waves) occur around the Australian coastline. However, the increase in coastal water level has been less than 0.1 m in NSW. The impact of tsunamis on lake levels has not been considered as it is outside the scope of this study.

4.3.2. Nature of the Hazards

Foreshore flooding results from a combination of stillwater and wave runup inundation.

Stillwater refers to the general lake water level without the effects of waves. The term is somewhat misleading because during storms there is always some wave action as a result of ocean and local wind activity, and water levels even with wave effects excluded are not still, but tend to rise and fall in response to wind gusts, wave sets, currents, etc.

Wave runup refers to the increase in water level that occurs along a foreshore when waves break and expend their remaining energy by running up the foreshore. The height the waves reach depends upon a number of factors such as the beach profile, foreshore exposure to the prevailing winds, and/or the presence of structures on the foreshore (vegetation, rock walls, buildings). These are discussed in Section 5.3.3.

The hazards associated with stillwater inundation and wave runup impacts differ as a result of their different characteristics. Peak stillwater levels will last for hours and so will persist long enough to inundate building floors below the peak level regardless of how far they are from the foreshore, even if doors and windows are closed. However the water will rise relatively slowly and without a significant velocity component. The relatively shallow depth of inundation, low velocities and ease of access to high ground means that the risk to life is low.

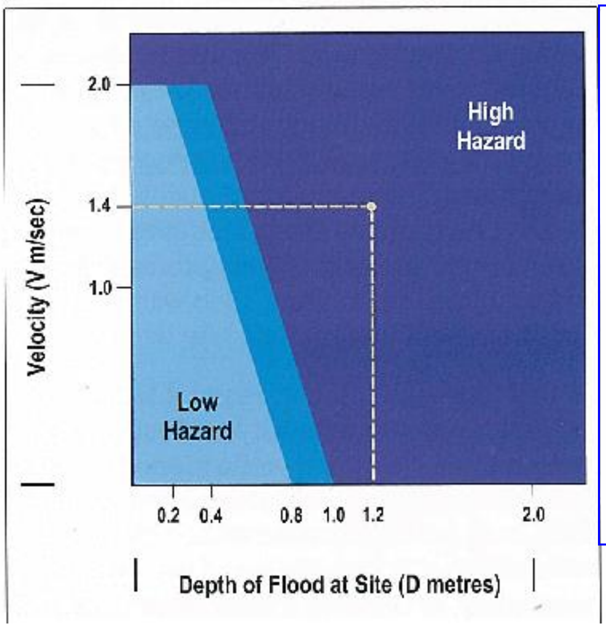
Wave runup will also occur over an extended period of time but within this time the peak level will be reached only a few times as large waves and surges impact on the foreshore. This will probably be near the peak of the storm and around the maximum stillwater level period. Wave runup (in isolation) will probably not cause inundation of floor levels if doors and windows are closed but, dissipation of the wave energy will erode banks and damage foreshore structures. The impacts of wave runup will mainly be restricted to the immediate foreshore area, with properties further back less affected as the wave energy dissipates. Wave runup does increase the risk of life, but residents can generally still easily and safely move to high ground.

4.3.3. Approach

The Floodplain Development Manual (Reference 1) defines two hazard categories:

- **High Hazard:** *possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings.*
- **Low Hazard:** *should it be necessary, a truck could evacuate people and their possessions; able bodied adults would have little difficulty in wading to safety.*

The process to define hazard involves firstly the evaluation based on hydraulic principles, and then refinement in light of other relevant factors affecting the safety of individuals. The provisional hydraulic hazard categories are defined in the figure below (taken from Reference 1).



Notes

The degree of hazard may be either -

- reduced by establishment of an effective flood evacuation procedure.
- increased if evacuation difficulties exist.

In the transition zone highlight by the median colour, the degree of hazard is dependant on site conditions and the nature of the proposed development.

Example:

If the depth of flood water is **1.2 m**
and the velocity of floodwater is **1.4 m/sec**
then the provisional hazard is **high**

FIGURE L2 - Provisional Hydraulic Hazard Categories

Provisional hazard categorisation based on the limited depth and velocity data that are available in over bank areas indicate that the majority of the existing developed areas on the floodplain is Low hazard (refer Figures in Appendix B). To identify the true hazard taking into account all factors, land is classified as either *low* or *high* hazard for a range of flood events. The classification is a qualitative assessment based on a number of factors as listed in Table 5.

Table 5: Hazard Classification

Criteria	Weight (1)	Comment
Rate of Rise of Floodwaters	Low	Due to the large storage capacity of Wallis Lake itself, the rate of rise of floodwaters is likely to be slow, and occur some hours after the main rainfall event itself.
Duration of Flooding	Medium	Wallis Lake is likely to be elevated for a number of hours (>6 hours) following on from a flood or tidal event.
Effective Flood Access	Low	There is sufficient high ground surrounding the floodplain.
Size of the Flood	Medium	There is a 0.6 m increase in level between the 5 year and the 100 year ARI events.
Effective Warning and Evacuation Times	Low	Due to the slow rate of rise of floodwaters there should be sufficient warning and evacuation time available, assuming the appropriate measures are in place
Additional Concerns such as Bank Erosion, Debris, Wind Wave Action	High	The most significant factor is likely to be wind wave action along parts of the foreshore.
Evacuation Difficulties	Medium	For the majority of the floodplain (foreshore) there are few evacuation difficulties as there is easy access to high ground. The exception is at Point Road, Tuncurry where the distance to high ground increases the hazard.
Flood Awareness of the Community	High	The lack of recent flooding means that the floodplain community has little awareness of flooding.
Depth and Velocity of	Medium	For the majority of the developed areas this factor is of minor

Floodwaters	significance, the exception is in the Point Road, Tuncurry area where the depth and velocity of floodwaters are greater than in most other developed areas in the floodplain. However the velocity is still relatively low (< 0.8m/s).

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

Based upon the above classification, and in the absence of significant wave runup action, the provisional hazard classification (as shown in Appendix B) will not change for events up to the 100 year ARI except at Point Road. The main factors influencing the Low classification is the available warning time, easy access to high ground and slow rate of rise. At Point Road the main issue is that residents may become isolated and will have their access to high ground cut. Higher overland velocities will also be experienced in this area. Based on the above the true hazard at the Point Road area is High for all events greater than say a 10 year ARI.

In events larger than the 100 year ARI or if sea level rise and/or rainfall increases occur the hazard will be greater. In the PMF the entire foreshore area becomes High Hazard due to the likely rate of rise of floodwaters, the significant depths of inundation, the evacuation difficulties to land above the PMF and the likely lack of appreciation by the community of the magnitude of such an event.

With wave runup action the hazard is High in the immediate area adjoining the lake affected by such action. This High hazard band may extend up to 50 m from the shoreline at some locations around the lake. Beyond that distance, any wave energy will be dissipated by obstructions and the shallow bed conditions. The lateral extent along the foreshore (at any one time) will vary depending upon the prevailing wind strength and direction at the time, the depth of the water and obstacles and barriers blocking and dissipating the wave energy. Thus any land within 50m from the foreshore (taken as 0 mAHD) and below the design wave runup level is potentially High hazard due to wave runup (a note is provided on all hazard maps to this effect).

Climate change will change the hazard classification depending upon the magnitude of any ocean level or rainfall increase and has been discussed in Section 6.1 with maps provided in Appendix B.

4.4. Flood Damages

4.4.1. General

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

- the magnitude (depth, velocity and duration) of the flood,
- land usage and susceptibility to damage,
- awareness of the community to flooding,
- effective warning time,
- the availability of an evacuation plan or damage minimisation program,

- physical factors such as erosion of the river bank, flood borne debris, sedimentation.

Flood damages can be defined as being tangible or intangible. Tangible damages are those for which a monetary value can be assigned, in contrast to intangible damages, which cannot easily be attributed a monetary value (stress, injury, loss to life, etc.).

4.4.2. Tangible Damages

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

4.4.3. Intangible Damages

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

Isolation

Isolation may become a significant factor for local residents in some areas. There is also a high level of community support and spirit, which can to some extent negate the effects of isolation and can certainly assist in a flood. However, isolation is of significant concern if a medical emergency arises during a flood.

Population Demographics

There are no particular features of the population demographics of the community on the foreshores of Wallis Lake that would contribute to additional intangible damages (aged or particularly young population) except for a high proportion of visitors along the foreshore.

Stress

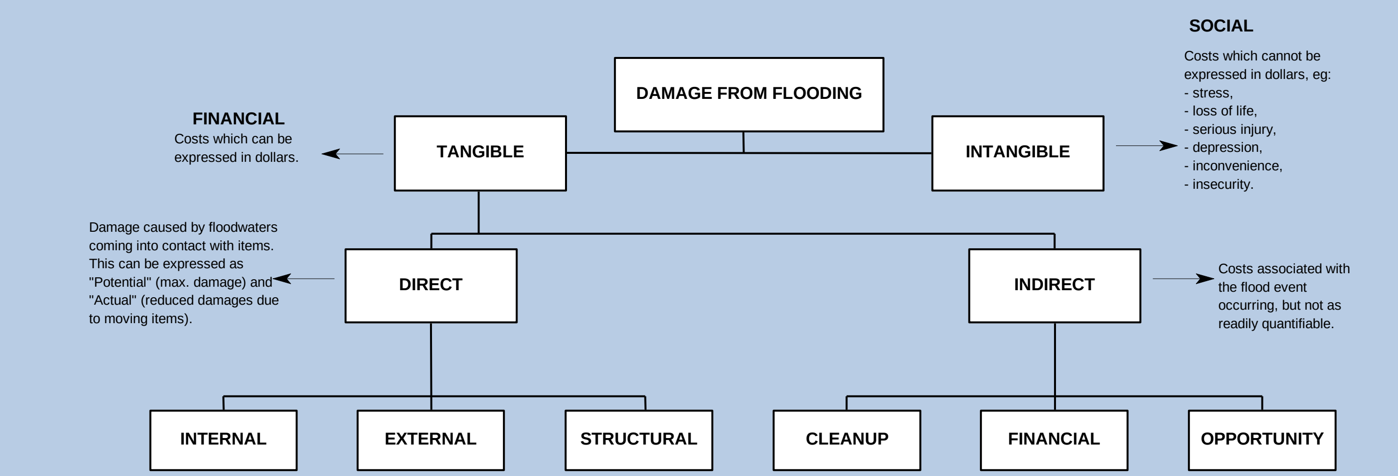
In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.,) many residents who have experienced a major flood are fearful of the occurrence of another flood event and its associated damage. The extent of the stress depends on the individual. This is impossible to evaluate at Wallis Lake due to the absence of recent flood events.

Risk to Life and Injury

During any flood event there is the potential for injury as well as loss of life. At Wallis Lake the absence of high velocities as well as high flood depths (< 1m) means that the risk is smaller than in other flood liable communities. However the risk is increased due to the duration of inundation and the length of some evacuation routes (at Point Road).

4.4.4. Summary

A summary of the nature of flood damages is provided in the diagram below.



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

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

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

4.4.5. Flood Damages Assessment

A flood damages assessment was undertaken for existing development on the foreshore of Wallis Lake based on a floor level database provided by Great Lakes Council as part of Reference 4. The exact source (survey methodology, accuracy, date of survey) of this database is unclear and it has not been updated to include any recent developments or removal of existing developments (if this has occurred since the database was established).

The damages assessment considered multiple houses per property (units, etc.) as well as two storey houses (habitable/non-habitable ground floor) and applied an adjustment factor to represent the anticipated damages. It took into account residential and commercial damages where possible, as well as damages to tourist facilities (caravan parks). It does not include damages to public structures, boat sheds, jetties or landscaping works.

Figure 5 provides a graph of the number of buildings versus floor level at Forster, Tuncurry, Point Road at Tuncurry, Green Point as well as the remaining properties at Coomba Park, Charlotte Bay, Whoota, Elizabeth Beach, Yarric, Tiona, Pacific Palms, Elizabeth Beach, Elim, Wallis Island and Booti Booti. Buildings (vans, units and other residential buildings) are shown separately. Data for commercial buildings was collected and this showed that only 51 commercial buildings had floors below the 100 year ARI flood level and all of these buildings are in Forster.

A breakdown of the flood damages (to private property excluding damage to public structures) and buildings inundated is provided in Table 6 with the inundated floor information provided on Figures 6 and 8.

Table 6: Flood Damages Assessment

	5y	10y	20y	50y	100y	200y	PMF
Buildings Inundated	44	75	94	237	417	758	2997
Land	346	436	542	998	1400	1712	3021
Total Damages (‘000)	$1,485	$2,267	$3,038	$7,597	$14,476	$26,133	$228,651

The estimated Annual Average Damages (AAD) for the foreshore area is $1.9million with the contribution for each of the seven areas shown in Table 7.

Table 7: AAD for each Area

Areas	AAD
Caravan Parks	$87,000
Coomba Pk, Charlotte Bay, Whoota, Yarric, Tiona, Pacific Palms, Elizabeth Beach, Elim, Wallis Island, Booti Booti	$39,000
Forster	$144,000
Forster Keys	$354,000
Green Point	$15,000
Point Rd, Tuncurry	$554,000
Tuncurry	$717,000
TOTAL	**$1,910,000**

4.4.6. Wind Wave Damages

Wave runup impacts are difficult to quantify due to the highly variable theoretical level of wave runup at each individual foreshore property. The height of the wave runup is dependant on the foreshore profile, which typically varies from property to property due to, for example, ad-hoc foreshore works or boat ramps located on private property.

The extent of above floor inundation would also depend upon:

- whether the wave can propagate to the building without significant interference from any obstruction(s) that may exist between the foreshore and the building, and, if so,
- whether the water can actually enter the building. For example, the number of and locations of the openings in the building (such as doors or windows) and/or the structural integrity of the building, which in turn may depend upon the duration of the storm/wave impact.

For the above reason wind wave damages have not been quantified in this study.

4.5. Impacts of Flooding on Public Infrastructure

Public sector (non-building) damages include:

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

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

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

4.6. Impacts of Flooding on Commercial and Industrial Activities

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

4.7. Environmental Impacts of Flooding

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

However, as natural areas become permanently inundated by rising sea and lake levels, and tidal and flood regimes change, ecosystems will be affected by the changes to hydrology. Foreshore ecosystems such as mangroves, saltmarsh, and wetlands may be inundated, or suffer from changes in salinity, groundwater, and tidal inundation.

Assessment of the environmental impact of property protection and flood modification measures needs to consider changes in baseline environmental conditions caused by sea level rise, such as permanent inundation of tidal saltmarsh. For example, protection works such as berms or sea walls could affect ecosystems such as saltmarsh, and/or block off possible areas for ecosystem retreat. Filling and changes to local drainage patterns could also affect ecosystems dependent on a particular hydraulic pattern of wetting and drying.

Strategic planning for areas affected by permanent inundation and increased flooding must include consideration of ecosystem adaptation and retreat, particularly for tidal saltmarsh, and foreshore and coastal wetlands. The future protection and conservation of ecosystems dependent on lake water levels should be included in the development of local area adaptation plans that are recommended as part of this study and plan.

4.8. Flood Emergency Response Classification

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

Based on the guidelines, communities are classified as either, Flood Islands, Road Access Areas, Overland Access Areas, Trapped Perimeter Areas or Indirectly Affected Areas (refer Table 8). From this classification an indication of the emergency response required can be determined.

Table 8: Emergency Response Classification of Communities

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

The guideline was applied for the community and for all foreshore management areas of Wallis Lake the community was classified as Low Flood Island based on the following criteria:

- There are homes and access roads below the PMF,
- Vehicle evacuation routes are cut before homes are inundated,
- There are no habitable areas for refuge (except the homes themselves),
- The homes are first surrounded by floodwaters and then inundated, and
- Thus vehicle evacuation must be completed before the route is closed.

In summary, a local flood action plan should be prepared for each foreshore management area and communicated with the community. Due to the extensive area and number of people requiring the services of the SES, the main focus for many residents will be on self-help during a flood.

4.9. Implications of Climate Change and Sea Level Rise

4.9.1. Background

Climate change is predicted to cause an increase in sea level and possibly changes to design rainfall intensities. The likely impacts of a rise in sea-level include:

- an increase in the intensity and frequency of storm surges;
- increased foreshore erosion and inundation of low lying coastal lands;
- further loss of important coastal wetland ecosystems; and
- damage to and destruction of human assets and settlements.

In developed areas such as Wallis Lake, changes in the climate, such as an increase in storm activity, together with a rise in sea level are likely to influence future building design, standards and performance as well as energy and water demand and in particular coastal/estuary planning.

Given that Wallis Lake has a wide foreshore, future development and redevelopment of foreshore areas will need to factor how future sea-level rise will impact on the developments. Many residential and commercial properties will be at least partially affected by a 0.9m rise in sea levels affecting their future use and development. Public land such as Council reserves, Crown land, and National Parks will also be impacted and rising sea and lake levels will affect construction and reconstruction of foreshore structures, such as seawalls, fixed jetties and boat ramps, and public foreshore access in the future. Mitigation and adaptation options to address the potential impacts of climate change, particularly for coastal communities, will become increasingly more expensive and problematic.

The 2005 Floodplain Development Manual (Reference 1) and 2010 Flood Risk Management Guide (Reference 7) requires that Flood Studies and Risk Management Studies consider the impacts of sea level rise and climate change on flood behaviour.

4.9.2. Key Developments

Since completion of the Forster/Tuncurry Flood Study and Floodplain Management Study (References 2 and 4) in 1989 and 1998, current best practice for considering the impacts of climate change (sea level rise and rainfall increase) have been evolving rapidly. Key developments in the last three years are summarised in the Wallis Lake Flood Study Review (Reference 3).

4.9.3. How will Climate Change Affect Water Levels in Wallis Lake?

Climate change has the potential to alter the water level in both non-flood and flood times.

During Non Flood Times

The main impacts in non-flood times will be:

- The “normal” water level in the Wallis Lake will rise from the current 0.1 mAHD average lake water level. The predicted increase in lake levels is the same as the expected sea level rise (by 0.5 m in 2060 to 0.6 mAHD and by 0.9 m in 2100 to 1.0 mAHD), as determined by the NSW State Government’s 2010 Flood Risk Management Guide (Reference 7).
- Through-out the year, a series of elevated ocean levels (combination of high astronomic tides and/or storm surges) over a few days will “pump up” water levels in Wallis Lake. This “highest non-flood lake water level in a year” is estimated (Figure 4)

to be around 0.4 mAHD and will rise by an equivalent amount to the climate change sea level rise. Thus each year lake water levels of 0.9 mAHD (+0.5m sea level rise) and of 1.3 mAHD (+0.9m sea level rise) will occur as a result of elevated ocean levels.

- It is possible that the tidal range and seasonal variation in water level within the lake (i.e change in tidal prism) may change in response to rainfall or temperature changes but the extent is unknown at this time.

The increase in the "normal" water level in Wallis Lake in "non-flood" times may result in increased maintenance costs and/or modifications costs for existing developments and infrastructure due to more frequent inundation in non-flood times. For example, low lying roads will be more frequently inundated. Inflows of water from Wallis Lake to sewer surcharge vents in backyards may also occur more frequently. The increased cost for residents and Great Lakes Council to maintain the existing developments and infrastructure is unknown. A separate study is required to quantify the effect in non flood times but it is likely that at some time in the future the existing services in particularly low lying areas (say a road) will become unable to be maintained and it will have to be relocated or re-built. This may affect service standards to existing developments.

The increase in water levels during non-flood times may also see some areas of land that are currently dry become flooded most of the time. This will affect the current use of that land and strategic planning is necessary to reduce the economic impact resulting from this flooding.

Any change in the "normal" water level regime will impact on the ecology of Wallis Lake. The implications of this are largely outside the scope of this Floodplain Risk Management Study and Plan.

During Flood Times

There are several broad ways in which climate change and sea level rise will affect water levels in Wallis Lake during floods, namely:

- *The increase in ocean level* will raise the "normal" water level in Wallis Lake as well as the assumed ocean level adopted for design flood analysis in the 2012 Wallis Lake Flood Study Review (Reference 3). In this study an ocean dominated and rainfall dominated design flood scenario were examined. For each of these design scenarios the adopted ocean levels will rise due to climate change. The results are provided in Table 1.
- *The increase in peak rainfall intensity and storm volume* will increase design flood levels in Wallis Lake. The sensitivity of the lake flood levels to increased rainfall was investigated and the results are provided in Reference 3.
- *A change in entrance conditions* has not been investigated but it is likely that the effects of any change will be relatively small and have not been considered further at this stage.
- *A change in wind activity* on Wallis Lake will change the "wave runup" flood level around the foreshores. At this time the impact of this effect is unknown.

Are the Implications of Climate Change Significant?
A rise in the "normal" lake water level, annual peak lake water level and the design flood levels will have a significant effect.

4.9.4. Assessment of Change in Flood Damages

Figure 8a provides graphs that show the likely impact of ocean level rise on buildings inundated, flood damages, frequency of inundation and increase in average annual damages for the two ocean level rise scenarios of +0.5m (year 2060), +0.9m (year 2100). The results indicate that even a relatively small increase in ocean level of +0.5m will increase the number of building floors inundated in the 100 year ARI event by nearly threefold and increase the annual average damages by a similar magnitude. Also of significance is that the frequency of inundation will increase, thus the existing 100 year ARI level will be equalled or exceeded on average once in every say 50 years rather than once in every 100 years.

On a lake system the effect of an ocean level rise is magnified, compared to a river system, as the ocean level rise affects a large lake foreshore area with many surrounding buildings having floor levels a similar amount above the existing lake level. Thus a large number of buildings are affected. Figure 8b shows the increase in number of building floors inundated for caravan parks, Forster, Forster Keys, Tuncurry, Point Road Tuncurry, Green Point and the remaining properties combined together for the two ocean level rise scenarios of +0.5m (year 2060), +0.9m (year 2100). This information is summarised in Table 9.

Table 9: Building Floors Inundated

EXISTING							
Area	5y	10y	20y	50y	100y	200y	PMF
Caravan Parks	1	11	15	17	30	42	135
Coomba Pk etc,	1	2	3	5	11	17	76
Forster	0	0	0	3	8	14	742
Forster Keys	7	11	14	37	86	270	734
Green Point	0	0	0	4	4	10	28
Point Rd, Tuncurry	26	32	33	43	54	76	80
Tuncurry	9	19	29	128	224	329	1202
TOTAL	44	75	94	237	417	758	2997
0.5m Ocean Level Rise							
Caravan Parks	20	27	33	43	52	70	135
Coomba Pk etc,	6	9	11	19	22	25	76
Forster	4	6	9	19	63	153	744
Forster Keys	43	68	89	316	446	534	734
Green Point	4	4	6	12	17	22	28
Point Rd, Tuncurry	45	48	56	76	76	77	80
Tuncurry	157	209	232	357	514	677	1210
TOTAL	279	371	436	842	1190	1558	3007
0.9m Ocean Level Rise							
Caravan Parks	44	50	59	68	84	111	135
Coomba Pk etc,	19	22	23	25	27	34	77
Forster	38	74	135	180	213	308	744
Forster Keys	380	439	488	533	573	635	734
Green Point	13	17	19	22	24	24	28
Point Rd, Tuncurry	76	76	76	77	77	78	80
Tuncurry	475	566	636	708	784	896	1211
TOTAL	1045	1244	1436	1613	1782	2086	3009

Draft flood risk mapping taking into account ocean level rise is provided in Appendix B. Table 10 provides a tabulation of the number of properties in Low and High hazard areas under existing and 0.5m and 0.9m ocean level rise scenarios.

Table 10: Hazard in the 100 Year ARI with Ocean Level Rise

		Ocean Level Rise	
Classification of Property	**Existing**	**0.5m**	**0.9m**
Low Hazard	8343	10881	9996
High Hazard	10285	14565	17095
Total	18628	25446	27091
	% Increase	37%	45%
How Property Changes with Ocean Level Rise Compared to Existing			
Remains Low		4063	1533
Remains High		10285	10285
Not Previously Inundated Becomes Low		6818	8463
Low Becomes High		4280	6810

4.9.5. Implications of Future Development

Due to the limited availability and relatively small scale of residential zoned land in the contributing catchments, the hydrologic impacts (increased runoff) of increased building construction will have no significant impact on the flood regime (increased runoff or rate of runoff). Council's Development Control Plan requires new developments to not increase stormwater run-off into lake catchments

Future filling of the foreshore (for roads or building pads) will reduce the available temporary floodplain storage capacity. However, given the large foreshore surrounding the lake, the area of the lake (85 km^2), and the likely scale of the filling, it is considered that filling of the foreshore will have no significant impact on flood levels. All filling proposals must still be considered in terms of their potential impact on local drainage, affects on foreshore processes, and overland flow paths in the foreshore areas.

5. RISK MANAGEMENT MEASURES

5.1. General

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

Flood modification measures modify the flood's physical behaviour (depth, velocity and redirection of flow paths) and include flood mitigation dams, retarding basins and levees. At Wallis Lake this would also include any works that modify the entrance to the Pacific Ocean.

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

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

A number of the measures mentioned above were clearly not applicable to the flood situation at Wallis Lake and were deleted from consideration (refer Section 5.2) at an early stage of the study process. Measures which were subjected to more detailed consideration are discussed in the subsequent sections.

5.1.1. Relative Merits of Management Measures

A number of methods are available for judging the relative merits of competing measures. The benefit/cost (B/C) approach has long been used to quantify the economic worth of each option enabling the ranking against similar projects in other areas. The benefit/cost ratio is the ratio of the net present worth (the total present value of a time series of cash flows). It is a standard method for using the time value of money to appraise long-term projects of the reduction in flood damages (benefit) compared to the cost of the works. Generally the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health and other social and environmental effects). In this study the reductions in tangible damages to public utilities, non-residential and agricultural activities as a result of a floodplain management measure have not been included.

The potential environmental or social impacts of any proposed flood mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using the classical B/C approach. For this reason a matrix type assessment has been used which enables a value (including non-economic worth) to be assigned to each measure. Due to the limited number of options available this matrix was not rigorously used for each option. It is a recommendation of this report that multi-variate decision matrices be developed for specific foreshore management areas, allowing detailed benefit/cost estimates, community involvement in determining social and other intangible values, and local assessment of environmental impacts. The matrix in Table 11 is designed to set out a general scheme to illustrate how a local matrix might be developed.

5.1.2. Management Matrix

The criteria assigned a value in the management matrix are:

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

The scoring system for the above criteria is provided in Table 11 and largely relates to the impacts in a 100 year ARI event. These criteria and their relative weighting may be adjusted in the light of community consultations and local conditions.

Table 11: Matrix Scoring System

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

5.2. Measures Not Considered Further

Early in the study the Floodplain Management Committee was advised of possible floodplain management measures which could be applied in the study area. The measures were classified with regard to reduction in flood level, social effect, environmental impact, cost to implement and benefit/cost ratio. The Committee identified a number of measures that were not worthy of further consideration and these are summarised in Table 12 and in the following sections.

Table 12: Risk Management Measures Not Considered Further

Measure	Impact				
	Reduction in Flood Level	**Social Effect**	**Environ-mental Impact**	**Cost to Implement**	**Benefit/ Cost Ratio**
FLOOD MODIFICATION MEASURES:					
Flood Mitigation Dams, etc.	Yes	Nil	Very High	Very High	Low
Floodways and River Improvement Works	Yes	Very High	Medium	Very High	Low
Entrance Modifications	For flood events, yes but for tidal events, no	High	High	High	Low
Catchment Treatment	Minimal	Nil	Low	Low	Nil
PROPERTY MODIFICATION MEASURES:					
Voluntary Purchase of all Buildings Inundated in the Extreme Flood	Nil	High	Nil	Very High	Low
Rezoning of all Flood Liable Land	Nil	Very High	Some	Moderate	Unknown
RESPONSE MODIFICATION MEASURES:					
Flood Insurance	Nil	Some	Nil	Minor	unknown

5.2.1. Flood Mitigation Dams, Retarding Basins, On-Site Detention

Flood mitigation dams have been used in the past in NSW to reduce peak flows downstream (Glenbawn Dam, upstream of Muswellbrook on the Hunter River). However the dams also act as a water storage facility for irrigation. Dams are rarely constructed solely as a flood mitigation measure to protect existing development on account of the:

- high cost of construction,
- high environmental damage caused by construction,
- possible sterilisation of land within the dam area,
- high cost of land purchase,
- risk of failure on the dam wall,
- likely low benefit cost ratios,
- lack of suitable sites. A considerable volume of water needs to be impounded by the dam in order to provide a significant reduction in flood level downstream.

Large flood mitigation dams within the catchment are not viable on economic, social and environmental grounds. Construction of retarding basins (say up to 50 000 m^3) and the use of on-site stormwater detention or retention systems are increasingly being used in developing catchments. These measures are appropriate for use in controlling flooding in small catchments (say up to 5 km^2) or to mitigate the effects of increased runoff caused by development. However, these structures would have negligible impact upon flood levels in Wallis Lake.

5.2.2. Floodways and River Improvement Works

Floodways are lower overbank areas which act as second channels, carrying significant flow during floods. Floodways could be constructed along the major river tributaries however they would not reduce peak flood levels in the lake (and in fact may cause an increase by conveying floodwaters to the lake quicker). Combined with the high environmental, economic and social costs, this measure was not considered further.

River improvement works, such as desnagging, dredging or removal of hydraulic restrictions, reduces flood levels by increasing the hydraulic capacity of a channel. However, increasing the capacity of the rivers entering the lake, or the lake itself would have no impact upon the design lake levels. Dredging of the lake would also have no impact unless the dredging was undertaken above the normal water level. Even then the likely percentage increase in storage (compared to the total volume of the lake) would be minimal and consequently would provide no benefit in terms of reduced flood levels. Additionally there are considerable social, environmental and economic costs associated with such works.

5.2.3. Entrance Modifications

The present entrance from Wallis Lake to the Pacific Ocean is in the north-east corner, separating the townships of Forster and Tuncurry. It is approximately 80 m wide and 6 m deep. Changes could be made to the entrance, including deepening, widening or even constructing a second entrance, which would allow water out of the lake quicker than at present. This would reduce levels due to a rainfall induced event. However, during an ocean induced event (storm surge, wave setup, climate change), water levels may increase as more water is let into the lake. Combined with high social, environmental and economic costs this measure was not considered further.

5.2.4. Catchment Treatment

Catchment treatment modifies the runoff characteristics of the catchment to reduce inflows to the lake. For an urban catchment, this involves planning to maximise the amount of pervious area, maintaining natural channels where practical and the use of on-site detention. For a rural catchment, this involves limiting deforestation or contour ploughing of hill slopes. This measure can be effective on small catchments but has a negligible impact on large catchments such as Wallis Lake.

As a general concept, catchment treatment techniques should be encouraged (e.g. on-site detention, limit on-site imperviousness for developments, controls on rural land use) along with water quality and other environmental concerns as they are beneficial for purposes other than flood mitigation.

5.2.5. Voluntary Purchase of all Residential Buildings

Voluntary purchase of all the residential buildings inundated above floor level in the 100 year ARI flood (say $500,000 per building) cannot be economically or socially justified. Generally, government funding is only available for voluntary purchase of buildings that are frequently flooded in a high hazard area. As far as we are aware no residential building floors have been inundated since 1927.

However Figures 5 and 6 indicates that 26 building floors in the High Hazard Point Road, Tuncurry area are inundated in the 5 year ARI event, and 7 additional ones inundated in the 10 year ARI event. Thus potentially these buildings may be eligible for funding through a voluntary purchase scheme.

Voluntary purchase may introduce a number of social problems (residents are unwilling to sell or find alternative accommodation with similar attributes) which can be difficult to resolve. There was little support for this measure from the Committee or the public in the previous studies.

5.2.6. Rezoning

The 2010 NSW Coastal Planning Guideline: Adapting to Sea Level Rise (Reference 10) sets out principles for strategic and statutory land use planning in coastal areas. Principle 3 of the Guideline is to “avoid intensifying use in coastal risk areas…” and Principle 4 is to “consider options to reduce land use intensity in coastal risk areas where feasible”. While it seems “common sense” to prevent additional development in vulnerable areas this could, in effect, ‘freeze’ new development in all flood affected foreshore areas. This is contrary to the aim of the NSW Government’s 2005 Floodplain Development Manual (Reference 1) which seeks to allow new development in flood affected areas, provided the risk is adequately assessed and managed.

In general, it is likely to increase the risk to persons and property, if more buildings, infrastructure and people are located in flood hazard areas, particularly high hazard areas and areas vulnerable to permanent inundation. So, land in the existing Year 2012 flood hazard areas should not be re-zoned if it increases development intensity. Individual developments that increase development intensity within current zonings, should be assessed against the increased risk to persons and property as a result of the development to ensure there is no increase in risk.

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

The wholesale rezoning of all flood liable lands is not appropriate, but this measure could be used on a local scale as a means of removing or improving flood liable buildings. Rezoning to a lower land use intensity is supported for existing and future high hazard areas. However this approach is difficult to implement and may have financial implications for the land owner.

The above discussion relates to the existing Year 2012 flood hazard areas. For areas that become high hazard with sea level rise (refer Appendix B) detailed consideration needs to be made whether these areas should be developed and the nature of those developments. If these areas are developed in full consideration of sea level rise and inclusion of appropriate adaptation measures then they can proceed. Given the wide range of types/nature of developments possible more substantial guidelines cannot be provided at this time.

Council will need to review their sea level rise policy in light of the September 2012 decision of the NSW Government to repeal its 2009 Sea Level Rise policy.

5.2.7. Flood Insurance

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

Insurance companies will not cover damage from storm surge, but the Flood Study shows that it is rainfall events in the catchment that cause severe lake floods, with ocean induced lake levels significantly lower than rainfall induced levels.

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

5.3. Flood Modification Measures

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

- dams (not considered further – see 5.2.1),
- retarding basins (not considered further – see 5.2.1),
- entrance modifications (not considered further – see 5.2.3),
- levees, flood gates, pumps,
- local drainage issues,
- wind wave runup.

Discussion on each of the latter measures is provided in the following sections.

5.3.1. Levees, Flood Gates and Pumps

DESCRIPTION

Levees are built to exclude previously inundated areas of the foreshore from flooding or inundation from the lake up to a certain design event. They are commonly used on large river systems (e.g. Hunter and Macleay Rivers) but can also be found on small creeks in urban areas. They are used less frequently on coastal estuaries, but there are flood levees to mitigate lake flooding at, for example, North Entrance on Tuggerah Lakes in Wyong Council LGA.

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

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

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

DISCUSSION

There are no levee systems on the foreshores of Wallis Lake. On Tuggerah Lakes (south of Newcastle) there is a levee with associated flood gates at The Entrance North with Wilfred Barrett Drive acting as the levee bank. Photographs from the February 1990 and June 2007 floods indicate that in both events there was considerable flooding within the levee area. It is unclear whether this was due to the local catchment runoff being unable to drain away successfully to the lake or inflow from malfunctioning flap gates from the lake. Certainly Wilfred Barrett Drive (the levee) was not overtopped.

Some of the key issues regarding levees are summarised in Table 13.

Table 13: Key Features of Levee Systems

ISSUE	COMMENT
ADVANTAGES:	
"Environmentally Sensitive Measure"	A well-designed vegetated earthen embankment set back far enough from the foreshore to retain beaches and foreshore access, and that does not interrupt local drainage, can have minimal environmental impact. However, in many locations it is hard to meet all these criteria, and it will become increasingly difficult as lake levels rise and permanently inundate foreshore areas.
Protects a large number of buildings.	A levee system could protect a large number of buildings from being inundated up to the 100 year ARI or even larger flood event. At Wallis Lake it may not be possible to protect to the PMF as this event is much greater. At many other locations this is not possible due to the large height difference between the design events.
Low maintenance cost.	A levee system needs to be inspected annually for erosion or failure. The annual cost of maintenance will be (say) less than $10 000 per annum.
DISADVANTAGES:	
Visually obtrusive to residents.	Residents enjoy living on the foreshores of Wallis Lake because of the visual attraction of the water and a (say) 2.0 m high embankment will significantly affect their vista. Anything which reduces the vista is unlikely to be accepted by the majority of residents. A freeboard of usually 0.5m should be added to the design flood level of the levee (level of protection afforded by the levee) to account for wave action, slumping of the levee or other local effects.
High cost	The cost to import fill, compact and construct an earthen levee is dependant on the availability of good quality fill and the associated transport costs, these will vary depending upon the locality. However, generally it is the landtake and associated costs (possible services re-location and access) which add considerably to the cost. For these reasons no detailed costings have been undertaken at this stage. It is likely that levees will cost several million dollars depending upon their size and location but may be the only viable mitigation measure to protect against sea level rise.
Low to medium benefit cost ratio	Whilst the levee system may protect a large number of buildings from being inundated in a (say) 100 year ARI event it is likely to have a low benefit cost ratio as there are few buildings floors inundated (and so being able to be protected) in the more frequent floods (less than a 10 year ARI event). However with sea level rise the benefit cost ratio will increase and it may become economically viable.
Local runoff from within the "protected area" or upstream may cause inundation.	The ponding of local runoff from within the "protected area" may produce levels similar to that from the lake itself. At present local runoff already causes problems in several areas. Constructing a levee will compound this problem. It can be addressed by the installation of pumps or flap valves on pipes but these add to the cost and the risk of failure. This issue is probably not as significant as in other areas as the protected areas have generally little relief thus there will be no significant ponding in the low lying areas.
May create a false sense of security.	Unless the levee system is constructed to above the PMF level it will be overtopped. When this occurs the damages are likely to be higher as the population will be much less flood aware (as

	happened in New Orleans, USA in August 2005).
Relaxation of flood related planning controls.	Most residents consider that following construction of a levee the existing flood related planning controls (minimum floor level, structural integrity certificate) should be relaxed. However, many experts consider that this should not be the case unless the levee is built to the PMF level and the risk of failure is nil. The general opinion is that a levee should reduce flood damages to existing development but should not be used as a means of protecting new buildings through a reduction in existing standards.
Restricted access to the water.	Access to the water for boating and other activities requiring easy access will be restricted. This can be addressed by (expensive) re-design of entry points.

A range of levee options were investigated as part of the 1998 Forster/Tuncurry Floodplain Management Study (Reference 4). The levees were assumed to be built to the 100 year ARI flood level plus 500 mm freeboard. The scenarios investigated were:

- levee and floodgate at Beach Street, Tuncurry,
- levee and floodgate at Helen Street, Forster,
- levee and floodgate on the Point Road peninsula, Tuncurry,
- levee and floodgate at The Lakes Way, Forster Keys.

The hydraulic impacts were assessed using the hydraulic (MIKE-11) model established as part of the study and the results showed an impact of less than ∀0.1m for all options. The high construction costs combined with the limited reduction in flood damages resulted in all levee options having a low benefit-cost ratio (0.1), except for the option at the Point Road peninsula, Tuncurry (benefit-cost ratio of 0.7). However, other impacts such as loss of visual amenity and restriction in foreshore access were particularly relevant for this option.

As a result a further two options were assessed, reducing the height of the Point Road peninsula levee and constructing a deflector levee. However, neither of these options was considered viable. The historical flood behaviour of Wallis Lake indicates that frequent flooding is not a major concern and that a levee would need to be effective against very large floods (in the order of magnitude of the 1927 or the 100 year ARI floods) in order to be justified from an economic basis. Similarly, although a deflector would reduce the velocity of floodwaters in the Point Road peninsula region, it would not reduce the flood level and thus produce no reduction in flood damages. As a result of this investigation, no levee options were recommended for flood mitigation in Wallis Lake.

The present review of this management measure, taking into account the economic, hydraulic and social issues confirms this view that levees are not a viable solution to the flood problem at Wallis Lake but may be the only solution to protect existing buildings from sea level rise.

Urban areas other than Forster and Tuncurry which are affected by flooding from Wallis Lake were not considered for levee protection due to there being no buildings inundated in events smaller than the 100 year ARI.

Whilst at first glance levees may appear a viable means of protection of existing developments from the effects of sea level rise the above concerns with levees still apply. Once it is realised that levees may be the only solution to protect existing developments from sea level rise there may be a greater acceptance by the community.

Pumps have been suggested as a means of addressing the "internal drainage" problem but are not widely used in levee type situations in NSW. Some of the drawbacks of employing pumps are:

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

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

SUMMARY

A preliminary review of the flood liable areas surrounding Wallis Lake indicates that Forster/Tuncurry is the only area where a levee system may be feasible. The main issues of any such scheme are landtake problems, the reduction in visual quality and access to the lake enjoyed by the residents and the likely low benefit/cost ratio. Few residents supported this measure. This measure should be re-evaluated if a future development (e.g. road) can form part of a levee system. Whilst a slight reduction in the 100 year ARI flood level has occurred as a result of updated modelling and use of ALS (Reference 3) this change will not significantly increase the benefit/cost ratio and will have little impact on the reasons this measure was rejected by the residents in the past.

Levees are a means of protecting existing development and are not a recommended strategy for justifying new developments on the floodplain. The levee system at The Entrance North would appear to not have worked successfully in the February 1990 or June 2007 event due to issues with internal drainage.

This measure is one of the only means of protecting existing buildings from sea level rise and therefore must be considered further. From an engineering perspective it is possible to construct levees at say Point Road, Tuncurry, however in the first instance community acceptance must be obtained, land availability assessed, and environmental and social impacts considered. It is likely that such levee systems will have much higher benefit cost ratios in areas that will be permanently inundated by sea level rise.

5.3.2. Works To Minimise Local Drainage Problems

DESCRIPTION

Local stormwater flooding is probably the flooding mechanism which is most widely identified by the community as being of concern as there has been no significant flood in the last 20+ years on Wallis Lake. Local flooding occurs in nearly all suburbs on the foreshores due to the relatively flat grades. Many residents consider that local flooding is a significant issue (possibly many view this as a greater issue than the more infrequent flooding of Wallis Lake) and report this to Council.

The urban areas on the Wallis Lake foreshore generally have a kerb and gutter drainage system with an underground pipe network. Local drainage issues are therefore likely to be limited to possible surcharging of pipes due to high tailwater levels, potential blockage of pipes as well as ponding of local runoff.

DISCUSSION

Local ponding results from rainfall over the local catchment being unable to quickly drain away. Water ponds at low points in streets and yards causing minor inconvenience. This results from a lack of relief from land to lake. Generally it only occurs after over 24 hours of semi-continuous rain and will not cause above floor inundation.

Ponding in yards still occurs and may take several days to drain away. It is likely to be associated with high water table conditions. Local drainage issues are a common problem in such areas which have developed over a period of years with limited development controls.

Upgrading the sub-surface system to improve yard to road drainage would improve the situation in the short term but is unlikely to solve the longer term problem with sea level rise and would not be cost effective (on the basis of a reduction in tangible damages). Flap gates on culverts can prevent back flow from the lake but apart from at Tuncurry or Forster Keys this is unlikely to be an issue.

Debris (litter, vegetation) in the piped system is not considered to be a major contributing factor according to Council officers. Installation of agricultural drains in the yards would assist in reducing the incidence of local flooding. As the benefits of the works are largely intangible (reduction in inconvenience) it is difficult to justify these works on economic grounds.

SUMMARY

Local flooding is a significant issue for many residents but preliminary investigation indicates that there is no viable economic solution. One approach would be to more closely identify the worst affected areas and provide a newsletter suggesting how residents could minimise the impacts of nuisance flooding. This could be combined with assistance from Landcare groups to control exotic vegetation in the watercourses. A community based approach with input from Great Lakes Council, is likely to be the most successful.

At a minimum the problem should be more closely monitored and identified by Council. This should be accompanied by a public education program to explain the difference between local and lake flooding and how the public can be involved in reducing the local flooding problem. Council will address these issues where appropriate. Council will also prepare a drainage plan (if not already completed) showing the major drainage lines and pipe sizes, topography and the location of any flap gated culverts. This will assist in identifying problem areas and obtaining solutions.

5.3.3. Assessment of Wave Runup

DESCRIPTION

The actual flood level caused by wave runup at a site depends upon a combination of the still water level and the effect of local wind/wave action (wave runup) within the lake.

DISCUSSION

The wave runup effect at Wallis Lake depends upon a number of interrelated factors summarised in Table 14.

Table 14: Factors Influencing Wave Runup Effects

General Factors	Comment
Maximum Fetch across Wallis Lake	The length of open water used to determine the wind wave condition (varies from <1km to 10km).
Direction of Maximum Fetch	Design wind data vary depending upon the direction (by over 100%).
Approximate Offshore Water Depth	Can vary from 1 m to 5 m. This influences the breaking of the waves.
Local Factors	**Comment**
Offshore Beach Profile	The slope of the lake bed can vary significantly.
Foreshore Beach Profile	The slope and vegetation type influence the extent of wave activity.
Embankment or Seawall	Some locations have stone or earthen embankments. The height, slope and location of these structures relative to the shoreline and buildings influences the breaking waves.
Location of Nearest Building	Some buildings are located on the shoreline whilst others are over 50 m away.

Wave runup was determined in the Foreshore Flooding Assessment report (Reference 6) for the nominated 33 sites (Figure 3). This analysis was based on an assumed 100 year ARI flood level in Wallis Lake of 2.28 mAHD. However as part of Reference 3 this level has been reduced to 2 mAHD (Table 2) and consequently the wave runup levels have been adjusted to reflect this. The updated results indicate (for the 100 year ARI event) that the maximum increase due to wave runup is 1.0 m, the minimum is 0.1 m and the average is 0.5 m, as summarised in Table 15 and Figure 7.

Table 15: Wave Runup Effects - 100 year ARI Flood

Number of Sites	Recommended Wave Runup Design Flood Level (mAHD)	Increase in Flood Level (m) above Still Water Level of 2.0 mAHD
4	2.2 (or less)	0.2
5	2.3	0.3
7	2.4	0.4
5	2.5	0.5
4	2.6	0.6
8	2.6 to 3.0	>0.6

The key points regarding the use of wave runup data are summarised below:

- Wave runup effects produce an increase in the design flood level (Table 15) and also require that the structural integrity of any proposed structure be more closely examined.
- Council has adopted a 0.5 m freeboard (for setting floor levels of residential buildings) above the 100 year ARI flood level. A component of this freeboard allowance is to cater for the effects of wave runup, the other components are uncertainties in design flood estimation, local factors, climate change induced increases in flood level and the cumulative effects of subsequent fill. Based upon the flooding regime at Wallis Lake the greatest allowance is for wave action.
- 21 of the 33 sites analysed have a wave runup effect of 0.5m or less which is approximately within the 0.5 m freeboard allowance. However an additional wave runup freeboard allowance should be considered by Council as the magnitude of this effect is greater than what would normally be considered reasonable within the standard 0.5m freeboard.
- Of the remaining 12 sites, at the majority of these there is no existing development or potential for future development.
- Wave runup effects will generally only occur over a small percentage of the lake foreshore in a given event (in the prevailing wind direction).
- The effects will vary in time and space as a result of changing foreshore profiles. This may occur naturally (sedimentation, erosion, vegetation growth) or as a result of human activities (construction).
- New buildings located close to the foreshore will experience the greatest wave runup impact (increased design flood level and increased potential for structural damage). Further away the impacts reduce significantly. The zone of influence of the wave runup effect varies considerably depending upon the topography of the area. In a relatively flat area the impact may be over 200 m whilst in a steeply rising foreshore area the impact may be 10 m or less.
- Of the factors influencing wave runup (Table 14) only three, foreshore beach profile, embankment or seawall and location of nearest building, can possibly be modified to reduce the impact. The likely adverse social impact, the high cost and likely low benefit cost ratio makes any modification measure impractical.

SUMMARY

Council should explicitly include consideration of the wind wave effect within the development approval process. This can be achieved by modifying the development approval process to ensure that the proponent of any development on the foreshore considers the possible effect of wind wave action in the Development Application. The two main issues are certifying that the development will not exacerbate the wind wave action on surrounding properties (e.g construct a wall that diverts waves onto the neighbouring property) and ensuring that the effect of wind wave action is incorporated into the design if applicable. This may mean that an additional wind wave freeboard allowance is required.

This action is considered adequate at this time. Further monitoring will ensure that wind wave runup is accurately quantified and if necessary Council's procedure should be modified as new information becomes available. The approval process should be modified to ensure that any proposed development on the foreshore does not exacerbate the situation for surrounding properties and might be considered within a separate foreshore adaptation plan.

5.4. Property Modification Measures

5.4.1. House Raising and Flood Proofing

DESCRIPTION

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

House raising is suitable for most non-brick single storey buildings on piers and is particularly relevant to those situated in low hazard areas on the floodplain. The benefit of house raising is that it eliminates inundation to the height of the floor and consequently reduces the flood damages. Council's database does not provide sufficient detail regarding the raising potential of all flood inundated buildings. This would need to be undertaken if this measure is to be implemented.

An alternative to house raising for buildings that cannot be raised is flood proofing or sealing of the entry points to the buildings. This measure has the advantage that it is generally less expensive than house raising and causes less social disruption. However this measure is really only suitable for commercial and industrial buildings where there are only limited entry points and aesthetic considerations are less of an issue.

The floor level database comprises some 3000 floors of which approximately 500 are potentially suitable for raising but only 149 of these 500 are first inundated in the 100 year ARI or smaller events. However it is likely that with more detailed review of these 500 buildings a large number will have brick fireplaces or such like which means they cannot be raised.

DISCUSSION

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

The relative merits of this measure are provided in Table 16.

Table 16: Relative Merits of House Raising

<table>
<tr><th>ISSUE</th><th colspan="5">COMMENT</th></tr>
<tr><td colspan="6">ADVANTAGES:</td></tr>
<tr><td>Can be cost effective (benefit/cost ratio >1).</td><td colspan="5">Generally the majority of suitable low lying buildings which would provide a B/C ratio of >1 have either already been raised or are not suitable (low economic value).</td></tr>
<tr><td>Nil maintenance cost.</td><td colspan="5">May provide additional underfloor usage.</td></tr>
<tr><td>Resident can still enjoy benefits of existing life style.</td><td colspan="5">Residents do not have to move but will be inconvenienced during the course of work.</td></tr>
<tr><td>Grants are available.</td><td colspan="5">Each application is assessed on its merits.</td></tr>
<tr><td colspan="6">DISADVANTAGES:</td></tr>
<tr><td rowspan="7">The benefit/cost ratio is small unless the building is frequently inundated.</td><td colspan="5">The B/C ratio for raising a residential building (assuming a cost of $60,000) are:</td></tr>
<tr><td>No. of Houses Inundated</td><td>Floor Level at (ARI)</td><td>Lake Level (mAHD)</td><td>Benefit Cost Ratio if Raised</td><td>Incremental No. of Houses suitable for raising</td></tr>
<tr><td>44</td><td>5 year</td><td>1.4</td><td>1.5</td><td>6</td></tr>
<tr><td>75</td><td>10 year</td><td>1.5</td><td>1.0</td><td>17</td></tr>
<tr><td>94</td><td>20 year</td><td>1.5</td><td>0.8</td><td>21</td></tr>
<tr><td>237</td><td>50 year</td><td>1.8</td><td>0.3</td><td>33</td></tr>
<tr><td>417</td><td>100 year</td><td>2.0</td><td>0.1</td><td>72</td></tr>
<tr><td>Grants only cover the basic costs of raising the structure.</td><td colspan="5">Residents may have to provide their own funds to raise (say) pergolas or garages attached to the house. This can be a significant drawback for many residents.</td></tr>
<tr><td>Many buildings are not suitable.</td><td colspan="5">Detailed inspection may preclude a number of buildings initially considered to be suitable (e.g. stone fireplaces).</td></tr>
<tr><td>Residents are dislodged for a period.</td><td colspan="5">The residents may have to move for several weeks.</td></tr>
<tr><td>Impact on streetscape.</td><td colspan="5">The visual character of the neighbourhood can be affected.</td></tr>
<tr><td>Low acceptance by residents.</td><td colspan="5">In some locations there is a low acceptance by the residents. Generally where the building is frequently inundated the residents take up the offer. However, where the building is less frequently inundated (possibly never in the owner's lifetime) the residents reject the offer. This is likely to be the case at Wallis Lake.</td></tr>
</table>

Funding is available for house raising in NSW and has been widely undertaken in rural areas (Macleay River floodplain) and urban areas (Fairfield and Liverpool). An indicative cost to raise a house is $60,000 though this can vary considerably depending on the specific details of the house. Home raising was the traditional method of eliminating tangible flood damages but is less prevalent today in NSW as:

- the majority of suitable buildings have already been raised,

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

The house raising potential at Wallis Lake cannot be accurately assessed due to the lack of detail in the floor level database. However it is acknowledged that there will be some that could be raised (though many may be impractical or the owners are unwilling). It is likely that only houses with floors below the 20 year ARI would be considered for house raising as raising higher floors produces a lower benefit cost ratio.

Flood proofing or sealing off the entry points to the building has issues of compliance and maintenance. Based upon our experience we do not consider flood proofing a viable measure for existing houses on the foreshores of Wallis Lake. However flood compatible building or renovating techniques should be employed for extensions or renovations where appropriate. Guidelines are provided in a booklet *"Reducing Vulnerability to Flood Damage"* prepared in 2006 for the Hawkesbury-Nepean Floodplain Management Steering Committee (Reference 11).

A house raising/re-building subsidy scheme has been considered whereby the home owner can put the payment towards the cost of a replacement house constructed in a flood-compatible way rather than raising the existing building. Such a scheme has been promoted in other flood prone communities in NSW where there are large numbers of houses that could be raised but many owners wish to re build and/or consider it more cost effective. This scheme would provide a financial incentive to undertake house raising or re-building works and would be available to all house owners whose house is flood liable. However such a scheme is not expected to receive funding from the federal or State Government's flood mitigation program and thus is unlikely to be affordable.

Slab-on-ground construction is probably the current most common method of housing construction. A significant issue with this mode of construction is that the building floor is generally not much higher than the ground level, thus there is a risk with overland flow or shallow depths of flooding that some above-floor flooding will occur. House raising has been undertaken for slab on ground houses in the past (Fairfield) and should be investigated further in order to protect existing buildings from sea level rise. Slab-on-ground construction is much harder to adapt if sea level rise or other climate changes require a more radical or speedier response than currently predicted.

Subsidies for house raising implies that Council and the State Government will be maintaining the existing services and infrastructure for the life of the building, including provision for sea level rise. This situation needs to be reviewed before approval is given to ensure that these services can actually be provided for the life of the asset.

House raising can also be a means by which a new house can be built at the existing FPL but is constructed in such a manner that it can be raised in the future as climate change impacts occur. This type of modular/adaptive housing construction is not common in NSW but is employed in the USA where the habitable floor may be several metres above the ground. A concern with this approach is that the surrounding ground in the property may remain saturated due to rising water tables and will also become more frequently inundated. Also of concern is the increase in maintenance required to ensure the condition of the roads remains acceptable and evacuation routes are maintained. These issues will need to be addressed if this type of housing construction is permitted.

As limited funding for house raising is available from the State Government, future dwellings in areas subject to sea level rise should incorporate adaptable design elements to enable them to be more easily raised in the future.

SUMMARY

For the majority of currently flood affected buildings around Wallis Lake house raising and flood proofing are not viable means of flood protection. However if advertised and favourable responses are obtained from the owners a house raising subsidy scheme could be further investigated (subject to ensuring that Council and the will be maintaining the existing services for the life of the building and including sea level rise and funding will be available).

In addition a house re-building subsidy scheme should be initiated in order to provide an incentive to all house owners whose house floor is flood liable. This scheme is not currently supported by the NSW Government funding program however other NSW Councils have embarked on this approach.

Council should also consider whether slab-on-ground construction is an appropriate form of house construction in areas that will be subject to a climate change induced sea level rise. An alternative is to require houses that can have service connections adjusted, their floors easily raised in the future, or be re-located if the risk becomes too great.

5.4.2. Strategic Planning Issues

DESCRIPTION

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

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

With sea level rise the continued habitation or re-development of an area may become increasingly difficult to sustain, as the risk increases, and the maintenance of services and infrastructure becomes increasingly expensive. There are several flood liable areas in NSW where past floods have caused relocation to higher ground (Terara village to Nowra on the Shoalhaven River following the 1860 and 1970 floods) or the gradual decline of an area with limited potential for re-development (Horseshoe Bend at Maitland following the February 1955 flood).

Development controls for Wallis Lake are included in a number of planning documents including the Local Environmental Plan (LEP) - (1996), Council's Flood Policy and the Subdivision Development Control Plan.

A summary of the key points of Council's Flood Policy in the LEP is:

- despite any other provision of this plan, the consent of the Council is required for development below the Mean High Water (MHW) mark other than minor development,
- all works require consent if on flood-liable land (other than minor),
- the provisions of Council's Flood Management Policy are to be taken into consideration,
- Council may refuse consent if the development will significantly:
  - adversely affect flood behaviour, including flood peak at any point upstream or downstream of the proposed development and the flow of floodwater on adjoining land,
  - increase the flood hazard or flood damage to property,
  - cause erosion, siltation or destruction of riverbank vegetation,
  - affect the water table on any adjoining land,
  - affect riverbank stability,
  - affect the safety of the proposed development in time of flood,
  - restrict the capacity of the floodway,
  - require the Council, SES or any government agency to increase facilities or other resources associated with an evacuation resulting from flooding,
  - increase the risk to life and personal safety of emergency services and rescue personnel.

The two issues of continued habitation or approval for re-development must be considered in light of future elevated flood levels and the "normal" lake level due to sea level rise.

DISCUSSION

Flood extent mapping has been undertaken as part of this study, based on the best available information (airborne laser scanning and accurate to ±0.15m) and should be used by Council to identify properties subject to flood related development controls and as a result of sea level rise.

It may be that some existing developed areas cannot be protected by adaptation (house raising) or defence (levees) mechanisms. For these areas Council and the community will need to establish some form of retreat or re-development strategy. While such measures will not be necessary for many years, planning should start now to allow sufficient time to develop suitable adaptation plans, funding models, and market mechanisms to make the transition as easy and equitable as possible.

Each of these areas must be examined in detail as it may be that some form of “land swap” or similar can be achieved (as has being envisaged following the January 2011 floods in south east Queensland). For example, current developable land is turned into open space or some other use that will not be as affected by sea level rise. Alternatively some form of insurance fund or similar might be established to “pay out” affected land owners. The details of such a scheme have not been evaluated. A retreat policy needs careful consideration and significant public consultation before it can be implemented.

Many residential properties have land at 1 mAHD and during non-flood times this land is not inundated as the “normal” water level is around 0.1 mAHD with a maximum annual water level of around 0.4 mAHD.

With sea level rise the “normal” water level in Wallis Lake will rise by a similar amount to the ocean. This means that low lying land will be more frequently inundated by tides and at times of elevated ocean levels (storm surge, for example). With a 0.9 m sea level rise all land below 1 mAHD will be permanently inundated. It is predicted that this level will be the “normal” water level in Wallis Lake by approximately the year 2100. Consideration needs to be given to planning for when the land becomes unsuitable for habitation due to frequent inundation.

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

Filling

Filling of the foreshore is generally not considered an acceptable means of permitting future development as it “destroys” the ecology of the area, disrupts the lake foreshore processes, and affects local drainage. On riverine floodplains filling can raise flood levels by eliminating temporary floodplain storage and, in some cases, reduce the hydraulic conveyance. At Wallis Lake the hydraulic affect on flood levels will be negligible given the size of lake storage in the existing foreshore and the likely quantity of fill. If the ecological issues can be overcome this will provide a means of permitting future re-development at higher levels at the subdivision scale.

Filling close to the shoreline is more problematic, as it will have a greater environmental impact, and will be affected by rising lake levels. Even if the land surface is raised, rising ground water levels, foreshore recession, and increasing difficulty with drainage means filling close to the lake shoreline may not be a suitable or effective solution.

Managed filling could also be adopted for infill development as long as care is taken to ensure local drainage issues are not exacerbated and services (roads, sewer, water) can be accommodated. Possibly a staged approach can be undertaken where the new buildings and garages are constructed on elevated pads and in time the remainder of the property and the roads are raised. This piece-meal approach can lead to disharmony within the community when there are some filled and some non-filled properties.

The advantage of this approach is that it allows existing land owners to remain on their property and still enjoy the qualities of the area without construction of levees.

Planned Retreat

Permanent inundation, increased flooding, and foreshore recession as a result of rising lake levels may make some land unsuitable for future development or re-development.

However there is uncertainty regarding the predicted sea level rise or its timeframe. Thus it may be possible to permit development in these areas with the proviso that if the sea level rise eventuates then the development must retreat according to a planned retreat strategy. This strategy could be based on a suite of conditions, or thresholds including groundwater levels, inundation in non-flood times, continued provision of services and infrastructure, or availability of access allowing residents to stay until site conditions are considered unsuitable. While such measures will not be necessary for many years, planning should start now to allow sufficient time to develop suitable adaptation plans, funding models, and market mechanisms to make the transition as easy and equitable as possible.

Limit the Extent of Development

Future residential development in low lying areas could be restricted to the “lowest residential” zoning. Thus any development that will increase the present residential density would not be permitted. Thus dual occupancy, sub division or increasing the site coverage (increasing the size of the building) would not be permitted. In affected areas already zoned for medium density residential or urban centres, this could mean “back-zoning” to a lower development density, which may have legal and financial ramifications for Council. Legislative and financial options for Council and property owners to help deal with these situations should be raised with the NSW and federal Governments, as the problem will occur in all coastal LGAs. There is also the possibility of establishing “transferable development rights” or similar schemes to encourage voluntary changes to inappropriate property zonings. These controls could be further refined through local area adaptation plans.

Ensuring Adequate Evacuation

For many of the existing flood liable areas (Point Road and Forster Keys), even if house raising, construction of a levee or filling was undertaken, and the services issues resolved, there is still no safe access to high ground in flood. Whilst in a medical emergency a helicopter or flood boat could access the area many residents will attempt to cross the floodwaters (collect children, leave house, obtain food). This represents a burden on the SES to “rescue” residents and a risk to life to the residents who cross floodwaters unprepared.

At present many locations do not have adequate flood access and this will be exacerbated with sea level rise. The lack of adequate access may mean that some areas should not be further developed.

Set Back from Normal Water Level

Should a minimum set back (e.g to minimise wind wave effects or providing a riparian corridor) from normal water level be required?

Building Materials

Some building materials are less susceptible to damage by floodwaters, or are easier to clean after a flood. By using such materials, flood damages can be minimised.

Structural Soundness when Inundated:

Floodwaters can impact upon the structural soundness of buildings in a number of ways relating to flow velocities, depths and associated debris loads. These should all be considered in relation to certification of the soundness of structures for the local hydraulic conditions.

Fencing:

Fences, whether solid or open, can impact upon flood behaviour by altering flow paths. This impact will depend upon the type of fence and its location relative to the flow path. At Wallis Lake this is unlikely to be a significant issue for lake flooding but is of relevance for local catchment runoff.

Public Assets:

It is essential that all public assets which may be damaged by floodwaters are located to minimise (or hopefully eliminate) such damage.

Non-Residential and Special Use Properties:

The flood related development requirements for all non-residential properties need to be clearly identified, including Special Use (hospitals, schools, halls).

Wave Runup:

This needs to be adequately addressed in the Flood Policy.

Climate Change:

This needs to be addressed (refer Section 6.1).

Flood Planning Levels:

The flood planning level (FPL) is used to define land subject to flood related development controls and is generally adopted as the minimum level to which floor levels in the flood affected areas must be built. The FPL includes a freeboard above the design flood level. It is common practice to set minimum floor levels for residential buildings as this reduces the frequency and extent of flood damages. Freeboards provide reasonable certainty that the reduced level of risk exposure selected (by deciding upon a particular event to provide flood protection for) is actually provided. It is common practice throughout NSW to use a FPL of the 100 year ARI event plus a 0.5 m freeboard. The different FPLs adopted by Council should be clearly listed in the Flood Policy.

Wording on 149 Certificates:

Refer Section 5.6.1.

Formalise Flood Policy:

It is essential that Council develop a clear and unambiguous flood policy which is located in a single document.

SUMMARY

Strategic planning is the main approach for reducing flood damages to future developments and in particular to adapt to the implications of the sea level rise benchmarks. In some areas where the FPL or other criteria can only be achieved at considerable additional cost, there is community resistance to implementing these measures. However at Wallis Lake these measures are unlikely to involve such resistance.

No detailed assessment of each foreshore area has been undertaken or the necessary public consultation to determine which strategy should be employed, through local area adaptation plans, for example. It is recommended that this process be undertaken (it may take several years) to develop an appropriate approach for each foreshore management area.

This study has nominated foreshore management areas, however these could be further sub-divided into smaller areas if required. The two areas likely to experience the greatest impact from sea level rise are Point Road and Forster Keys. In some areas there are fewer properties likely to be affected (to the south of the lake) and the adaptation issues may introduce less significant challenges. Based on feedback from the proposed community consultation program Council will need to initiate a program to examine each area.

5.4.3. Provision of Public Services

DESCRIPTION

The ability of public services (sewer pipes, pumps and treatment plants; water pipes and pumps, electricity, gas; roads, traffic facilities, cycleways, footpaths and bridges; stormwater drains, stormwater pits and treatment devices) to accommodate increased water levels due to climate change is unknown. Probably the most critical (if failure during a flood occurs) is provision of sewerage. This loss of service affects both flood liable and non-flood liable properties if they are connected to a pump station that fails.

As lake levels rise some services will be affected by permanent inundation, increased tidal inundation, and rising water tables. This is likely to increase maintenance costs (roads and other services such as drainage, sewer, water, gas and electricity), as assets are affected by salt water corrosion and saturation, and access for maintenance becomes more difficult and expensive. Local stormwater drainage infrastructure will become less effective, and may have to be redesigned and replaced.

This will add to the maintenance budget of Council and any supply authorities and may mean that, for example, the road standard will be reduced to a lesser standard in order to maintain a level of service. A reduction in service levels may have ongoing ramifications for public safety and amenity.

DISCUSSION

When the predicted sea level rise benchmarks are considered with regard to the existing service levels, such as sewer outlets and manhole levels, significant works and costs are required to maintain the service at working condition.

Council and supply authorities need to undertake reviews of the impact of sea level rise on the maintenance of the services provided. Suggested inclusions in such a strategy include:

- Incorporate predicted sea level rises when designing and constructing new infrastructure,
- Liaise with Council regarding any proposed foreshore protection works,
- Map key water and wastewater assets vulnerable to climate change impacts, including sea level rise,
- Develop guidelines for network servicing strategies to include consideration of sea level rise,
- Update condition assessment of critical assets, including mains, to include considerations of sea level rise and other climate change impacts.

The provision of public services is essential for the continued habitation of flood liable areas. For some (water, electricity, gas) they can be relatively easily modified for sea level rise, others (sewer, stormwater drainage systems, roads) are more difficult but can be achieved. Failure of the sewerage system can occur during floods for may occur for many reasons including:

- Loss of electricity supply (power outage or damage to power lines caused by storm damage),
- Failure at the pumping station,
- The pumps are turned off as the water level rises above toilets or sewer vents.

The loss of supply of a sewerage system represents a potential life threatening hazard to human life as raw sewage will enter the flood waters which residents will be wading around in. In addition residents who do not have a functioning sewage system should be evacuated from their homes. This would also include those houses that are not flooded but experience a failure of the sewerage system for several days. This will place considerable additional burden on the SES.

The most difficult service to adapt to rising water levels is the provision of roads. Whilst infrequent flooding will cause only minor damage it is the frequent inundation of the road base by elevated “normal” lake levels that will incur significantly increased maintenance costs. This can obviously be addressed by filling and raising of the road but again at significant cost and disruption to the community (driveway access and local drainage issues).

SUMMARY

Future refinement of the planning practices for public service infrastructure will continue to benefit from integrated development and assessment, conducted by relevant service providers in collaboration with Council, of the impacts of elevated lake water levels and other climate change impacts. This will allow service providers to develop appropriate solutions, in consultation with relevant local communities, as part of local area adaptation plans for each foreshore management area.

Following the adoption of this Floodplain Risk Management Study and Plan, Council needs to work with key infrastructure providers to ensure they integrate the Study findings and Management Plan recommendations in their climate change adaptation planning. Infrastructure providers will have to develop local planning and maintenance assessments for areas vulnerable to sea level rise and increased flooding, for consideration when local area plans are developed by Council and the community.

5.4.4. Minimise the Risk of Electrocution

DESCRIPTION

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

DISCUSSION

There is always the risk of electrocution in times of flood and whilst this has occurred elsewhere there is no record of injury or loss of life due to electrocution on the foreshores of Wallis Lake. In order to reduce the risk of electrocution a flood education program should be undertaken in vulnerable communities, especially with older housing stock.

SUMMARY

There is a risk of electrocution during flooding and from an increase in lake water levels due to sea level rise on the foreshores of Wallis Lake which needs to be addressed. At a minimum flood education programs should encompass this issue, and there may be role for specific programs targeted at tradesmen, for example, to encourage safer installations.

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

5.4.5. Voluntary Purchase of Isolated Properties

DESCRIPTION

Voluntary purchase of all flood liable properties is not viable (Section 5.2.5). However, consideration was given to the voluntary purchase of isolated properties which are in high hazard areas where no other measures are appropriate.

DISCUSSION

No isolated properties were identified (isolated, relatively high hazard and damage) in the field or during the community consultation process.

SUMMARY

No properties have been identified. Should they arise at a later date they should be considered at that time.

5.5. Response Modification Measures

5.5.1. Flood Warning

DESCRIPTION

It will be necessary for a number of residents on the Wallis Lake foreshore to evacuate their homes in a major flood or ocean event. Whilst not all will have their floors inundated, it is likely that their power, gas, water and sewerage systems will be affected. Many residents may leave on their own accord with the SES having the responsibility of evacuating people in a life threatening situation.

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

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

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

The SES has a Flood Plan, the main features of which are:

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

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

DISCUSSION

Flood warning and the implementation of evacuation procedures by the SES, are widely used throughout NSW to reduce flood damages and protect lives. The BOM is responsible for flood warnings on major river systems such as Wallis Lake and its tributaries. Flood warning systems are based on stations which automatically record rainfall or river levels at upstream locations and telemeter the information to a central location. This information is then provided to the SES who undertake evacuations or flood damage prevention measures (sand bagging or raising goods).

Consideration is also given to ocean storm surge and tidal anomalies (where applicable) by the use of a simple tidal algorithm. Analysis is then undertaken to determine the expected time and height of the flood peak. At present there is a relatively sophisticated system for Wallis Lake, with its major tributaries (Coolongolook River, Wallamba River and Wang Wauk River) monitored as well as the lake levels and ocean influence. Probably the major limitation is the lack of actual flood events to test and refine the system.

The present system has never been tested during an actual flood (the lake has not risen to above 1.1 mAHD in the last 20 years or longer) and for this reason relies upon limited historical data. This is particularly the case for assessing the ocean influence.

Although Council monitors the situation during flood events the responsibility for preparing regional flood warning rests with the BOM and based on this information the SES issues community level warnings. Council does not issue warnings but assists the SES with road closures and evacuations.

Flooding on Wallis Lake differs from flooding on the tributary creeks or on major river systems. Firstly, the rate of rise of the lake is relatively slow providing more time for preparedness and evacuation. Secondly, the magnitude of rise is not as large (approximately 2 m in a 100 year ARI event) with the level responding more to the volume of runoff rather than the magnitude of peak inflows. Finally, the ocean influence (tidal, storm surge) is more dominant than in most river systems.

As the lake rises relatively slowly, residents are unlikely to be caught complete unaware and should have time to prevent damages by moving items such as televisions, rugs, clothing and cars, as long as they are in the building at the time or nearby.

The main problems with all flood evacuations are:

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

We presume that there would be sufficient supplies of food, water and medical facilities within Forster and Tuncurry to cater for the period of evacuation.

SUMMARY

The ocean influence is significant and must be adequately taken into account in any forecasting system. This effect is incorporated but due to the lack of floods has never been tested in a real event and relies upon very limited historical data. Whilst it takes a long duration rainfall event to produce an elevated lake level, the critical rise which produces the peak, can occur within the order of 6 to 12 hours. This is a short time in terms of the need to protect people and minimise damages.

It is considered that the present recently upgraded flood warning procedure should be adequate to predict the time and magnitude of the peak lake level. This would enable the SES to effectively manage their response to provide the maximum benefit. The linking of the floor level database used in this study to the flood warning system would ensure that the warning can be tailored to residents who would be affected rather than a blanket warning to all residents. The flood warning system should also be used to indicate where and when roads are inundated.

The greatest improvement in the accuracy of any flood warning predictions generally only occurs following major flood events. It is imperative therefore that a post flood assessment report be prepared following each future flood event.

Improving the flood warning system is relatively inexpensive and is likely to have a high benefit/cost ratio. It has no apparent environmental or social disbenefits. Contact has been made with the BOM and there is no requirement to upgrade the present system.

5.5.2. Flood Emergency Management

DESCRIPTION

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

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

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

DISCUSSION

The SES has the skills and experience to undertake the necessary evacuations.

SUMMARY

The SES should ensure that the Local Flood Plan for all settlements surrounding Wallis Lake is up to date. This might include floor level and ground level details provided in this report. In addition, input from the local community (e.g Council, RFS, and community representatives) through a Community Flood Emergency Response Plan (CFERP)) is required to ensure that workable actions for the community are incorporated. Priority should be given to the implementation of this Plan once completed, which will involve ongoing community education and awareness.

5.5.3. Public Information and Raising Flood Awareness

DESCRIPTION

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

Flood Awareness: How aware is the community to the threat of flooding? Has it been adequately informed and educated? How aware is the community to the threat from sea level rise?

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

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

DISCUSSION

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are aware of the potential of the situation. On river systems which regularly flood, there is often a large, local, unofficial warning network which has developed over the years and residents know how to effectively respond to warnings by raising goods, moving cars, lifting carpets, etc. Photographs (of less importance with digital photography) and other non-replaceable items are generally put in safe places. Often residents have developed storage facilities, buildings, etc., which are flood compatible. The level of trauma or anxiety may be reduced as people have "survived" previous floods and know how to handle both the immediate emergency and the post flood rehabilitation phase in a calm and efficient manner. However the above is not likely to be the case at Wallis Lake due to the lack of significant flooding on the lake since 1927.

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

- *Frequency and impact of previous floods.* A major flood causing a high degree of flood damage in relatively recent times will increase flood awareness. If no floods have occurred, or there have been a number of small floods which cause little damage or inconvenience, then the level of flood awareness may be low. There have been no recent floods which caused inundation of areas which means that the community generally has a low level of awareness at this time.
- *History of residence*. Families who have owned properties for generations will have established a depth of knowledge regarding flooding and a level of flood awareness. A community which predominantly rents homes and stays for a short time will have a

low level of flood awareness. It would appear that there is a mixture of residents and there are also a number of tourists in the town at any one time, with the population doubling during the Christmas season and they would not be familiar with the hazard.

- *Whether an effective public awareness program has been implemented.* It is understood that no large scale awareness program has been implemented, however the SES and Council have made available booklets on how to deal with flooding.

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

A major hurdle is often convincing residents that major floods (such as April 1927) will occur in the future. Many residents hold the false view that once they have experienced a large flood then another will not occur for a long time thereafter. This viewpoint is incorrect as a 100 year ARI (or sometimes termed a 1% AEP event) has the same chance of occurring next year, regardless of the magnitude of the event that may have recently occurred. A similar analogy is after "tossing" a coin say 5 times and coming up with "heads" each time, the chance of "heads" on the next throw is still 50:50.

Some NSW Councils (Rockdale, Pittwater, Maitland) have initiated catchment-wide flood awareness strategies (for residential and commercial). For Wallis Lake only a residential strategy is required as there are few significant commercial areas in flood hazard areas. Many Councils (Lake Macquarie, Pittwater) and the SES websites also provide excellent information on flood awareness and other flood related and climate change information.

SUMMARY

Based on feedback and general discussions, the residents of the townships surrounding Wallis Lake have a low level of flood awareness and preparedness.

The SES has a medium level of awareness of the problem and the requirements necessary to effect evacuations. Although the SES have never had direct experience of actual floods on Wallis Lake. It is important that a high level of awareness is maintained through implementation of a suitable Flood Awareness Program. Table 17 provide examples of methods that can be used.

Table 17: Relative Merits Flood Awareness Methods

Method	Comment
Letter/pamphlet from Council	These may be sent (annually or biannually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive and effective measure. The pamphlet can inform residents of ongoing implementation of the Risk Management Plan, changes to flood levels, climate change or any other relevant information.
Council website	Council should continue to update and expand their website to provide both technical information on flood levels as well as qualitative information on how residents can make themselves flood aware. This would provide an excellent source of knowledge on flooding on the foreshores of Wallis Lake (and elsewhere in the LGA) as well as on issues such as climate change. It is recommended that Council's website continue to be updated as and when required.
Community Working Group	Council should initiate a Community Working Group framework which will provide a valuable two way conduit between the local residents and Council.
School project or local historical society	This provides an excellent means of informing the younger generation about flooding and climate change. It may involve talks from various authorities and can be combined with topics relating to water quality, estuary management, etc.
Displays at caravan parks or similar	This is an inexpensive way of informing the tourist/holiday maker community and may be combined with related displays.
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advise of potential hazards. These are inexpensive and effective but in some flood communities not well accepted as it is considered that they affect property values.
Articles in local newspapers	Ongoing articles in the newspapers will ensure that the flood and climate change issues are not forgotten. Historical features and remembrance of the anniversary of past events are interesting for local residents.
Collection of data from future floods	Collection of data (photographs) assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible (as occurred successfully after the June 2007 long weekend event).
Types of information available	A recurring problem is that new owners consider they were not adequately advised that their property was flood affected during the purchase process. Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. This information also needs to be provided to all visitors who may rent for a period. Some Councils have conducted "briefing" sessions with real estate agents and conveyancers.
Establishment of a flood affectation effects database and post flood data collection program	A database would provide information on (say) which houses require evacuation, which public structures will be affected (e.g. telephone or power cuts). This database should be reviewed after each flood event. It is already being developed as part of this present study. This database should be updated following each flood with input from the community.
Flood preparedness program	Providing information to the community regarding flooding helps to inform it of the problem and associated implications. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program would ensure that the community is adequately prepared. The SES would take a lead role in this.
Develop approaches to foster community ownership of the problem	Flood damages in future events can be minimised if the community is aware of the problem and takes steps to find solutions. The development of approaches that promote community ownership should therefore be encouraged. For example residents should be advised that they have a responsibility to advise Council if they see a problem such as blockage of drains or such like. This process can be linked to water quality or other water related issues including estuary management. The specific approach can only be developed in consultation with the community.

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

5.6. Other Management Measures

5.6.1. Issuing of s149 Certificates

DESCRIPTION

Councils issue planning certificates to potential purchasers under Section 149 of the Environmental Planning and Assessment Act of 1979. The function of these certificates is to inform purchasers of planning controls and policies that apply to the subject land. Planning certificates are an important source of information for prospective purchasers on whether there are flood related development controls on the land. They need to rely upon the information under both Section 149(2) and 149(5) in order to make an informed decision about the property. It should be noted that only Part 2 is compulsory when a house is purchased and thus detail in Part 5 may not be made known to the purchaser unless it is specifically requested. Under Part 2 Council is required to advise if it is aware of the flood risk as it is of any other known risk (bush fire, land slip etc.).

DISCUSSION

Because of the wide range of different flood conditions across NSW, there is no standard way of conveying flood related information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on the type of flooding, whether from major rivers or local overland flooding, and the extent of flooding (whether widespread or relatively confined). New technology allows the possibility of this information being available through an on-line property inquiry.

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

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

In addition the hazard category could be provided and also advice regarding climate change increases in flood level.

Flood related development controls (such as stipulation of a minimum floor level at say the 100 year ARI plus a freeboard of 0.5m – termed the Flood Planning Level or FPL) are the most constructive measure for reducing flood damages to new residential developments. Developments more vulnerable to flooding (hospitals, electricity sub stations, “seniors” housing) must consider rarer events greater than the 100 year ARI when determining their FPL. With predicted sea level rise the FPL is increased to account for climate change for the life of the development. However, the FPL does not address the full range of issues when considering flood and permanent inundation risk such as access and failure of essential services.

The 0.5 m freeboard should still be included in the FPL and, as recommended in the 2010 Flood Risk Management Guide (Reference 7), it should not be assumed that the freeboard can take full account of climate change. According to the 2005 Floodplain Development Manual (Reference 1) the *purpose of the freeboard is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of a FPL is actually provided given the following factors*:

- uncertainties in estimates of flood levels,
- differences in water level because of "local factors",
- increases due to wave action,
- the cumulative effect of subsequent infill development on existing zoned land, and
- climate change.

In a real flood some of these factors may reduce the flood level (local factors) or not apply at all (no wave action). Whilst climate change is included as one of the above factors there is no advice as to what the contribution for each factor should be. The 2010 Flood Risk Management Guide (Reference 7) states "*Freeboard should not be used to allow for sea level rise impacts, instead these should be quantified and applied separately*..". The 0.5 m freeboard allowance allows for uncertainties, thus, if the best advice is that sea levels will rise by 0.9 m by the year 2100, the FPL should be calculated to include this rise in the modelled flood heights. The climate change component in the 0.5 m freeboard allowance accounts for any uncertainty in estimation of the 0.9 m sea levels rise, and other climate change factors that are more difficult to predict such as changes in rainfall intensities and storm frequencies.

Whilst raising the floor levels will ensure that the floors are not flooded in the design event (with sea level rise) there is still the issue of whether adequate services (sewer, roads) can be provided and that the private land will be suitable for habitation (i.e not permanently or regularly inundated so as to make the land unsuitable).

SUMMARY

It is recommended that Council consider issuing Section 149 Certificates and to include notification about areas likely to be permanently inundated by the "normal" lake level in the year 2100. There is an option for separate notifications for flooding, and for permanent inundation as a result of predicted sea level rise by the year 2060 and 2100. However this matter would have to be reviewed by Council following NSW Government's decision to repeal its 2009 sea level policy in September 2012.

As Council information for 149 Certificates is obtained mainly from computerised databases and maps, Council should investigate ways to make property-based flooding information more accessible via its web-site.

5.6.2. Planning Regulations for Tourist/Caravan Parks

5.6.3. Controls on Caravan Parks in the Floodplain

DESCRIPTION

There are currently eight caravan parks located on or near the Wallis Lake foreshore at Forster and Tuncurry (Figure 2). Whilst these are referred to as caravan parks it is recognised that much of the accommodation may be in cabins and permanent vans. An accurate estimate of flood damages on caravan parks is not possible, due to the large variability in the number of vans at any point in time, as well as the potential for vans to be moved during times of flood.

Caravan parks within the floodplain present their own unique problems, these may include:

- there is generally poor access with a single entrance/exit which may be controlled by gates,
- only a poor (or no) site map is generally available to show the internal road system or the types of vans,
- fixed annexes which may contain high cost equipment such as freezers or stoves,
- there is poor internal lighting which may fail during a flood,
- there is generally no flood emergency plan or it has not been tested recently,
- there is a problem in communicating to the residents due to the lack of or failure of the public address system or telephone network,
- short term residents will have little flood awareness of the flood risk or damage minimisation measures,
- a large number of vans may be vacant thus increasing the workload and possible risk to life for the rescuers involved with removing the vans,
- there is the risk that vans may float and crash into each other or obstruct exit routes,
- caravans have little structural integrity and thus can easily be damaged by flowing water,
- the internal fittings (cupboards, fridges, beds) are usually non-removable and made from materials quickly damaged by floodwaters.

DISCUSSION

In theory caravans can be easily moved to high ground in a flood, however, in practice experience has shown that this is unlikely to occur for some of the above reasons.

Wallis Lake has a much slower rate of rise than a river system and there is nearby high ground where vans could be moved. In events up to the 20 year ARI flood the risk to life is low. In larger events the risk increases as vans may float and crash into each other. However this can be mitigated and some Councils (Shoalhaven City Council) have special provisions for caravan parks on the floodplain such as:

- rapid knock down annexes,
- quick release ties on the vans to prevent them floating away,
- an effective evacuation strategy documented in a Flood Action Plan,
- restrictions on the type of vans, e.g. untowable vans not permitted in certain areas, no rigid annexes,
- specific inclusion of caravan parks in the SES Local Flood Plan.

SUMMARY

Caravan parks on the floodplain can represent a significant hazard during a flood. Although it should be noted that compared to the flooding situation on river systems, the risk at Wallis Lake is probably still low due to the relatively long warning time, low overbank velocities and ease of access to high ground. This issue should be investigated further through a detailed inspection by the park manager and the SES to accurately assess the hazard at each park. Following this, consideration should be given to implementing adequate safety provisions which would probably mean updating their existing flood evacuation plan. Consideration should also be given to introducing some of the special provisions indicated above. At a minimum at risk parks should be clearly identified in the SES Local Flood Plan.

The caravan park owners should prepare/update an evacuation plan for the sites and the plan should be reviewed every two years or after a significant flood.

6. DEVELOPMENT MEASURES

This chapter discusses measures to deal with future development within or near the study area to ensure that it will not significantly affect the flooding regime, or if it does, that the impacts are addressed.

6.1. Climate Change

6.1.1. Possible Adaptation Strategies - Existing Developments

At some localities in NSW an increase in flood level or the normal water level will have little impact on the existing or development potential of the area. For the floodplain surrounding Wallis Lake this is not the case and both a rise in the normal water level and the design flood levels will have significant implications for the area and needs to be addressed. Possible adaptation strategies for existing properties are described below.

Flood Warning and Awareness: Flood warning and flood awareness are measures that are currently employed within Great Lakes LGA to lessen the impacts of flooding. It is unlikely that significant advances can be made in these measures to negate the adverse impacts of climate change. However the present flood awareness program by the SES and Great Lakes Council should be updated to include potential climate change impacts.

Flood Modification Measures: Flood modification measures such as dredging the existing entrance channel or forming a 2nd entrance should be further examined but may still be unviable. Currently these measures are cost prohibitive and may introduce environmental issues that would need to be addressed. In other areas measures considered are a Thames River style barrage to prevent elevated ocean levels from entering. Unfortunately such a barrier is unlikely to be successful for all events as the same meteorological event that produces elevated ocean levels (storm surge) also produces intense rainfall causing flooding. Thus a barrier would provide little benefit in such a scenario at Wallis Lake.

Levees: Levees are one such measure that could be used to protect existing development. Whilst at first glance levees may appear a viable means of protection there are a number of concerns with their application, including:

- High cost,
- Landtake cost and can the land be obtained?
- Flooding from rainfall within the leveed area can itself be a major problem. Pumps or gravity systems to remove this runoff are not always successful,
- Levees restrict access (boating, fishing etc) and views of the water are the main reason why residents live in such areas,
- To be 100% secure they need to be constructed to the PMF level,
- Vehicle access to the leveed area and services relocation will generally require extensive additional works,
- Levees require on-going maintenance and a failure in any part during a flood (bank collapse, flap gated culvert fails) renders the structure of little value.

In conclusion levees can provide a mitigation measure but for the reasons given above it is likely that for many areas this will not be a viable measure.

House Raising: House raising has been used at many places in NSW (Maitland, Lismore, Kempsey, Fairfield) as a viable means of flood protection. It is likely that some of the existing flood liable buildings could be raised but not all buildings are viable for raising for the following reasons:

- It is more cost effective to construct a new house,
- Generally only single storey houses can be raised,
- Generally only timber, fibro and other non masonry construction can be raised,
- Generally only pier and non slab on ground construction can be raised,
- There can be many additional construction difficulties (brick fire place, brick garage attached to house, awnings or similar attached to house).

In conclusion it will not be possible to raise all the flood liable buildings and other measures need to be employed. However for existing houses raising is a viable solution if the area remains serviceable (adequate sewer and roads).

Areas that Cannot be Protected by Adaptation Measures: It may be that some areas cannot be protected by the above adaptation measures. For these areas Council will need to establish a retreat policy.

6.1.2. Possible Adaptation Strategies - Future Developments

These are discussed in Section 5.4.2.

6.1.3. Related Issues that may threaten the Long Term Viability of Areas

Evacuation Requirements: For some of the existing flood liable areas (Point Road) even if house raising or construction of a levee was undertaken and any services issues resolved there is still no safe access to high ground in flood. The lack of adequate access may mean that some areas should not be further developed.

Frequency of Inundation of Land in Non Flood Times: With ocean level rise then the normal water level in Wallis Lake will rise by a similar amount to the ocean level rise. This will mean that low lying land will be more frequently inundated and with a 0.9m ocean level rise all land below approximately 1 mAHD will be permanently inundated. Consideration needs to be given to when the land becomes unsuitable for habitation due to frequent inundation.

Maintenance of Services: A rise in the normal water level in Wallis Lake and more frequent inundation during floods, as a consequence of an ocean level rise, will impact on the maintenance of services (mainly roads but presumable many other services as well, such as sewer, gas and electricity) and ongoing ramifications for public safety or such like.

6.1.4. Summary

According to the world's experts a climate change induced ocean level rise is inevitable and the NSW Government's benchmark for the rise is 0.4m by the year 2050 (0.5m by 2060) and 0.9 by the year 2100. As such Great Lakes Council must include the effects of climate change in their flood related development controls and in conjunction develop an ocean level rise adaptation strategy for both existing and future developments. This strategy would examine each of the floodplain management areas, consider each of the possible adaptation measures and propose a preferred approach. It is possible that different approaches will be undertaken in different areas and differences for green-field sites compared to infill development. These issues would need to be canvassed with Council Officers.

Development of this ocean level rise adaptation strategy may take two years and involve input from a range of disciplines as well as extensive community consultation. As an interim measure the following should be employed.

- All new developments must include a ocean level rise component of 0.9m in the Flood Planning Level,
- The Section 149 certificates should be modified to include text on the potential implications of climate change,
- There should be no increase in the current density of residential development unless there is flood free access to suitable high ground in the 100 year ARI event plus 0.9m ocean level rise.

In December 2008 Great Lakes Council placed the following Draft Climate Change Policy on exhibition (this policy has now been adopted by Council):

- *Council adopt as a matter of policy, a sea level rise of 0.91m to the year 2100 with a linear rise over the intervening period.*
- *On large subdivisions and rezonings where there is limited impact on adjoining properties, ground levels be raised to a level equivalent to the 1% flood level with allowance for climate change to the year 2100. Developments on this land be required to have floor levels 500mm higher than the 1% flood level.*
- *For infill development floor levels be raised to 500mm above the 1% flood level with allowance for climate change to the year 2060 unless such house raising will have an adverse impact on access, neighbouring properties or the surrounding streetscape.*
- *In conjunction with any application involving extensive areas of filling, the applicant be required to submit a flood study to indicate that such filling will not adversely impact on storm flows or flooding in the area. Such studies to be based on full allowance for climate change.*
- *Applications upstream of the river mouth be required to submit a flood study to indicate flood levels including any impacts from climate change to enable assessment by Council officers.*

Council should now consider whether this policy should be reviewed in light of the NSW Government's decision of September 2012 to repeal its 2009 sea level rise policy.

6.2. Further Development in the Upper Catchment

DESCRIPTION

All catchments draining to the lake have development in their lower reaches with increasing pressures on Council to permit further subdivisions, increase the density of development and permit infill development within the catchment.

Catchment development has the potential to impact on the lake system in a number of ways including:

- deforestation and other rural activities will increase the amount of runoff entering the lake. However, it is unlikely that they will have any measurable impact on flood levels,
- a likely increase in the amount of pollutants and sediments generated. This may result in a further reduction in the quality of the creeks and lake system. This is unlikely to affect the peak flood levels within the lake. Pollutants may promote the growth of excessive vegetation and possible algal blooms,
- a likely increase in erosion and consequent sediment load in runoff as a result of construction activities. As with the pollutants, this is likely to enter the lake system but will have little impact upon flooding,
- an increase in runoff volume due to a decrease in the extent of permeable land. This is a relatively small impact which will have little impact upon lake levels,
- a decrease in the time of travel and thus an increase in the peak flow. This results from an increase in hydraulic conveyance in pipes and lined channels and a reduction in temporary floodplain storage due to filling. This effect has the greatest potential for increasing peak flows within the contributing creek system but will have little impact upon lake levels.

The potential for development in the lower catchment to impact upon lake levels as a result of filling is considered in Section 6.3.

DISCUSSION

Water quality issues are becoming increasingly important and Government bodies are encouraging people to minimise pollution, recycle materials and not dispose of harmful material to our drainage systems. Whilst these impacts will have no significant impact upon lake levels, community awareness and acceptance of these issues will assist in a better appreciation of other water related and environmental matters. It is hoped that this will provoke a more pro-active solution to the problem rather than an adversarial developer versus Council position.

Council should consider the construction of gross pollutant traps, macrophyte ponds or other pollution control devices to minimise the adverse effect downstream. The cost of these structures is much reduced if they can be incorporated into redevelopment of an area rather than retro-fitted. Increased public awareness of these issues (TV, radio, newspaper, Council notices) will assist in reducing the increase.

SUMMARY

Further development in the upper catchment is controlled by Council's existing development policies and consequently should have no significant impact upon lake levels. The principles of catchment treatment (as discussed previously) to minimise runoff and improve water quality should be encouraged by Council.

6.3. Filling of Land Surrounding the Lake

DESCRIPTION

Filling of low lying land is generally undertaken to raise the level of a building pad to ensure that the floor level is above the nominated standard. If the land is within the floodplain it can result in:

- the loss of temporary floodplain storage which could cause an increase in peak flow and flood level downstream,
- the loss of available flow path which could result in an increase in flood level upstream,
- redirection of local runoff onto adjoining properties.

DISCUSSION

The hydraulic impacts (raising of lake levels or change in velocity or flow path) of filling on the floodplain of a lake system such as Wallis Lake are much less significant than on a creek system. The effect of a loss of temporary floodplain storage within the floodplain of Wallis Lake (as a result of filling land or building construction) can also be effectively ignored as it represents such a small percentage of the total amount available. In most circumstances the loss of flow path is not a significant issue and can be ignored. The only exception to this may be at Point Road, Tuncurry where there is the potential to adversely affect flood levels, velocities and flow paths. As advised previously, a rigorous flood study is required for any filling or development proposed in this area. The most significant impact of filling is likely to be the redirection of local runoff (say) onto adjoining properties. The extent of this impact depends upon the topography of the local area. The locations of fences or other hydraulic impediments will also have a large effect. Whilst all these matters must be addressed in the development process the impact of a redirection of local runoff on flood levels in Wallis Lake will be negligible.

SUMMARY

Each application by a developer to fill land within the floodplain of Wallis Lake should be considered on its merits. In general any reasonable amount of filling (say for the building pad) should not be rejected on account of the impact on lake levels. However, the location of the fill and the likely impacts on the surrounding local drainage of the properties must be addressed. At present this issue is not considered within Council policies. Council should keep a database (plan and text) of all approved fill applications so that the cumulative effects can be monitored. A detailed flood study is required for any proposed development in the Point Road, Tuncurry area or when large scale filling is proposed. At this time there is no such proposal for large scale filling and for this reason the hydraulic effects of filling have not been modelled as part of this study.

7. WALLIS LAKE FLOODPLAIN RISK MANAGEMENT PLAN

7.1. Introduction

The Wallis Lake Floodplain Risk Management Plan has been prepared in accordance with the NSW Floodplain Development Manual (April 2005) and the August 2010 Flood Risk Management Guide – Incorporating sea level rise benchmarks in flood risk assessment and:

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

Wallis Lake lies approximately 250 kilometres north of Sydney in the Great Lakes region of the mid-north coast of NSW. It is bounded on the south by the Smith Lake and Myall Lake catchments, on the west and north by the Manning River catchment and in the north-east by the Khappinghat Creek catchment. The lake is a relatively large body (85 km^2) with moderate depths (average depth of approximately 2 m) and is approximately trapezoidal in shape, 40 km in the north-south direction, and 30 km to 40 km in the east-west region (Figures 1, 2 and 3).

The present rock breakwater entrance to the Pacific Ocean is in the north-east corner separating the townships of Forster and Tuncurry. However, breakouts to the ocean will have undoubtedly occurred in the past along the narrow strip adjacent to Seven Mile Beach near Tiona (Figure 1).

The highest recorded water level in the lake is of the order of 2.3 mAHD in April 1927. However since that time there are no records of lake levels above 1.1 mAHD, though subsequent construction of a breakwater at the entrance will have had a large impact on flood levels in the lake.

Flooding causes significant hardship (tangible and intangible damages) to the community, and the impacts will increase as sea levels rise, and for this reason Great Lakes Council has undertaken a program of studies to address the management of flood risks.

The present review was initiated by Great Lakes Council in order to consider projected sea level rise using the NSW Government's sea level rise benchmarks (NSW Sea Level Rise Policy Statement, 2009). These were based on projections by the Intergovernmental Panel on Climate Change (IPCC) and the CSIRO/BoM technical report (Climate Change in Australia, 2007). Possible increases in rainfall intensities due to climate change also have the potential to affect future flood behaviour.

In September 2012 the NSW State Government withdrew the sea level rise policy, instead requiring individual councils to select and justify their own benchmarks. Great Lakes Council proposes to utilise the previous benchmarks on the basis that they serve as responsibly conservative guides pending the outcomes of the 5th IPCC review in 2014. The primary objective of the review is to assess potential scenarios that would arise due to climate change and investigate suitable risk management responses.

7.2. Risk Management Measures Considered

A matrix of possible management measures taking into account a range of parameters was used in this Floodplain Risk Management Study to assess the various measures. This process eliminated a number of flood risk management measures (refer Section 5.2) including:

- Flood mitigation dams and retarding basins: - on the basis of high cost, large footprint, and environmental impact,
- Modifying the existing entrance channel or constructing a new entrance at another location: - on the basis of high cost, may exacerbate flooding, and environmental impact,
- Catchment treatment, to increase soil infiltration and storage of rainfall in the catchment: on the basis of minimal reduction in flood levels,
- Voluntary purchase of flood affected buildings, as it is uneconomic and has a high social impact,
- Providing universal or subsidised flood insurance: on the basis that it is outside the scope of this present study and is currently being re-assessed as part of the Commission of Inquiry into the South East Queensland floods of January 2011.

The full range of measures was evaluated in Section 5 and the outcomes are summarised in Table 18. Community opinion on the full range of options was canvassed during the public exhibition period of the management study in May 2011. However it should be noted that these outcomes may change in time if community expectations change as a result of climate change implications and/or as an outcome of preparation of local area adaptation plans.

Table 18: Summary of Management Measures Investigated in Study

MEASURE	PURPOSE	COMMENT
FLOOD MODIFICATION:		
FLOOD MITIGATION DAMS, RETARDING BASINS, ON-SITE DETENTION (See 5.2.1)	Reduce the peak flow from the catchment into the lake by increasing the volume of flood storage in the catchment.	Not considered further as these measures have negligible impact on lake flooding. The size of storages required to make a difference to lake floods are very large, making them impractical on environmental, social and economic grounds. Smaller on-site detention can help water quality and local drainage, but has little impact on lake flooding.
RIVER IMPROVEMENTS AND ENTRANCE MODIFICATIONS (See 5.2.2 & 5.2.3)	Increase the flow rates and volumes of exchange between the ocean and the lake.	Not considered further as it may exacerbate the peak height of most lake floods due to increased penetration into the lake of ocean tides, storm surge and wave set up. May make tidal inundation from sea level rise worse by increasing tidal range in the lake.
CATCHMENT TREATMENT (See 5.2.4)	Reduce volume of runoff from catchment by maximising water retention and absorption, and minimising impervious surfaces such as roofs and roads.	These measures can be effective in small catchments, to protect local creeks, and to improve water quality, but are not effective in larger catchments or in reducing lake flood levels.
EARTHEN OR CONCRETE LEVEE BANKS, FLOODGATES, AND PUMPS PREVENTING FLOODING AND PERMANENT INUNDATION (See 5.3.1)	Prevent or reduce the frequency of flooding of protected areas. Prevent or delay permanent inundation from rising sea levels.	Relatively expensive for larger structures but may be economically feasible for smaller structures. May cause local drainage problems and social problems due to restriction of waterfront access and views. No specific sites have been investigated or identified at this time. In some cases this may be the only option to prevent inundation from sea level rise. Levees were previously rejected by the local community in previous studies.
WORKS TO MINIMISE LOCAL DRAINAGE PROBLEMS (See 5.3.2)	To reduce the incidence of local runoff ponding in yards and streets.	Flooding in this manner does not usually enter buildings but it occurs frequently and causes significant inconvenience. In low-lying areas with little or no fall to drainage basins (the lake) there is no easy or cheap solution. Flap-gates on drains can reduce local flooding from high tides. A community based approach should be introduced to monitor, identify and (possibly) resolve some problem areas.

MEASURE	PURPOSE	COMMENT
REDUCE THE IMPACTS OF WAVE RUNUP (See 5.3.3)	To prevent wave run up increasing flood levels and flood damage in foreshore areas.	The wave runup effect is site specific and varies significantly around the lake depending on local aspect and weather conditions. Seawalls and other foreshore structures can protect against waves, but may not be effective in times of flood and can shift the problem to neighbouring properties. Properties should be identified as liable to wind wave action and the effects addressed in the DA process.
PROPERTY MODIFICATION:		
HOUSE RAISING (See 5.4.1)	Prevent flooding of existing buildings by raising the floor level above the floodwaters.	All flood damages will not be prevented. Only suitable for non-brick buildings on piers. The cost is approximately $60,000 per house, but can vary considerably and is unlikely to be cost effective. Only suitable for a small number of buildings and not attractive to all residents. Nevertheless it should be investigated further as, along with levees, house raising is one of the only measures to mitigate increased flood levels from sea level rise, although it is not appropriate in areas where the land beneath buildings becomes permanently or frequently inundated. Council should consider whether “slab on ground” construction is appropriate if there is the possibility that the house may require raising in the future.
FLOOD PROOFING (See 5.4.1)	Prevent flooding of existing buildings by sealing all the entry points.	Generally only suitable for brick, slab on ground buildings. Less viable for residential buildings but should be considered for non residential buildings of slab on ground construction.
VOLUNTARY PURCHASE OF INDIVIDUAL BUILDINGS (See 5.2.5 & 5.4.5)	Purchase and removal of the most hazardous flood liable buildings to reduce risk to property and people.	High cost per property. Applicable for isolated, high hazard properties in flood liable areas. None have been identified in the study.
MINIMISE THE RISK OF ELECTROCUTION (See 5.4.4)	Design new electrical work, retro-fit existing electrical work, and educate residents, to prevent live wires going underwater in floods.	New circuits in habitable dwellings are installed at or above the 100 year ARI flood level plus 0.5m freeboard. A risk and adaptation assessment to be undertaken to look at ways to encourage residents to retro-fit existing properties, with circuit breakers, for example. Use education and awareness campaigns to alert residents to the danger and suggest solutions.
RESPONSE MODIFICATION:		
FLOOD WARNING (See 5.5.1)	Enable people to prepare and evacuate, to reduce damages to property and injury to persons.	System currently in place based on water level and rainfall recorders but has never been tested in a flood. A more specific system that includes the effect of elevated ocean levels, wave runup and sea level rise could provide greater accuracy. The cost to improve the system is unknown but it is likely to be small and will provide a high benefit/cost ratio.
FLOOD EMERGENCY MANAGEMENT (See	To ensure that evacuation can be undertaken in a safe and efficient manner.	The SES Flood Plan could be updated to include more local Community Flood Emergency Response Plans for vulnerable communities. The cost to improve the Plan is unknown but it is likely to be small and will provide a

MEASURE	PURPOSE	COMMENT
5.5.2)		high benefit/cost ratio.
PUBLIC INFORMATION AND RAISING FLOOD AWARENESS (See 5.5.3)	Educate people to prepare themselves and their properties for floods, to minimise flood damages and reduce the risk.	A cheap effective method but requires continued effort.
OTHER MANAGEMENT MEASURES		
MODIFICATION TO THE S149 CERTIFICATE (See 5.6.1)	S149 certificates should clearly inform owners and purchasers of risks, planning controls and policies that apply to the subject land.	Council should review flood and permanent inundation related information on the Section 149 Certificate to bring it in line with the findings of this Floodplain Risk Management Plan. Council should make property information on flooding accessible on the internet. Continue to seek amendments to regulations to clarify information required on 149 (2) Certificate.
STRATEGIC PLANNING ISSUES (See 5.2.6 & 5.4.2)	Reduce potential hazard and losses from flooding, tidal inundation, and permanent inundation by appropriate land use planning.	Established processes are in place for dealing with land-use in flood hazard areas. However, permanent inundation and changes in flood hazard over time, as a result of rising lake levels, are new issues and will require new responses. Land use planning will have to consider the possibility that some foreshore areas may become unfit for habitation due to permanent inundation, loss of infrastructure and services, increased flood hazard, and loss of access. Protection measures (levees, filling etc), planned retreat, additional conditions on development, and changes in zoning are possible planning responses. Retreat and adaptation of foreshore ecosystems needs to be included in future land use planning. Local adaptation plans should be developed, in close consultation with affected communities, to consider these issues as they affect each area. One of the main outcomes is that Council should review its sea level rise policy in light of the real of the NSW Government's sea level rise policy in September 2012 and its flood related Development Control Plan. One of the main outcomes is that Council should review its sea level rise policy in light of the withdrawal of the NSW Government's sea level rise policy in September 2012. Great Lakes Council will continue to utilise the previous benchmarks on the basis that they serve as responsibly conservative guides pending the 5th IPCC review in 2014. Appropriate development control provisions should be included within Council's proposed LEP 2012. This should link to Flood Planning Area mapping also to be included with LEP Figures. Further integration of Council's Flood Policy (currently under review) as a component of the comprehensive DCP 2012 should also occur. Climate change adaptation pathways containing triggers and options relating to infrastructure and land use/land tenure transitioning should also be recognised within the DCP.

MEASURE	PURPOSE	COMMENT
PROVISION AND MAINTENANCE OF INFRASTRUCTURE AND SERVICES (See 5.4.3)	Ensuring infrastructure and services can be provided and maintained for the life of a development..	A risk and adaptation assessment to be undertaken for each service as part of local adaptation plans for each management area. Asset life and access to services will have to be determined when assessing individual developments. Establish and maintain consultation arrangements with other service providers in relation to asset management and adaptation to climate change challenges. This will assist coordination of adaptation pathways in relation to triggers and response options using appropriate measures of cost-effectiveness.
FLOOD INSURANCE (See 5.2.7)	To spread the risk of individual financial loss across the whole community through insuring against flood damage.	Does not reduce damage, but spreads the cost. Insurance against catchment (rainfall-induced) flooding is commercially available and governments are currently considering universal or subsidised schemes. Insurance against storm surge, tidal inundation, and permanent inundation from sea level rise (ocean-induced) is not available.
PLANNING REGULATIONS FOR TOURIST/CARAVAN PARKS (See 5.6.3)	To ensure that tourist and caravan park development is compatible with the flood hazard and temporary residents have an adequate level of flood awareness.	Review Council's policy on affected caravan parks located on or adjacent to the lake foreshore. Develop flood awareness program for temporary residents of caravan parks and other tourist accommodation in flood hazard areas. Review BCA and state requirements for moveable and fixed structures in high and moderate flood risk areas.

7.3. Floodplain Risk Management Measures in Plan

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

HIGH Priority

1. **Undertake a detailed assessment for each management area, in consultation with each affected community, of the implications and adaptation measures available to plan for and mitigate the effects of sea level rise (flooding and tidal inundation).**
   - **Cost:** moderate
   - **Responsibility:** Great Lakes Council
   - **Timeframe:** begin 2013 and aim to complete priority areas by the year 2015

2. **Undertake a detailed review of the provision and maintenance of services and infrastructure in the foreshore areas in the year 2050 and 2100.**
   - **Cost:** moderate
   - **Responsibility:** Great Lakes Council and other relevant service providers
   - **Timeframe:** by the year 2015 and/or in conjunction with development of plans in 1 above

3. **Establish criteria to define when land becomes "unsuitable" for current or proposed future use due to permanent inundation.**
   - **Cost:** moderate
   - **Responsibility:** Great Lakes Council and other relevant service providers
   - **Timeframe:** by the year 2013 and/or in conjunction with development of local area adaptation plans in 1. above

4. **Review the wording on the Section 149 certificates, development restriction certificates and flood control lot certificates to incorporate revised flood planning levels and new permanent inundation planning level.**
   - **Cost:** low
   - **Responsibility:** Great Lakes Council and Department of Planning and Infrastructure (EP&A Act and regulations)
   - **Timeframe:** by the year 2013

5. **Review strategic land use planning to accommodate adaptation to changed flooding and inundation due to sea level rises. The review needs to include suitable development densities and types, possible need for retreat areas, future protection and adaptation of foreshore ecosystems, foreshore access and recreation, and land required for infrastructure and protection works.**
   - **Cost:** moderate
   - **Responsibility:** Great Lakes Council and Land Property and Management

Authority (Crown reserves, foreshores and harbour areas)
- **Timeframe:** by the year 2013

6. **Review Council's flood related Development Control Plan provisions to ensure incorporates potential climate change and adequate flood related development controls.**
   - **Cost:** Low
   - **Responsibility:** Great Lakes Council
   - **Timeframe:** by the year 2013

MEDIUM Priority

1. **Undertake a review of the suitability of slab on ground construction in the foreshore areas and whether other forms of building construction can be undertaken that would reduce flood hazard and/or allow future adaptation such as house raising.**
   - **Cost:** Low - Moderate
   - **Responsibility:** Great Lakes Council and Department of Infrastructure and Planning
   - **Timeframe:** by the year 2014

2. **Undertake a review of the flood warning system and if necessary update.**
   - **Cost:** Low-Moderate
   - **Responsibility:** Great Lakes Council and the Bureau of Meteorology
   - **Timeframe:** by the year 2014

3. **Review Council's policy on Caravan Parks in the floodplain.**
   - **Cost:** Low
   - **Responsibility:** Great Lakes Council and caravan park owners
   - **Timeframe:** by the year 2014

4. **Investigate financial models to prepare for future costs of possible protection works, infrastructure up-grades, relocations, and other adaptation options**
   - **Cost:** Moderate
   - **Responsibility:** Great Lakes Council and other relevant service providers
   - **Timeframe:** by the year 2014

5. **Undertake a review of areas that should be considered for rezoning commensurate with the flood hazard.**
   - **Cost:** Moderate
   - **Responsibility:** Great Lakes Council and Department of Infrastructure and Planning
   - **Timeframe:** by the year 2014

LOW Priority

1. **Inform the SES of the outcomes of this Plan and the possible implications for flood evacuation. If necessary the SES should update their Flood Plan.**
   - **Cost:** Low
   - **Responsibility:** Great Lakes Council and SES
   - **Timeframe:** by the year 2013

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

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

8. ACKNOWLEDGMENTS

This study was carried out by WMAwater and funded by Great Lakes Council and the NSW State Government. The assistance of the following in providing data and guidance to the study is gratefully acknowledged:

- Great Lakes Council,
- NSW Office of Environment and Heritage,
- Commonwealth Government of Australia,
- Council's Floodplain Management Committee,
- Residents surrounding the foreshores of Wallis Lake.

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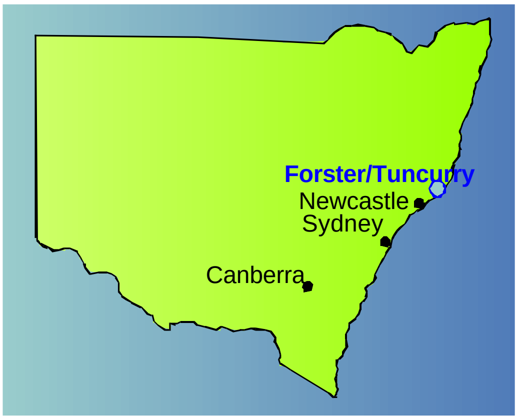
June 2006

Figures

FIGURE 1
CATCHMENT MAP



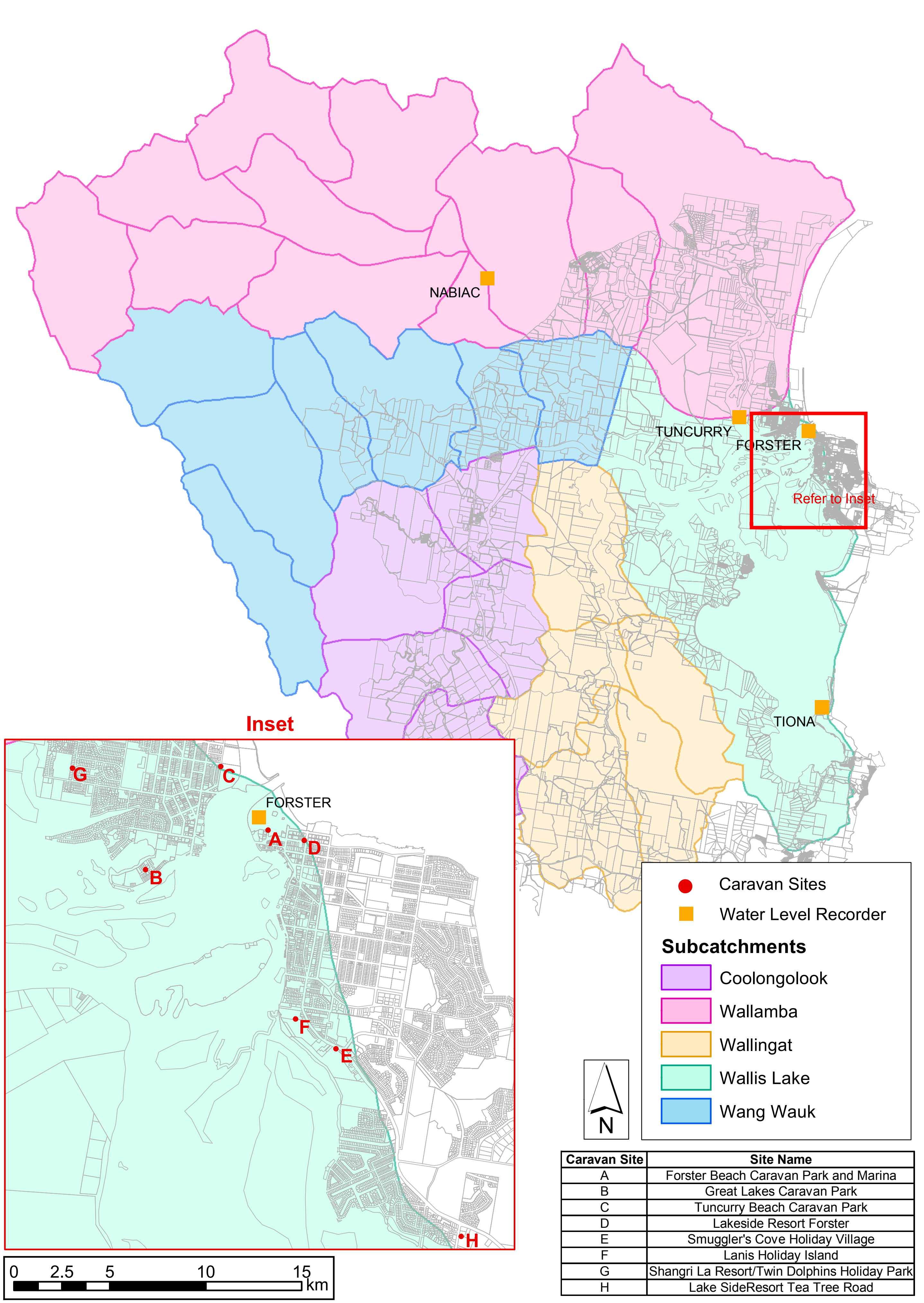
5 0 5 10 15 20 25km

SCALE

FILE > J:\JOBS\24021\FIGURES\FIG01_CATCHMENT.CDR > JANUARY 2005

FIGURE 2

WALLIS LAKE SUBCATCHMENTS



Caravan Site	Site Name
A	Forster Beach Caravan Park and Marina
B	Great Lakes Caravan Park
C	Tuncurry Beach Caravan Park
D	Lakeside Resort Forster
E	Smuggler's Cove Holiday Village
F	Lanis Holiday Island
G	Shangri La Resort/Twin Dolphins Holiday Park
H	Lake SideResort Tea Tree Road

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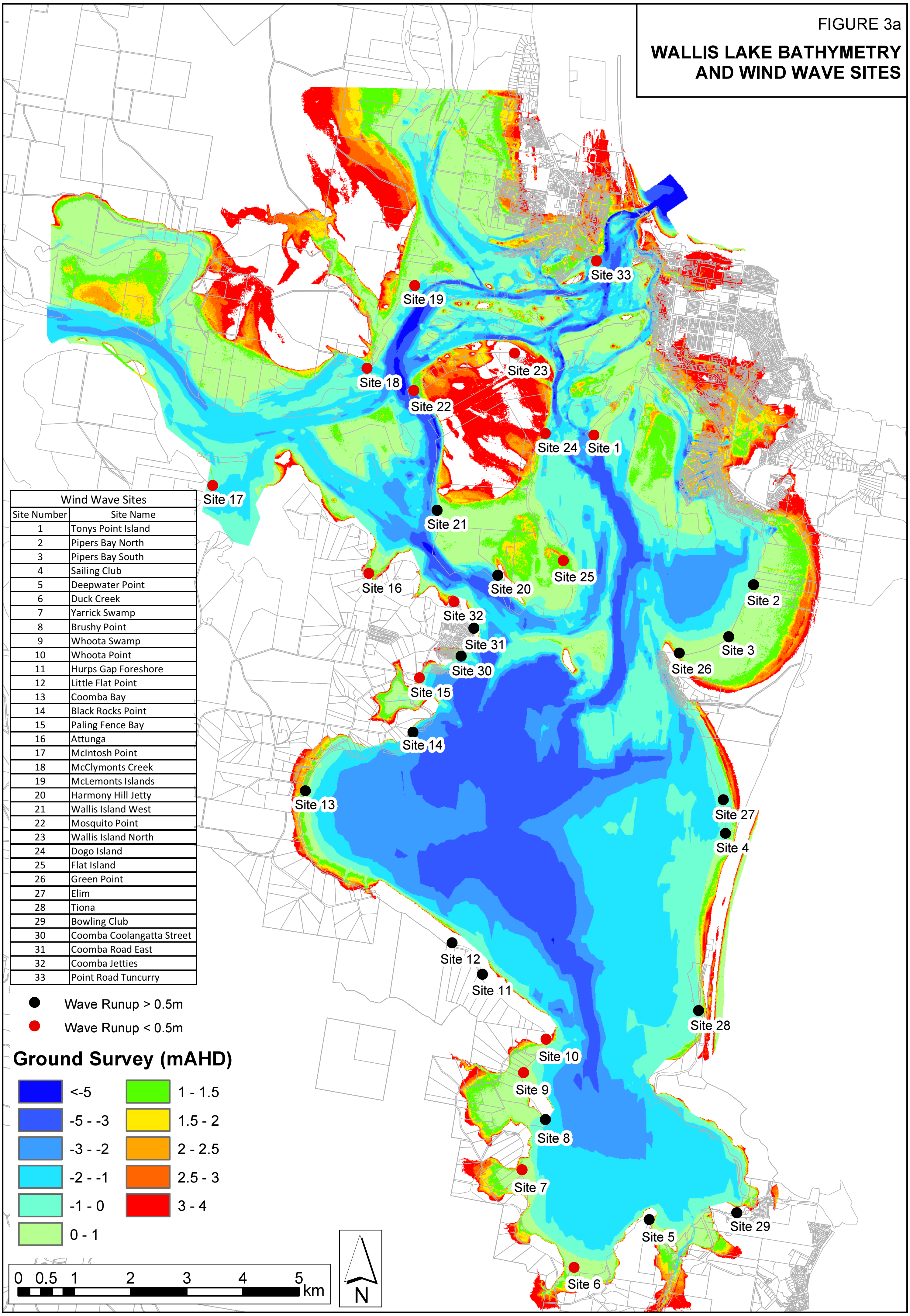
FIGURE 3a

WALLIS LAKE BATHYMETRY AND WIND WAVE SITES



Wind Wave Sites	
Site Number	Site Name
1	Tonys Point Island
2	Pipers Bay North
3	Pipers Bay South
4	Sailing Club
5	Deepwater Point
6	Duck Creek
7	Yarrick Swamp
8	Brushy Point
9	Whoota Swamp
10	Whoota Point
11	Hurps Gap Foreshore
12	Little Flat Point
13	Coomba Bay
14	Black Rocks Point
15	Paling Fence Bay
16	Attunga
17	McIntosh Point
18	McClymonts Creek
19	McLemonts Islands
20	Harmony Hill Jetty
21	Wallis Island West
22	Mosquito Point
23	Wallis Island North
24	Dogo Island
25	Flat Island
26	Green Point
27	Elim
28	Tiona
29	Bowling Club
30	Coomba Coolangatta Street
31	Coomba Road East
32	Coomba Jetties
33	Point Road Tuncurry

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FIGURE 3b

WALLIS LAKE BATHYMETRY DETAIL NEAR ENTRANCE

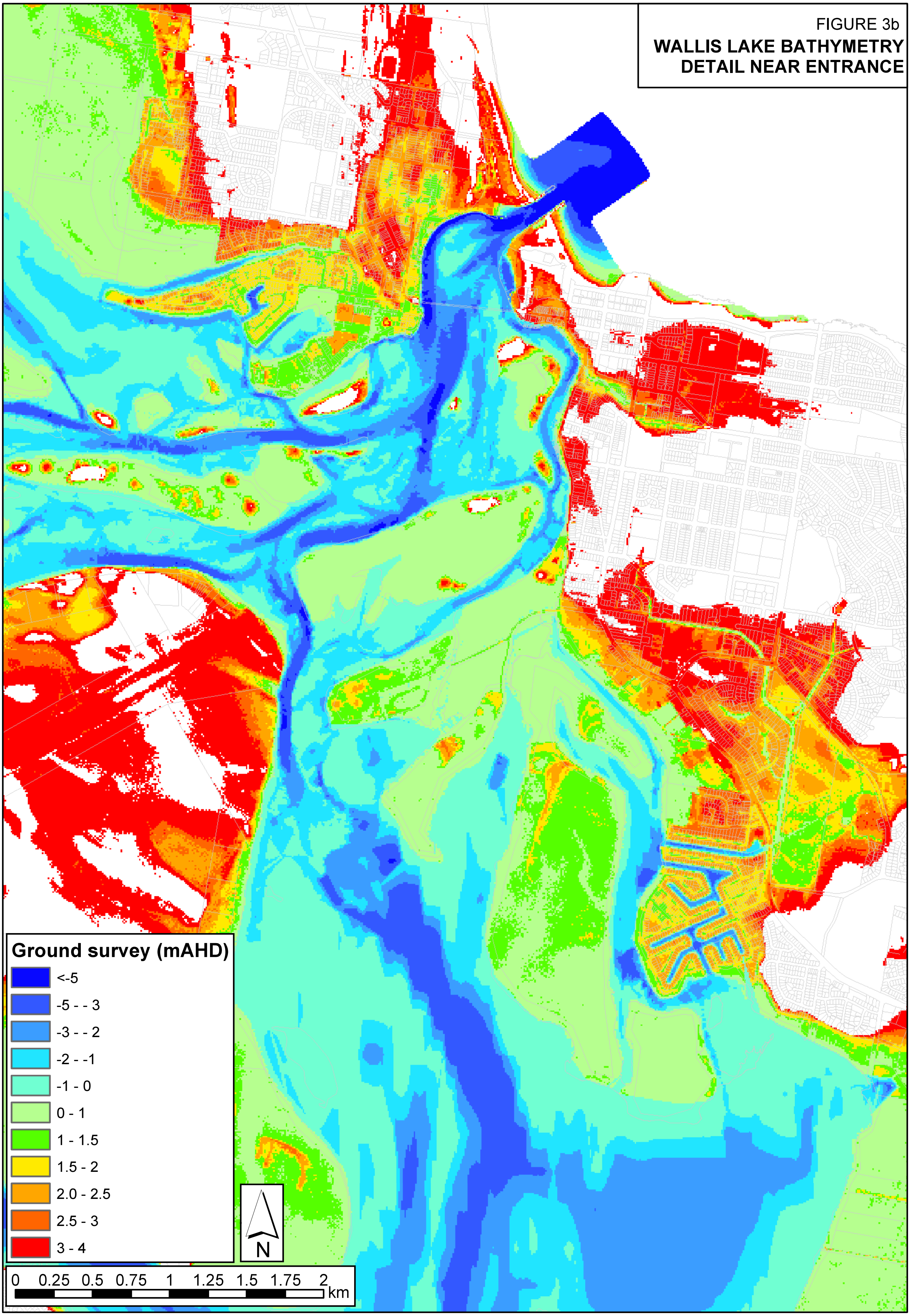

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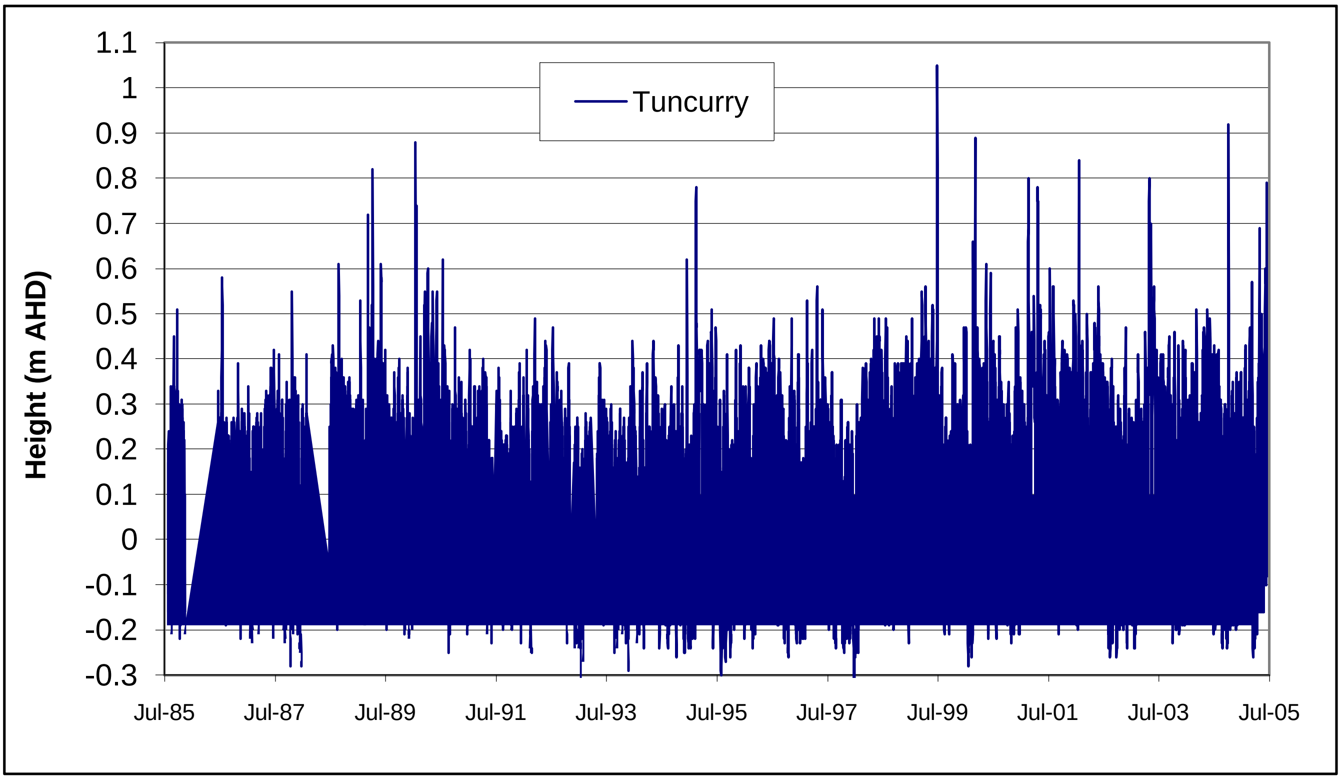
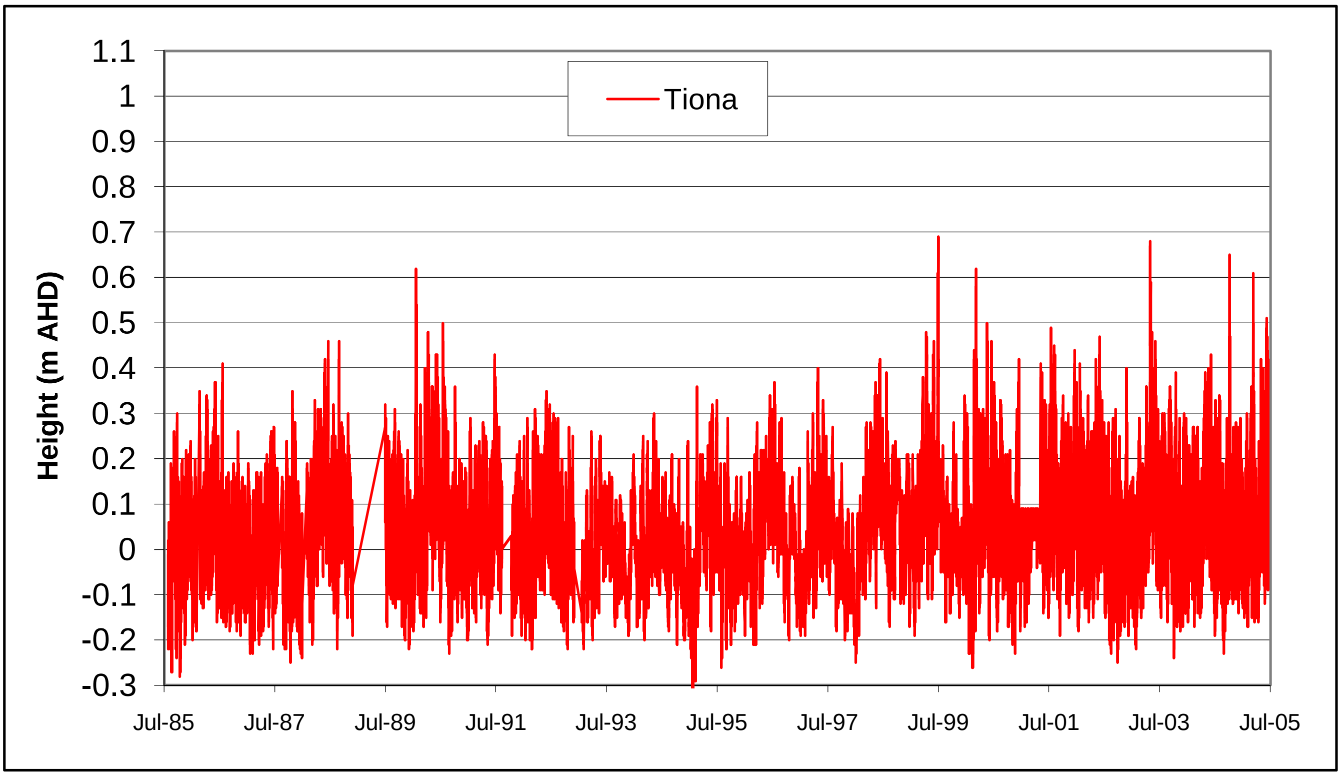
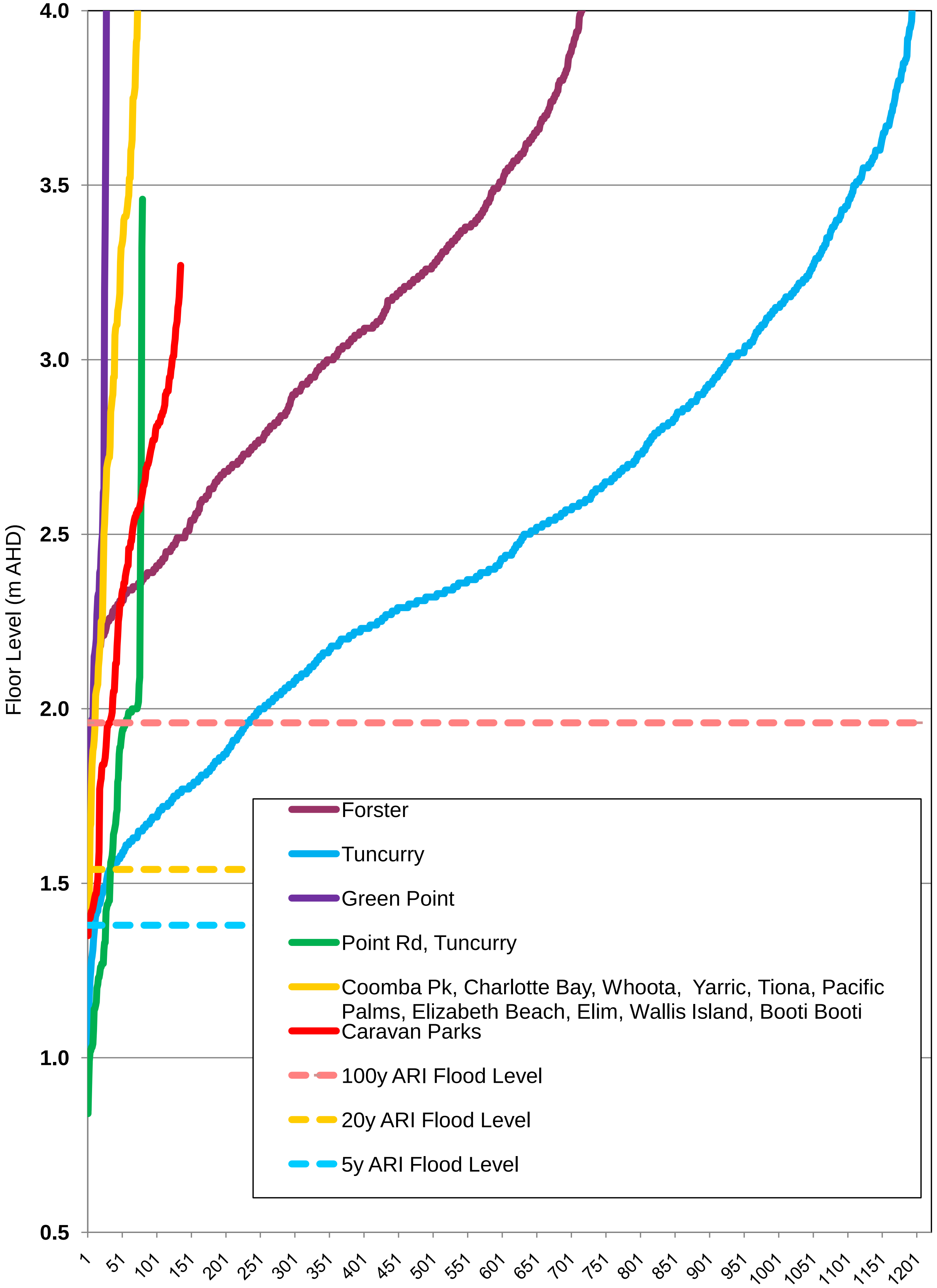
FIGURE 4
TIONA & TUNCURRY HISTORICAL RECORD





Note: Refer Figure 2 for location of gauges

FIGURE 5
BUILDING FLOORS



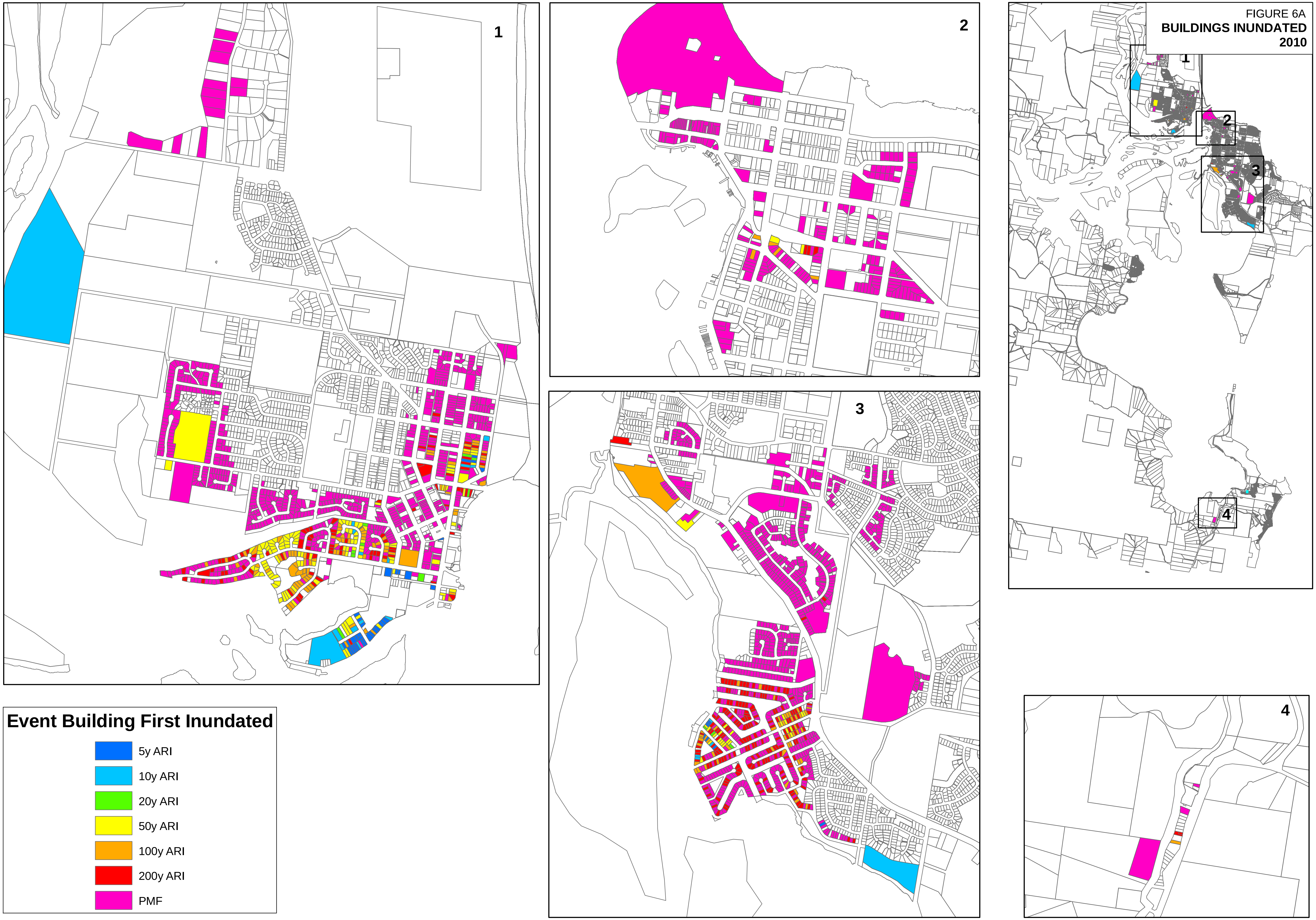
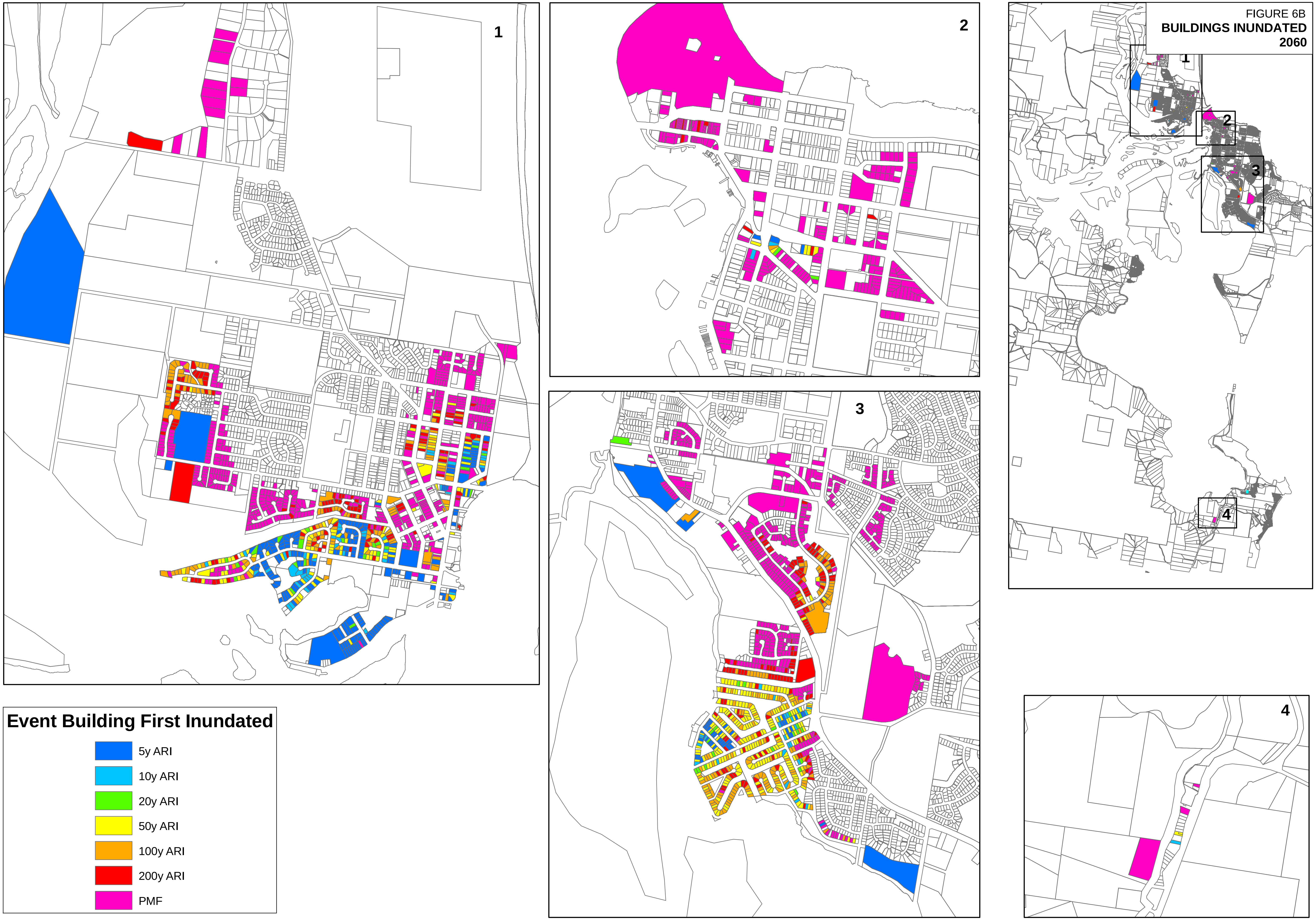


FIGURE 6A
BUILDINGS INUNDATED
2010

FIGURE 6B
BUILDINGS INUNDATED 2060



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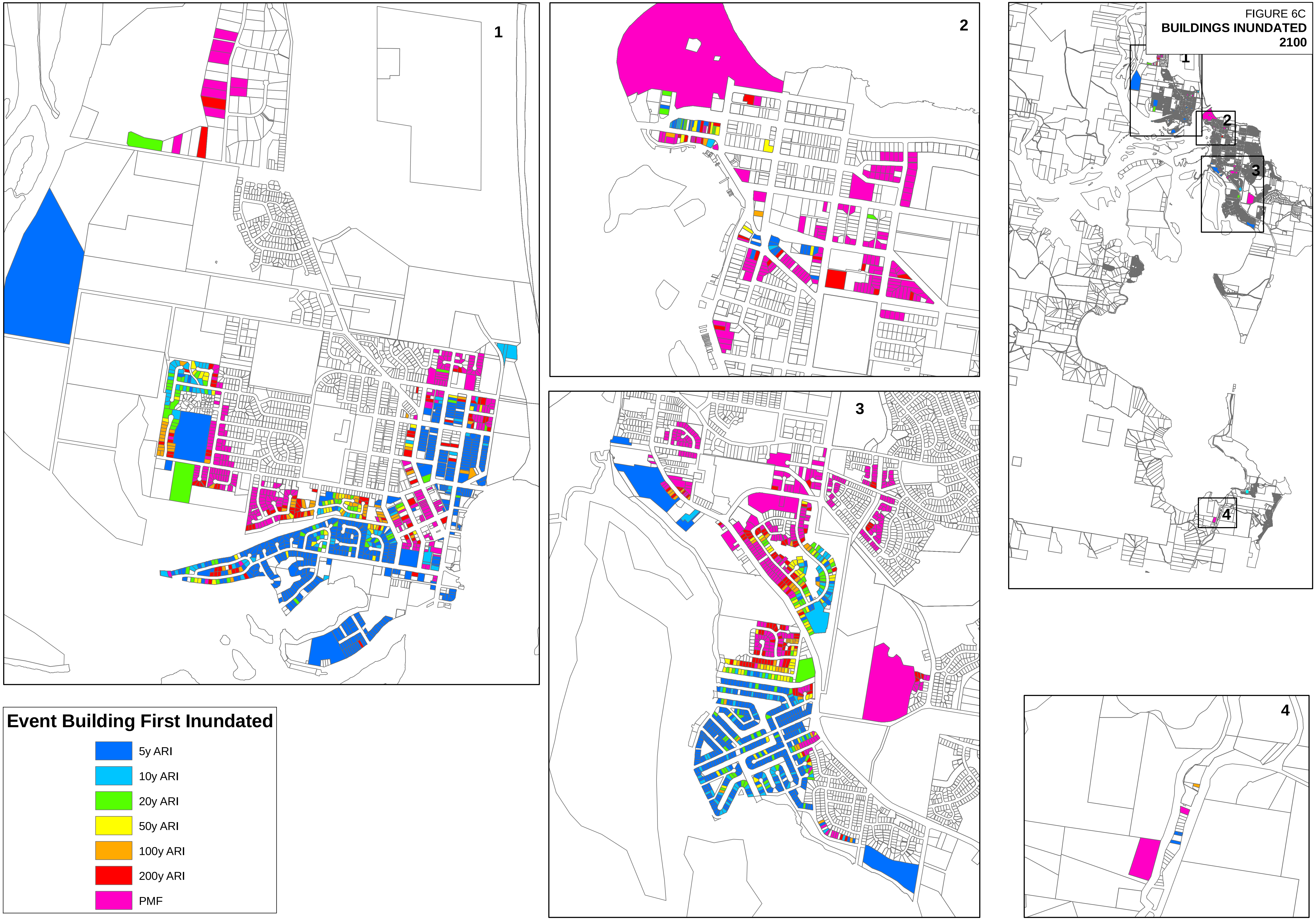


FIGURE 6C
BUILDINGS INUNDATED 2100

FIGURE 7
WIND WAVE FLOOD LEVELS

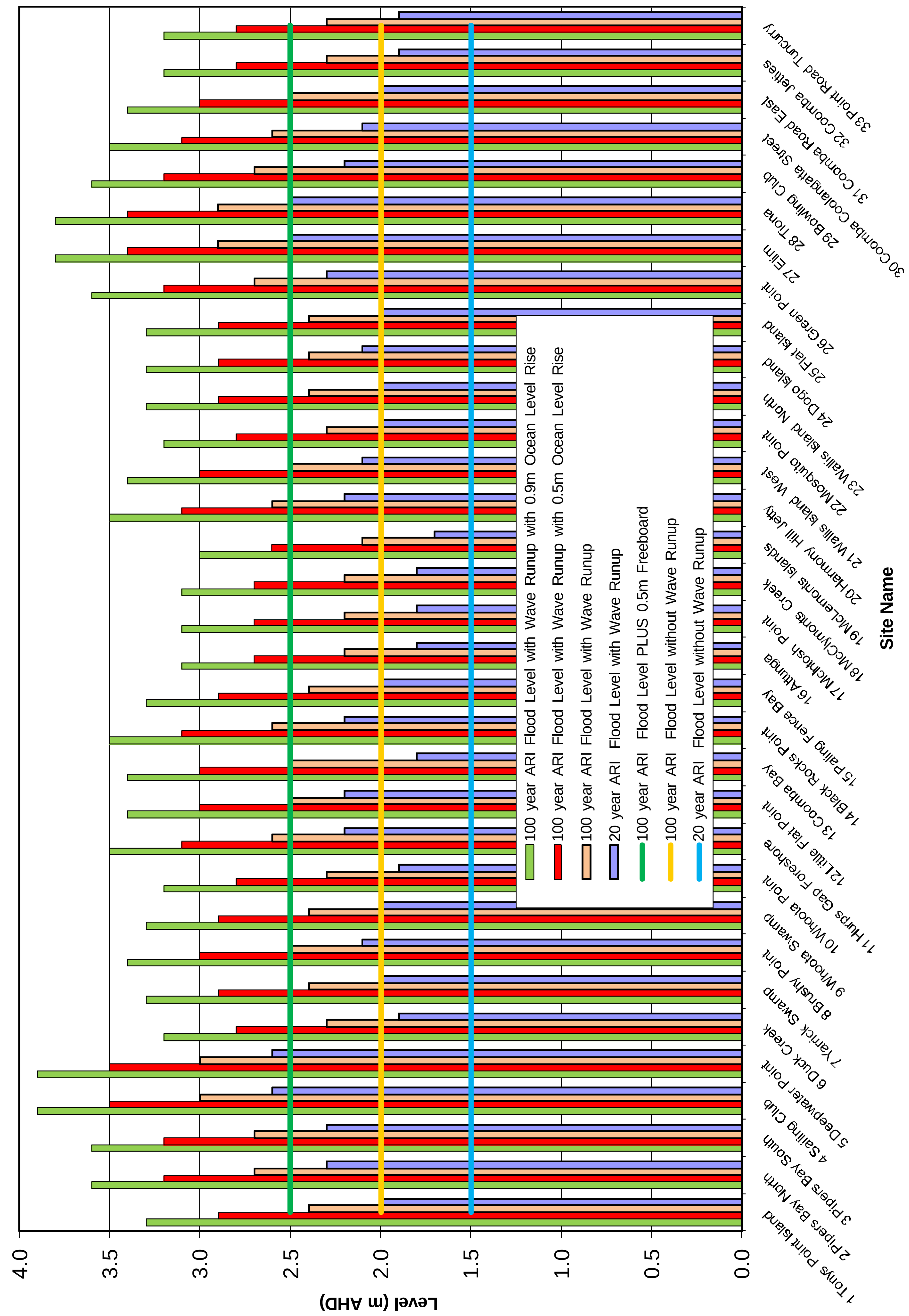
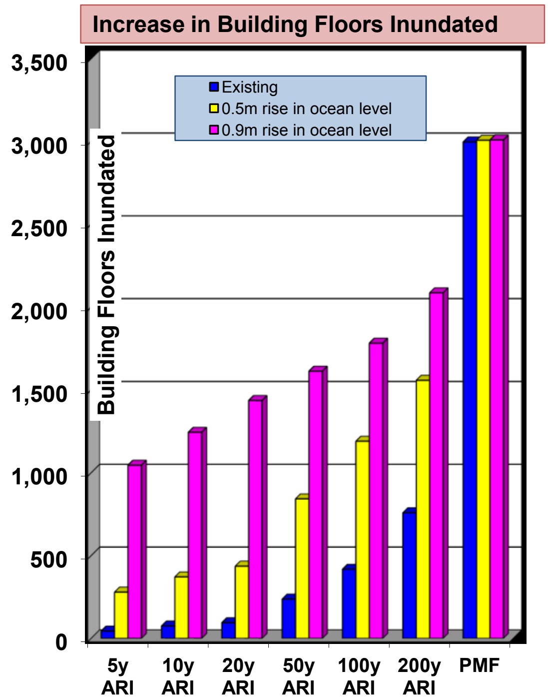
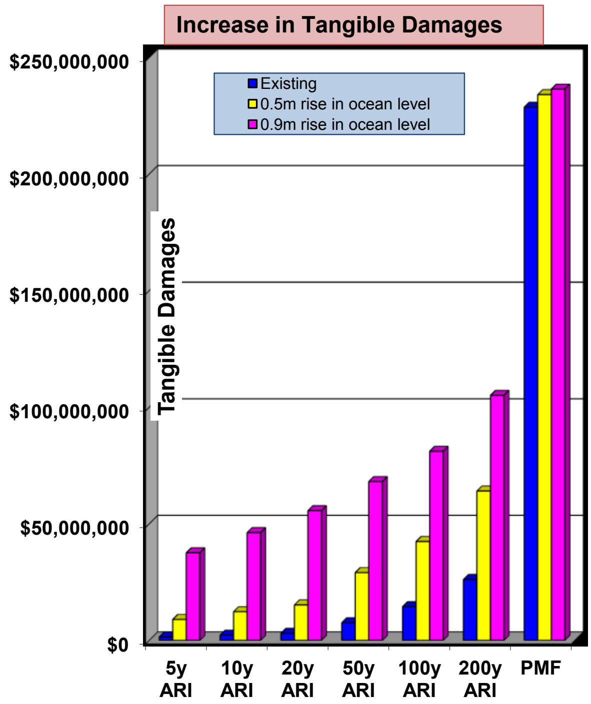
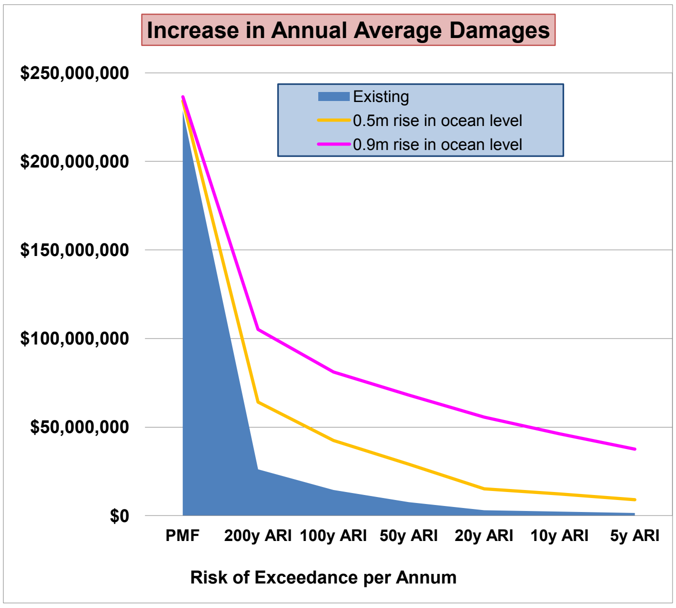


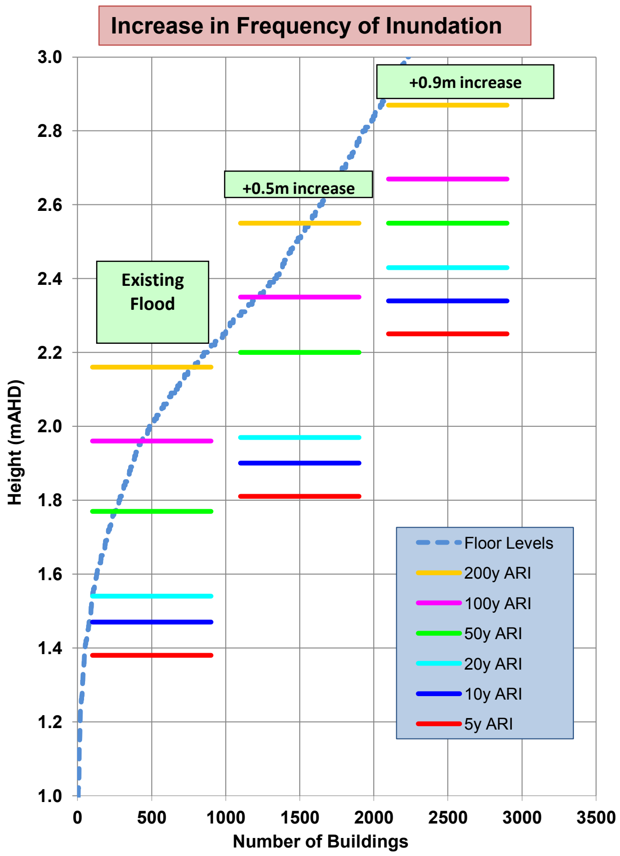
FIGURE 8a

ASSESSMENT OF CLIMATE CHANGE INCREASE IN FLOOD DAMAGES





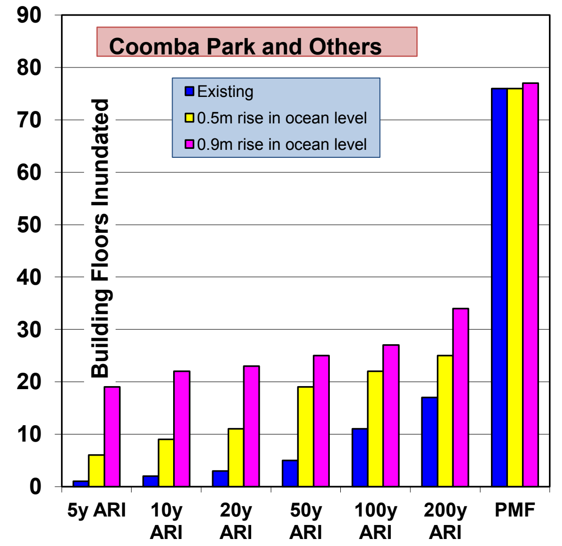


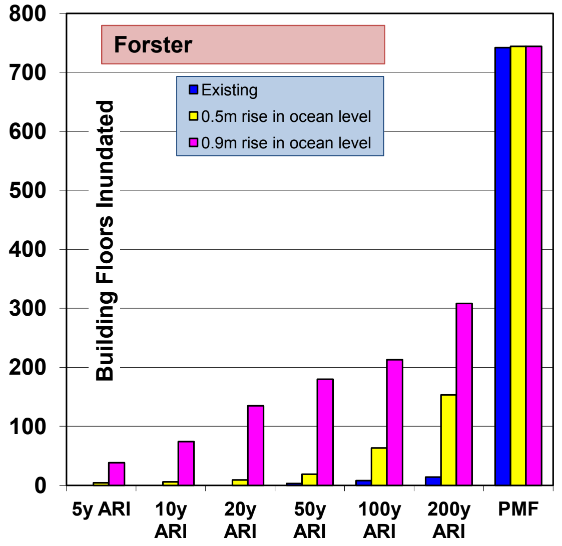


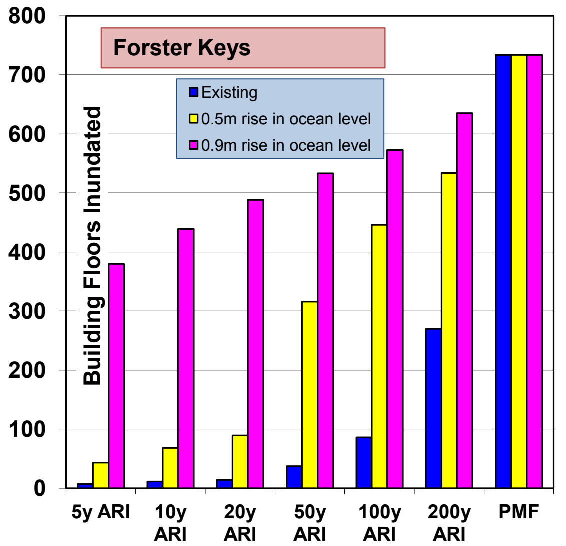
Scenario	AAD	% Increase
Current	$ 1.9 million	-
+0.5 m rise	$ 7.4 million	286%
+0.9 m rise	$ 25.7 million	1244%

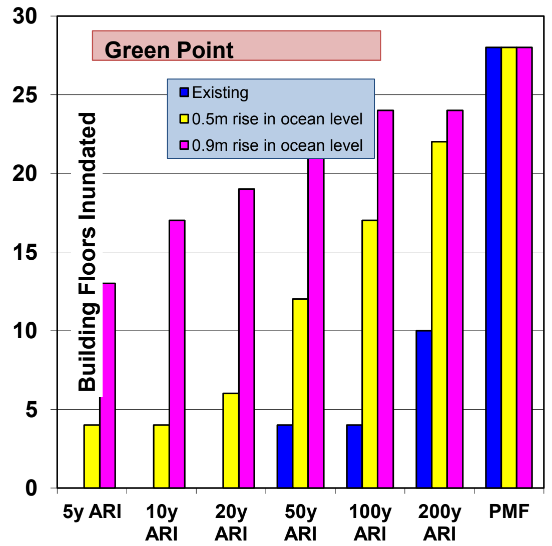
FIGURE 8b

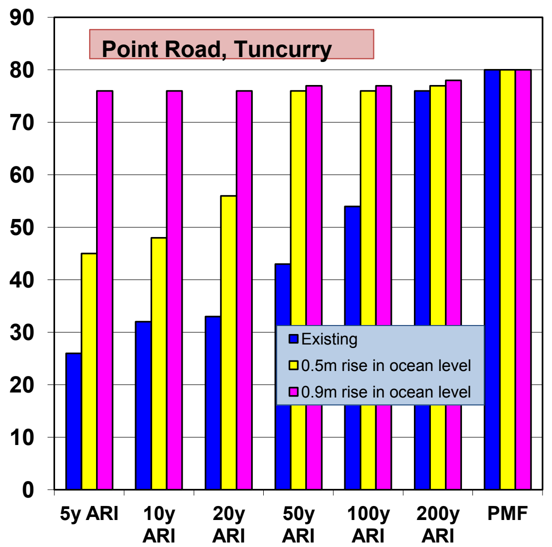
ASSESSMENT OF CLIMATE CHANGE INCREASE IN BUILDINGS INUNDATED











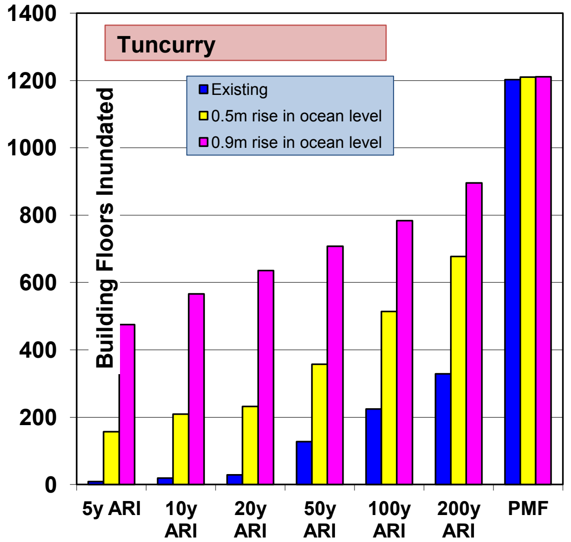
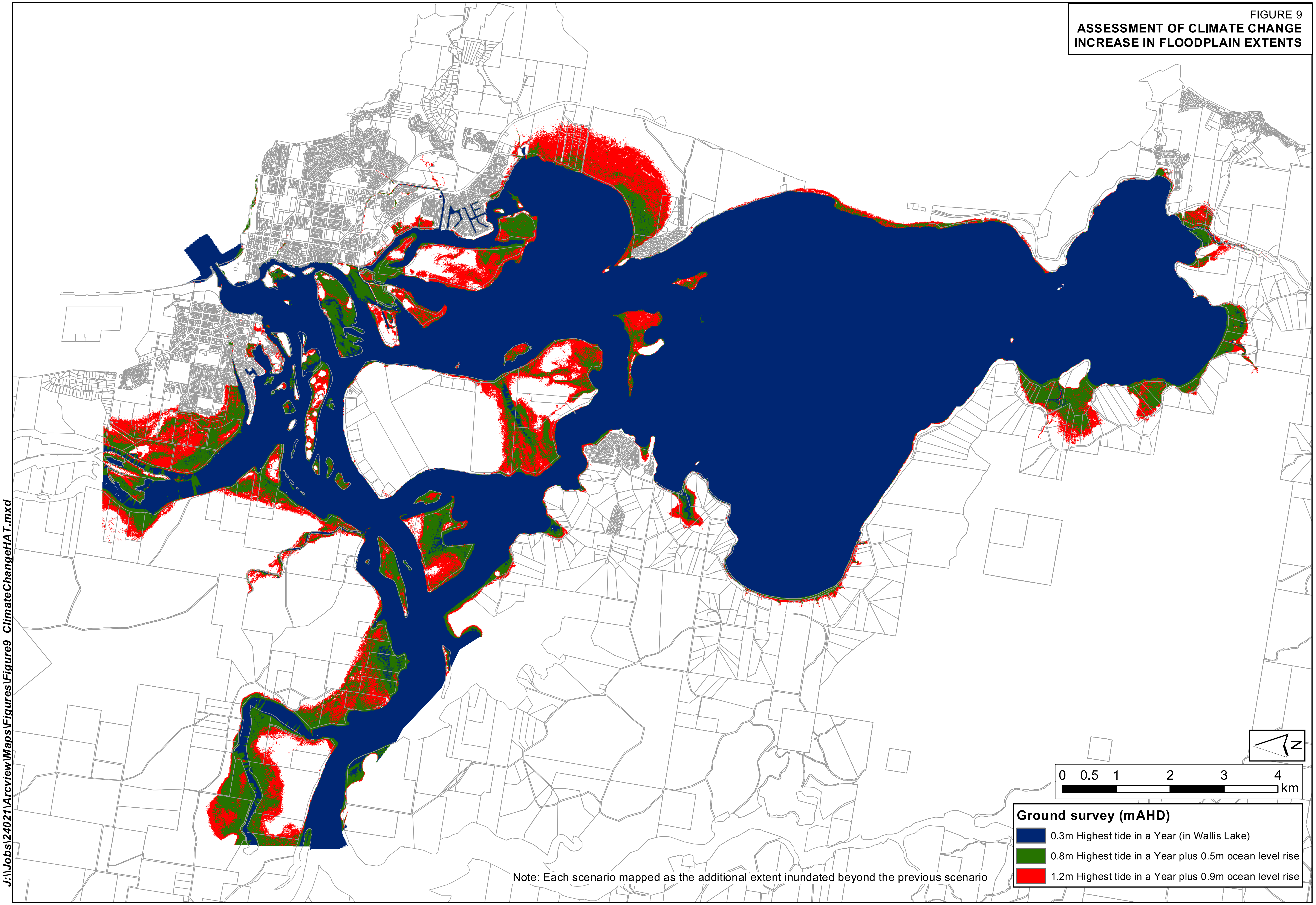


FIGURE 9

ASSESSMENT OF CLIMATE CHANGE INCREASE IN FLOODPLAIN EXTENTS



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Appendix A

APPENDIX A: GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

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

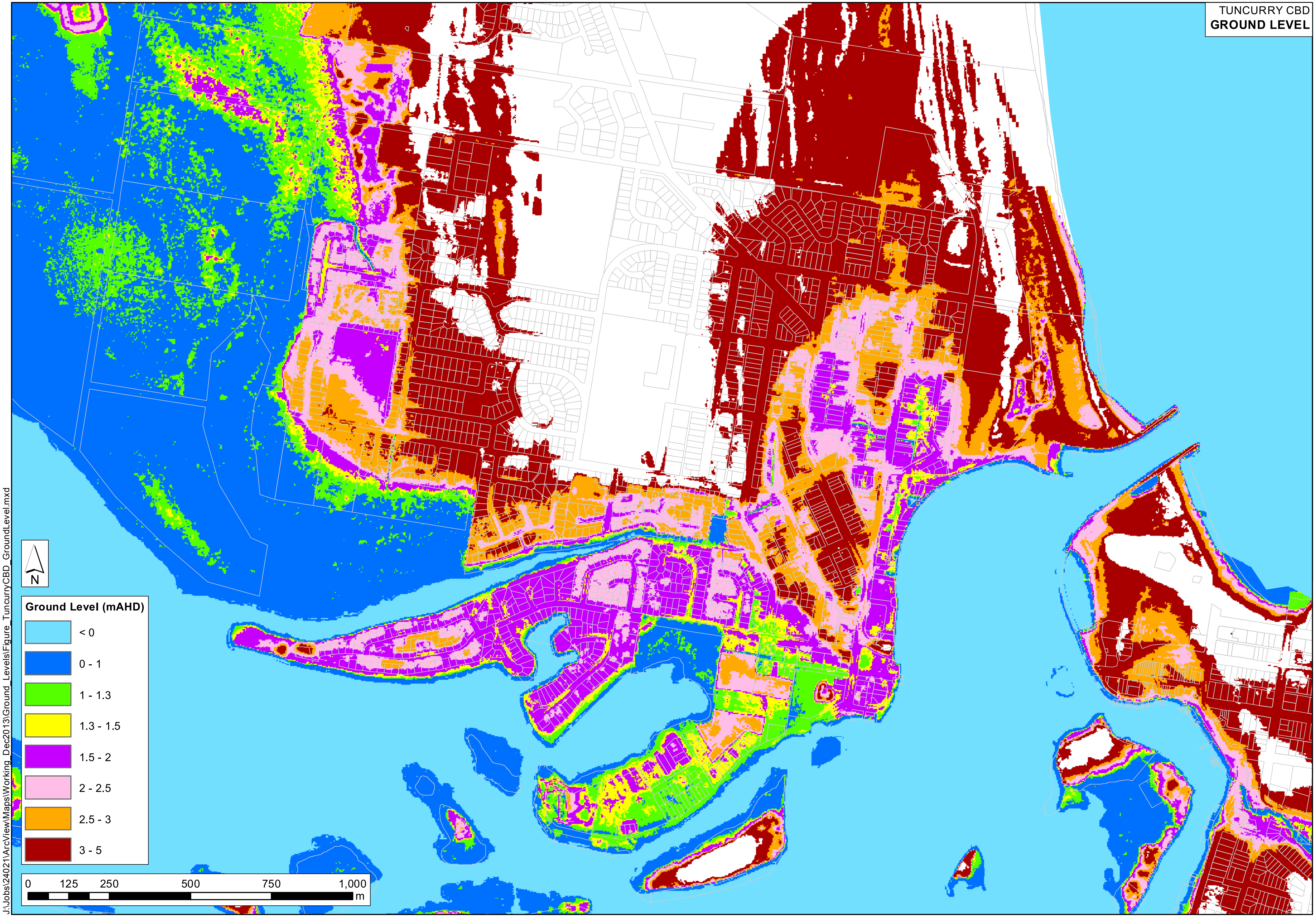
	connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different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

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

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

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

Appendix B



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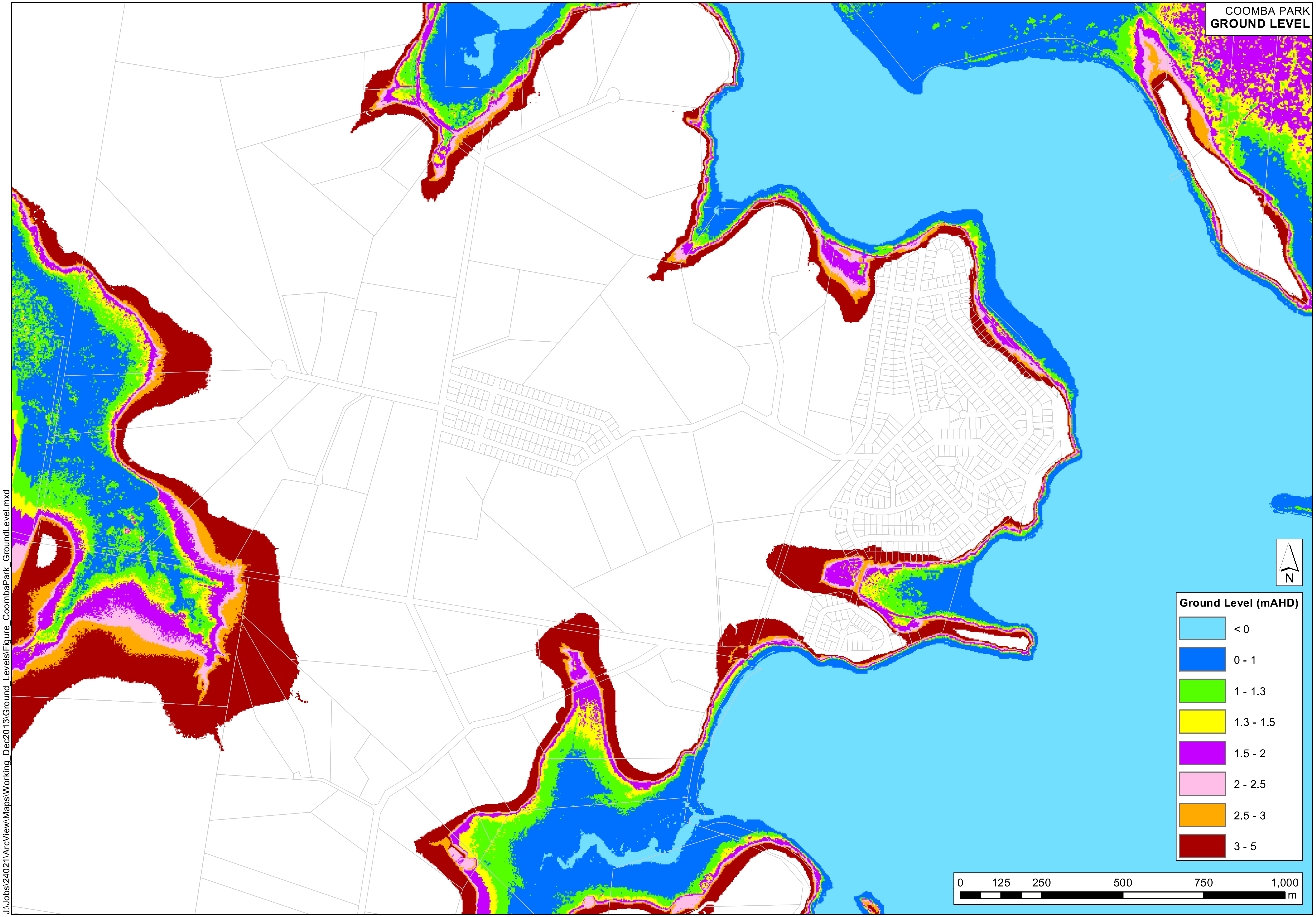

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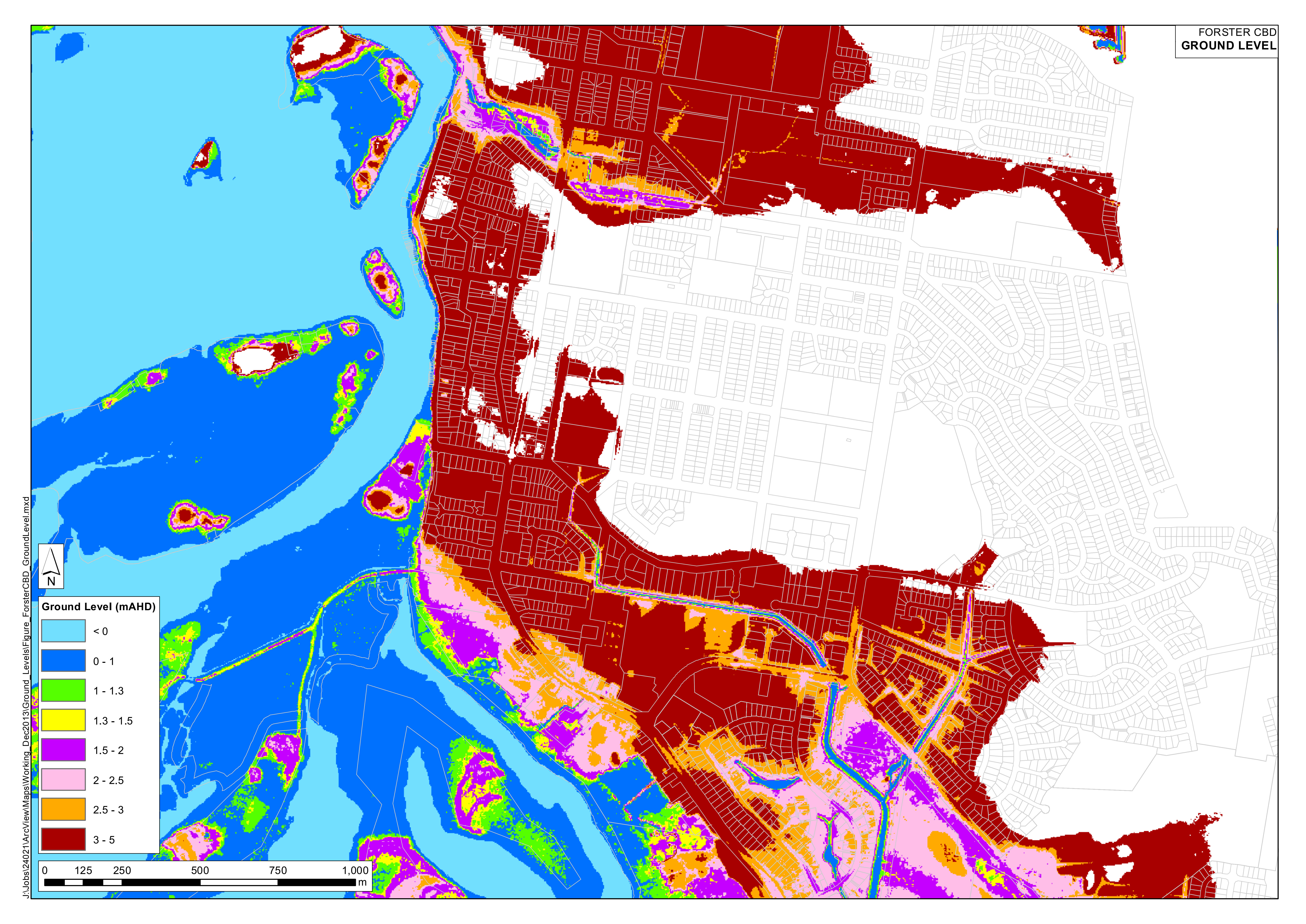

FORSTER CBD
GROUND LEVEL
N
Ground Level (mAHD)
< 0
0 - 1
1 - 1.3
1.3 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 5
0
125
250
500
750
1,000
m
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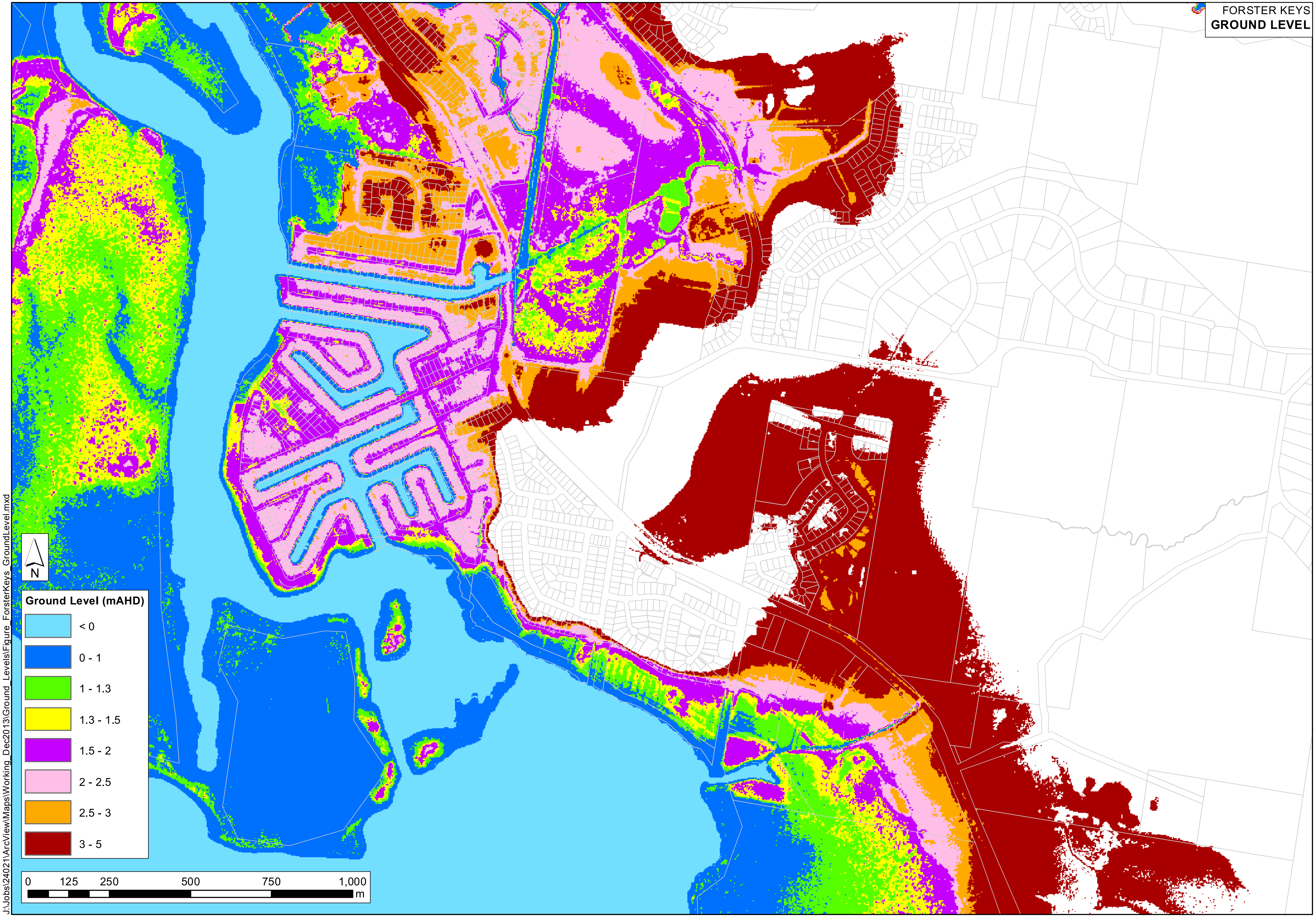

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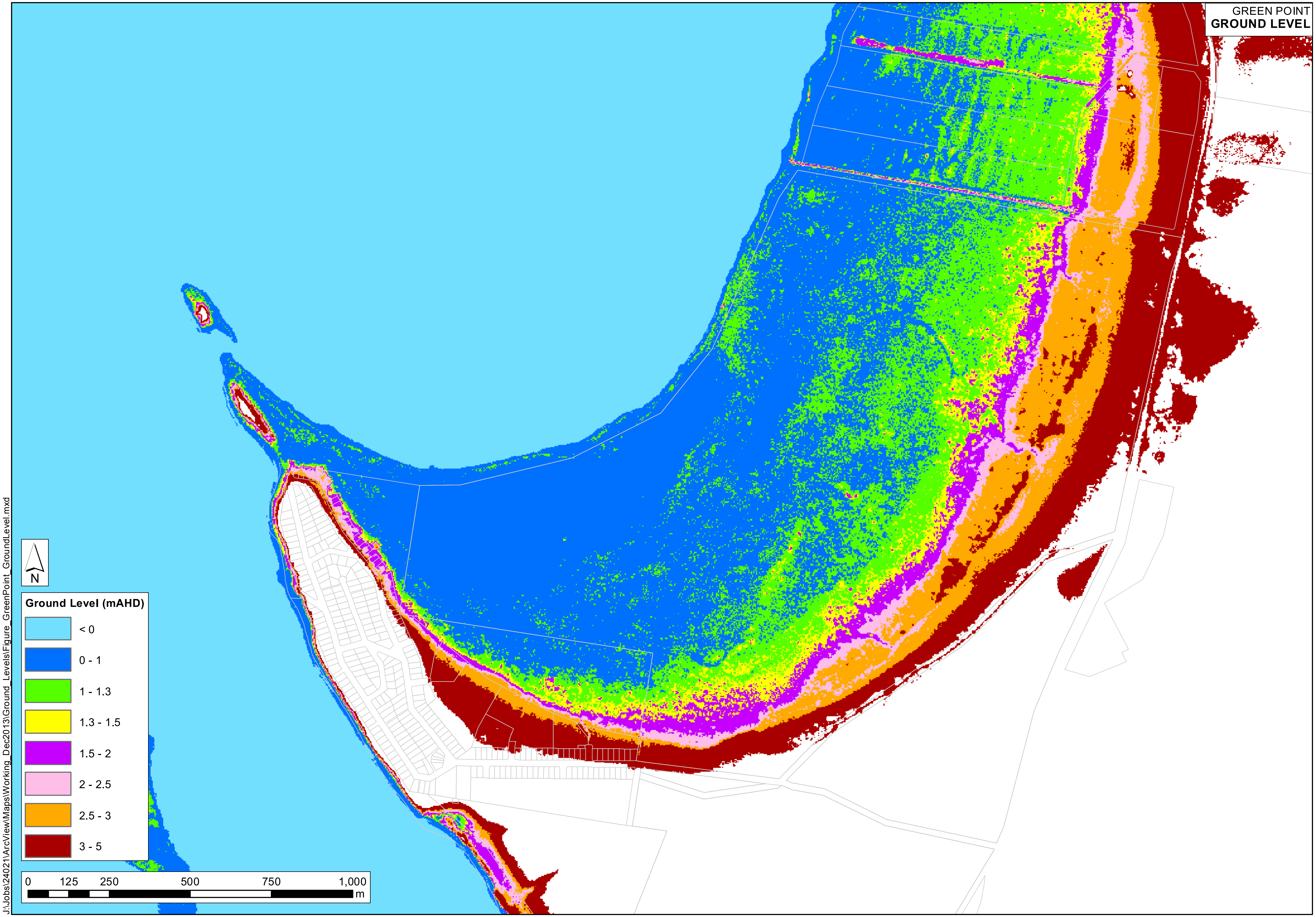

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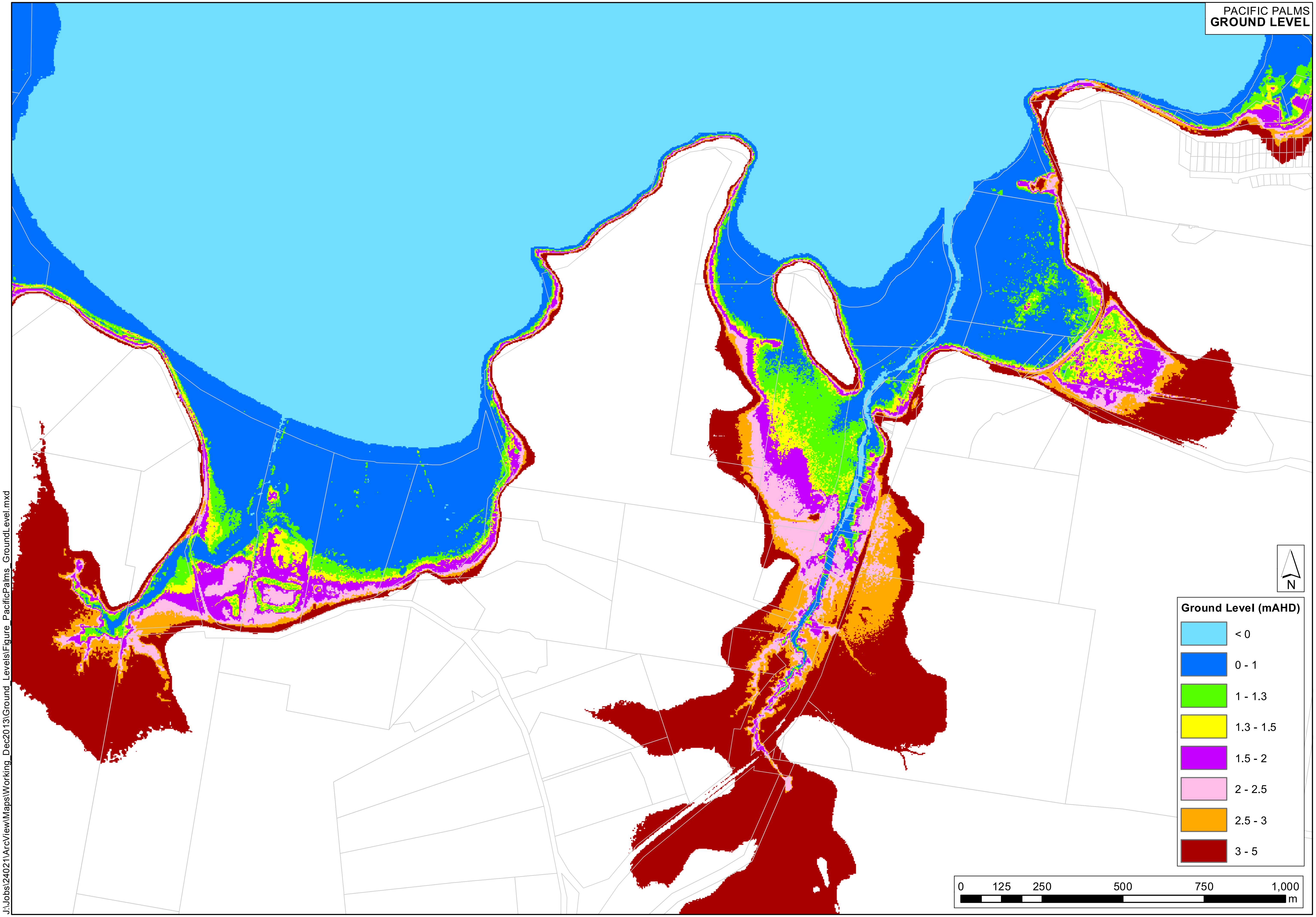

PACIFIC PALMS
GROUND LEVEL
N
Ground Level (mAHD)
< 0
0 - 1
1 - 1.3
1.3 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 5
0
125
250
500
750
1,000
m
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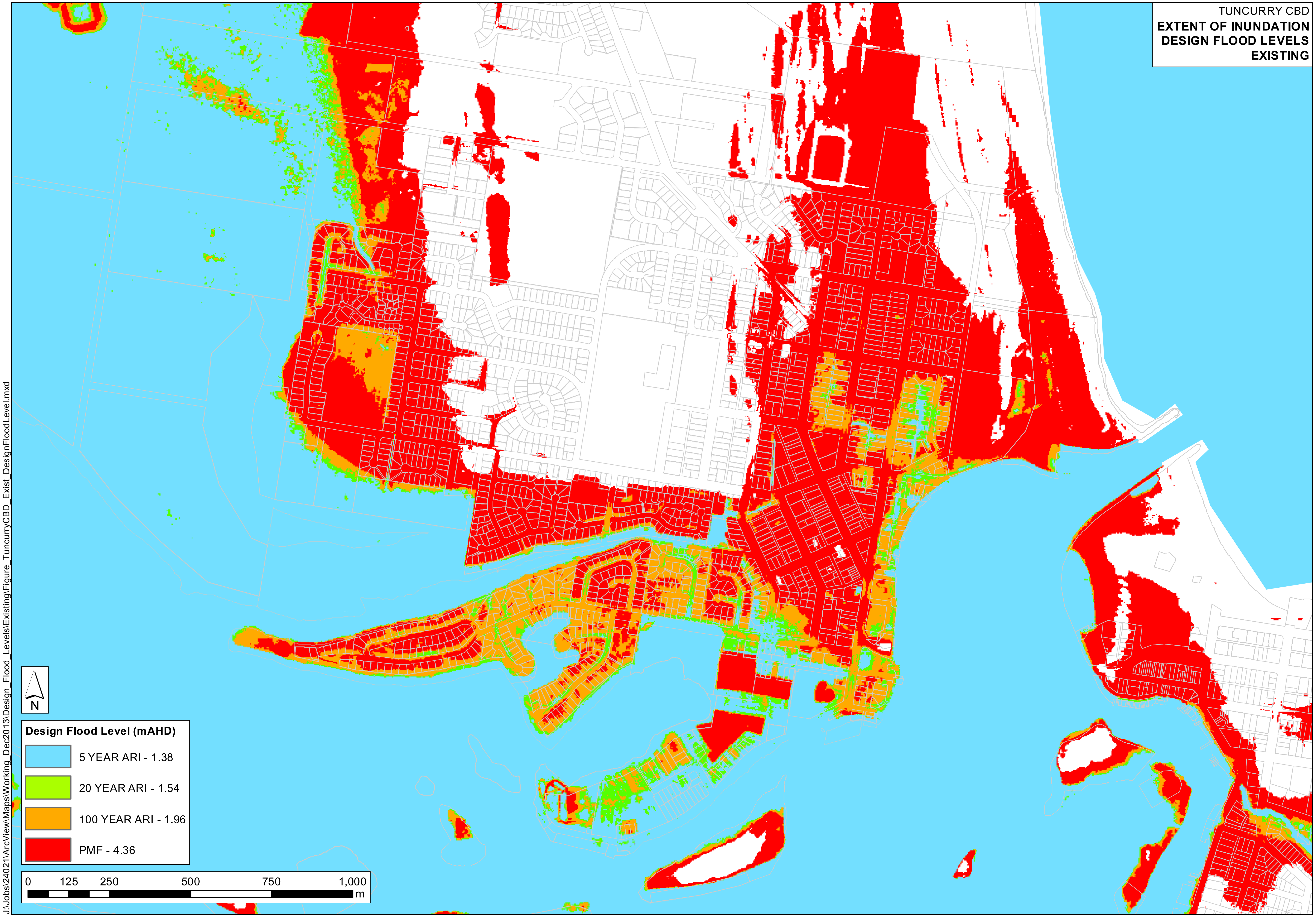

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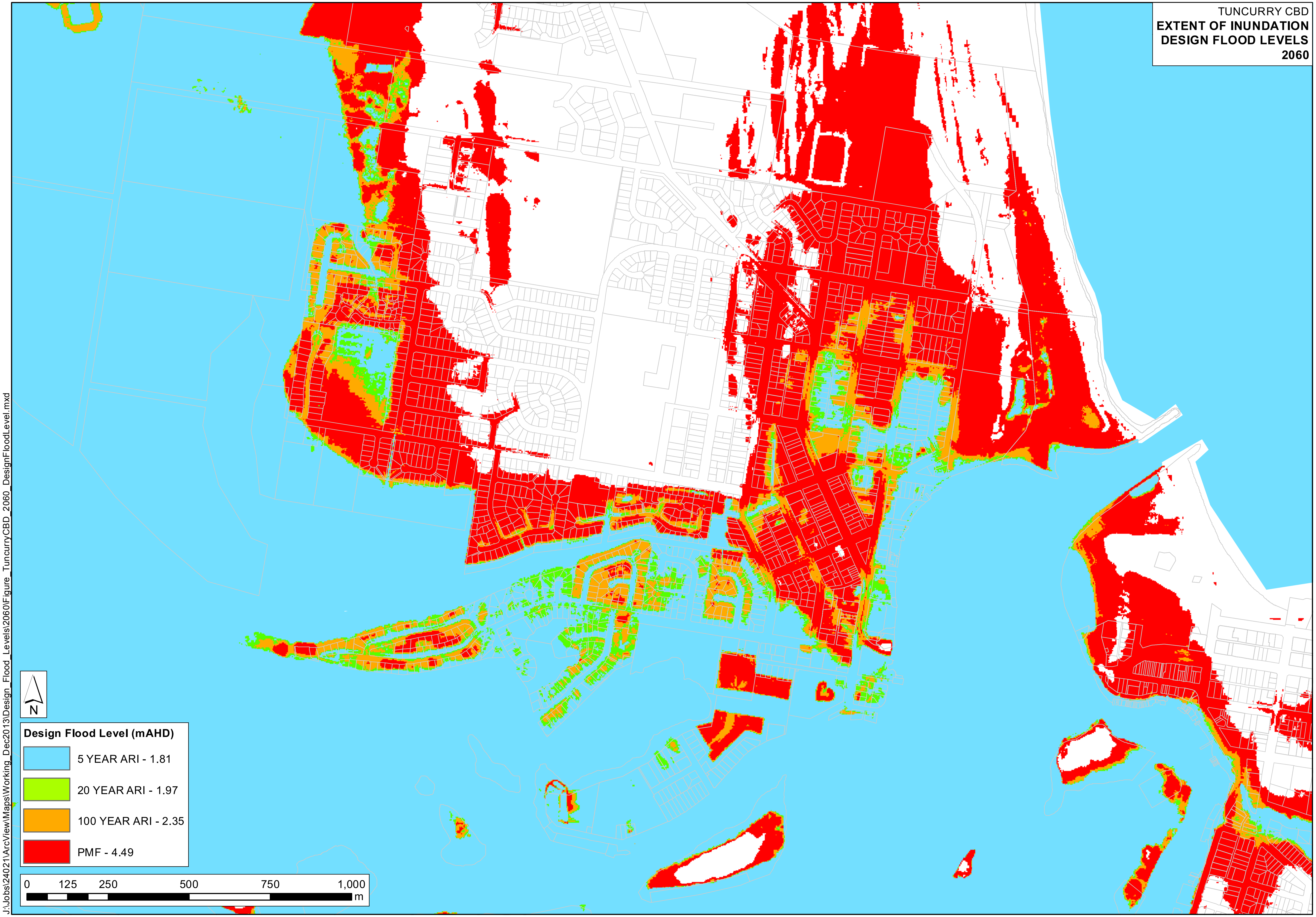

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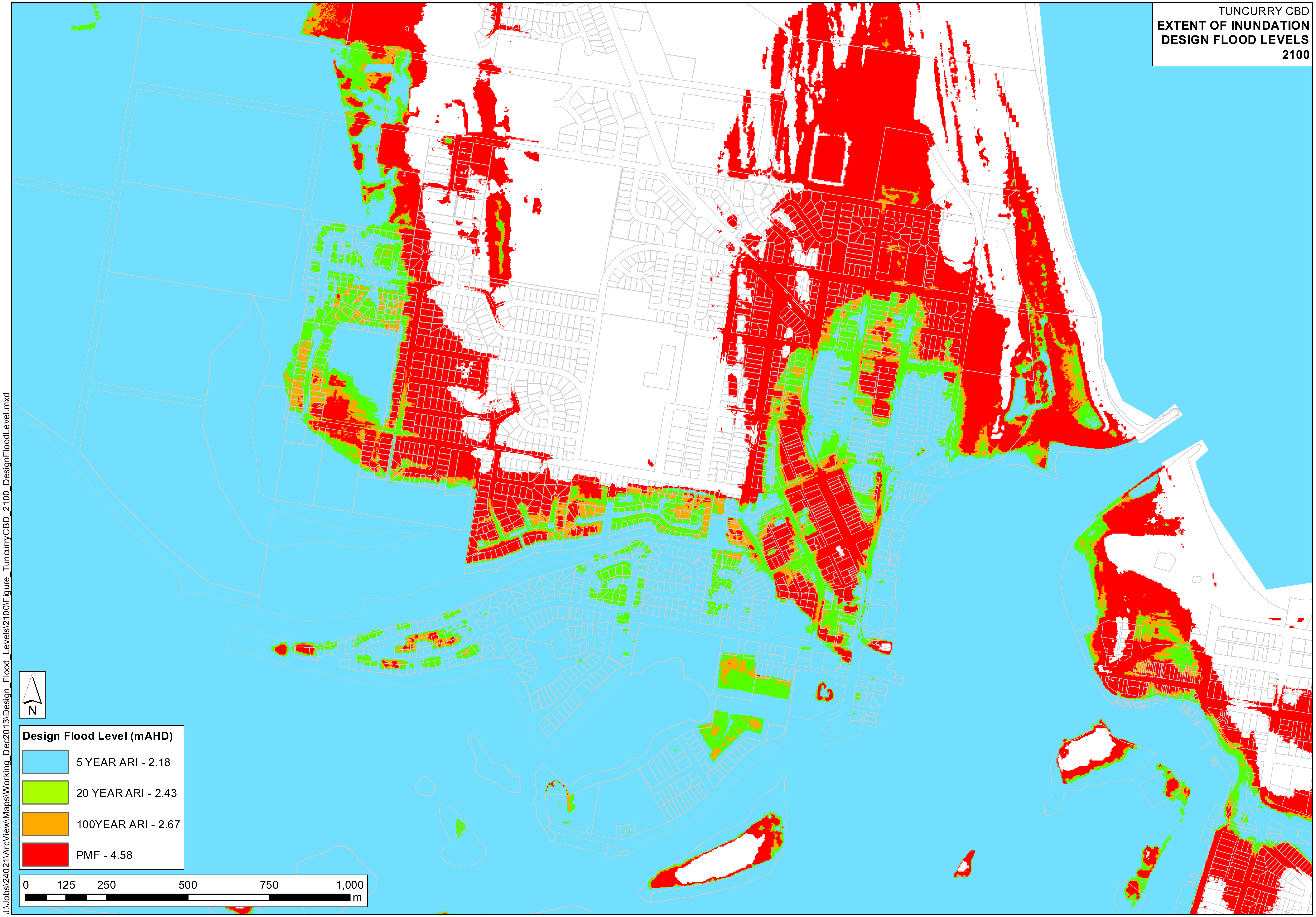

TUNCURRY CBD
EXTENT OF INUNDATION
DESIGN FLOOD LEVELS
2100
N
Design Flood Level (mAHD)
5 YEAR ARI - 2.18
20 YEAR ARI - 2.43
100YEAR ARI - 2.67
PMF - 4.58
0 125 250 500 750 1,000
m
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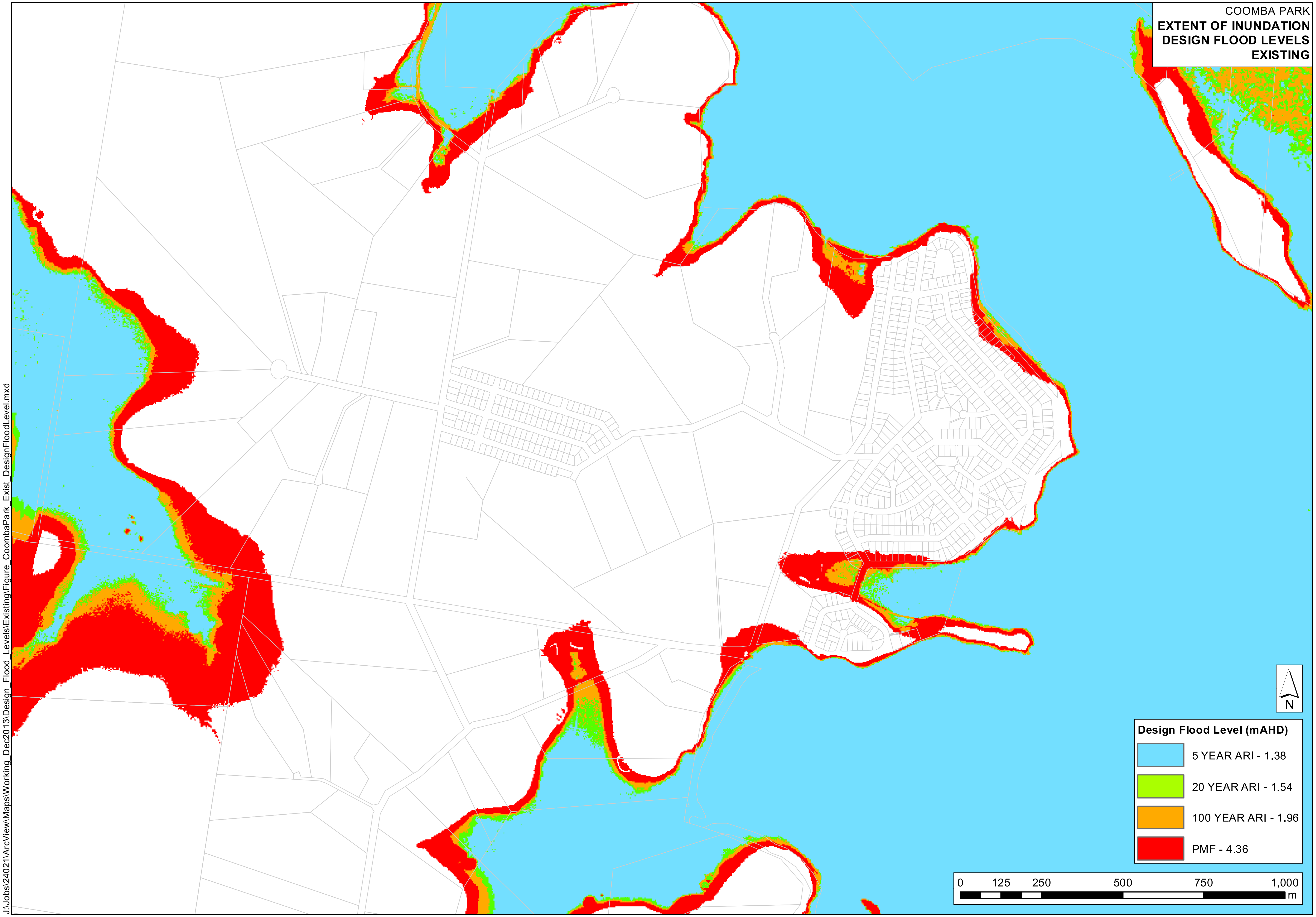

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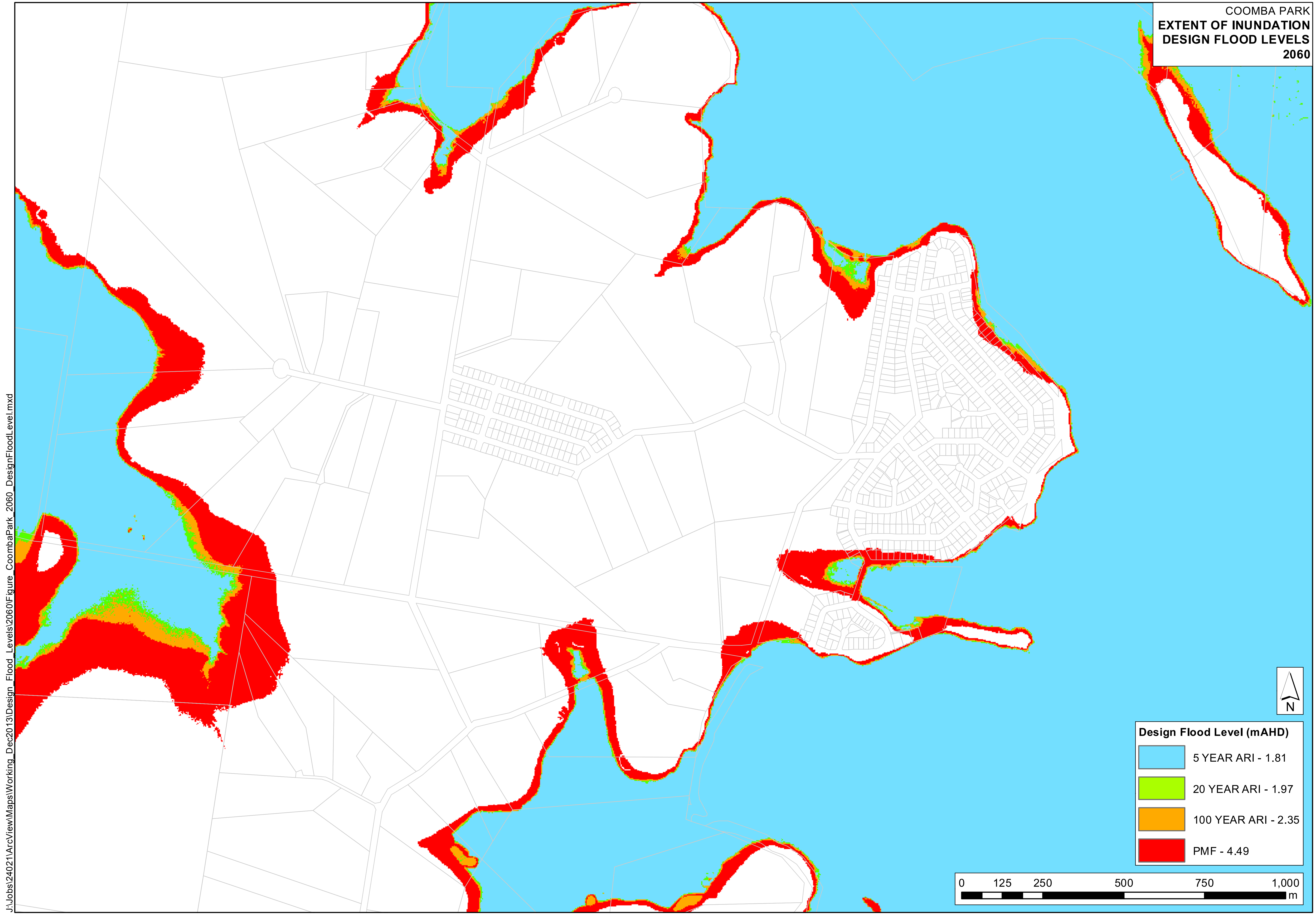
COOMBA PARK
EXTENT OF INUNDATION
DESIGN FLOOD LEVELS
2060
N
Design Flood Level (mAHD)
5 YEAR ARI - 1.81
20 YEAR ARI - 1.97
100 YEAR ARI - 2.35
PMF - 4.49
0 125 250 500 750 1,000
m
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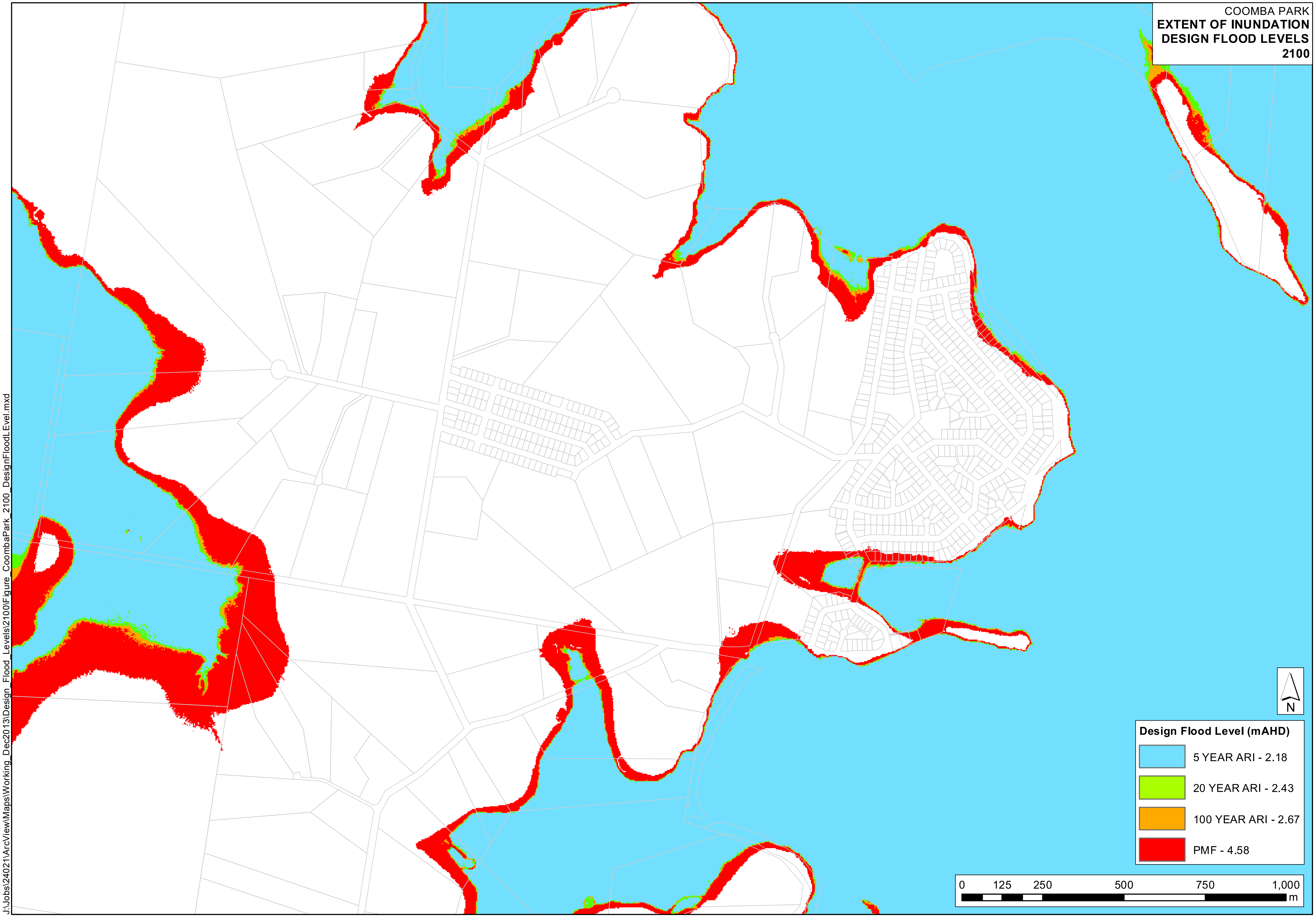

COOMBA PARK
EXTENT OF INUNDATION
DESIGN FLOOD LEVELS
2100
N
Design Flood Level (mAHD)
5 YEAR ARI - 2.18
20 YEAR ARI - 2.43
100 YEAR ARI - 2.67
PMF - 4.58
0 125 250 500 750 1,000
m
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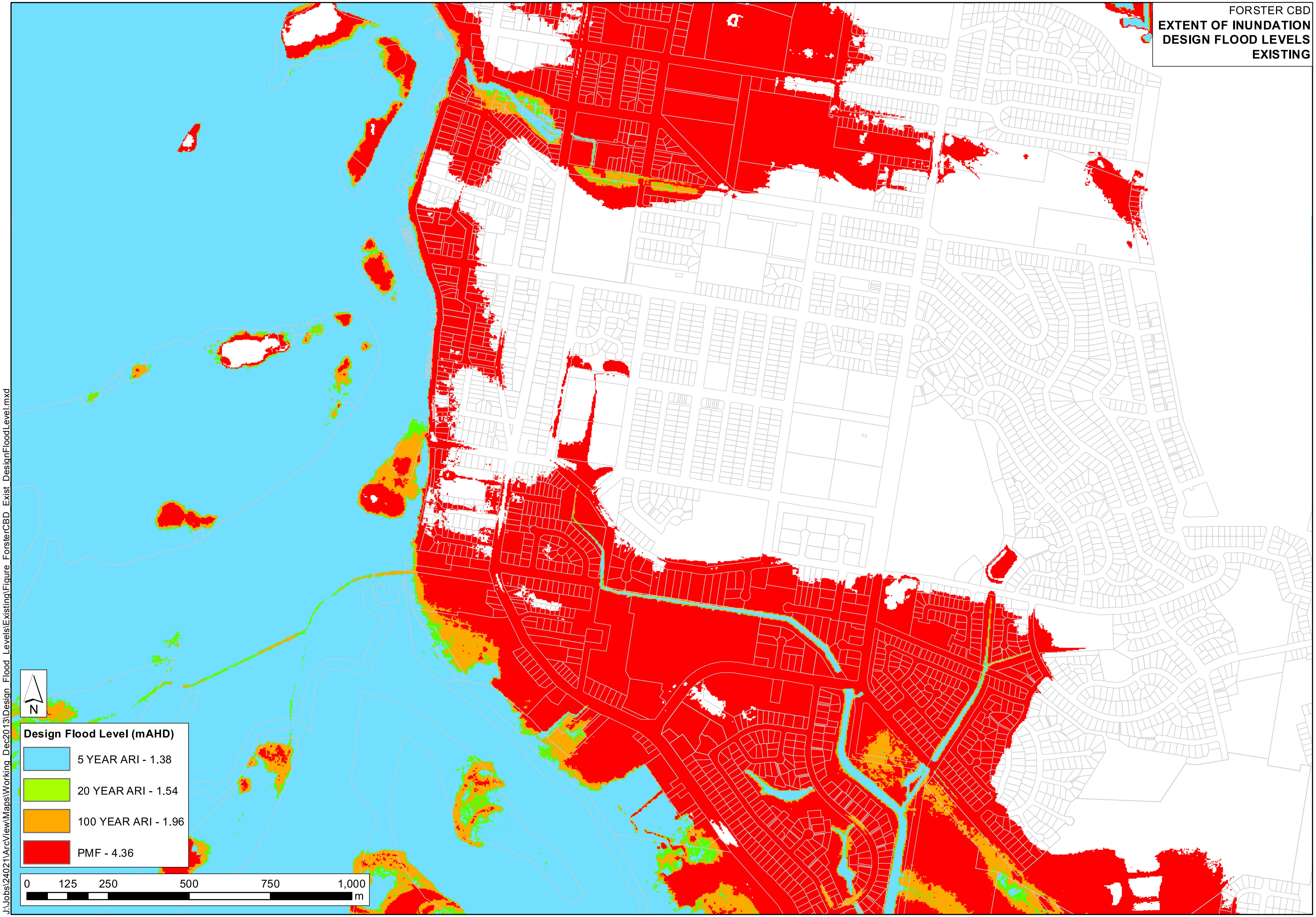
FORSTER CBD

EXTENT OF INUNDATION
DESIGN FLOOD LEVELS
EXISTING



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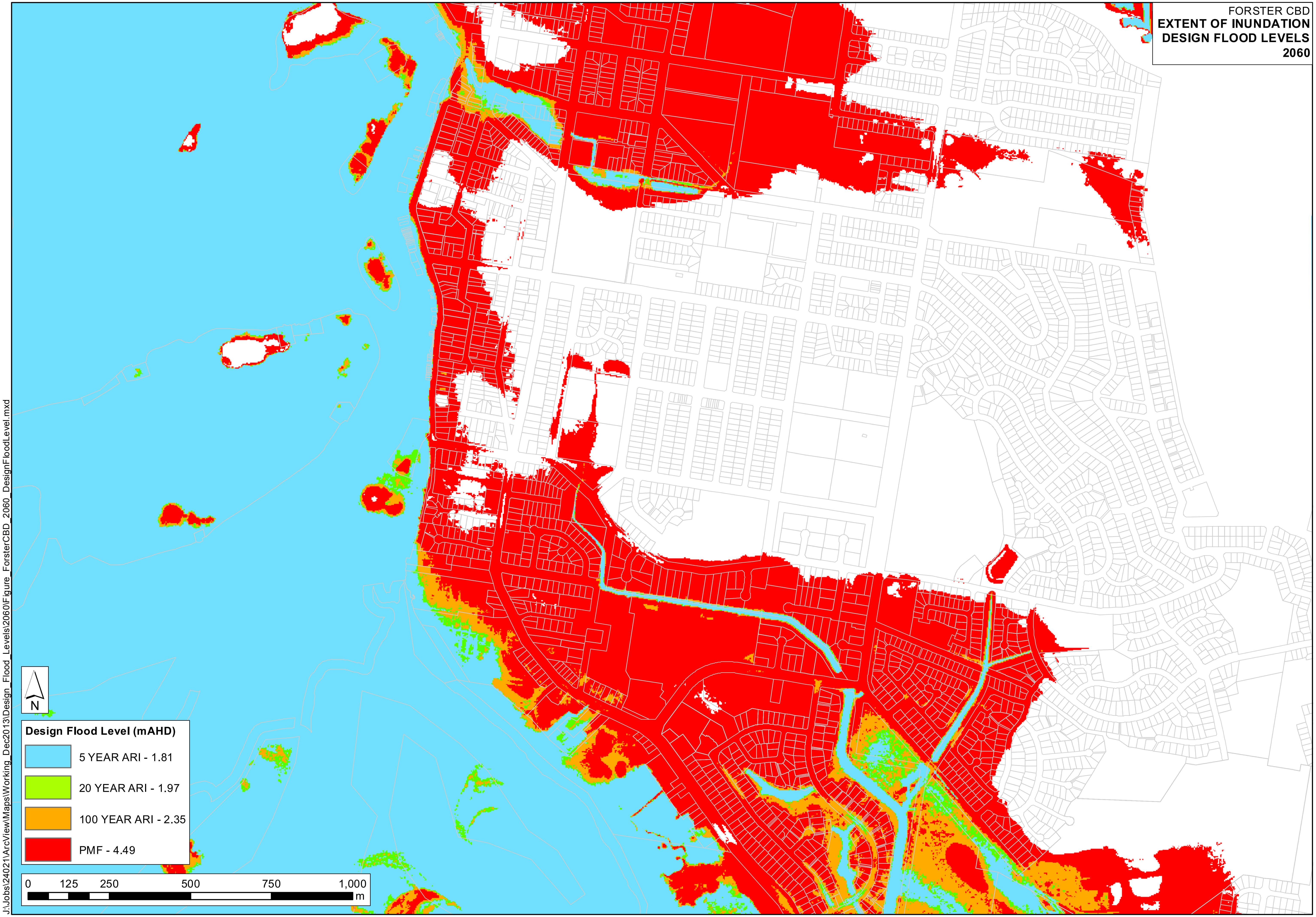

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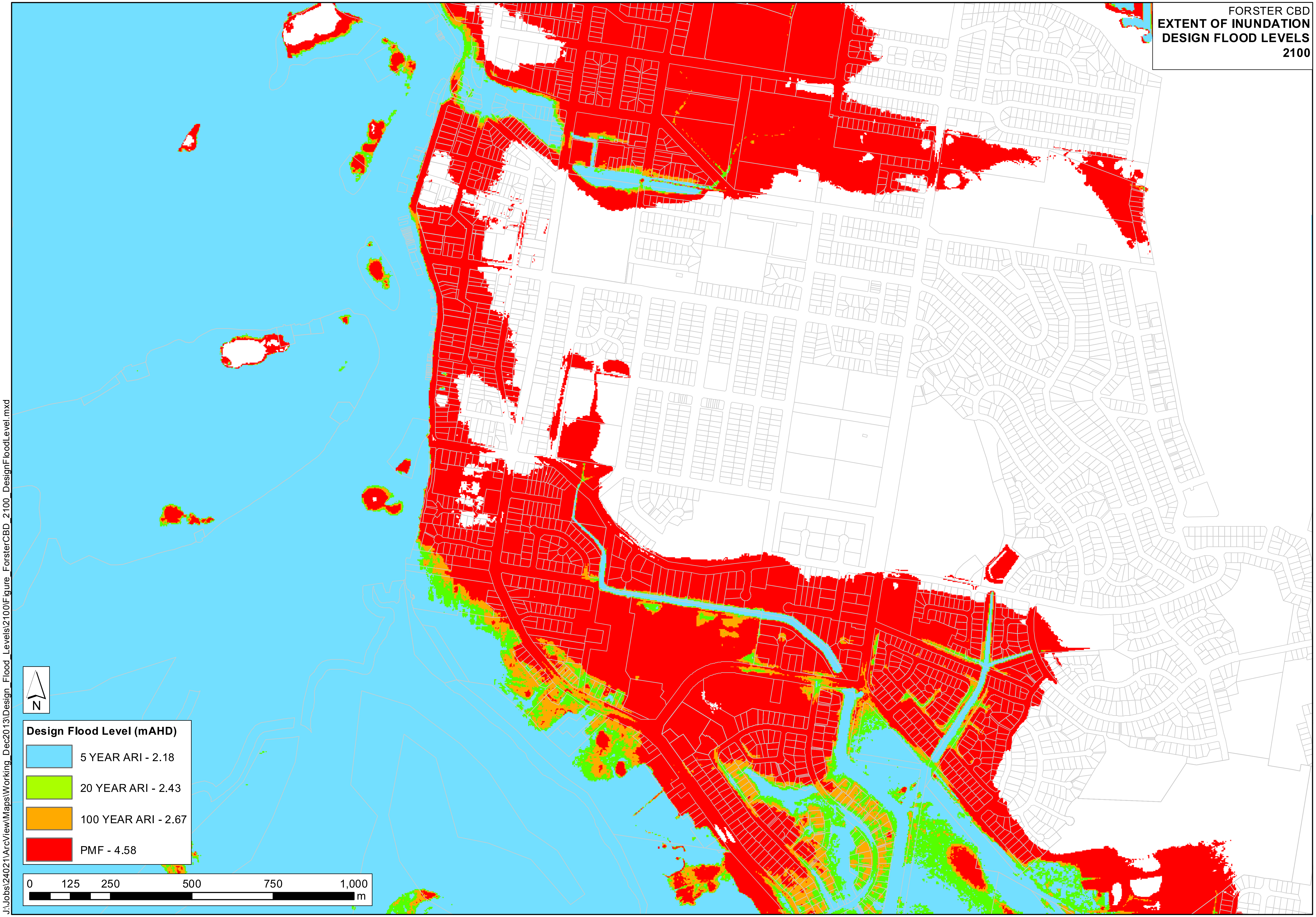

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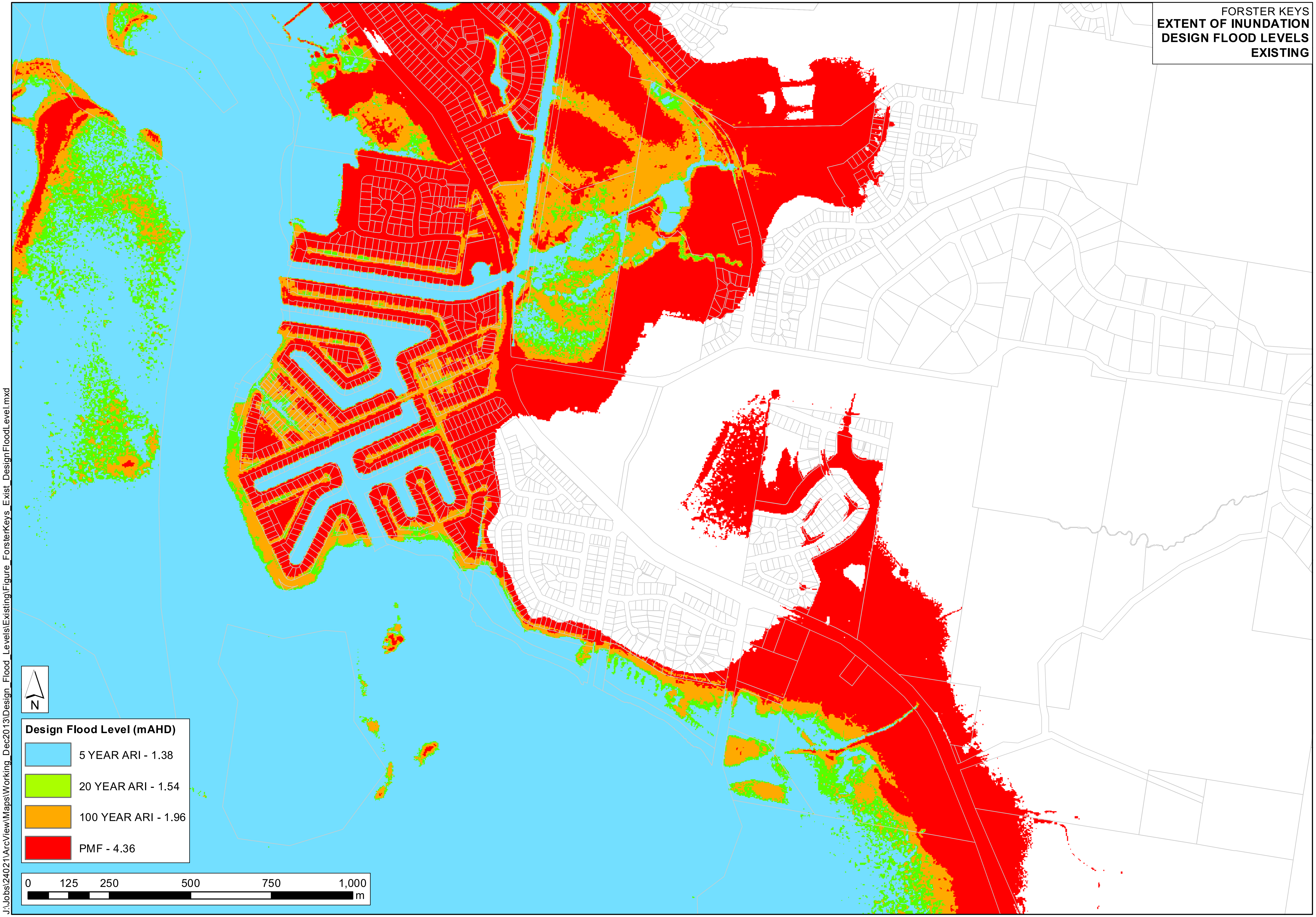

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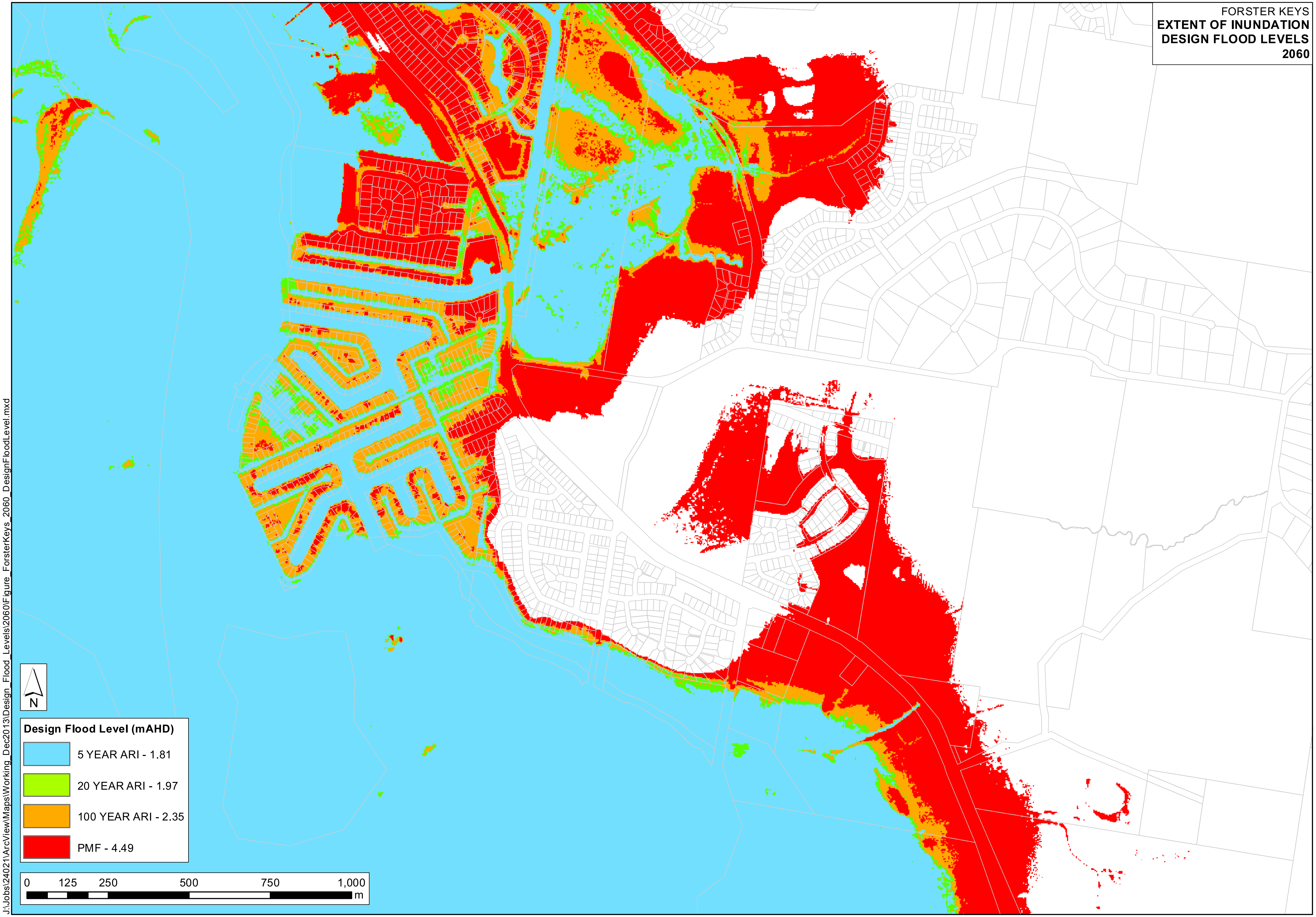
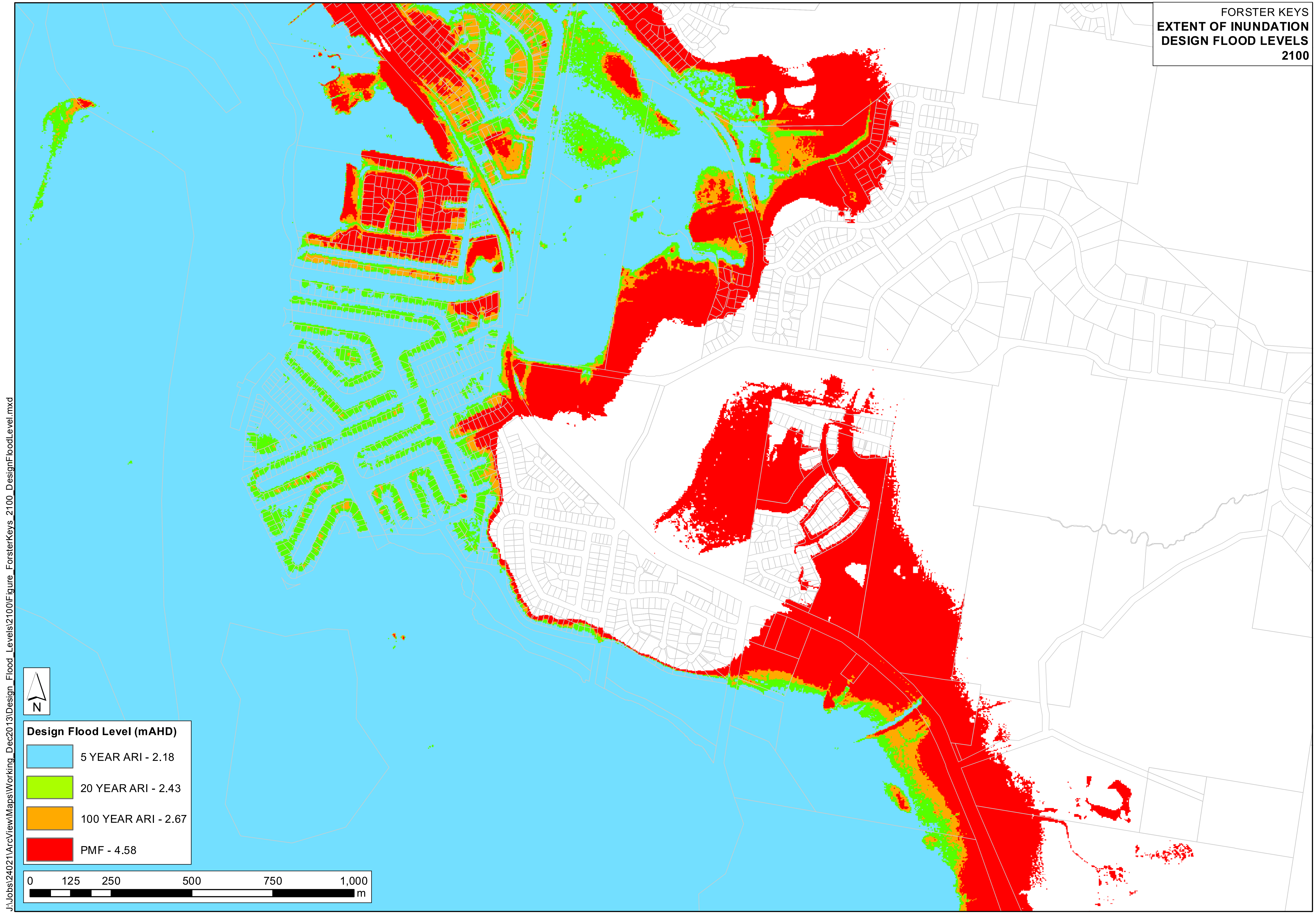
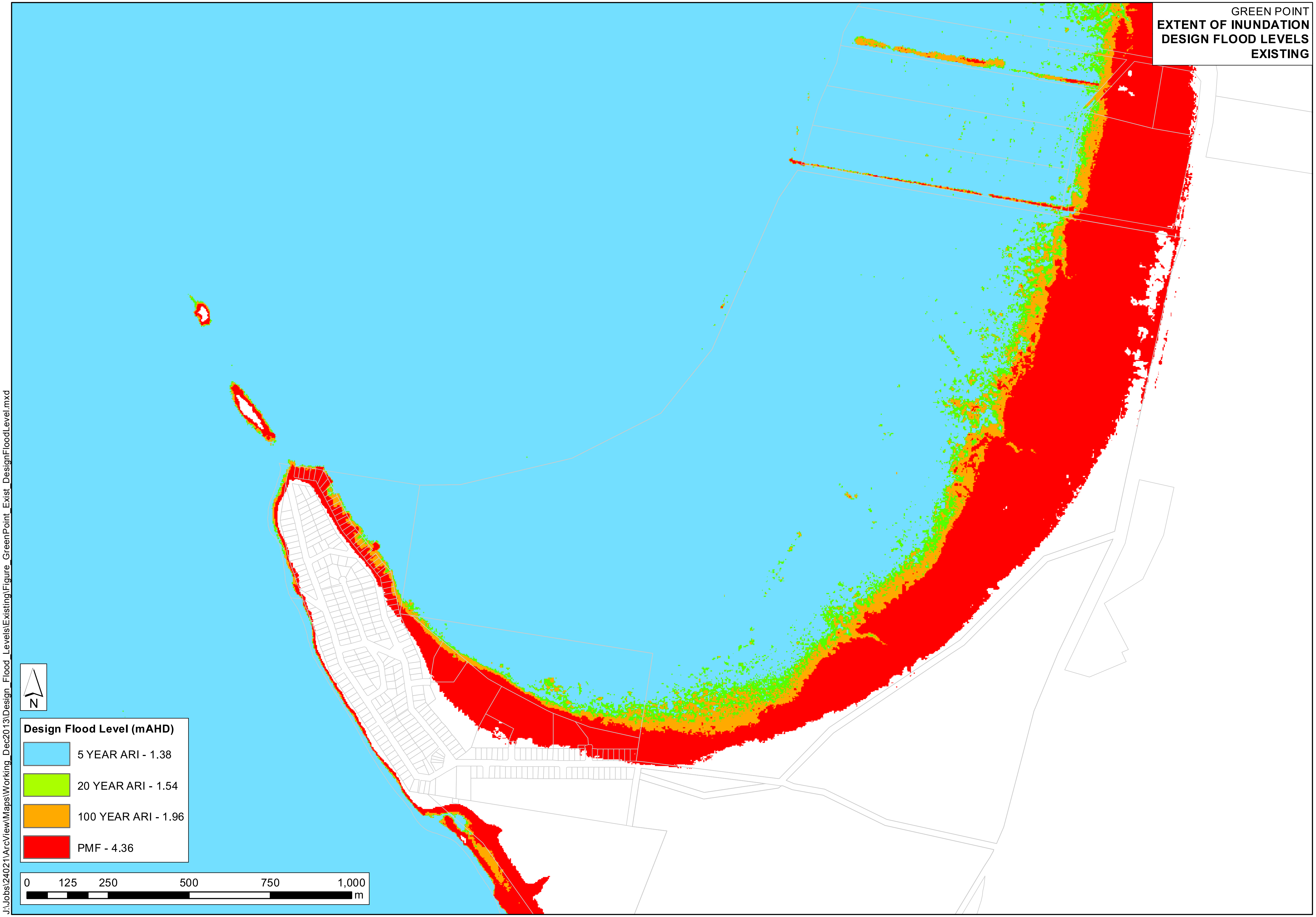
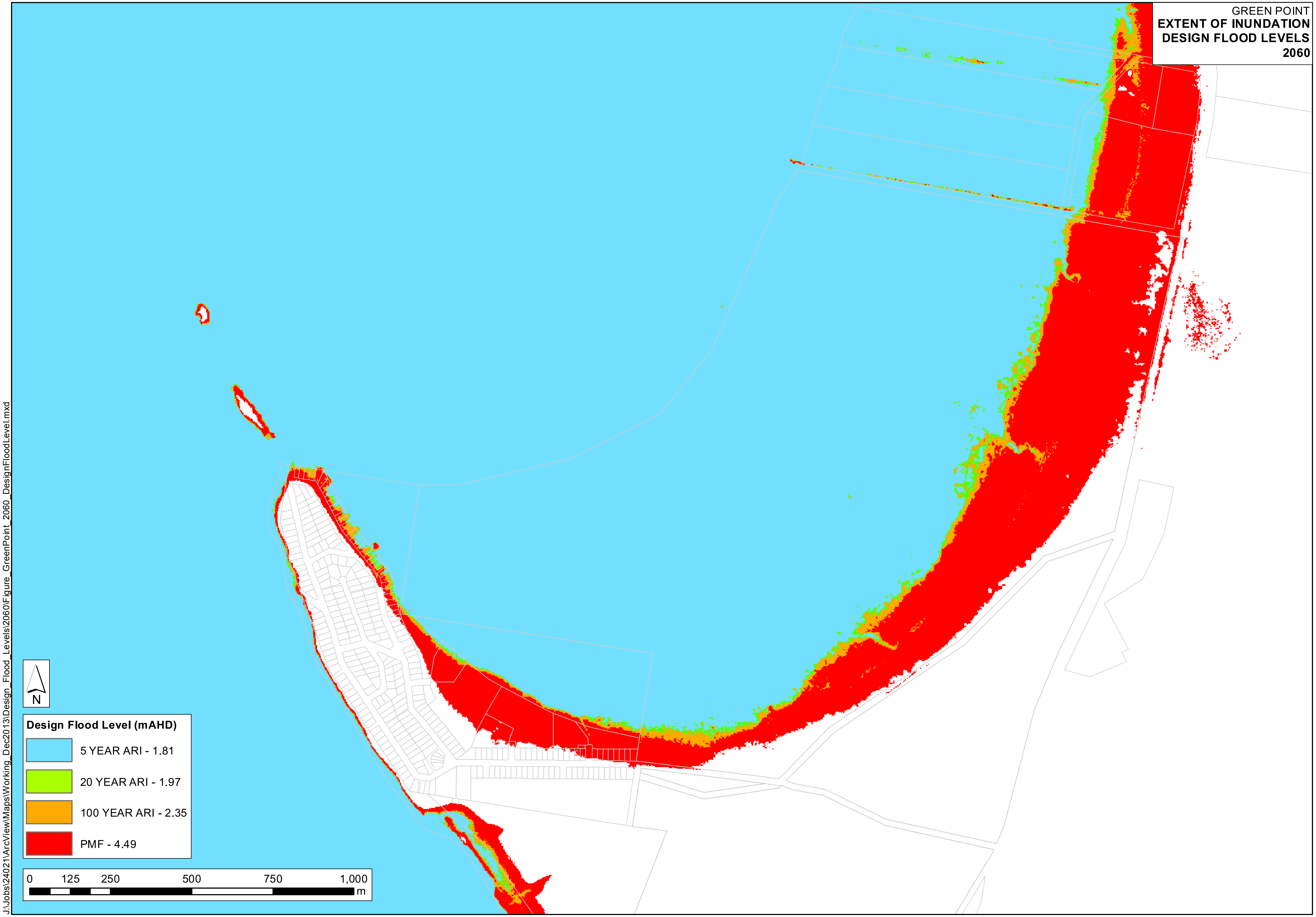

FORSTER KEYS
EXTENT OF INUNDATION
DESIGN FLOOD LEVELS
2060
N
Design Flood Level (mAHD)
5 YEAR ARI - 1.81
20 YEAR ARI - 1.97
100 YEAR ARI - 2.35
PMF - 4.49
0 125 250 500 750 1,000
m
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Design_Flood_Levels\2060\Figure_ForsterKeys_2060_DesignFloodLevel.mxd



FORSTER KEYS
EXTENT OF INUNDATION
DESIGN FLOOD LEVELS
2100
N
Design Flood Level (mAHD)
5 YEAR ARI - 2.18
20 YEAR ARI - 2.43
100 YEAR ARI - 2.67
PMF - 4.58
0 125 250 500 750 1,000
m
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Design_Flood_Levels\2100\Figure_ForsterKeys_2100_DesignFloodLevel.mxd



GREEN POINT
EXTENT OF INUNDATION
DESIGN FLOOD LEVELS
EXISTING
N
Design Flood Level (mAHD)
5 YEAR ARI - 1.38
20 YEAR ARI - 1.54
100 YEAR ARI - 1.96
PMF - 4.36
0 125 250 500 750 1,000
m
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Design_Flood_Levels\Existing\Figure_GreenPoint_Exist_DesignFloodLevel.mxd



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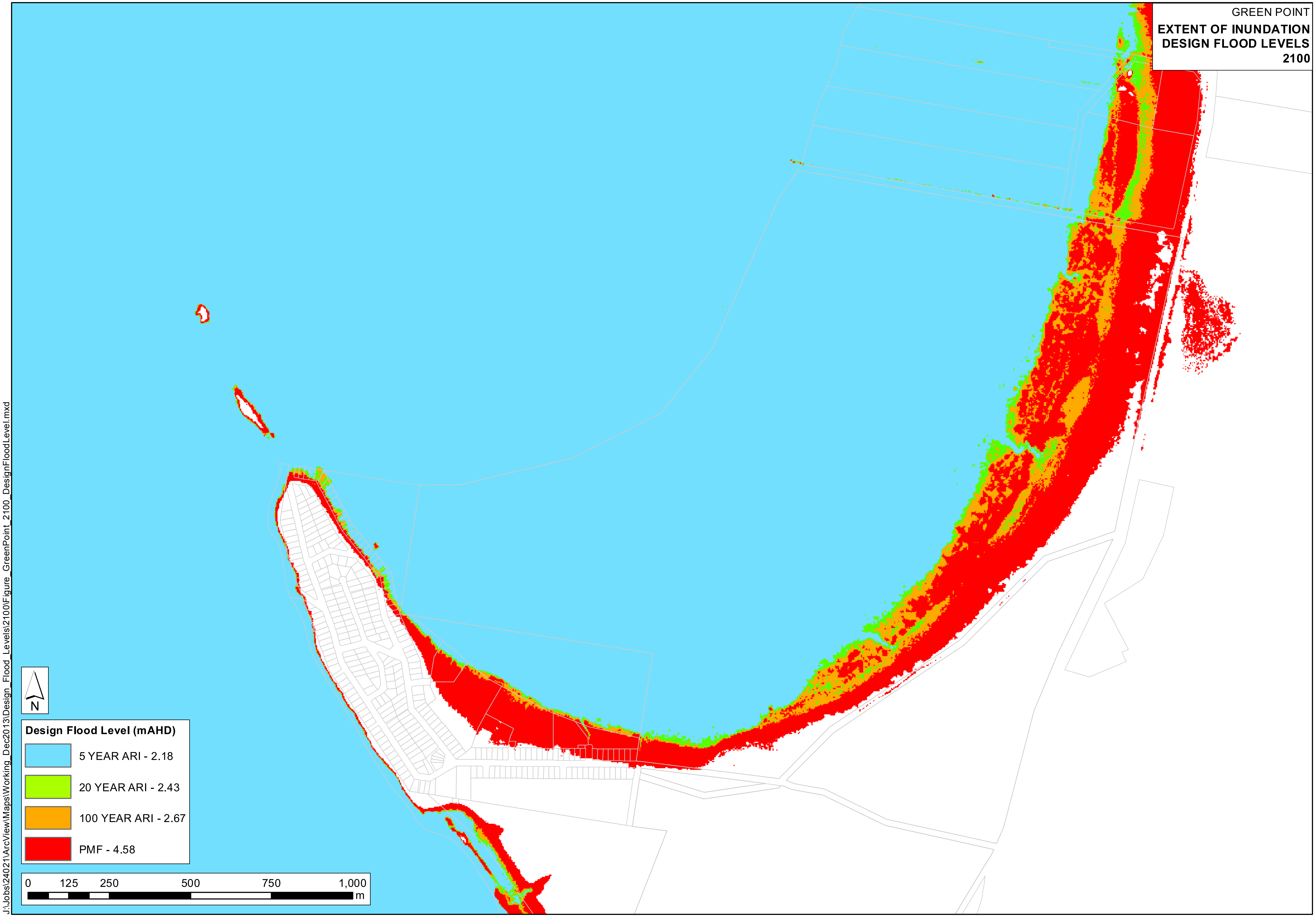
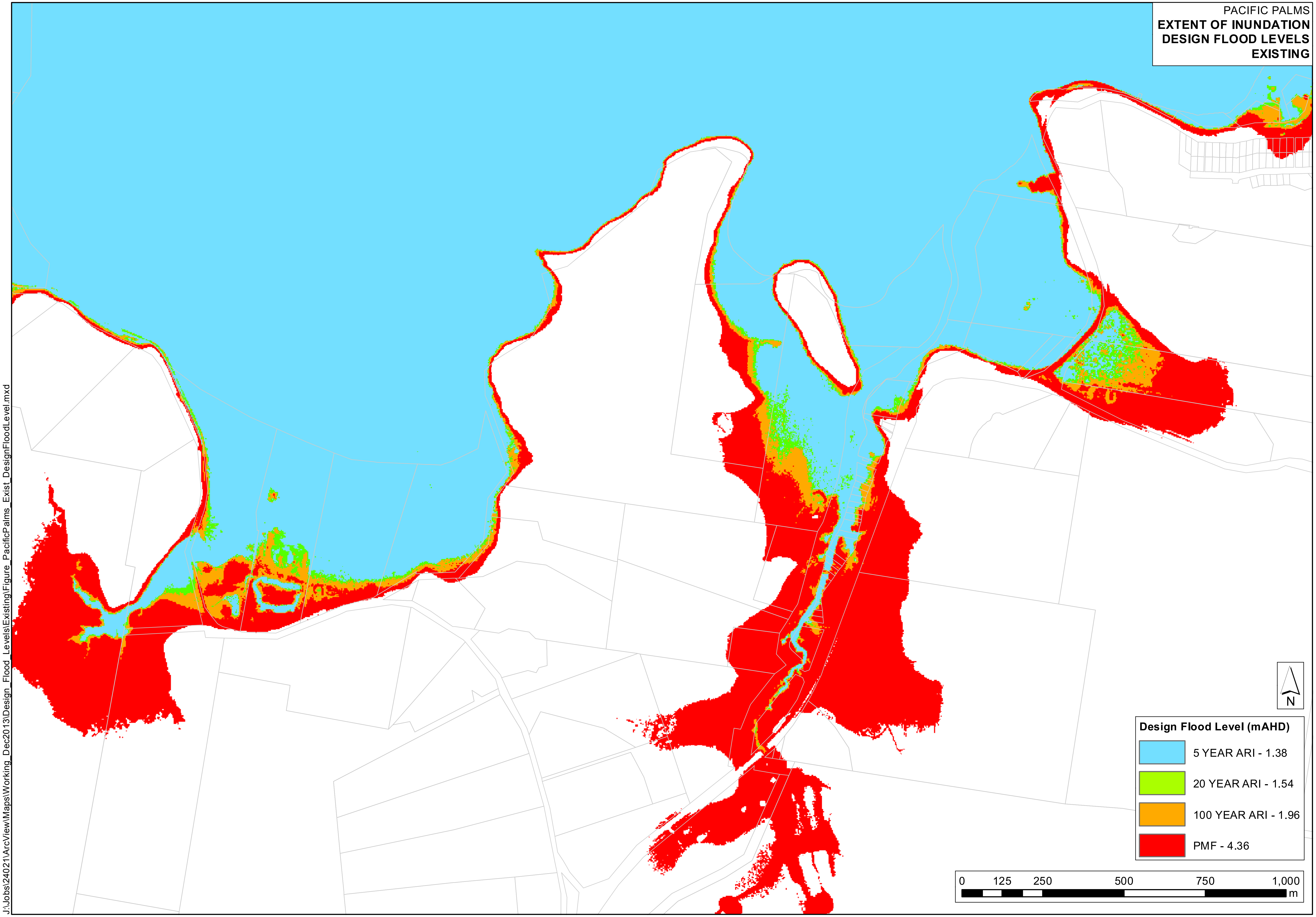

GREEN POINT
EXTENT OF INUNDATION
DESIGN FLOOD LEVELS
2100
N
Design Flood Level (mAHD)
5 YEAR ARI - 2.18
20 YEAR ARI - 2.43
100 YEAR ARI - 2.67
PMF - 4.58
0 125 250 500 750 1,000
m
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Design_Flood_Levels\2100\Figure_GreenPoint_2100_DesignFloodLevel.mxd



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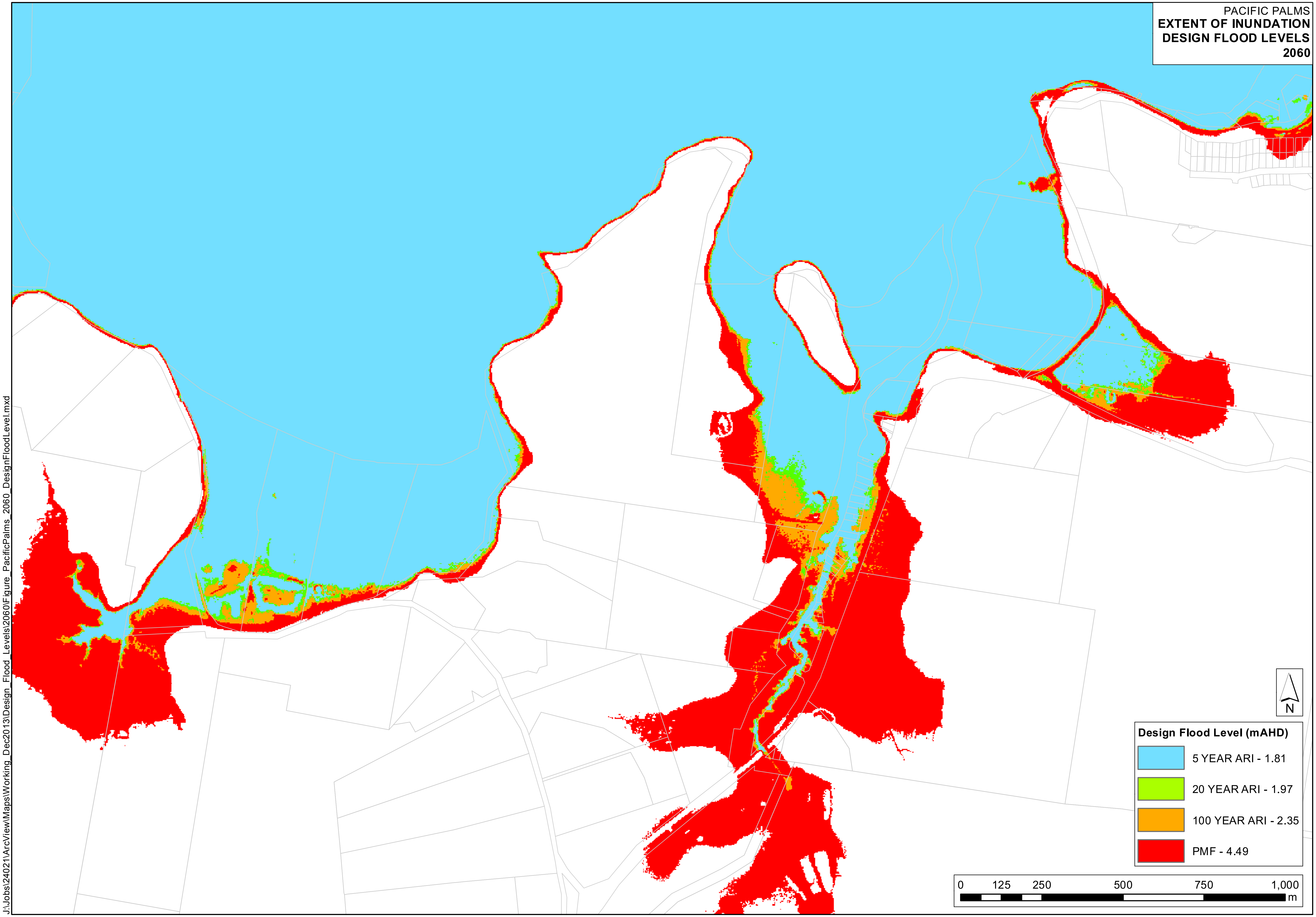

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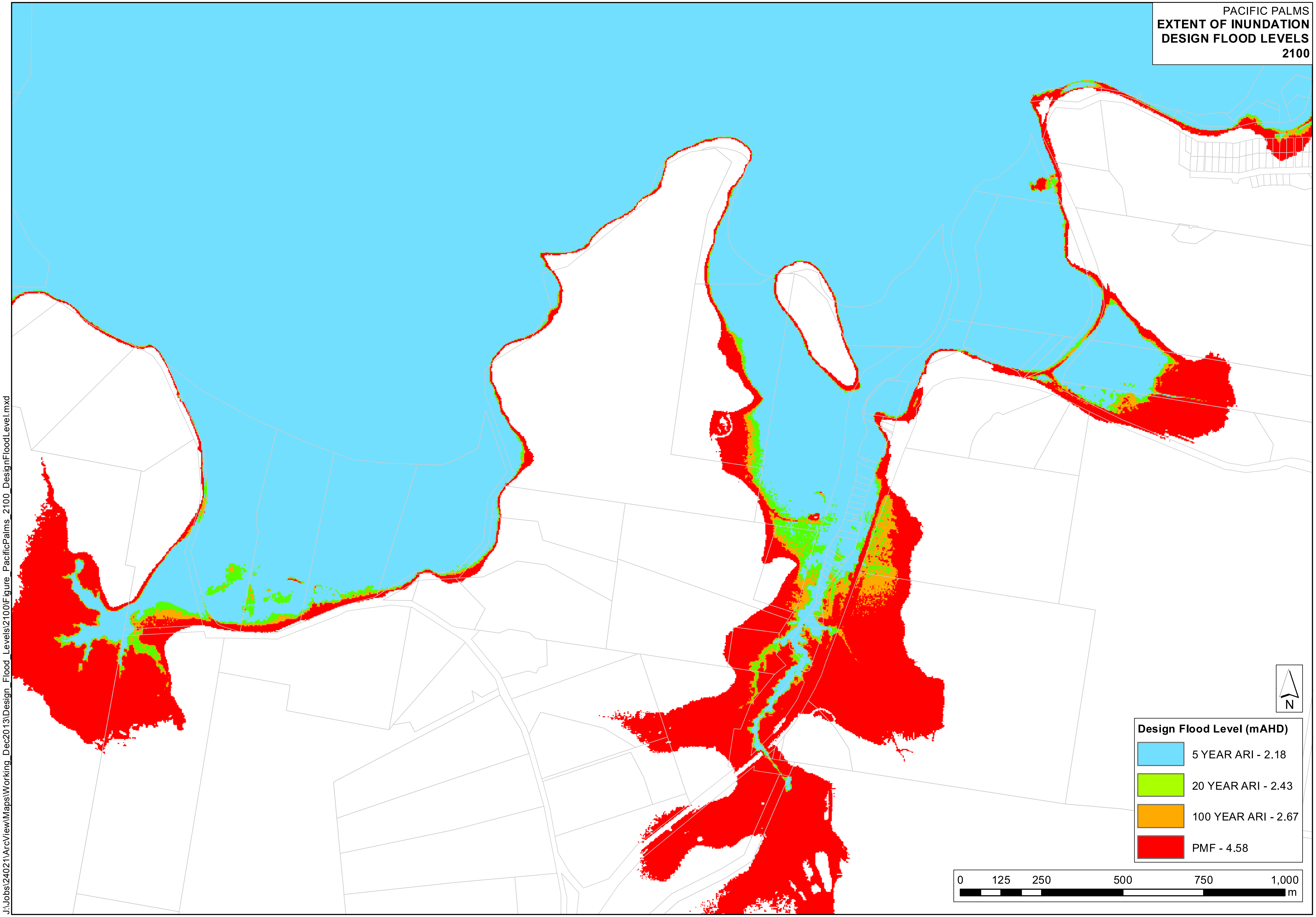

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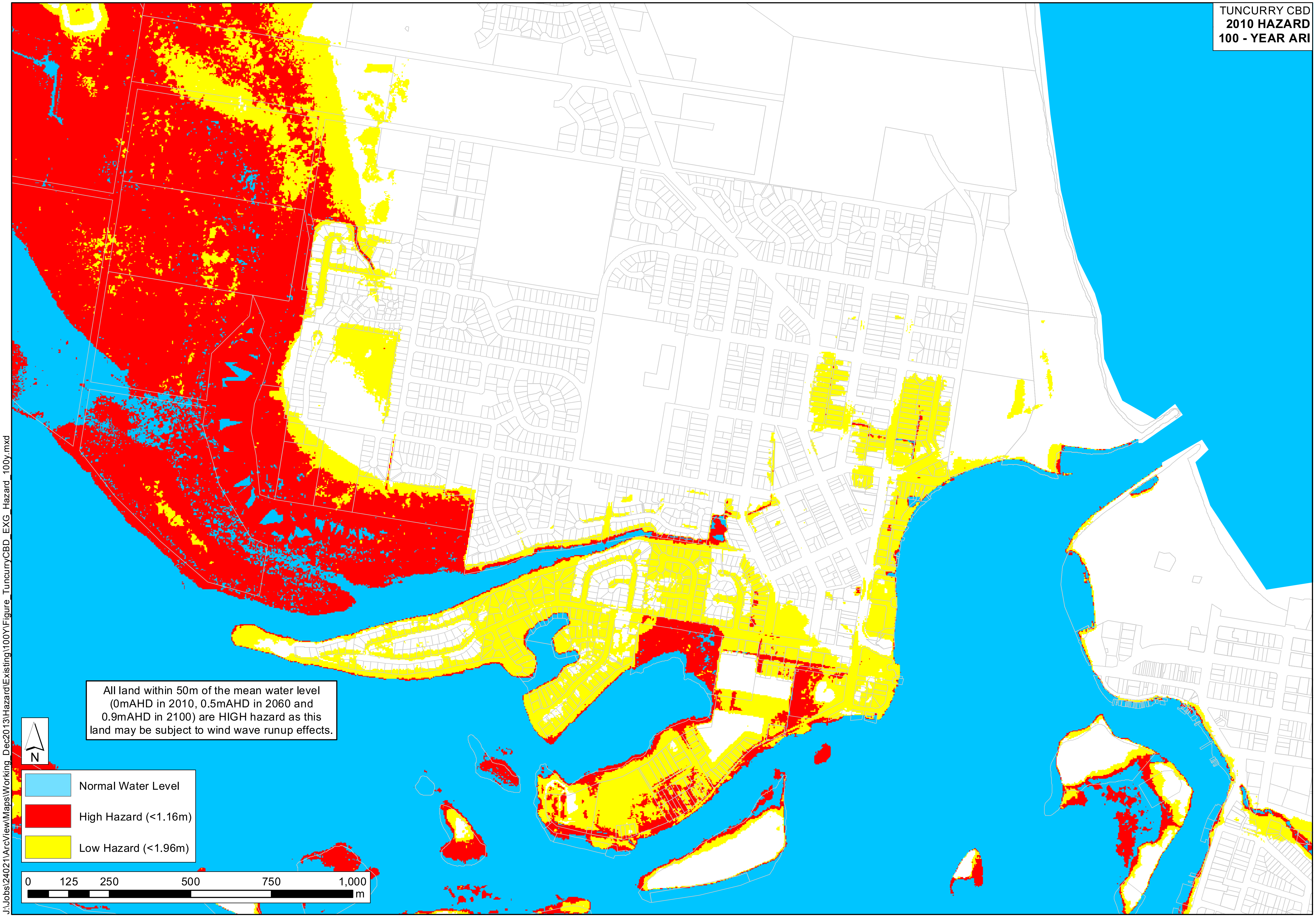
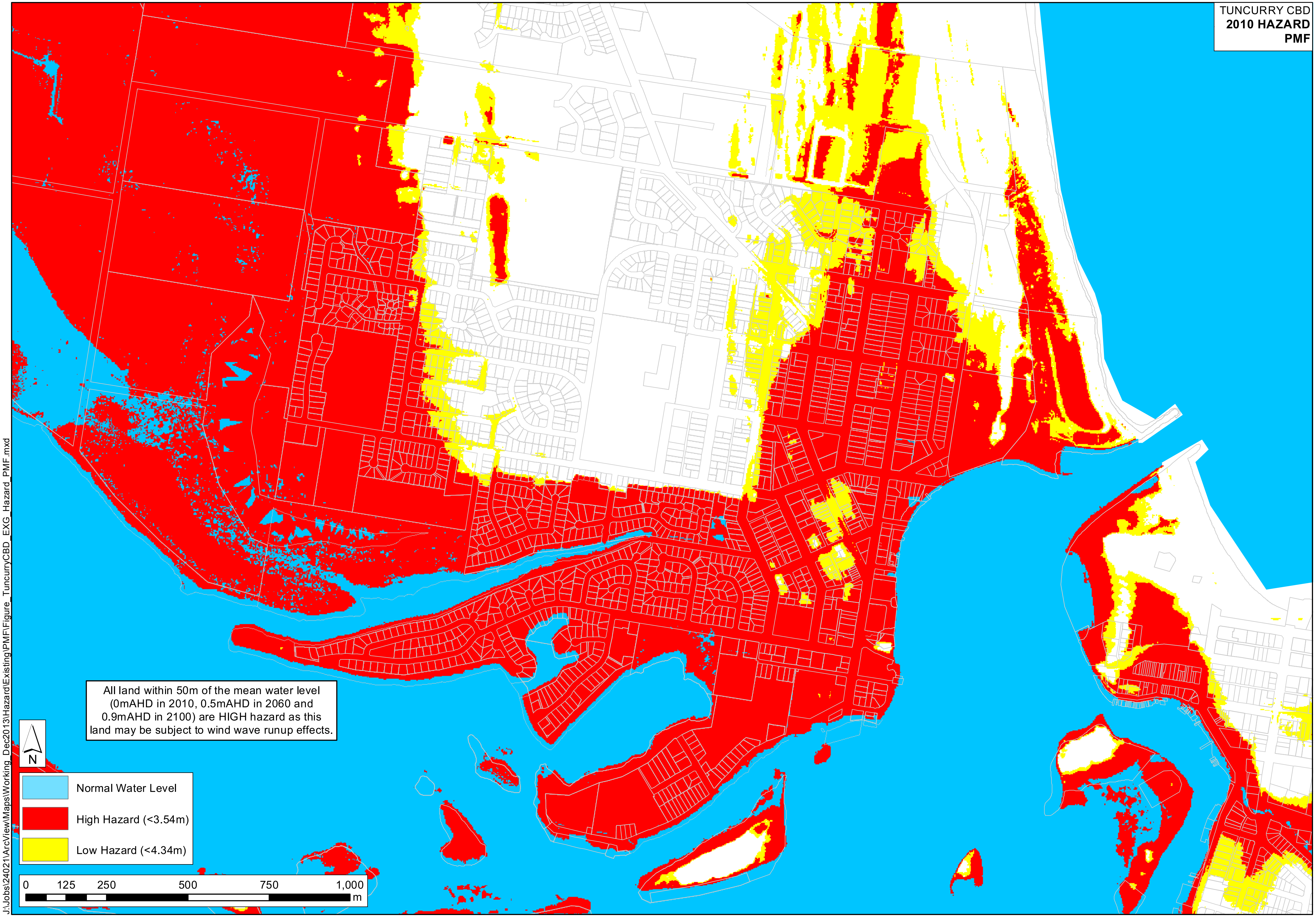
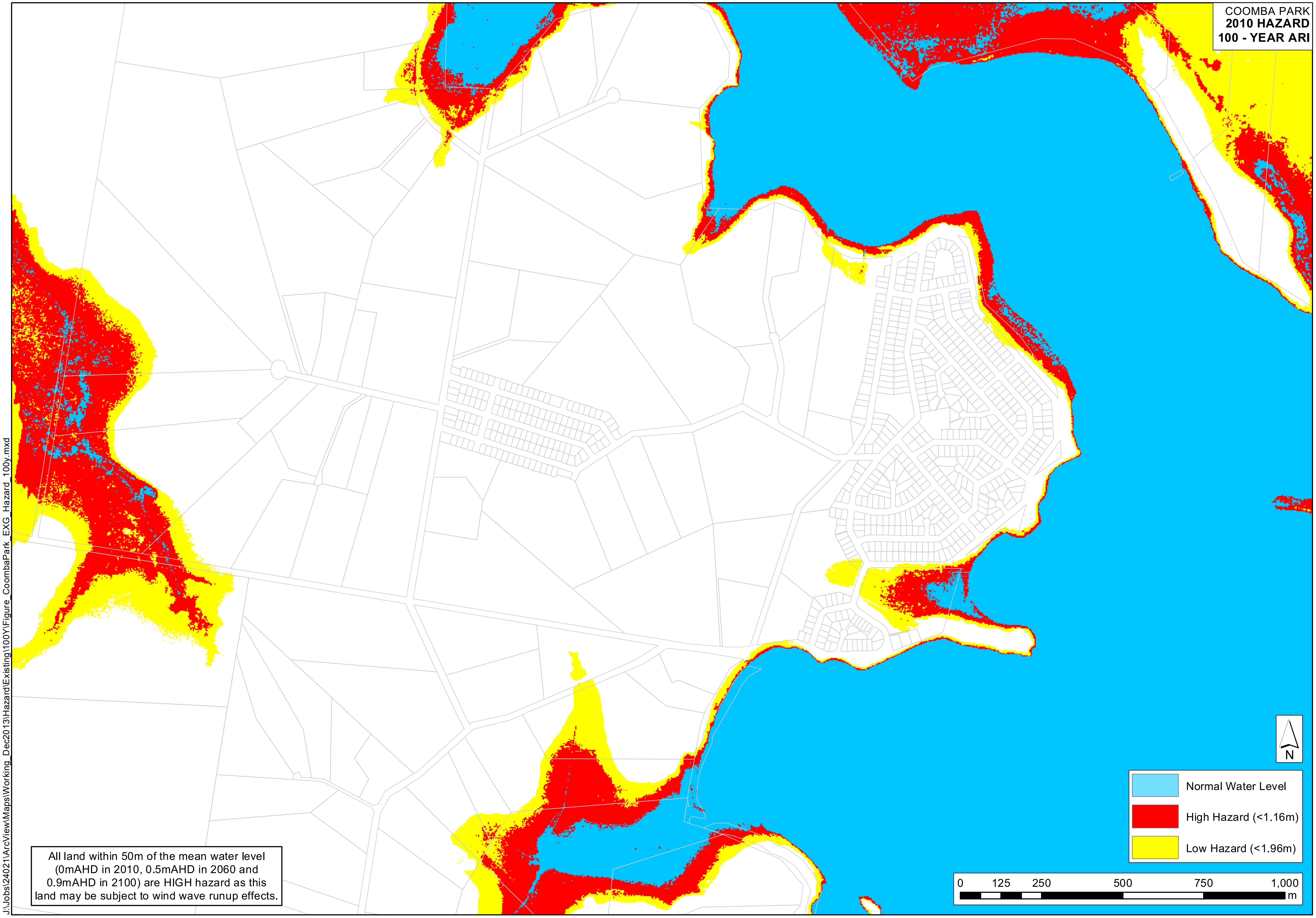
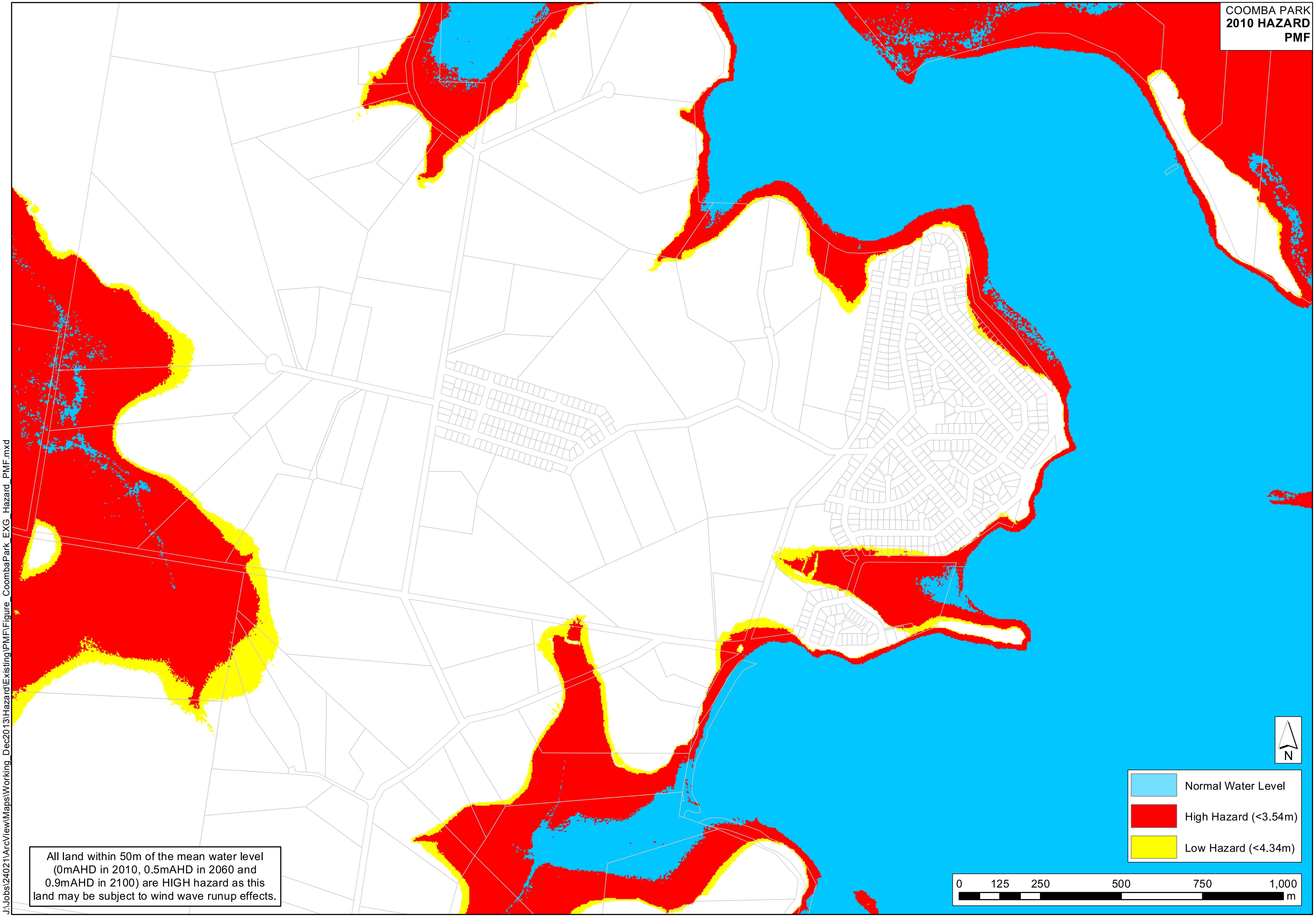


TUNCURRY CBD
2010 HAZARD
100 - YEAR ARI
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
N
Normal Water Level
High Hazard (<1.16m)
Low Hazard (<1.96m)
0 125 250 500 750 1,000
m
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Hazard\Existing\100Y\Figure_TuncurryCBD_EXG_Hazard_100y.mxd

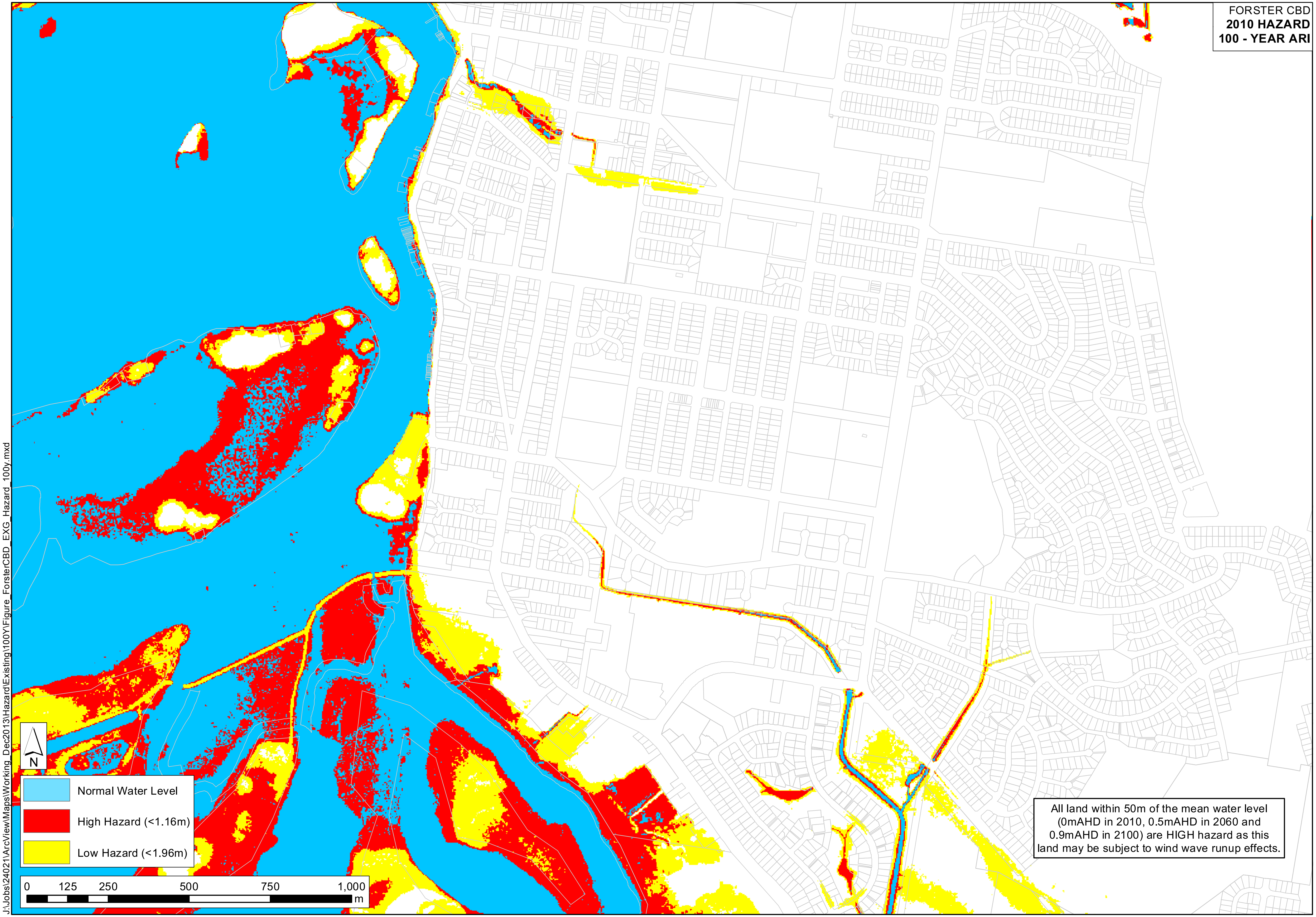


TUNCURRY CBD
2010 HAZARD
PMF
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
N
Normal Water Level
High Hazard (<3.54m)
Low Hazard (<4.34m)
0 125 250 500 750 1,000
m
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Hazard\Existing\PMF\Figure_TuncurryCBD_EXG_Hazard_PMF.mxd


COOMBA PARK
2010 HAZARD
100 - YEAR ARI
Normal Water Level
High Hazard (<1.16m)
Low Hazard (<1.96m)
0
125
250
500
750
1,000
m
N
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
J:\Jobs\24021\ArcView\Maps\Working_Dec2013\Hazard\Existing\100Y\Figure_CoombaPark_EXG_Hazard_100y.mxd



COOMBA PARK
2010 HAZARD
PMF
Normal Water Level
High Hazard (<3.54m)
Low Hazard (<4.34m)
N
0
125
250
500
750
1,000
m
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Hazard\Existing\PMF\Figure_CoombaPark_EXG_Hazard_PMF.mxd



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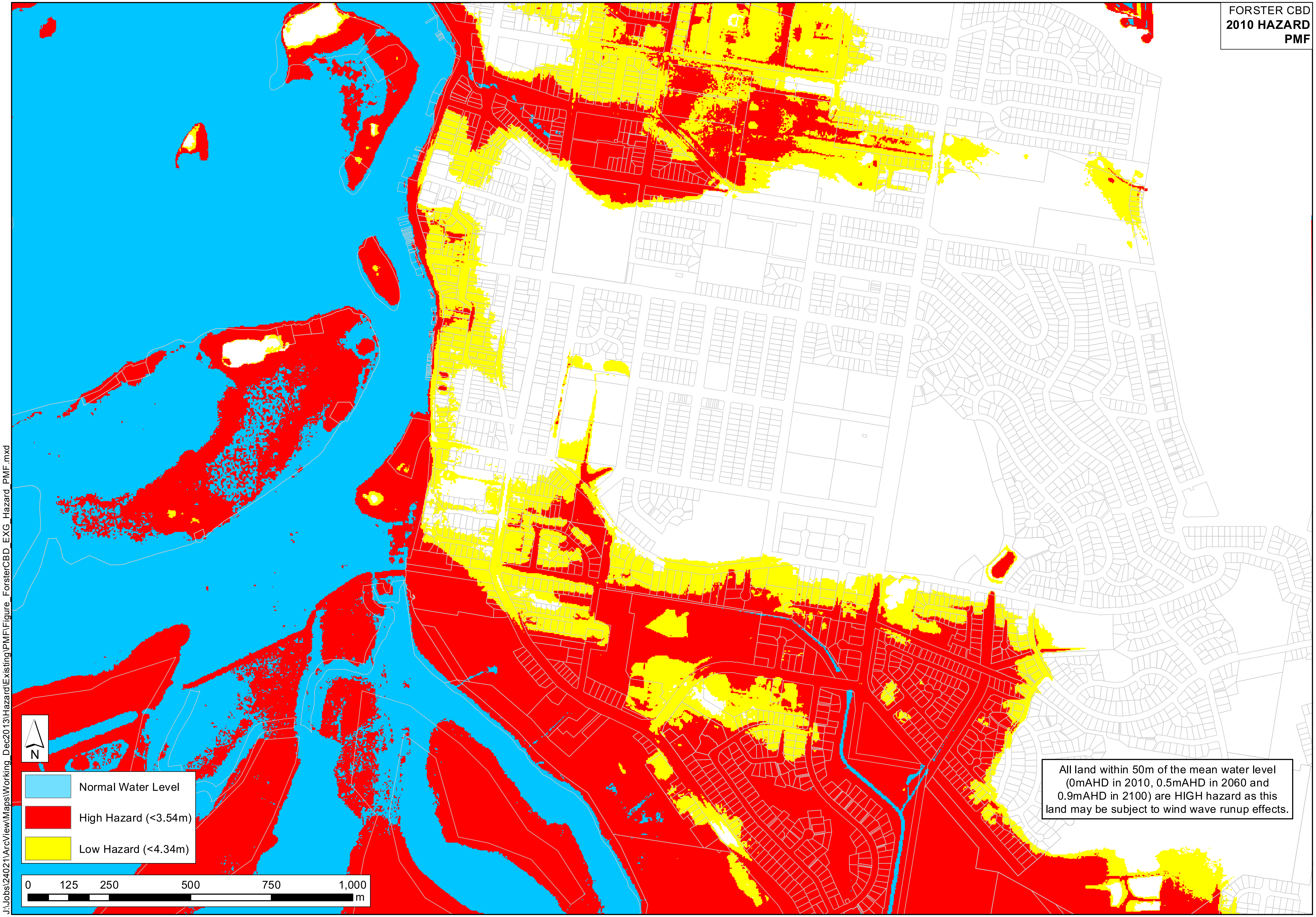

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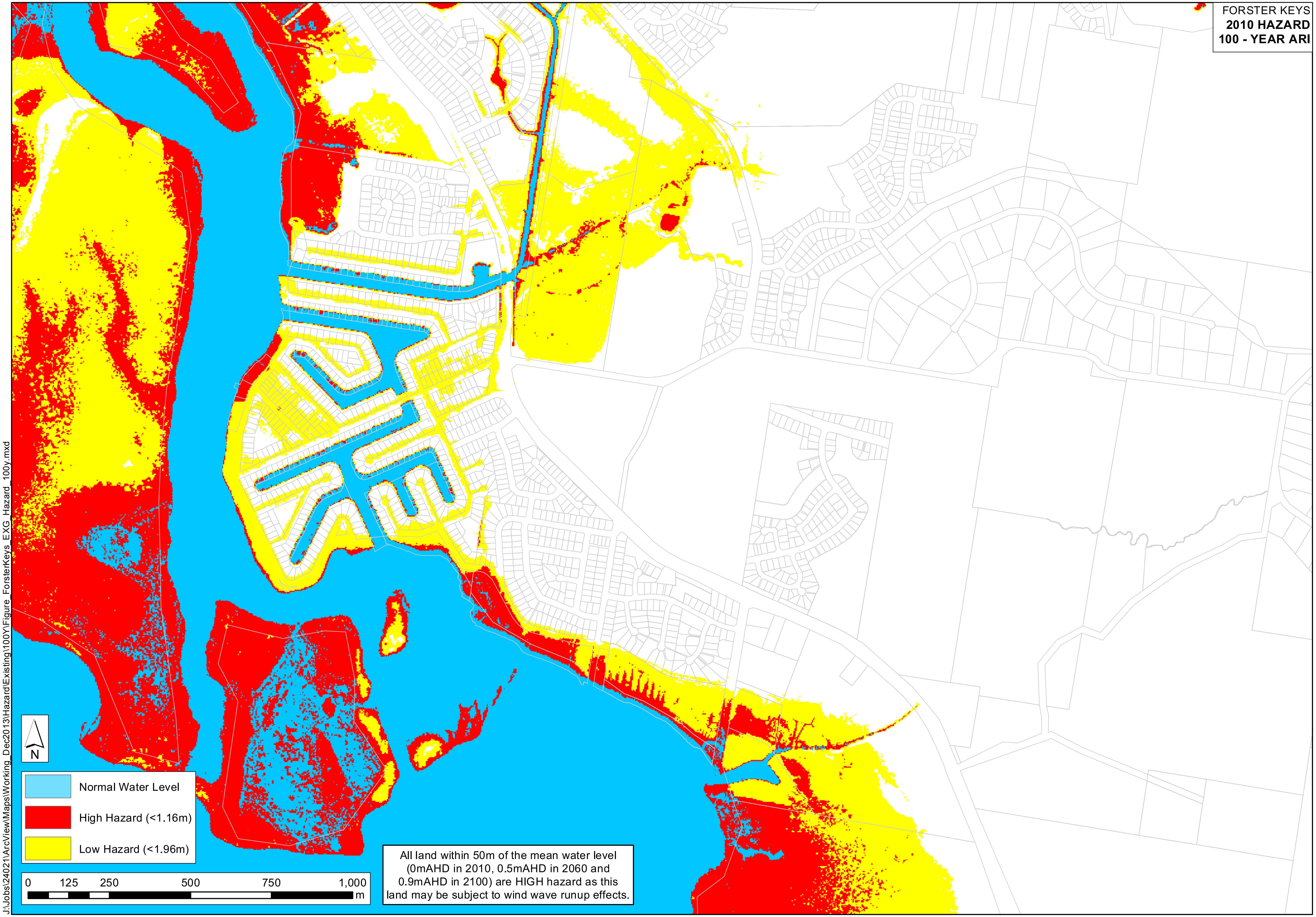

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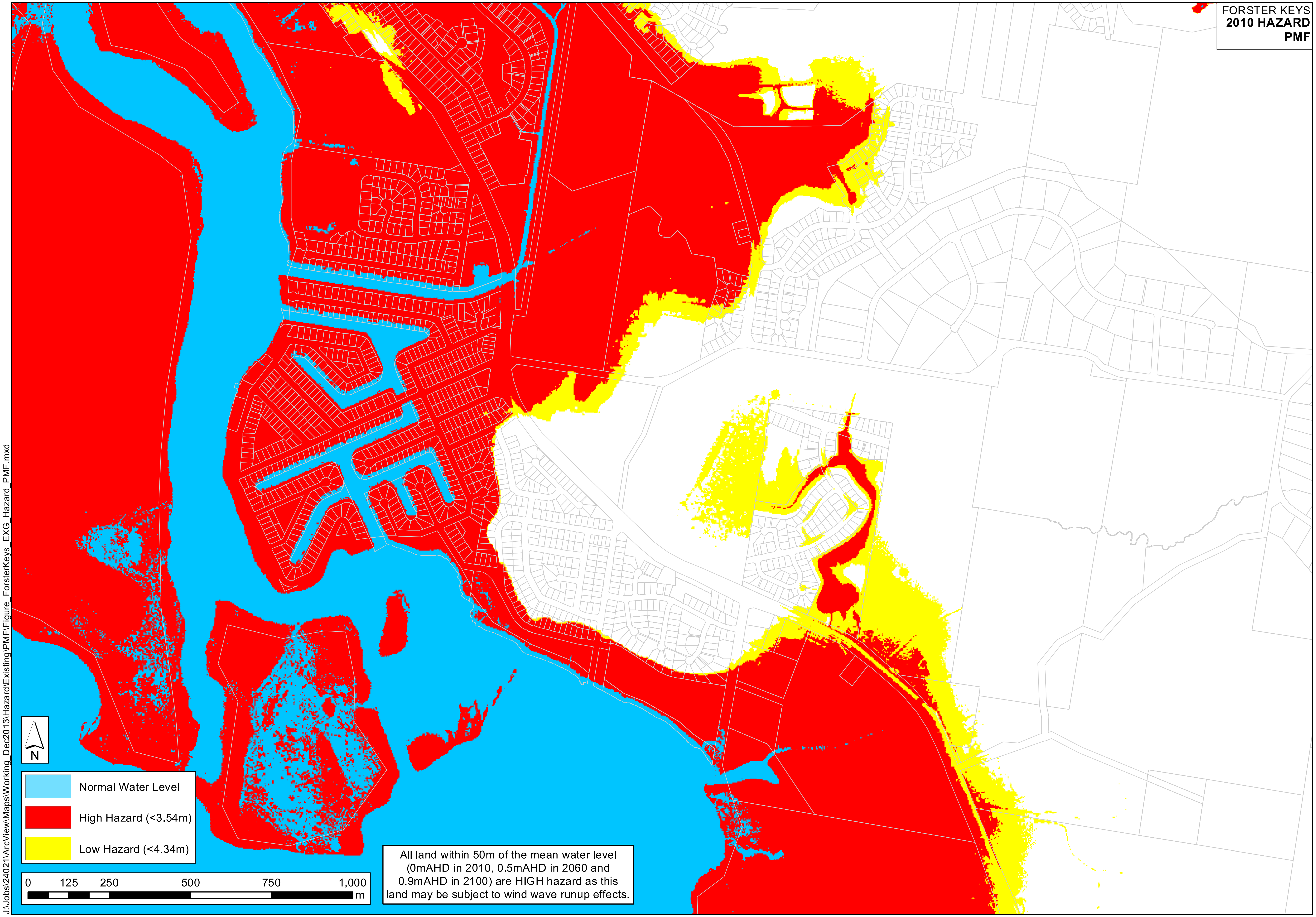
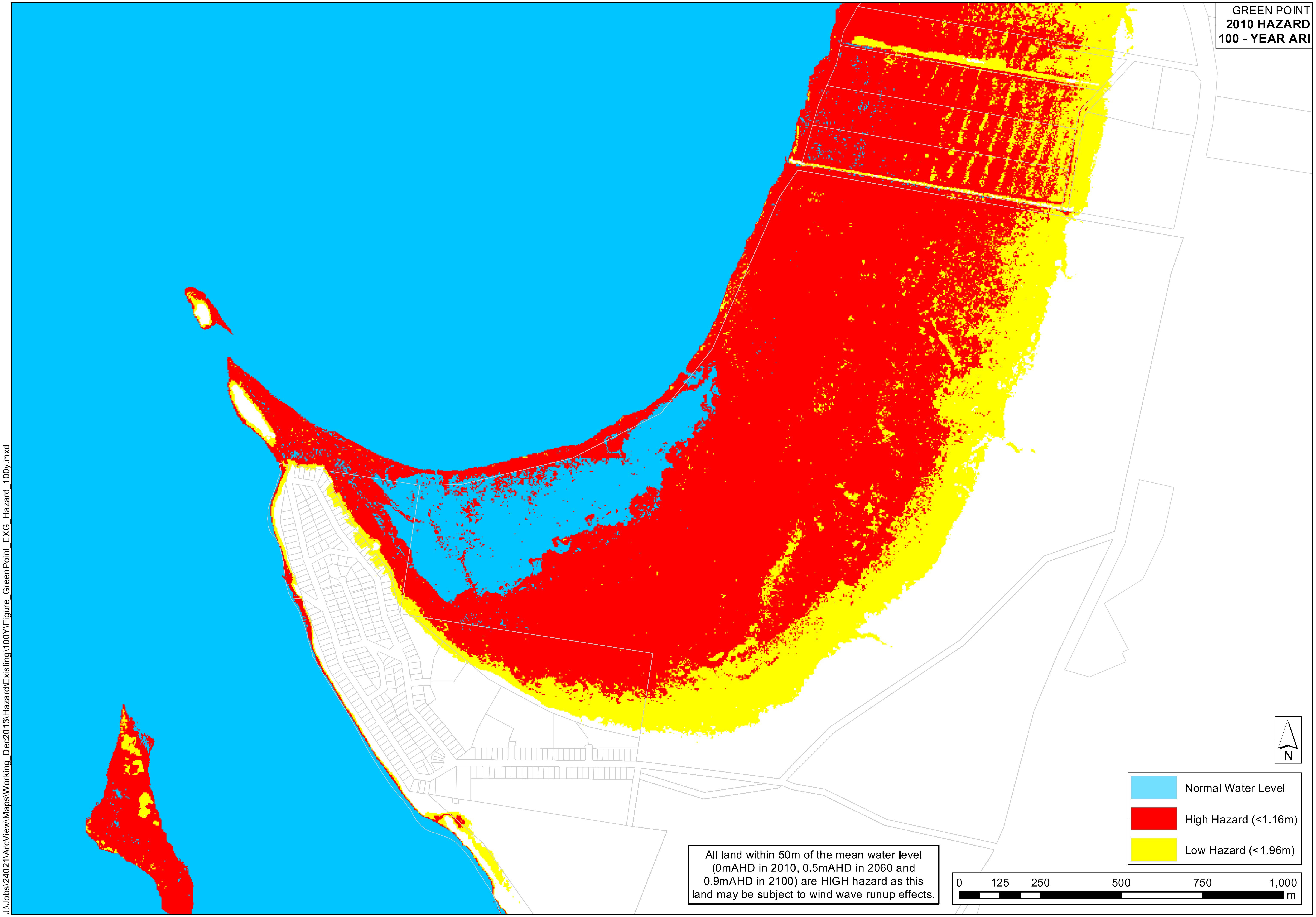


FORSTER KEYS
2010 HAZARD
PMF
N
Normal Water Level
High Hazard (<3.54m)
Low Hazard (<4.34m)
0 125 250 500 750 1,000
m
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Hazard\Existing\PMF\Figure_ForsterKeys_EXG_Hazard_PMF.mxd



J:\Jobs\24021\ArcView\Maps\Working_Dec2013\Hazard\Existing\100Y\Figure_GreenPoint_EXG_Hazard_100y.mxd


GREEN POINT
2010 HAZARD
PMF
N
Normal Water Level
High Hazard (<3.54m)
Low Hazard (<4.34m)
0 125 250 500 750 1,000
m
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
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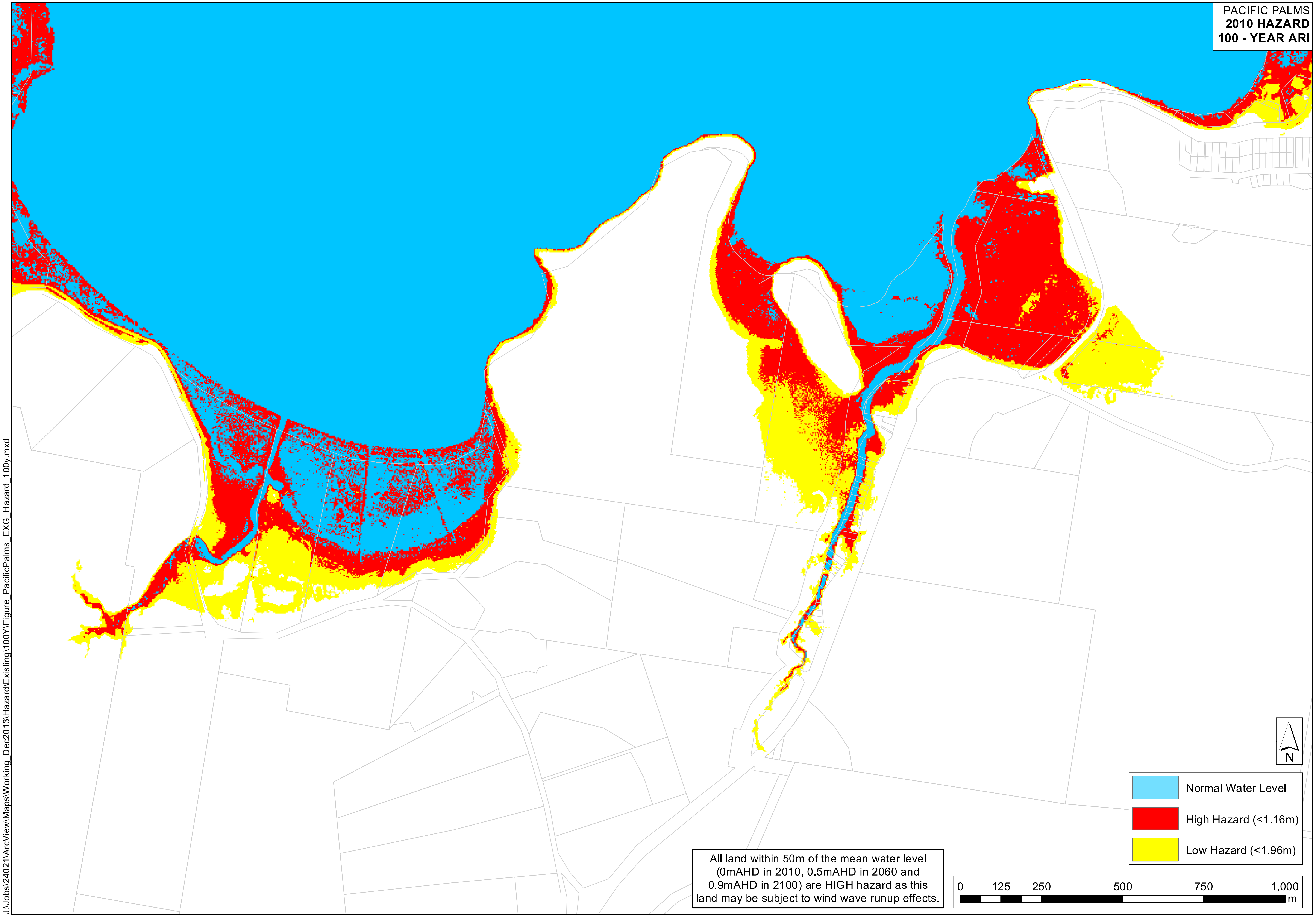
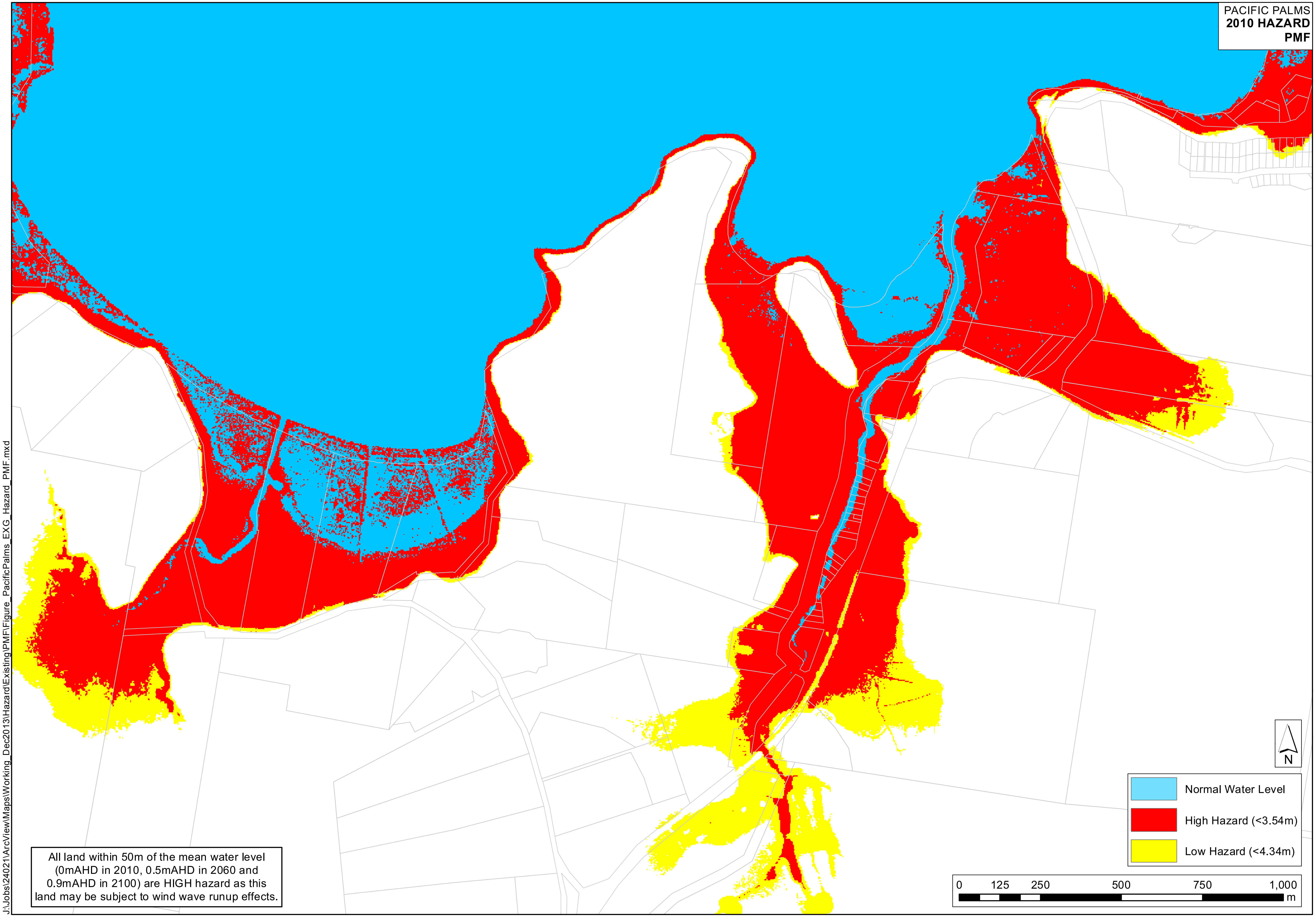
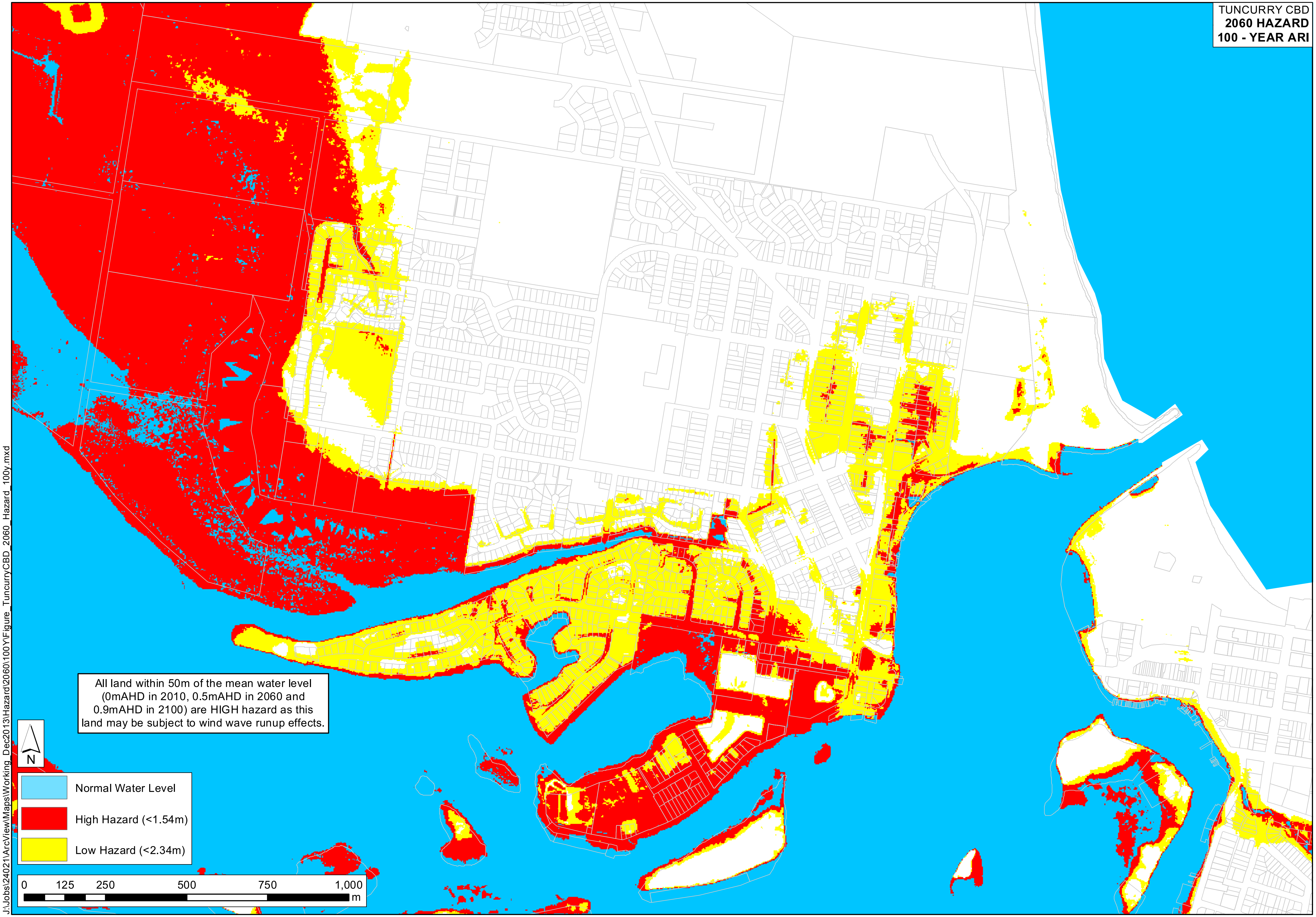
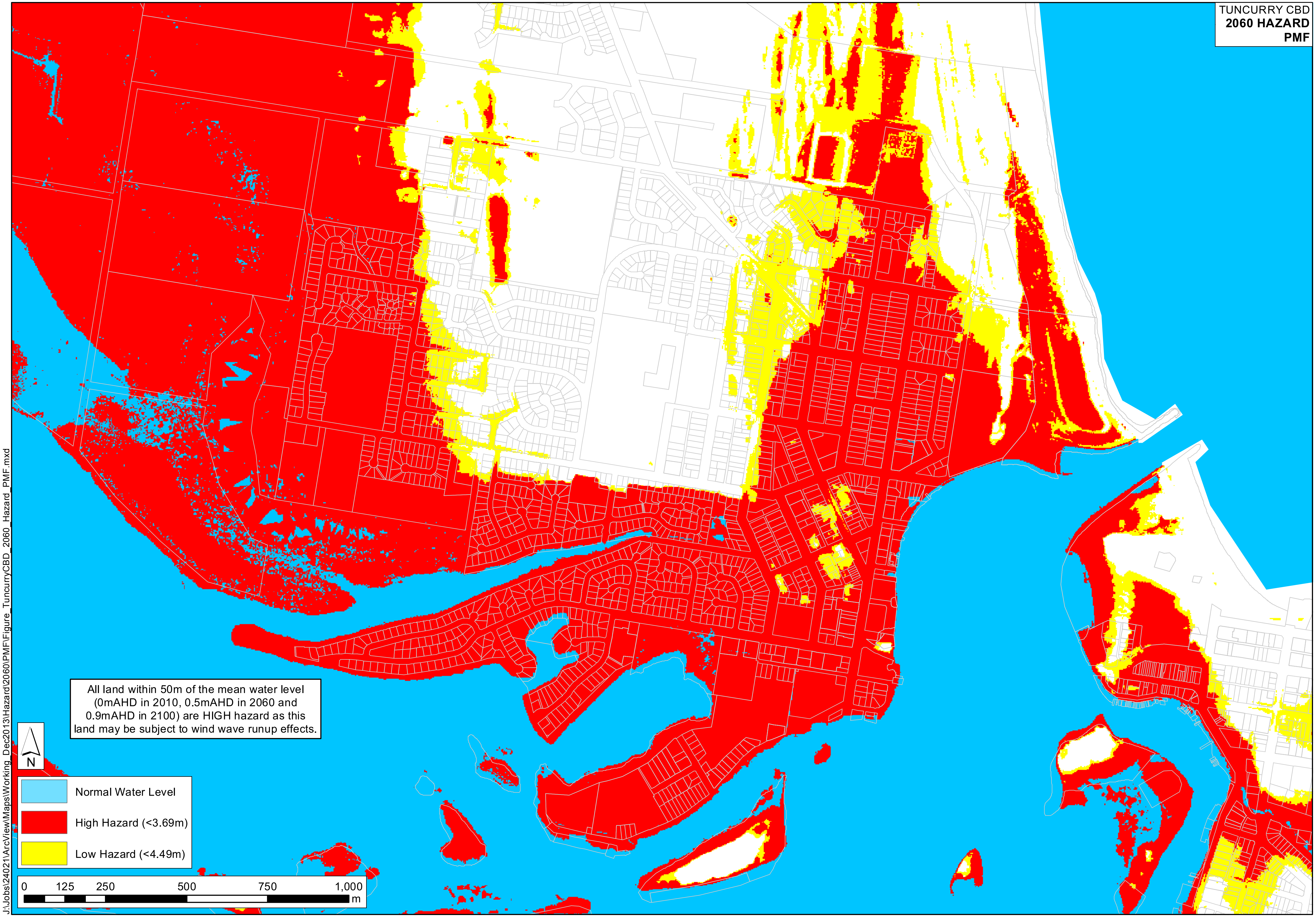


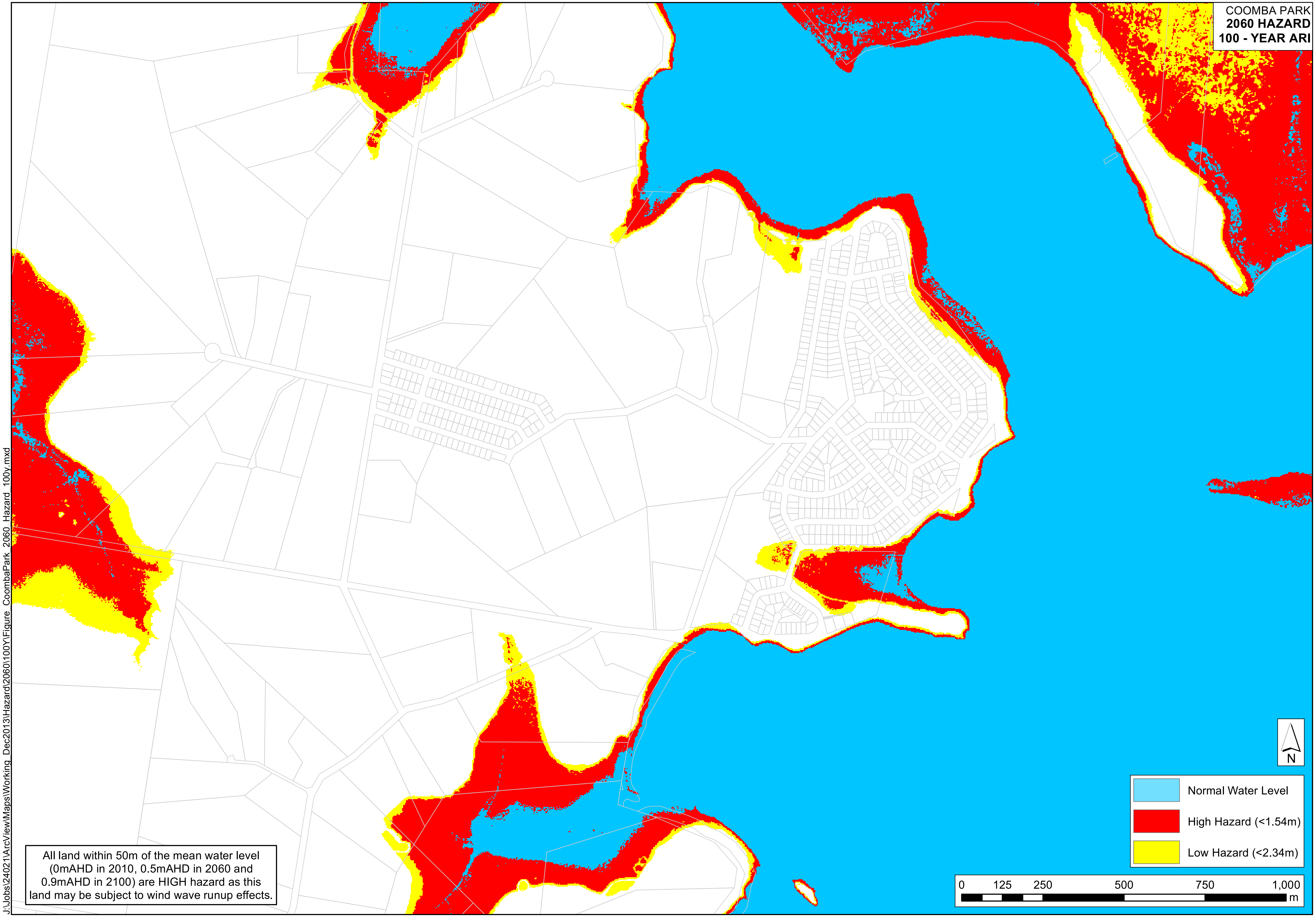
PACIFIC PALMS
2010 HAZARD
100 - YEAR ARI
N
Normal Water Level
High Hazard (<1.16m)
Low Hazard (<1.96m)
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
0 125 250 500 750 1,000
m
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Hazard\Existing\100Y\Figure_PacificPalms_EXG_Hazard_100y.mxd


PACIFIC PALMS
2010 HAZARD
PMF
Normal Water Level
High Hazard (<3.54m)
Low Hazard (<4.34m)
0 125 250 500 750 1,000
m
N
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Hazard\Existing\PMF\Figure_PacificPalms_EXG_Hazard_PMF.mxd



TUNCURRY CBD
2060 HAZARD
100 - YEAR ARI
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
N
Normal Water Level
High Hazard (<1.54m)
Low Hazard (<2.34m)
0
125
250
500
750
1,000
m
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Hazard\2060\100Y\Figure_TuncurryCBD_2060_Hazard_100y.mxd


TUNCURRY CBD
2060 HAZARD
PMF
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
N
Normal Water Level
High Hazard (<3.69m)
Low Hazard (<4.49m)
0 125 250 500 750 1,000
m
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Hazard\2060\PMF\Figure_TuncurryCBD_2060_Hazard_PMF.mxd



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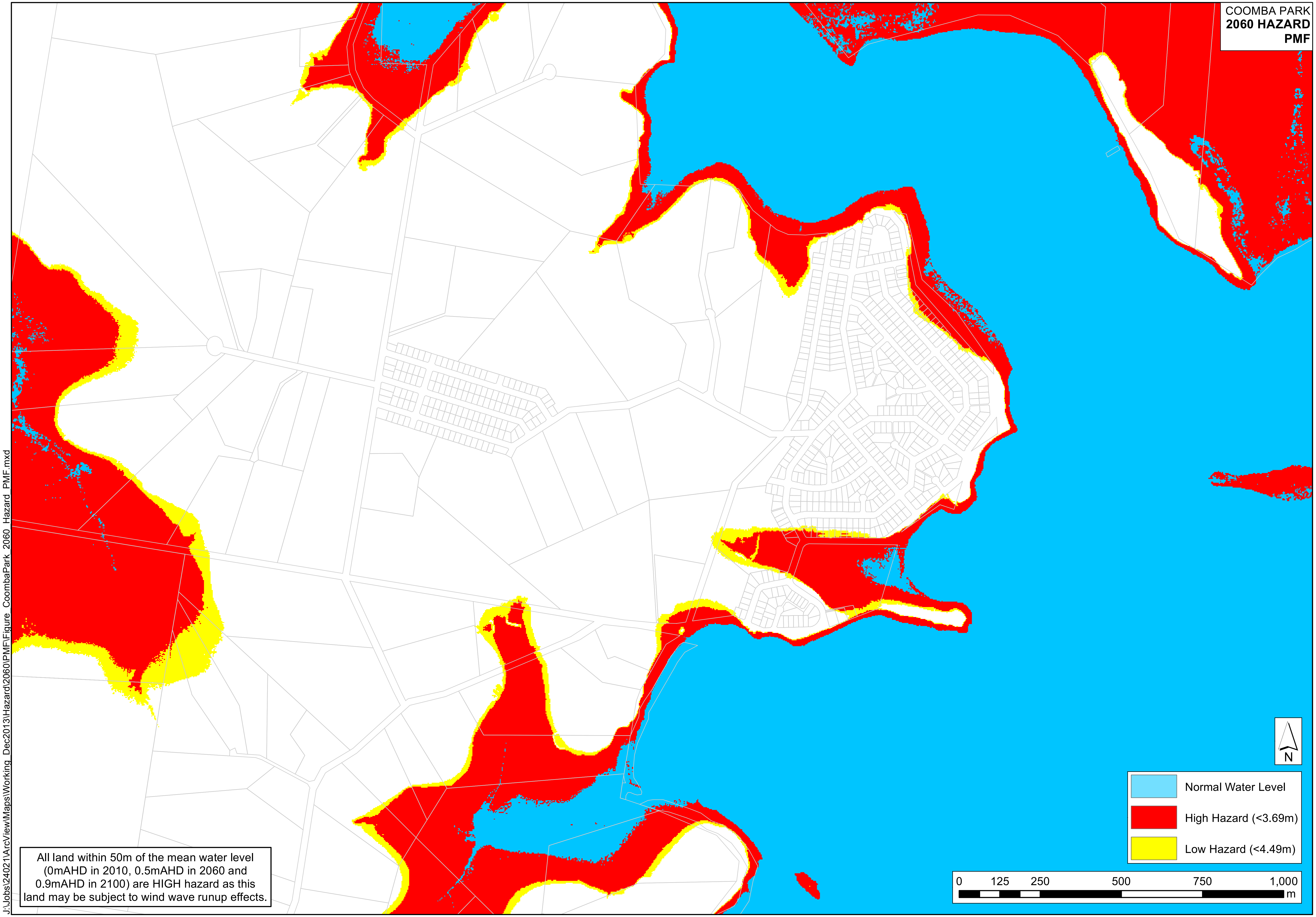

COOMBA PARK
2060 HAZARD
PMF
Normal Water Level
High Hazard (<3.69m)
Low Hazard (<4.49m)
N
0 125 250 500 750 1,000
m
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
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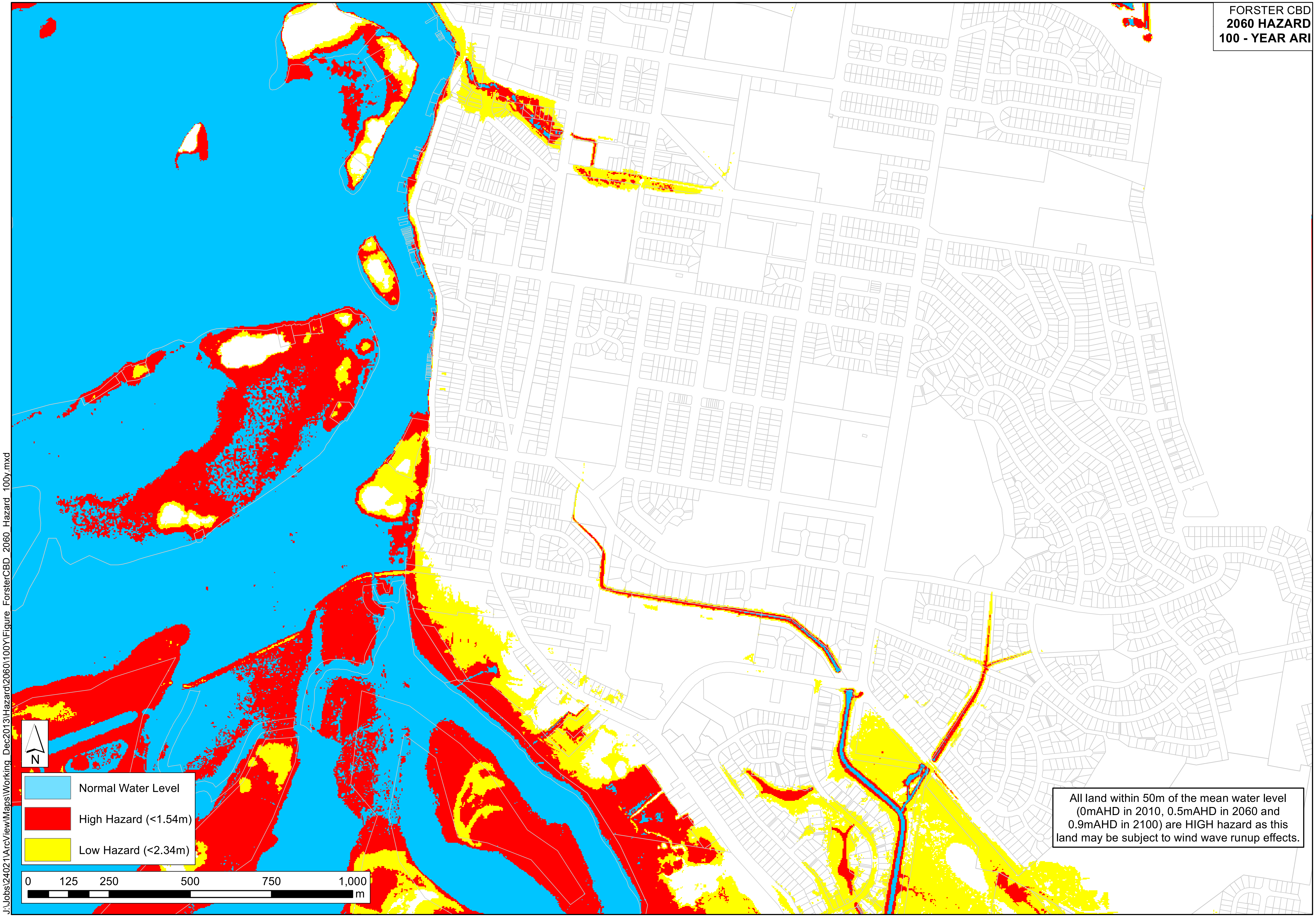

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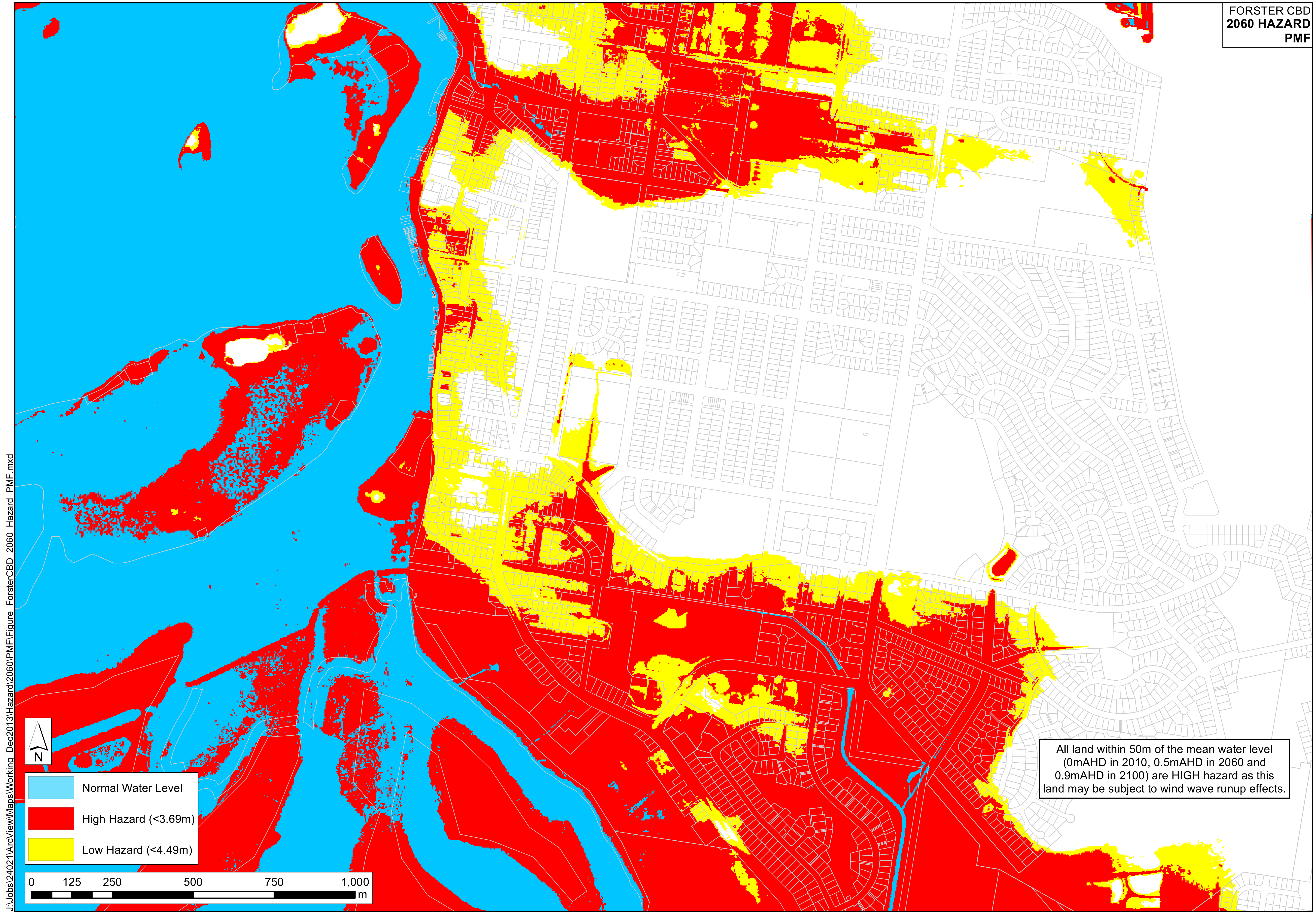
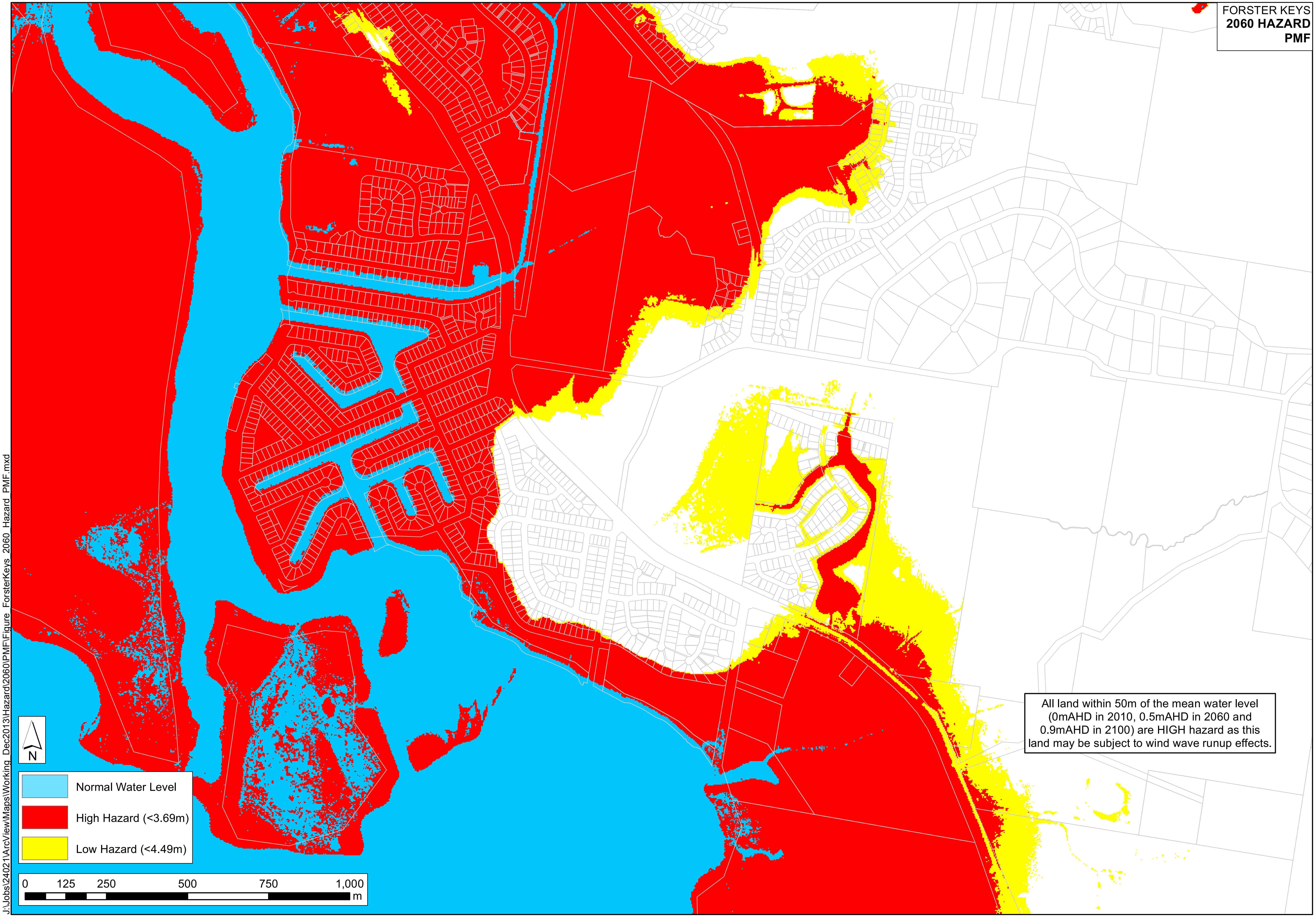
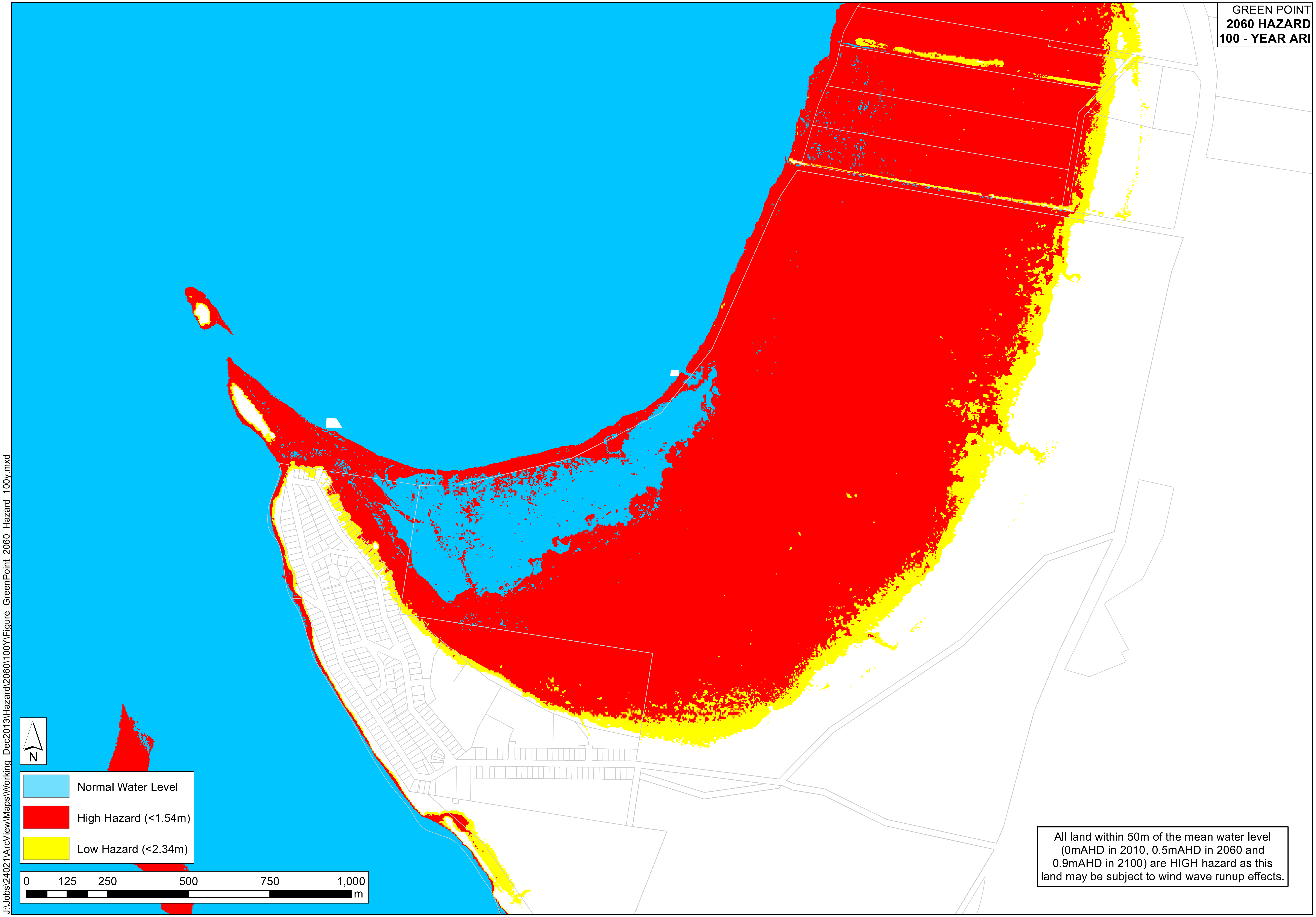


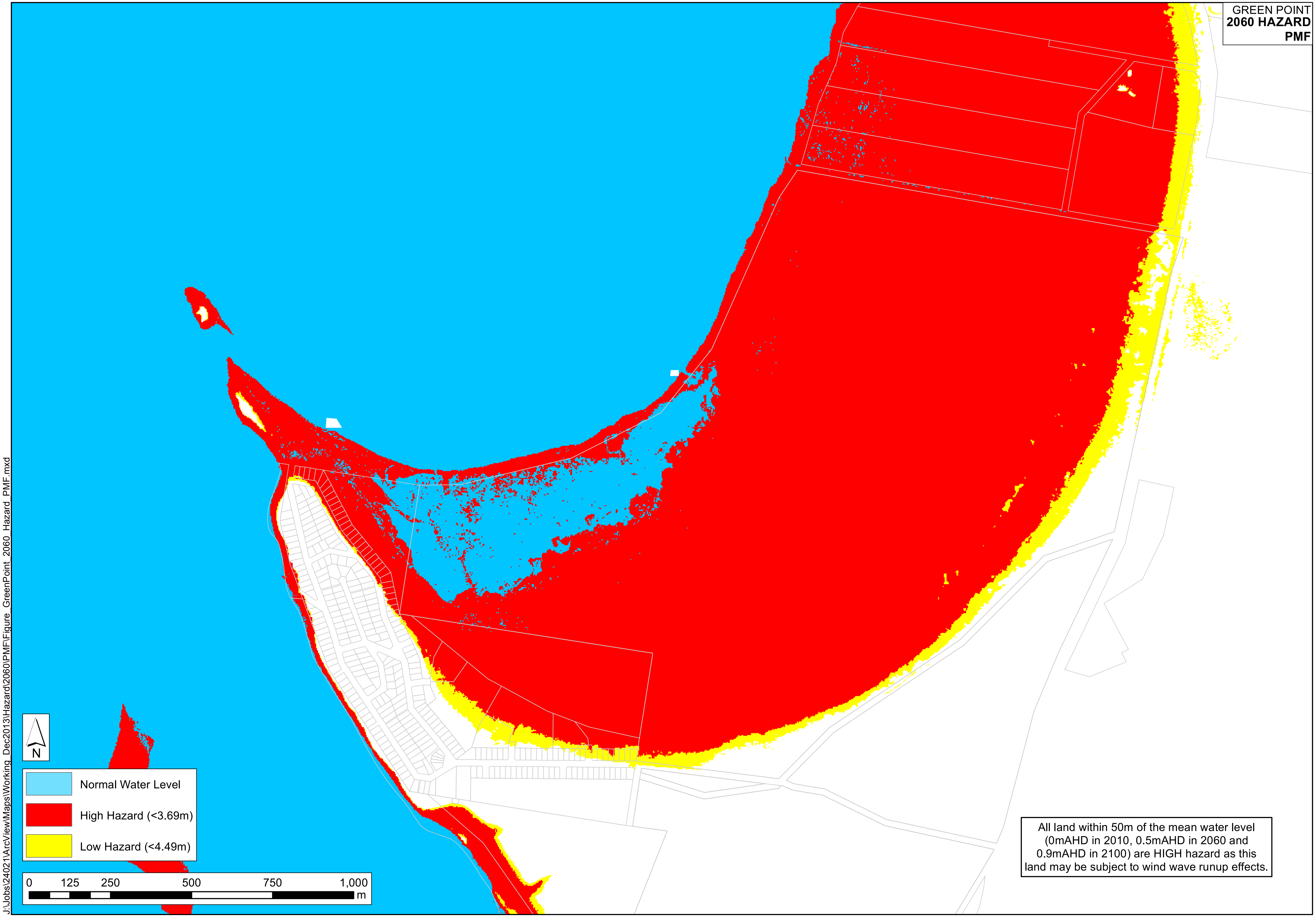
FORSTER CBD
2060 HAZARD
PMF
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
N
Normal Water Level
High Hazard (<3.69m)
Low Hazard (<4.49m)
0 125 250 500 750 1,000
m
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Hazard\2060\PMF\Figure_ForsterCBD_2060_Hazard_PMF.mxd


FORSTER KEYS
2060 HAZARD
100 - YEAR ARI
N
Normal Water Level
High Hazard (<1.54m)
Low Hazard (<2.34m)
0 125 250 500 750 1,000
m
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.


FORSTER KEYS
2060 HAZARD
PMF
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
N
Normal Water Level
High Hazard (<3.69m)
Low Hazard (<4.49m)
0
125
250
500
750
1,000
m
J:\Jobs\24021\ArcView\Maps\Working_Dec2013\Hazard\2060\PMF\Figure_ForsterKeys_2060_Hazard_PMF.mxd



GREEN POINT
2060 HAZARD
100 - YEAR ARI
N
Normal Water Level
High Hazard (<1.54m)
Low Hazard (<2.34m)
0 125 250 500 750 1,000
m
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
J:\Jobs\24021\ArcView\Maps\Working_Dec2013\Hazard\2060\100Y\Figure_GreenPoint_2060_Hazard_100y.mxd



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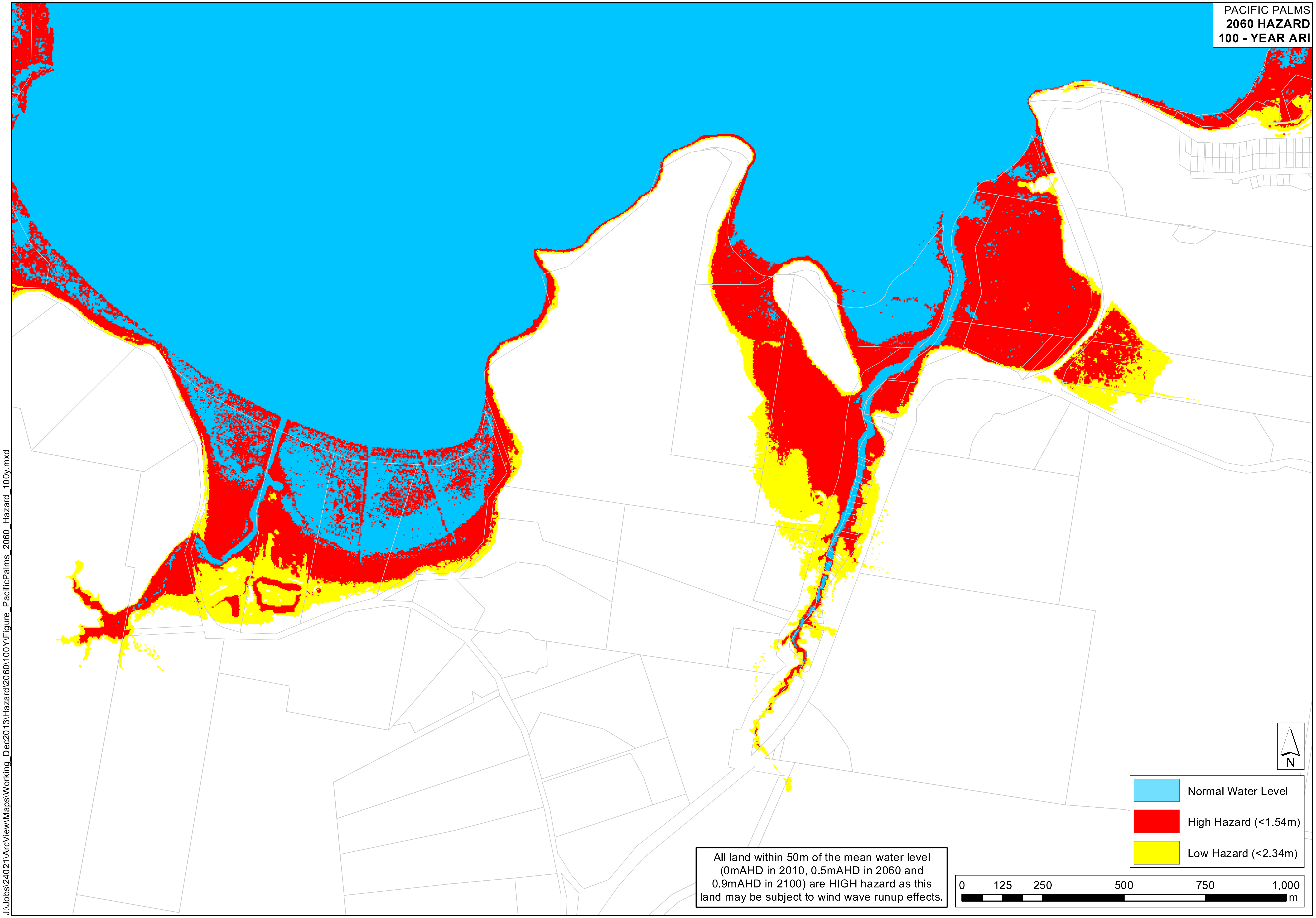
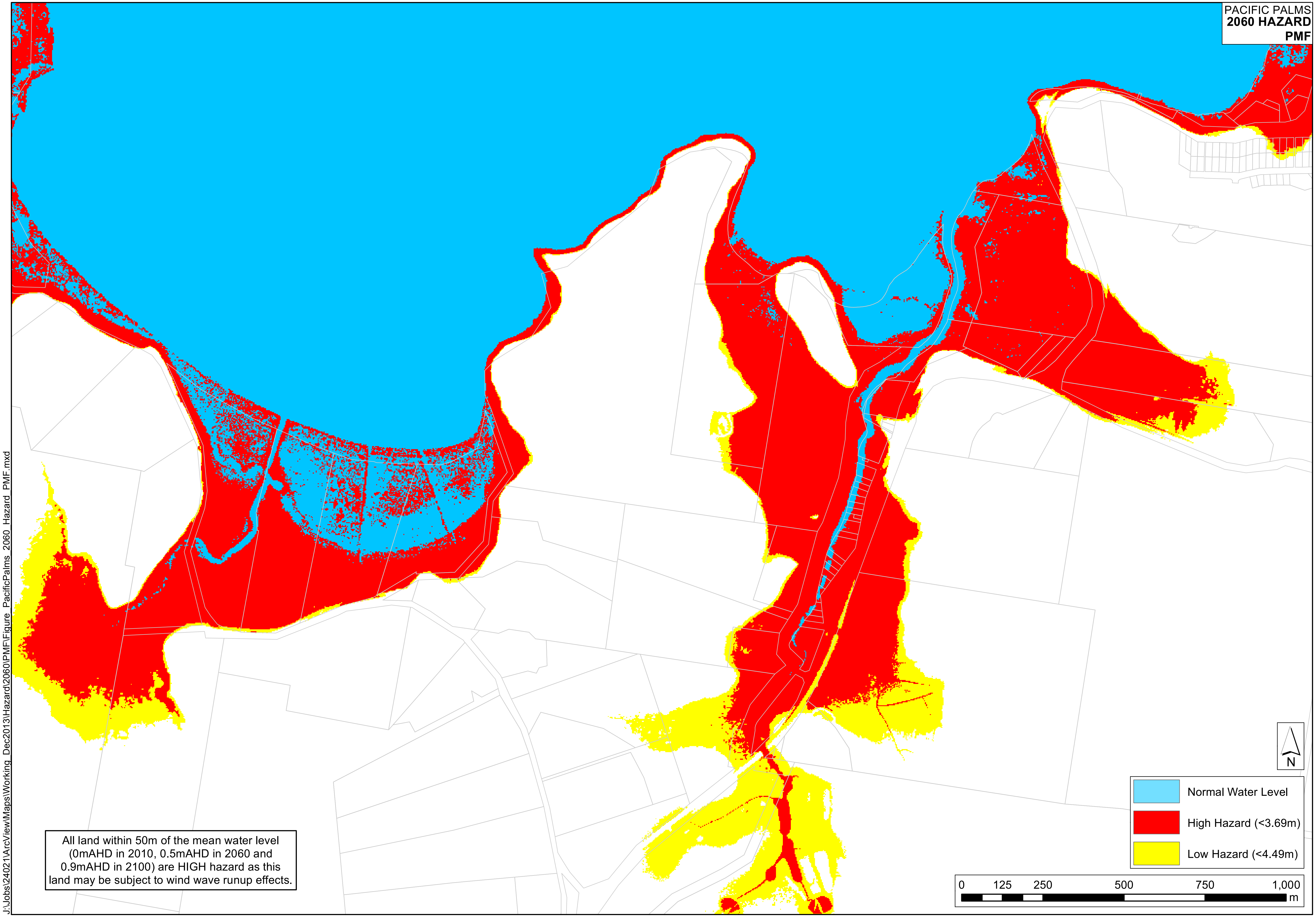


PACIFIC PALMS
2060 HAZARD
100 - YEAR ARI
N
Normal Water Level
High Hazard (<1.54m)
Low Hazard (<2.34m)
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
0 125 250 500 750 1,000 m
J:\Jobs\24021\ArcView\Maps\Working_Dec2013\Hazard\2060\100Y\Figure_PacificPalms_2060_Hazard_100y.mxd



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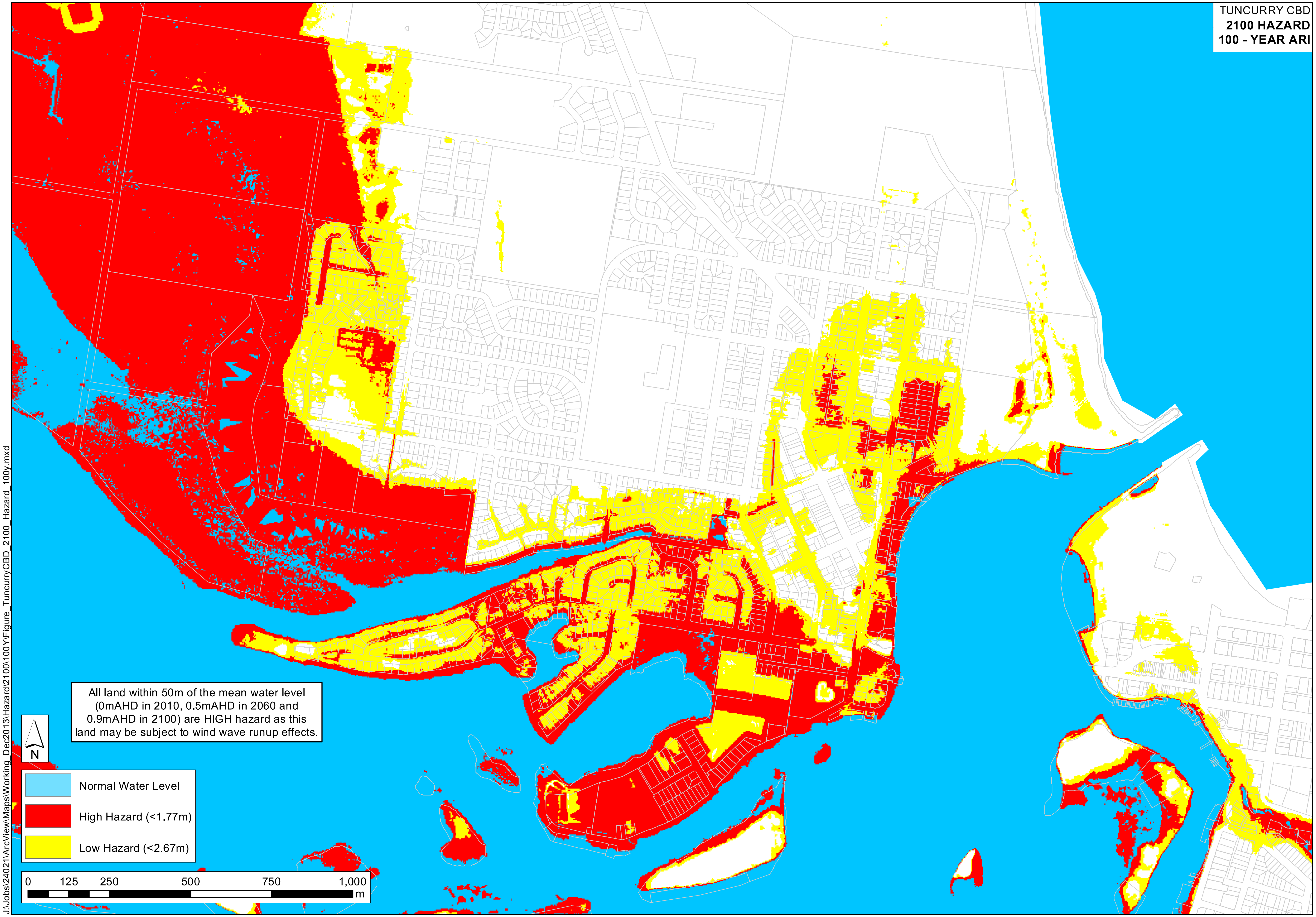

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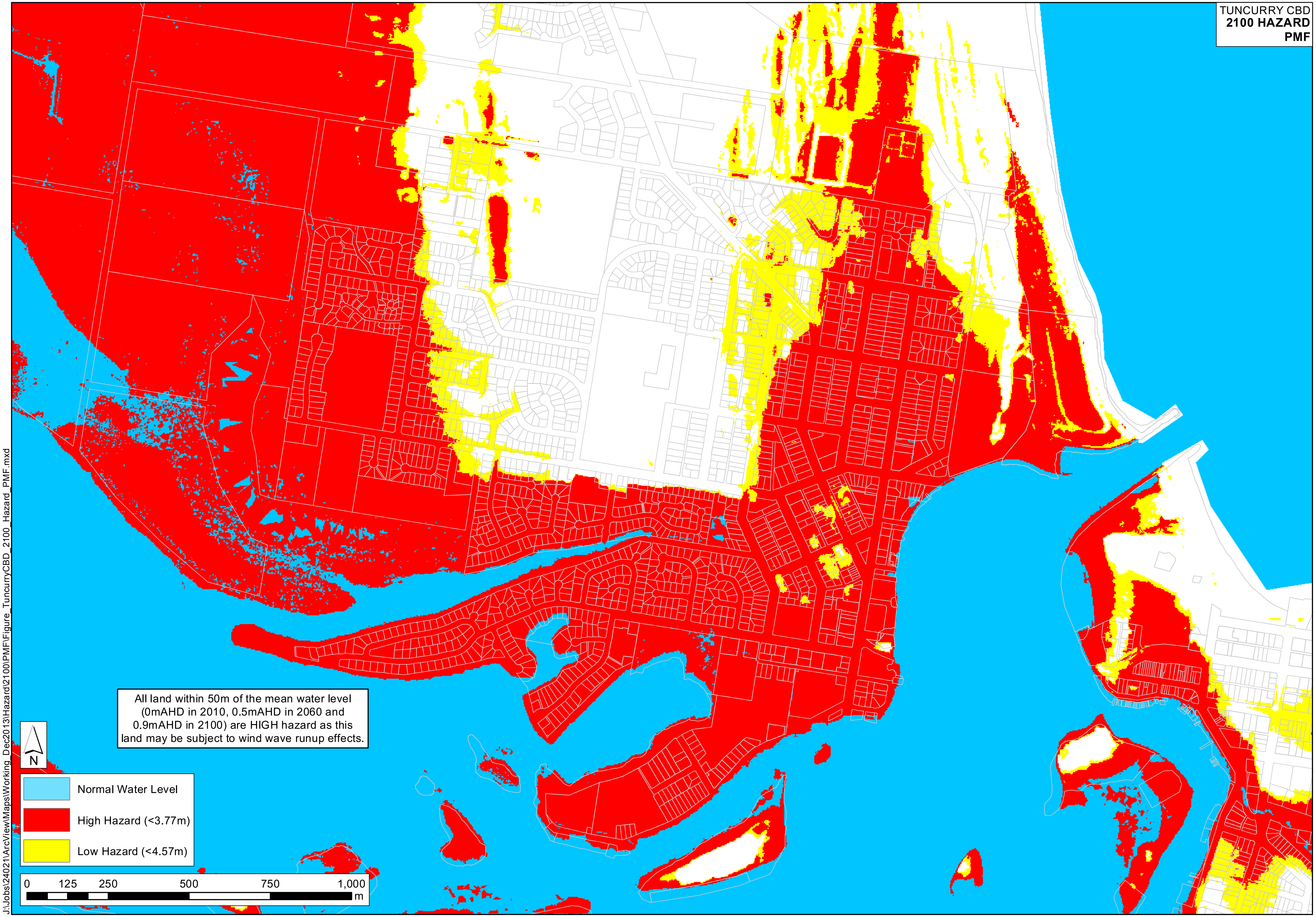

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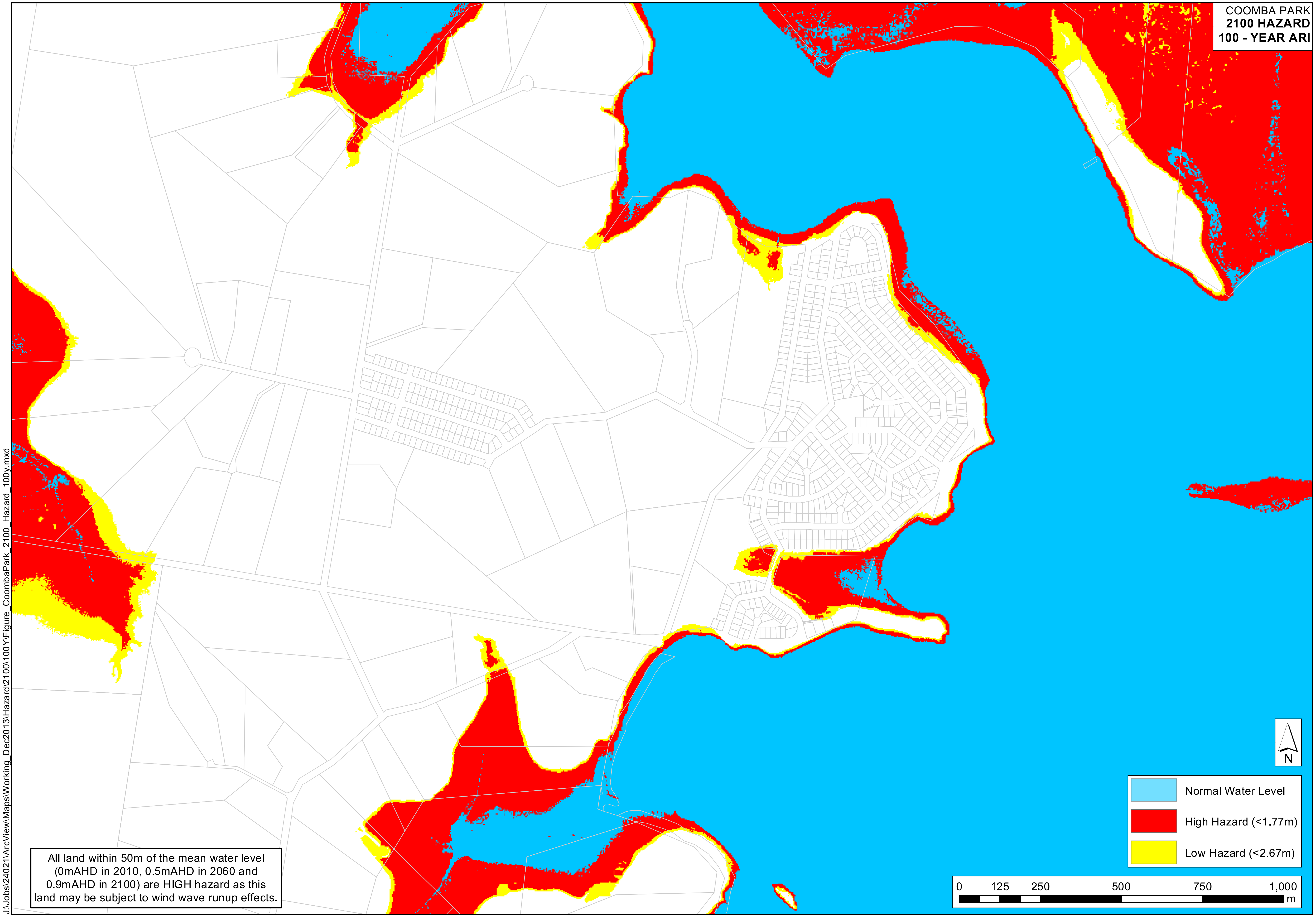
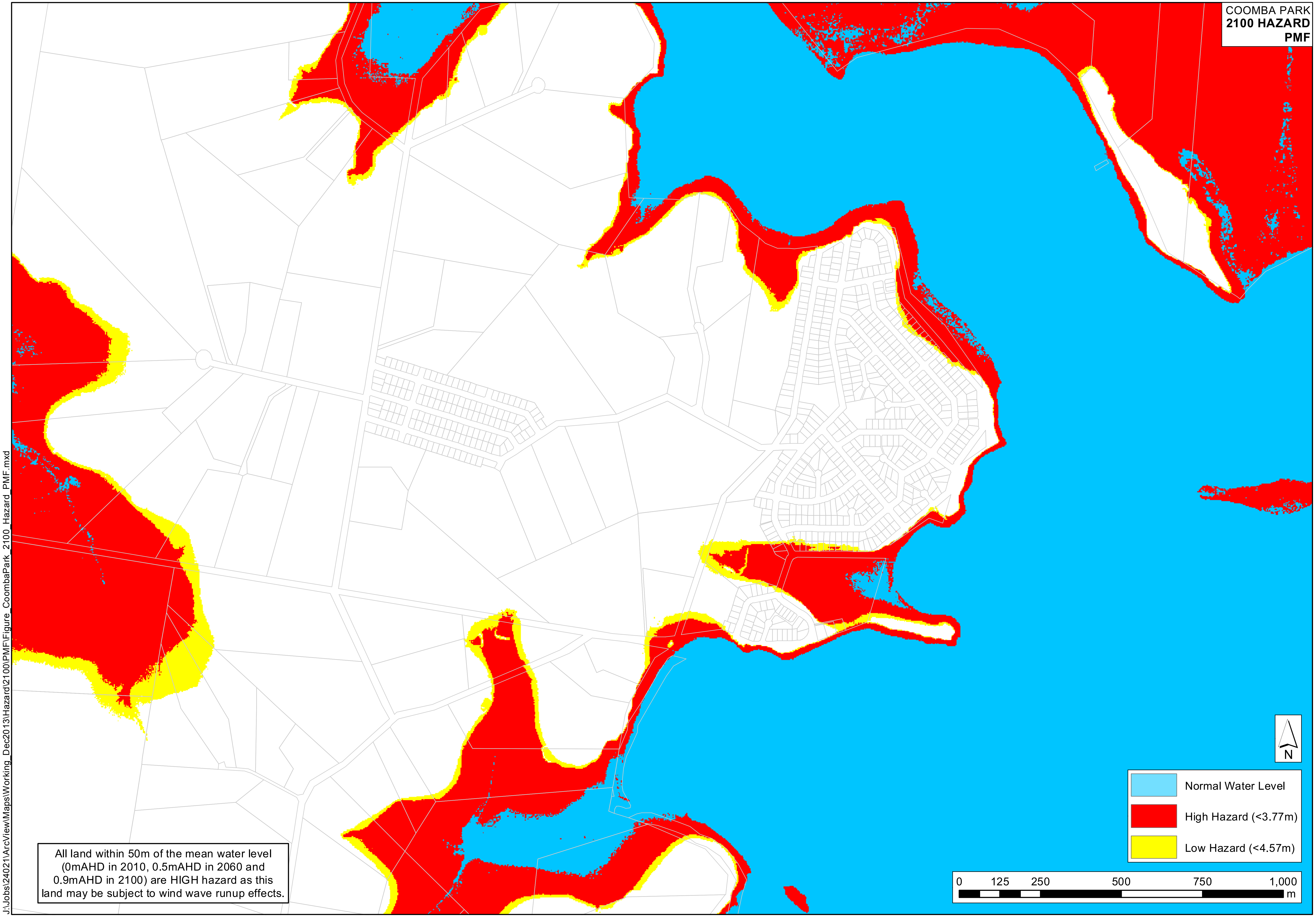


COOMBA PARK
2100 HAZARD
100 - YEAR ARI
N
Normal Water Level
High Hazard (<1.77m)
Low Hazard (<2.67m)
0 125 250 500 750 1,000
m
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
J:\Jobs\240211\ArcView\Maps\Working_Dec2013\Hazard\2100\100Y\Figure_CoombaPark_2100_Hazard_100y.mxd


COOMBA PARK
2100 HAZARD
PMF
N
Normal Water Level
High Hazard (<3.77m)
Low Hazard (<4.57m)
0 125 250 500 750 1,000
m
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
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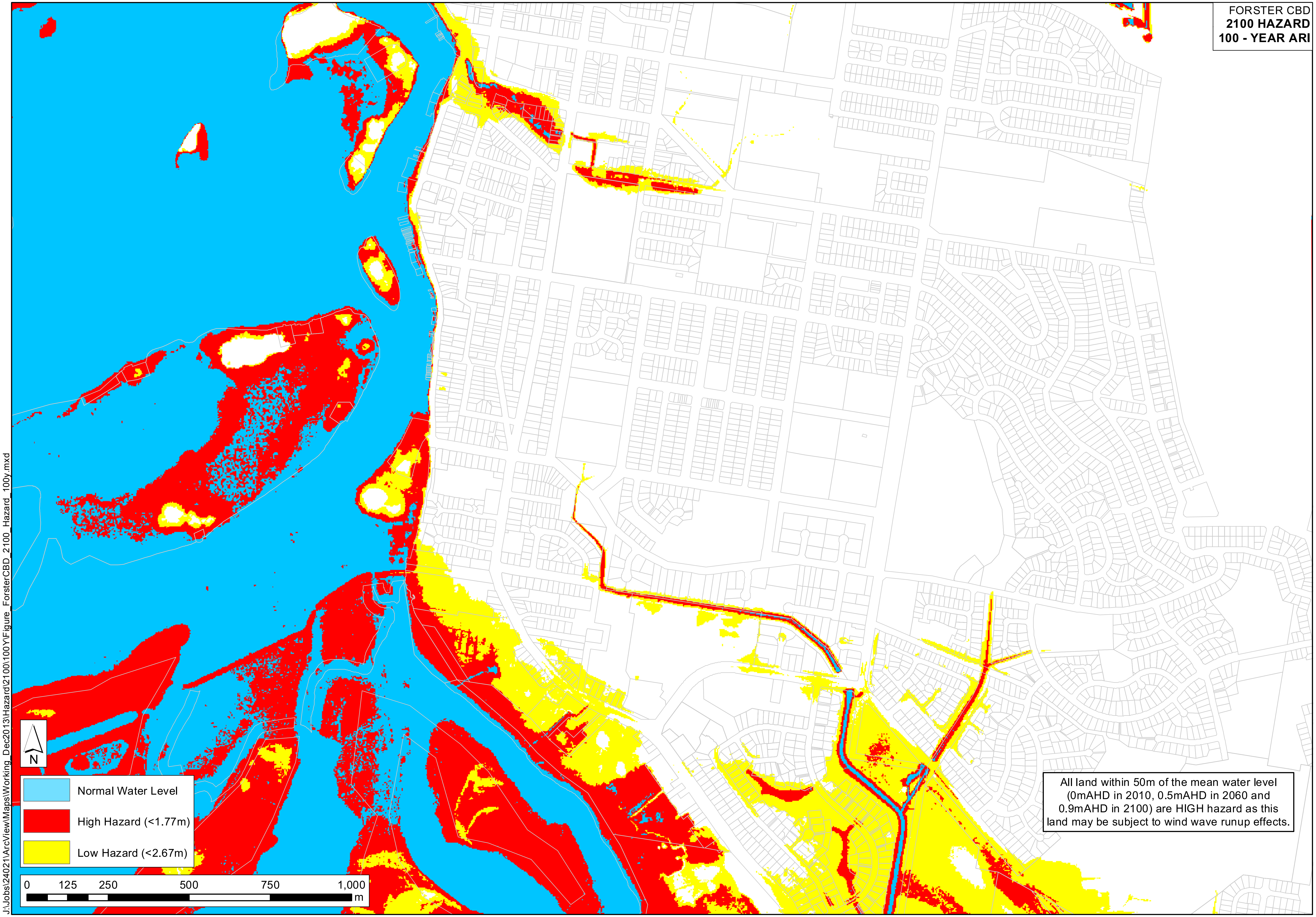

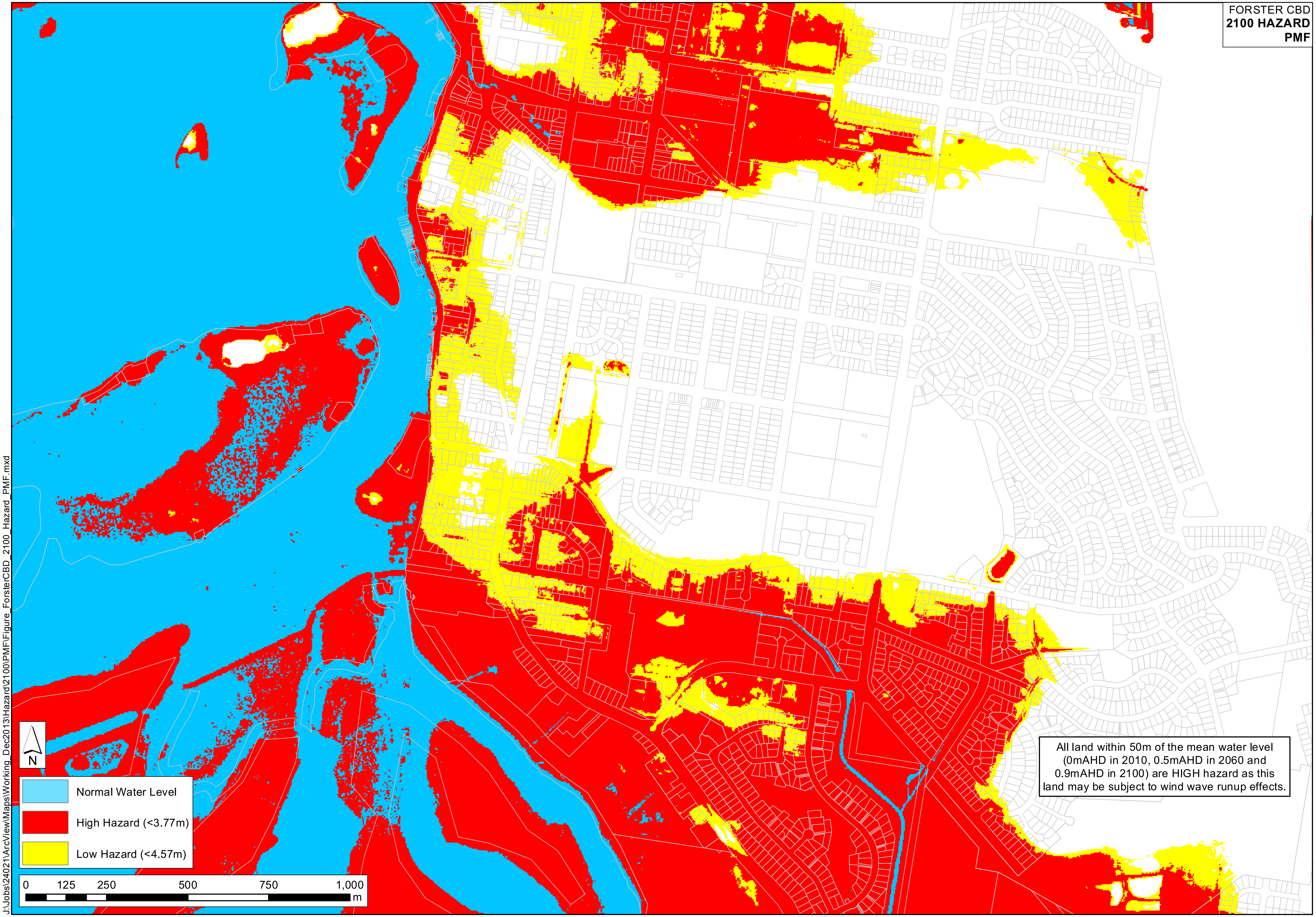
FORSTER CBD
2100 HAZARD
PMF
N
Normal Water Level
High Hazard (<3.77m)
Low Hazard (<4.57m)
0 125 250 500 750 1,000
m
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
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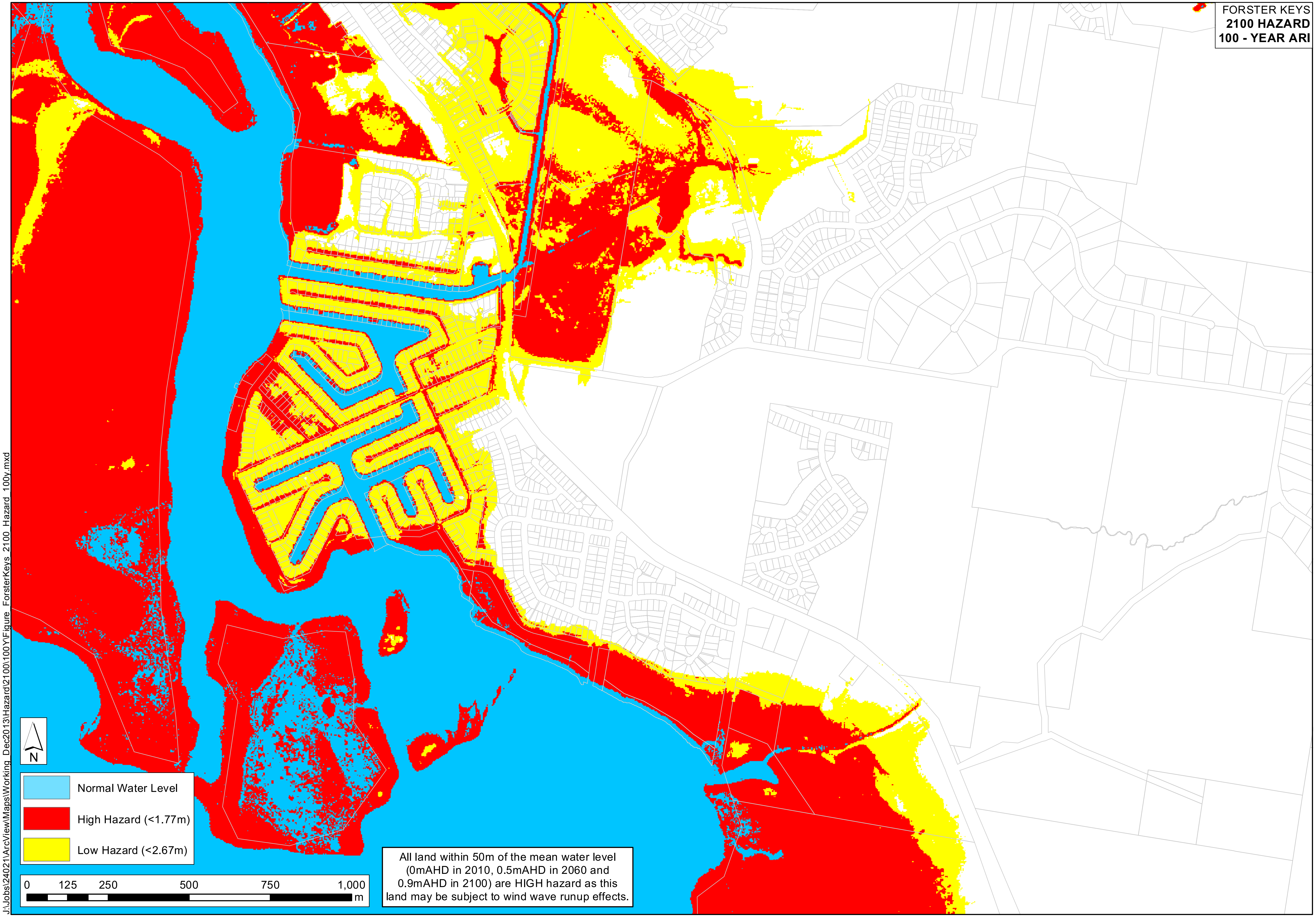

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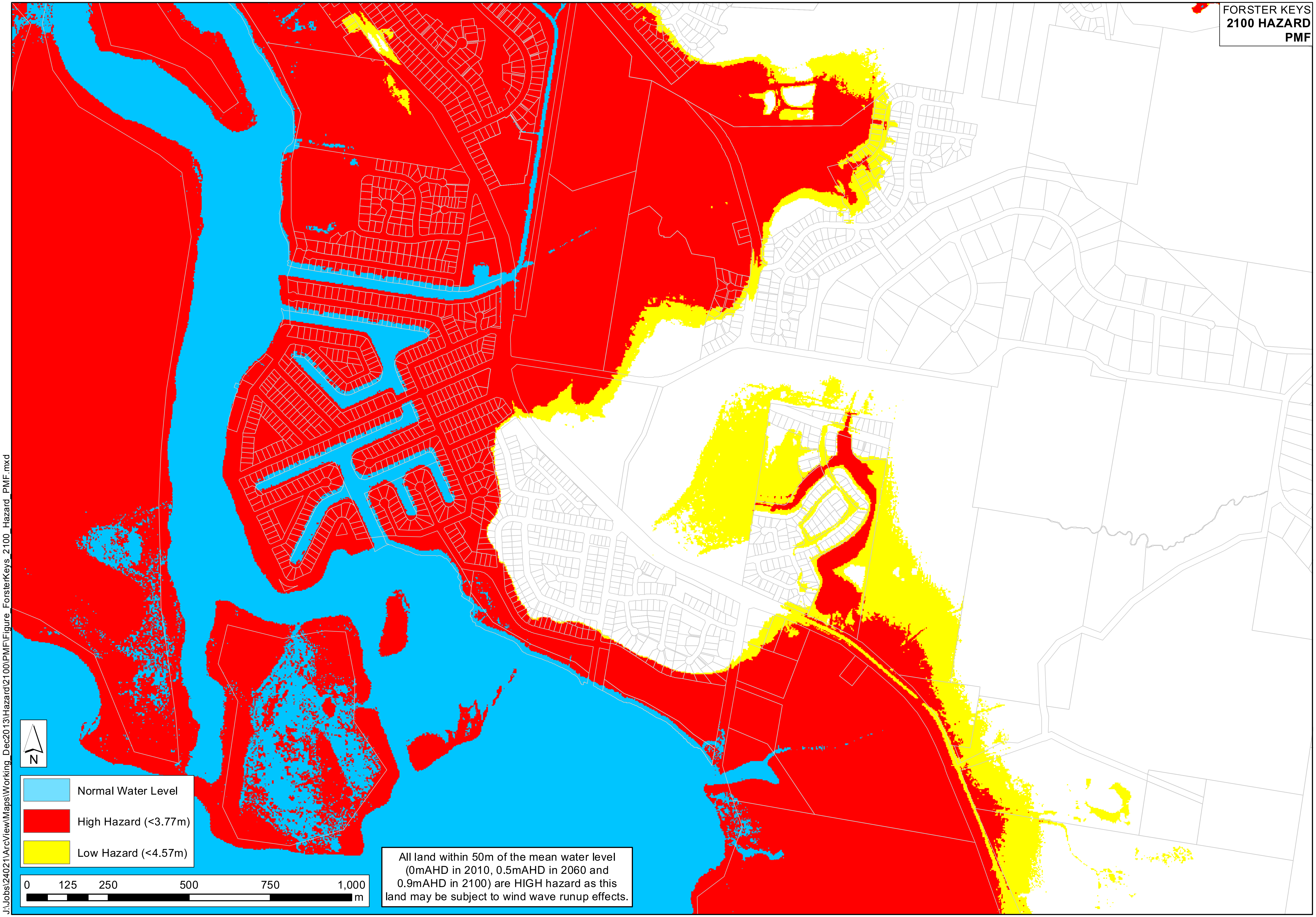

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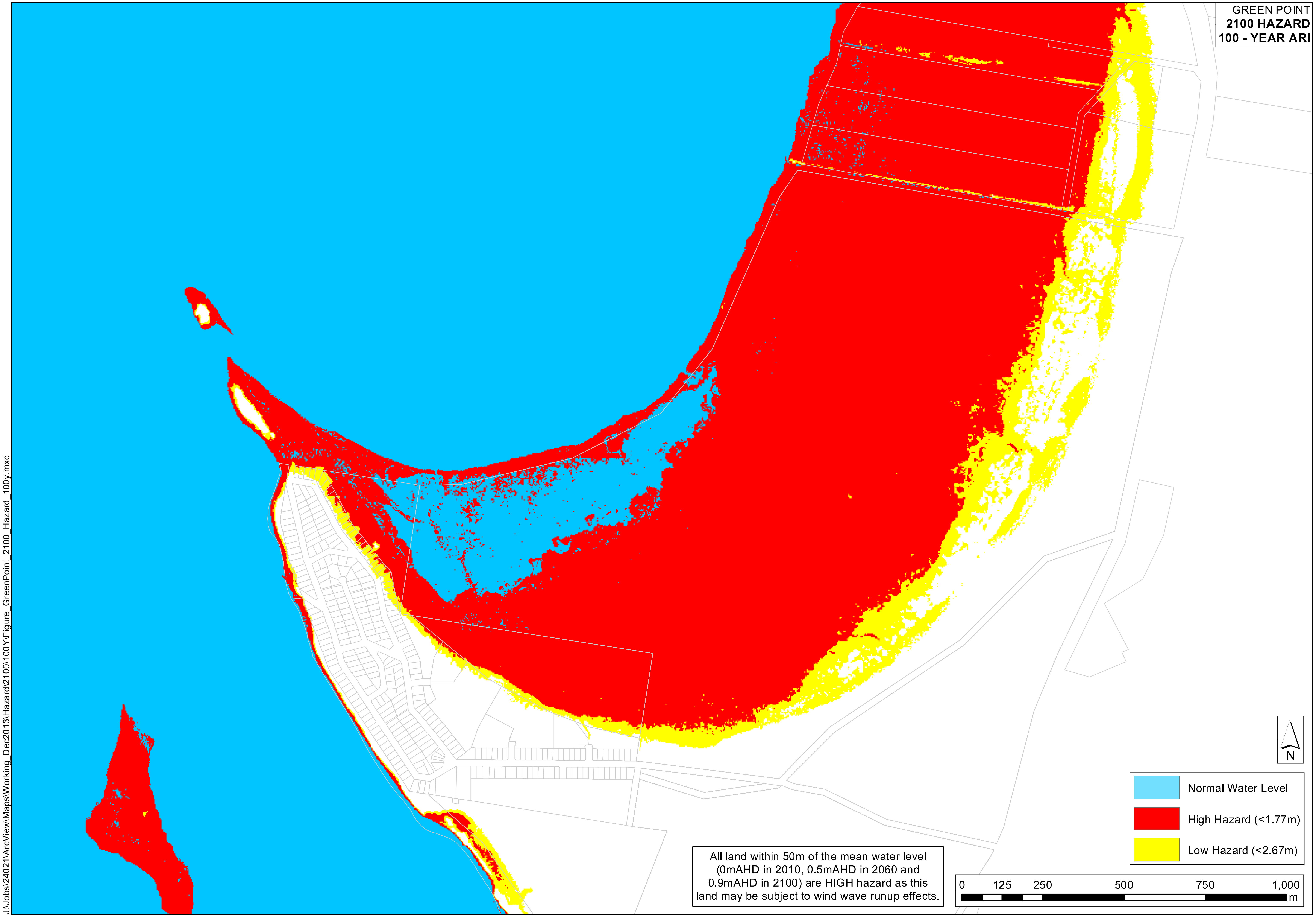

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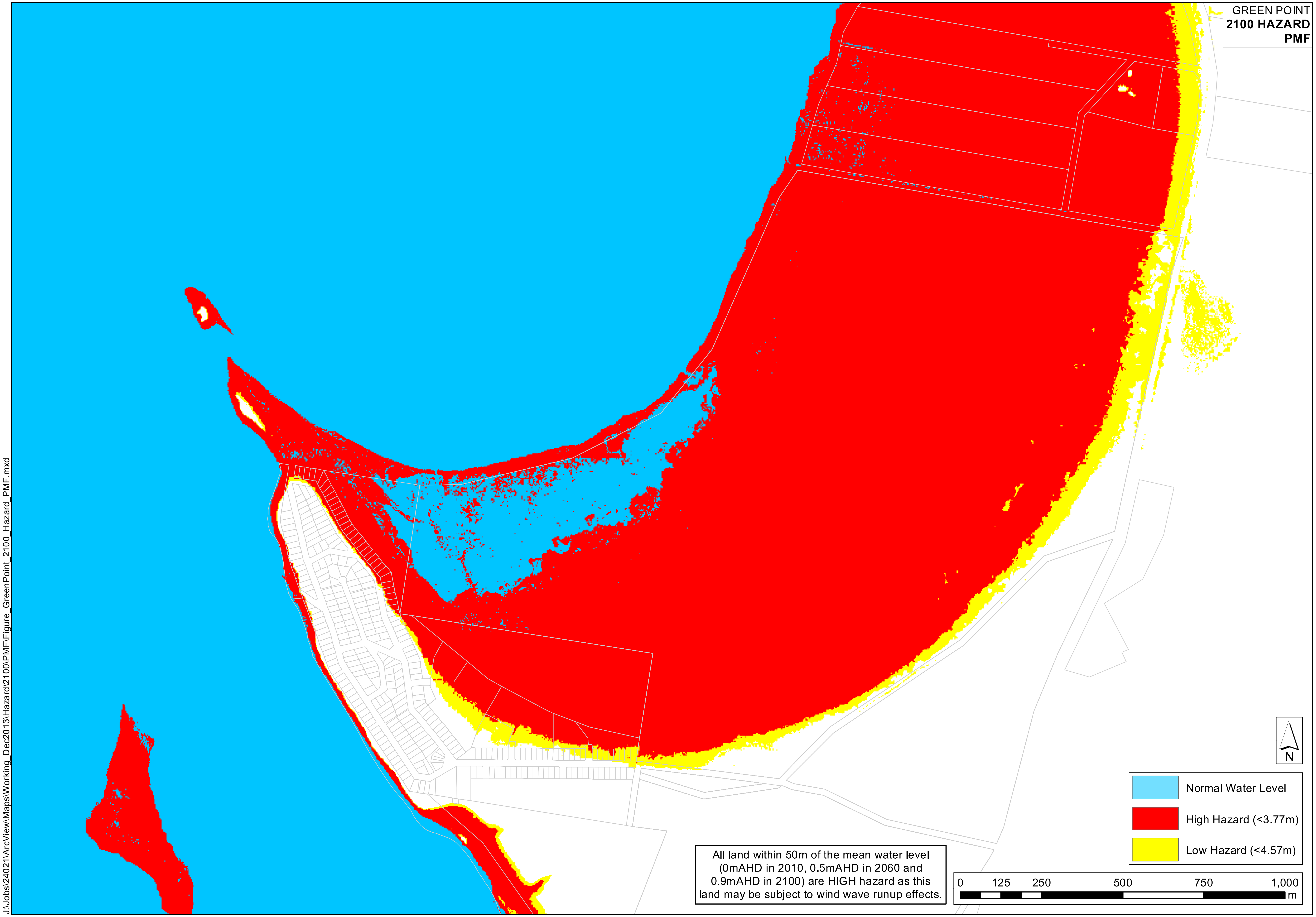

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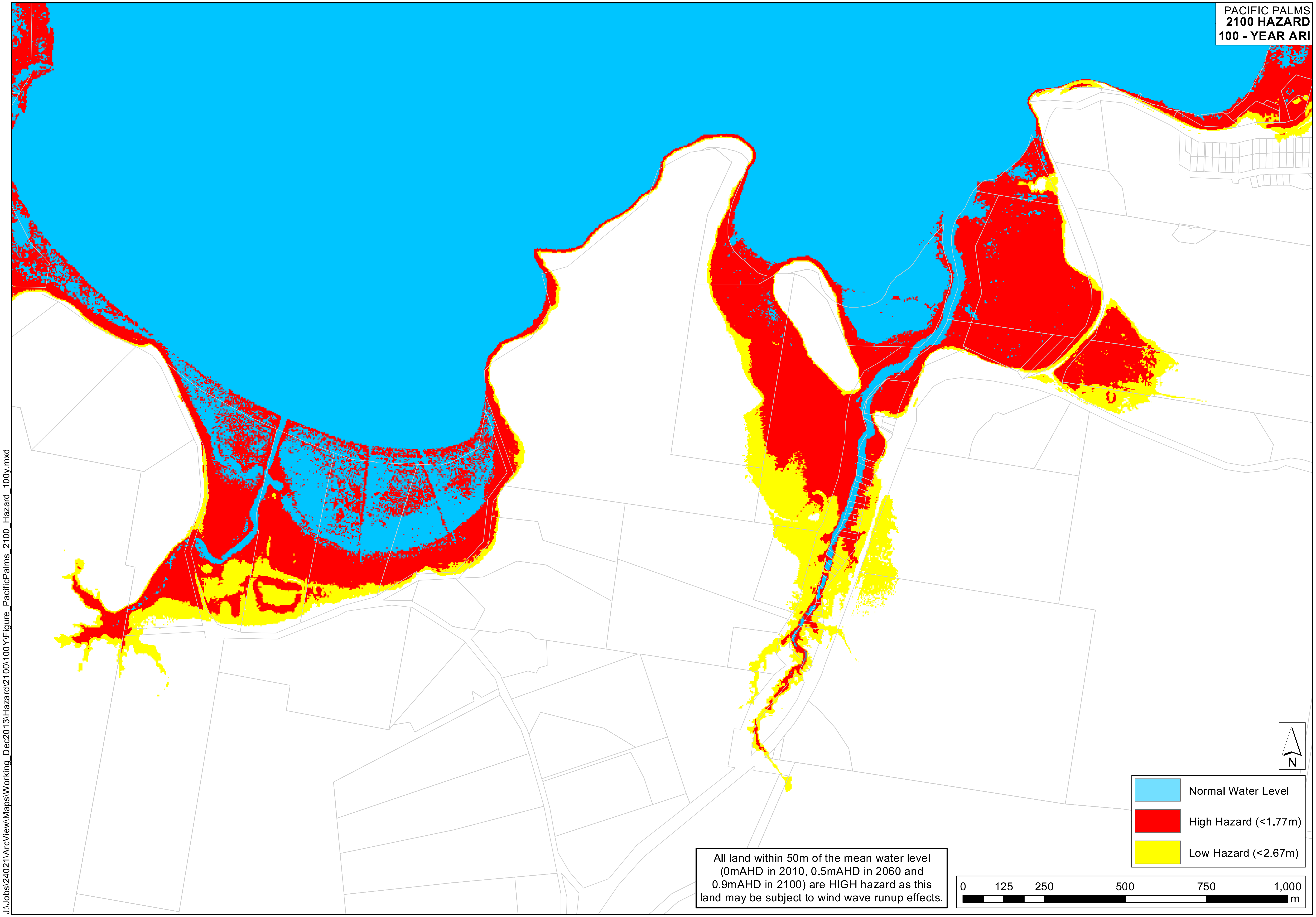

PACIFIC PALMS
2100 HAZARD
100 - YEAR ARI
Normal Water Level
High Hazard (<1.77m)
Low Hazard (<2.67m)
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
0 125 250 500 750 1,000
m
N
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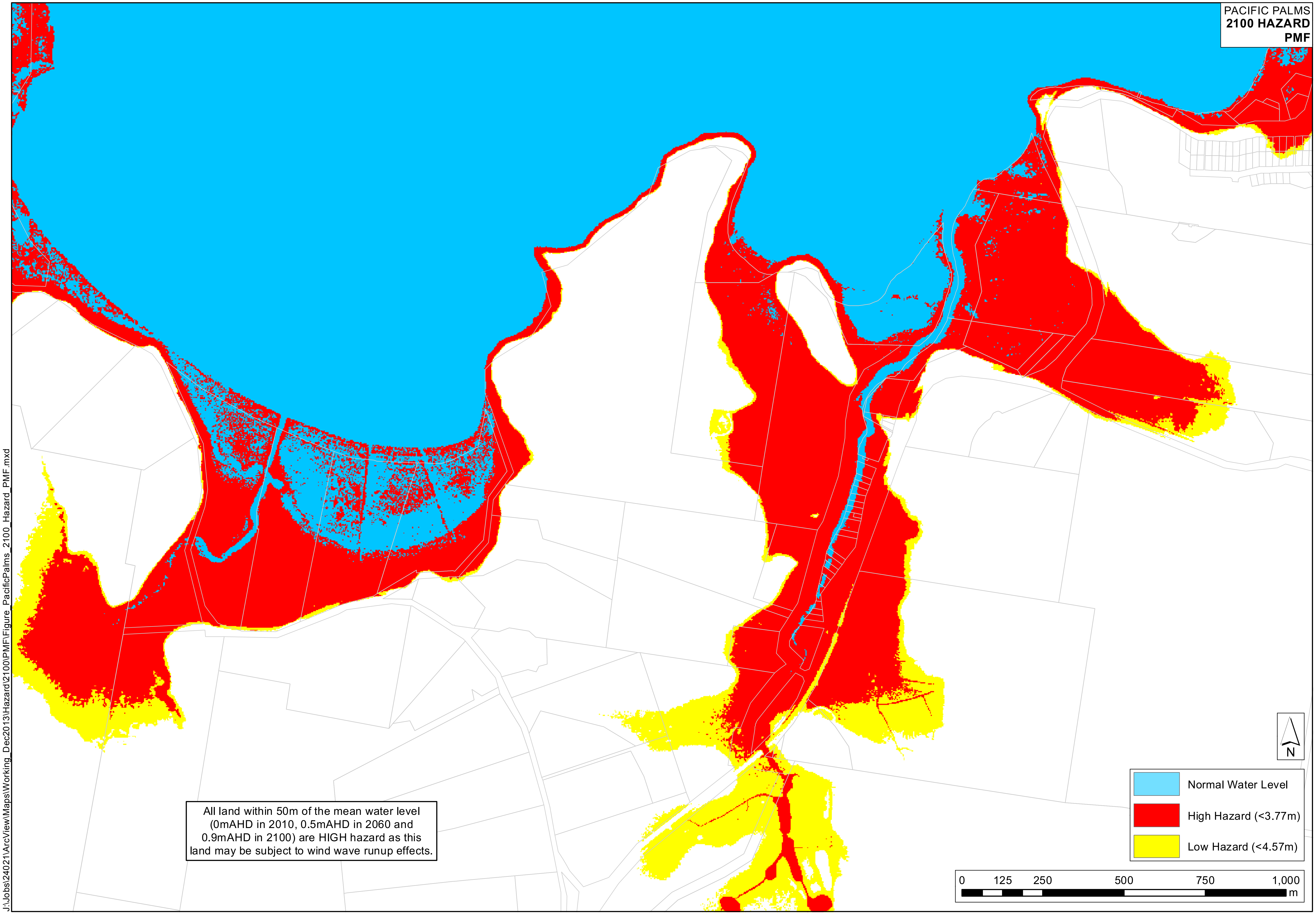
PACIFIC PALMS
2100 HAZARD
PMF
All land within 50m of the mean water level (0mAHD in 2010, 0.5mAHD in 2060 and 0.9mAHD in 2100) are HIGH hazard as this land may be subject to wind wave runup effects.
N
Normal Water Level
High Hazard (<3.77m)
Low Hazard (<4.57m)
0 125 250 500 750 1,000 m
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