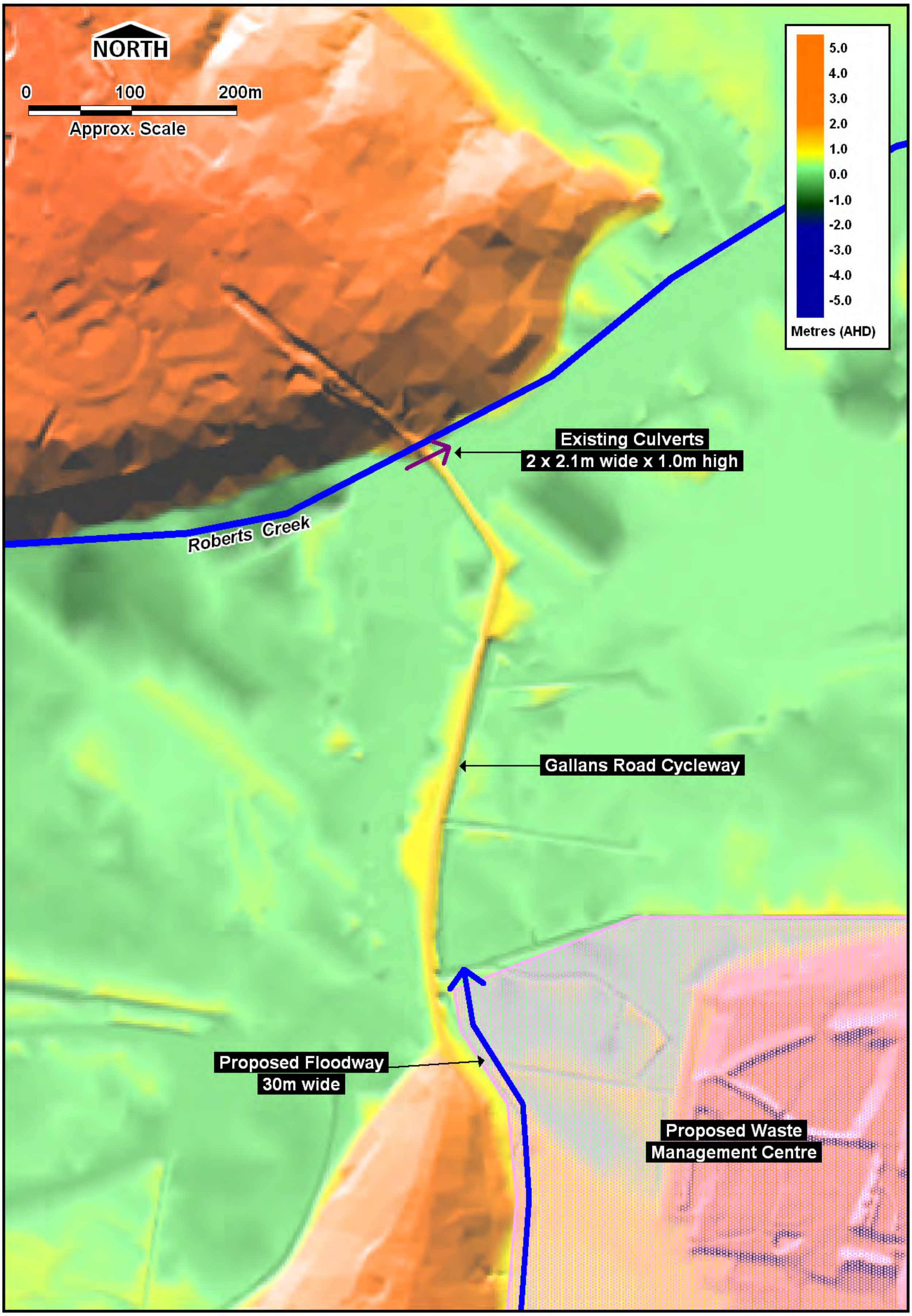
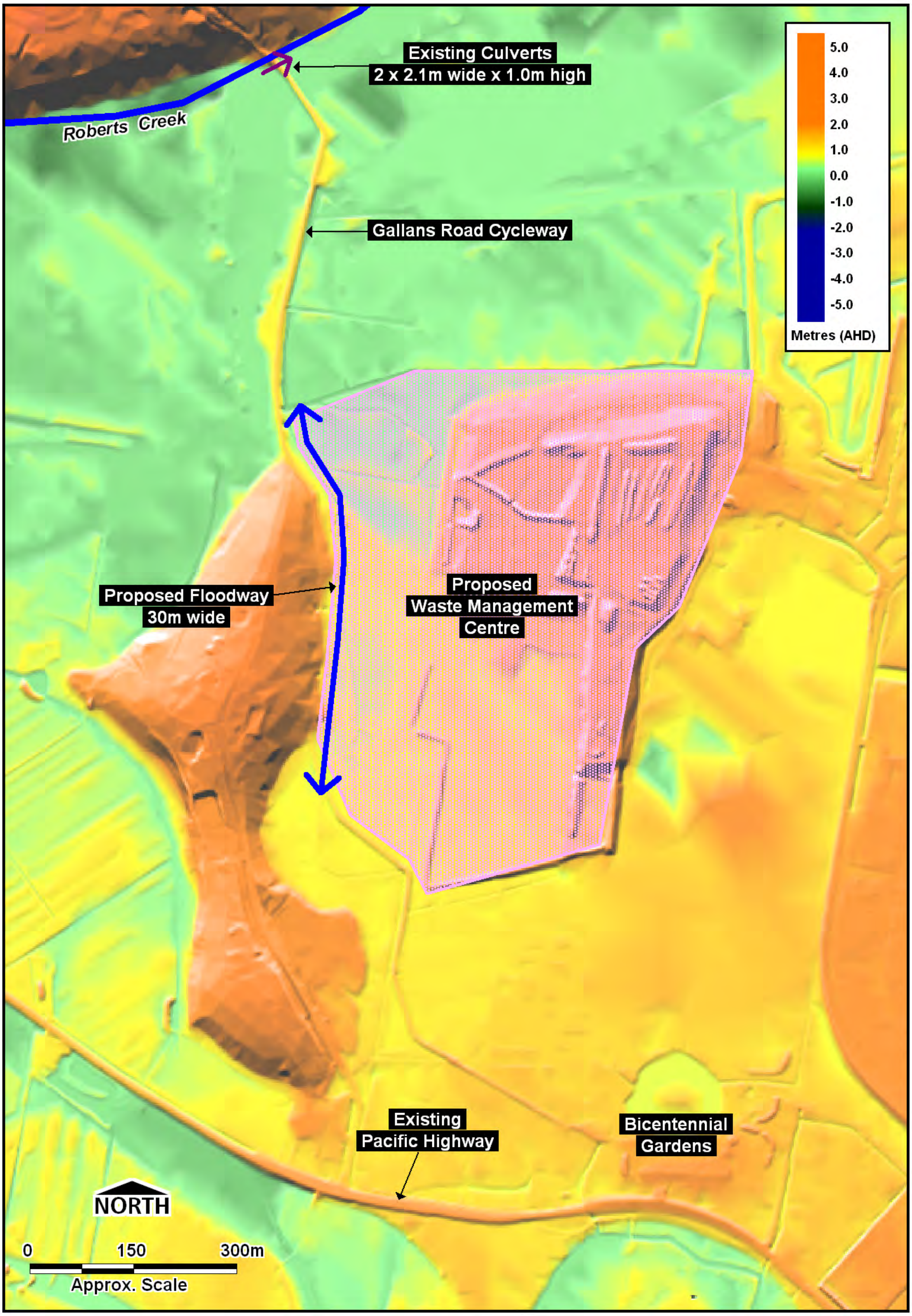
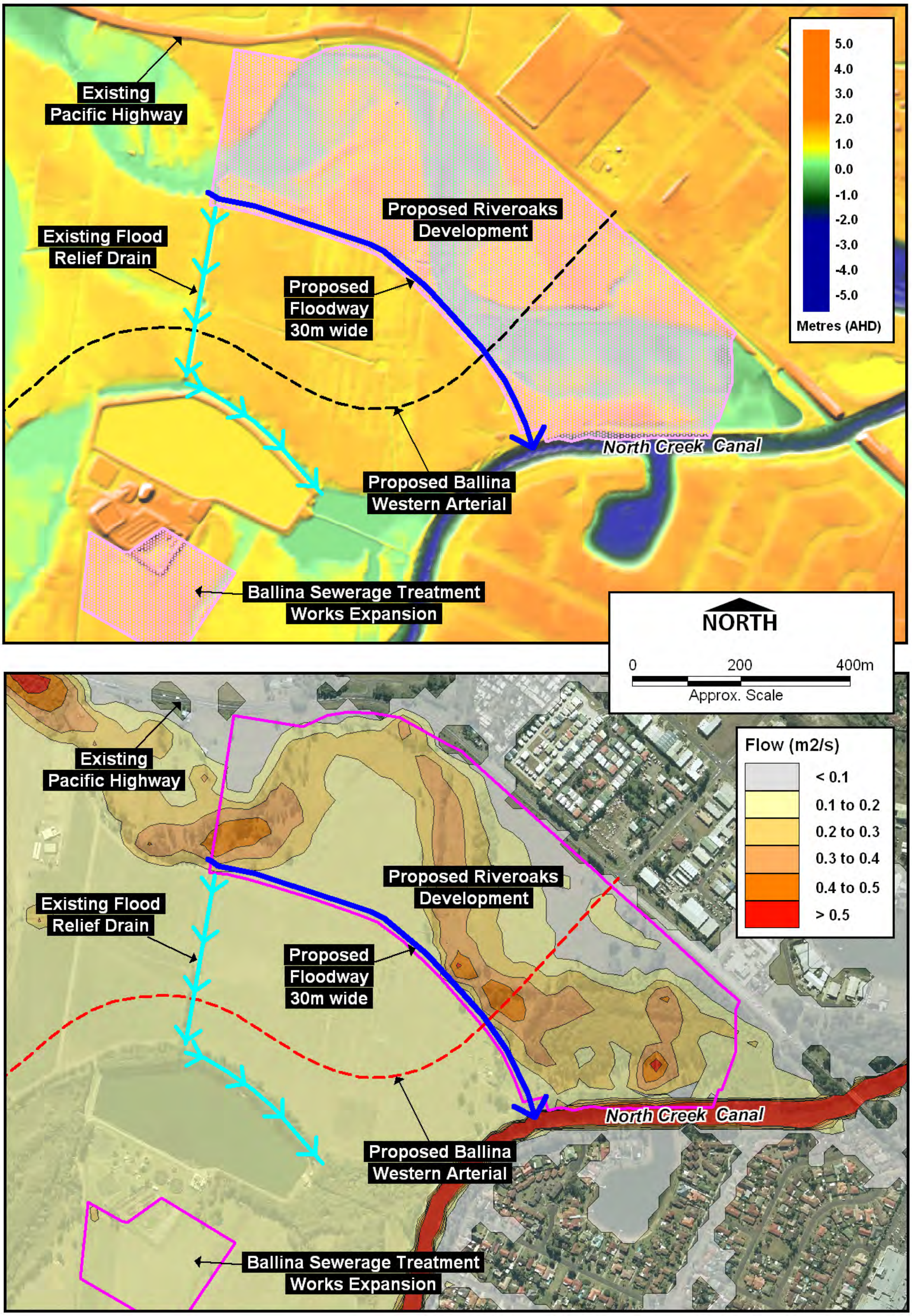


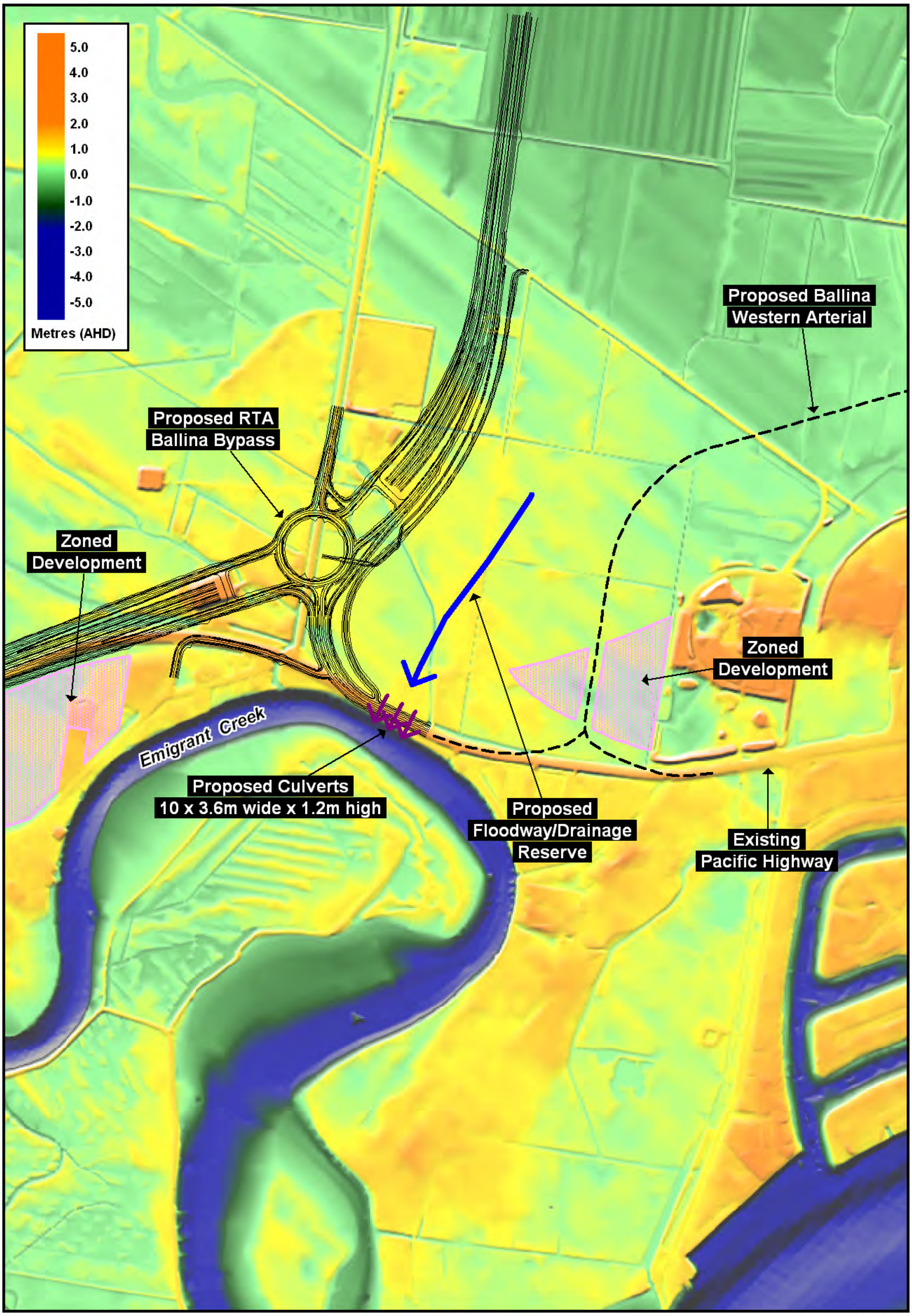
Gallans Road Cycleway Figure 8-6



Waste Management Centre Floodway **Figure 8-7**



Riveroaks Floodway **Figure 8-8**



Pacific Highway Floodway and Culverts **Figure 8-9**

Dredging Assessment - Dredging Locations

Figure 8-10

8.4 Mitigation Measure Summary

A summary of the mitigation measures that have been investigated is presented in Table 8-1.

Table 8-1 Summary of Mitigation Measures Investigated

Mitigation Measure	Required / Not Required	Comments
Cumbalum Floodway and Culverts	Required	40m wide floodway (invert level 0.0m AHD) between the Ballina Bypass flood relief bridge and Roberts Creek. 30 x 3m wide x 0.9m high box culverts (invert level 0.0m AHD)
Gallans Road Cycleway	Further Investigation Required	Indicates beneficial results
Waste Management Centre Floodway	Required	30m wide floodway (invert level 0.5m – 1.0m AHD)
Riveroaks Floodway	Required	30m wide floodway (invert level 0.0m AHD). Flood gates or weir required to prevent tidal intrusion.
Pacific Highway Culverts	Required	10 x 3.6m wide x 1.2m high box culverts (invert level 0.0m AHD). Flood gates or weir required to prevent tidal intrusion.
Fishery Creek Floodway	Not Required	Indicates insufficient benefit
Emigrant Creek to Fishery Creek Floodway Link	Not Required	Indicates insufficient benefit
North Creek Canal Dredging	Not Required	Indicates insufficient benefit
Richmond River, North Creek and Emigrant Creek Dredging	Not Required	Indicates adverse impacts, due to storm surge conditions
Emigrant Creek Bridge Enlargement	Further Investigation Required	Indicates beneficial results

8.4.1 Base Case Flood Impacts

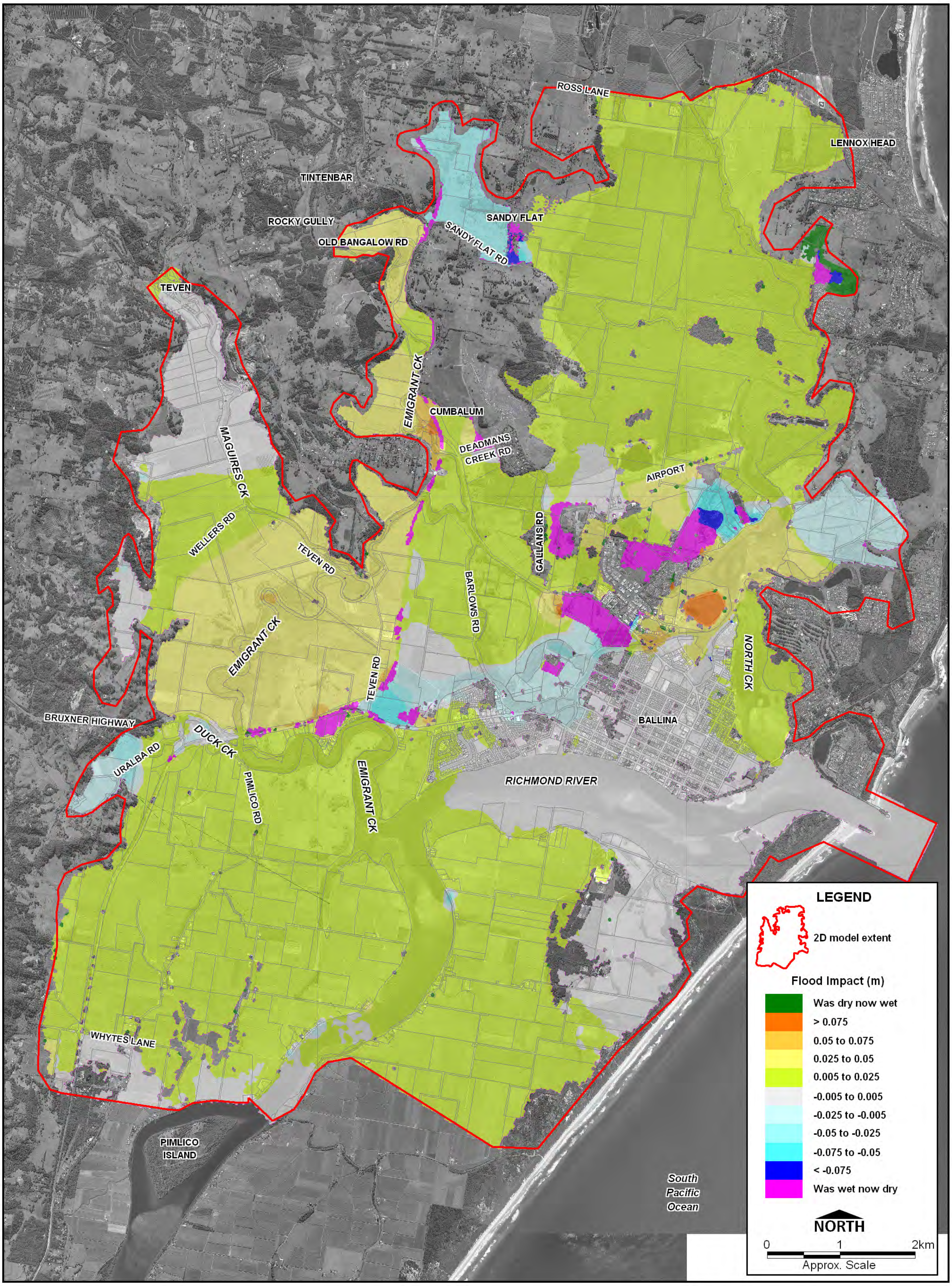
The current base case model, therefore, consists of the mitigation measures noted in Table 8-1. Adopting this mitigation strategy, peak flood level impacts are presented in Figure 8-11 for the 100 year ARI combined flood event. This figure demonstrates that there are only isolated occurrences where peak flood levels increase by more than 50mm. These areas are summarised below.

Ballina Racecourse

In the 100 year ARI event, increases greater than 75mm are experienced at the Ballina Racecourse. The effects are due to a perimeter levee bank. Minor drainage from the racecourse is not included in the flood model due to the small size.

Cumbalum

In the 100 year ARI event, there are increases immediately upstream of the RTA Ballina Bypass at Cumbalum. This impact exceeds the 50mm cumulative impact target and will need to be resolved with completion of the designs for the RTA Ballina Bypass and Cumbalum floodway.



Base Case Impact Results - 100 Year ARI Flood Event **Figure 8-11**

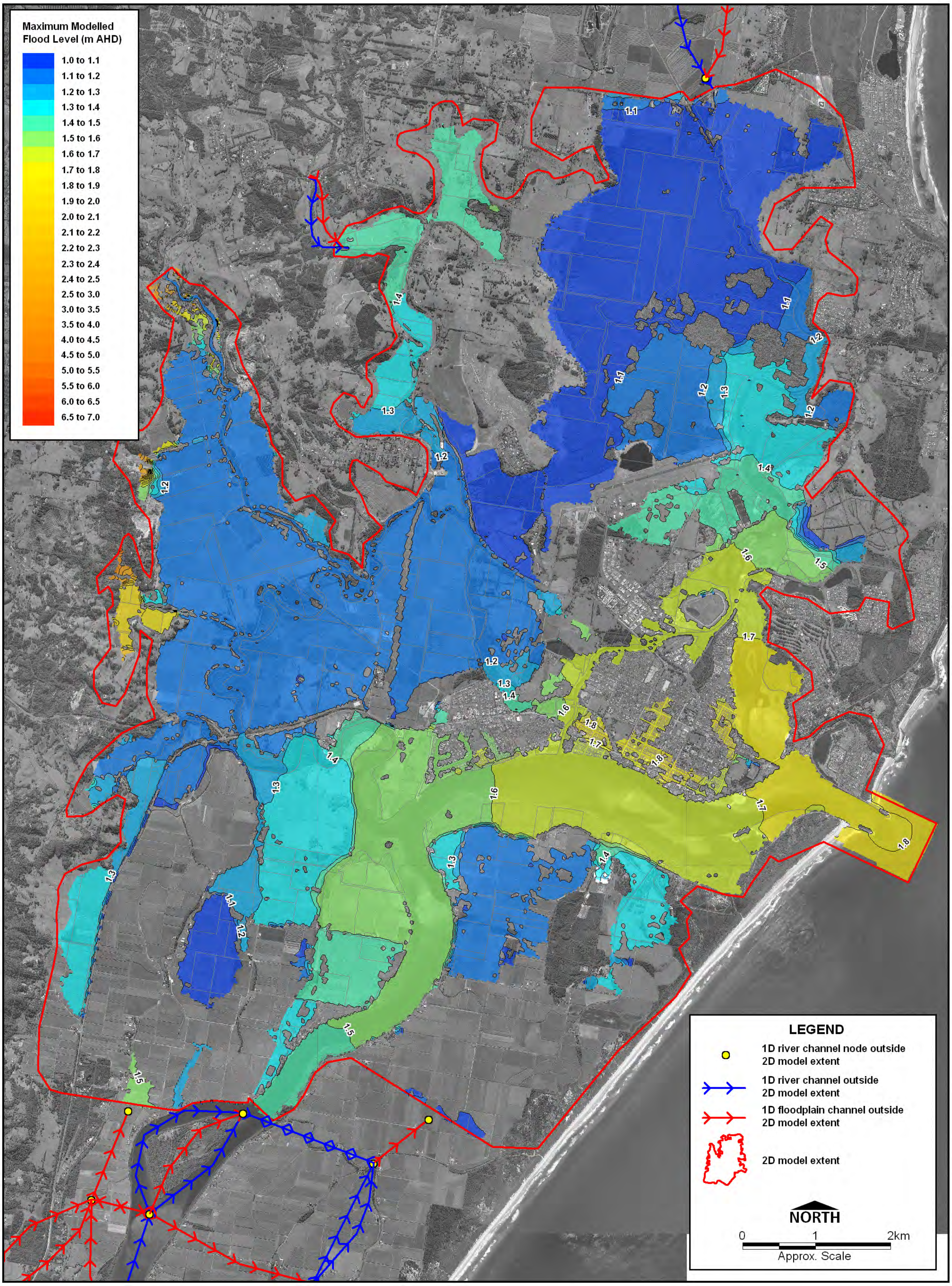
8.4.2 Base Case Peak Flood Levels

The peak flood levels for the 5, 20, 50, 100 and 500 year ARI combined events and the PMF event are presented in Figures 8-12 to 8-17.

8.4.3 Changes to the Minimum Fill Policy

One of the objectives for this flood study update is to undertake a review of the currently published minimum fill levels for the Ballina floodplain. For this review, the results of the Wardell and Cabbage Tree Island Flood Study by Patterson Britton and Partners were provided and combined with the results from this Ballina Flood Study Update. The result is a 2D grid of peak flood levels for the entire floodplain between Broadwater and the Richmond River mouth at Ballina.

Peak flood levels for the 50 and 100 year ARI events are presented in Figures 8-18 and 8-19 respectively. These maps will aide Council during their amendment to the current minimum fill level policy. In addition to the revised minimum fill levels, Council will amend the minimum freeboard requirement from 300mm to 500mm to coincide with the recommendations of the NSW Floodplain Development Manual.



Base Case Peak Flood Levels (mAHD) - 5 Year ARI

Figure 8-12

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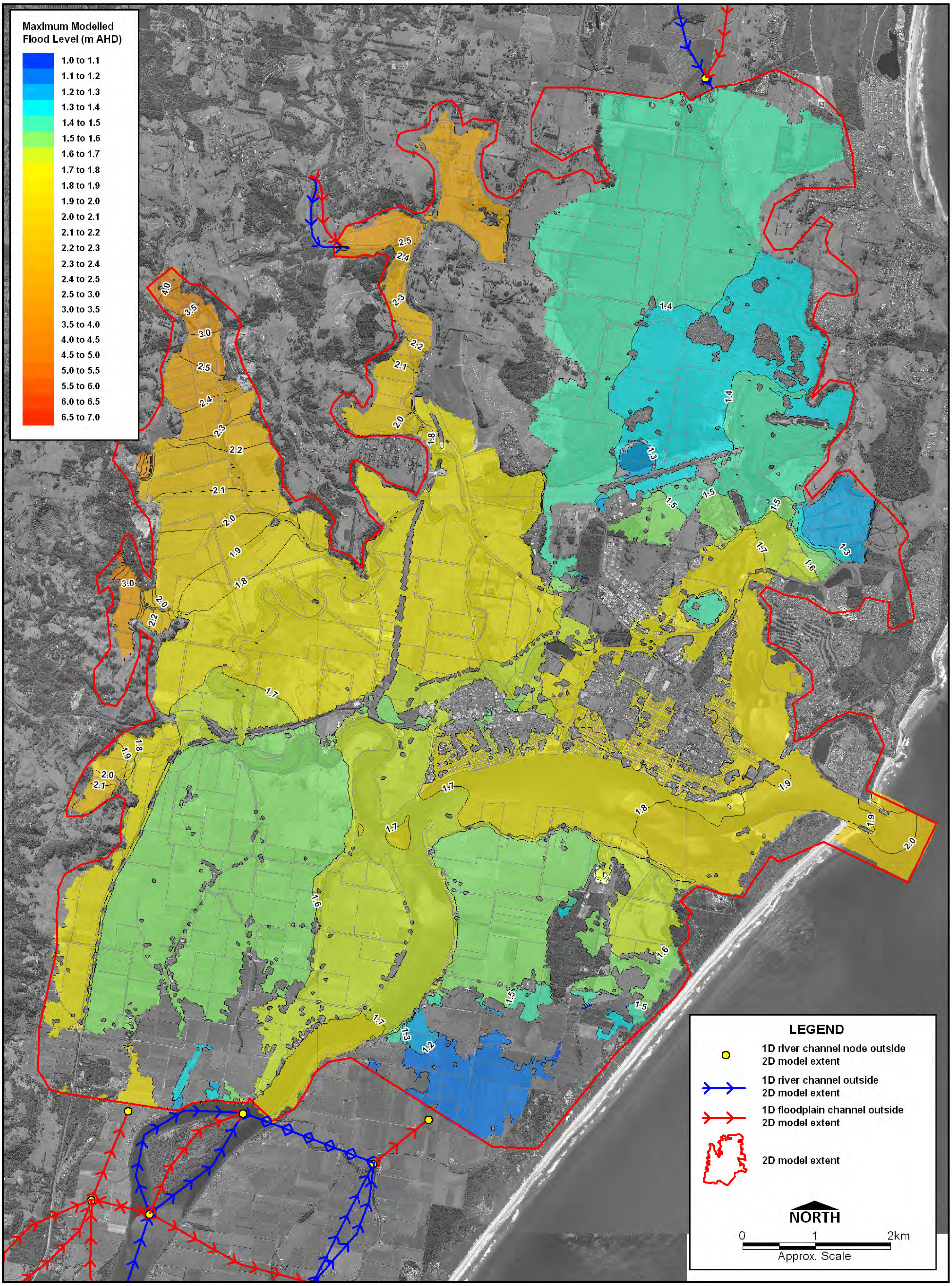
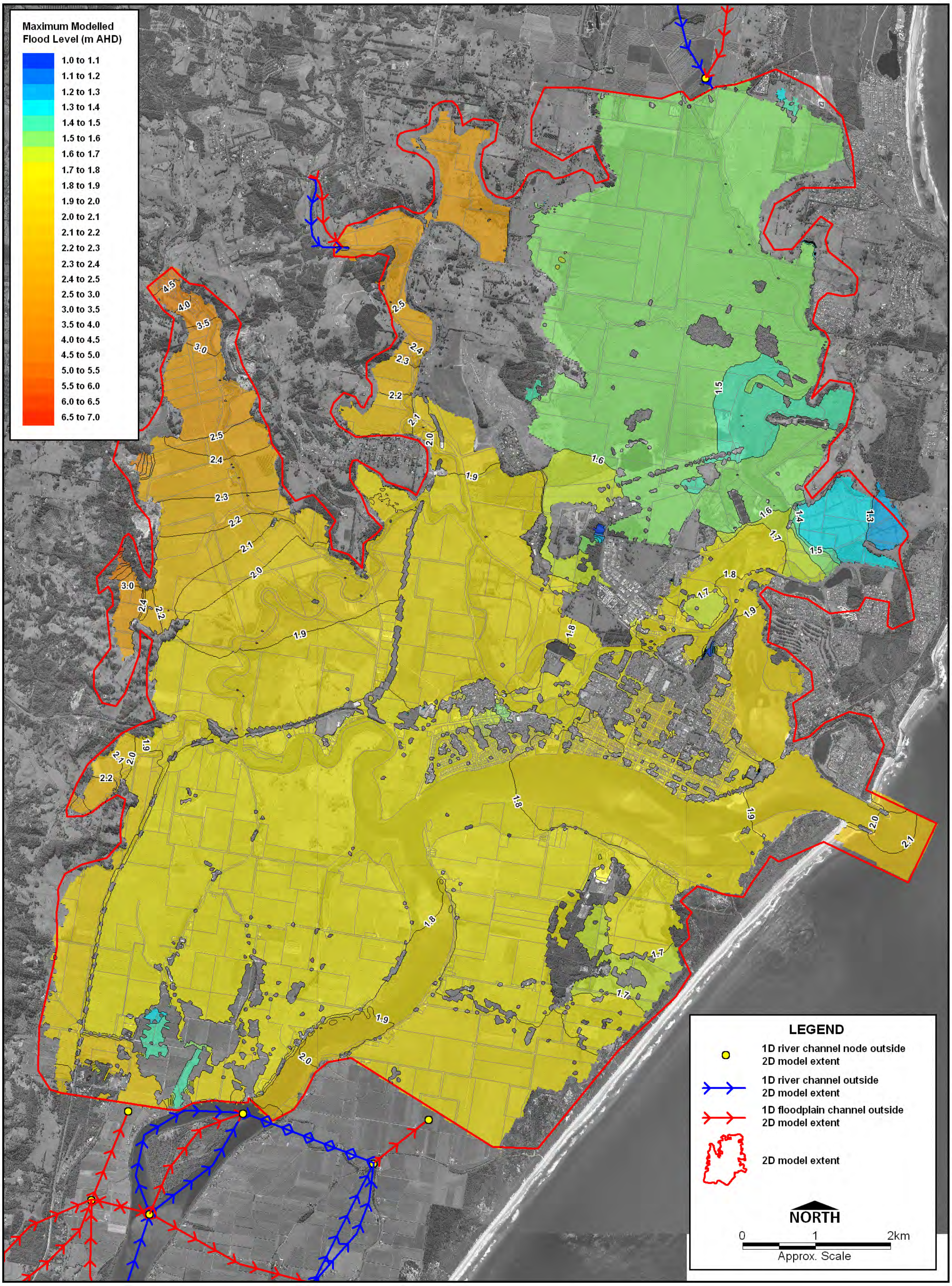
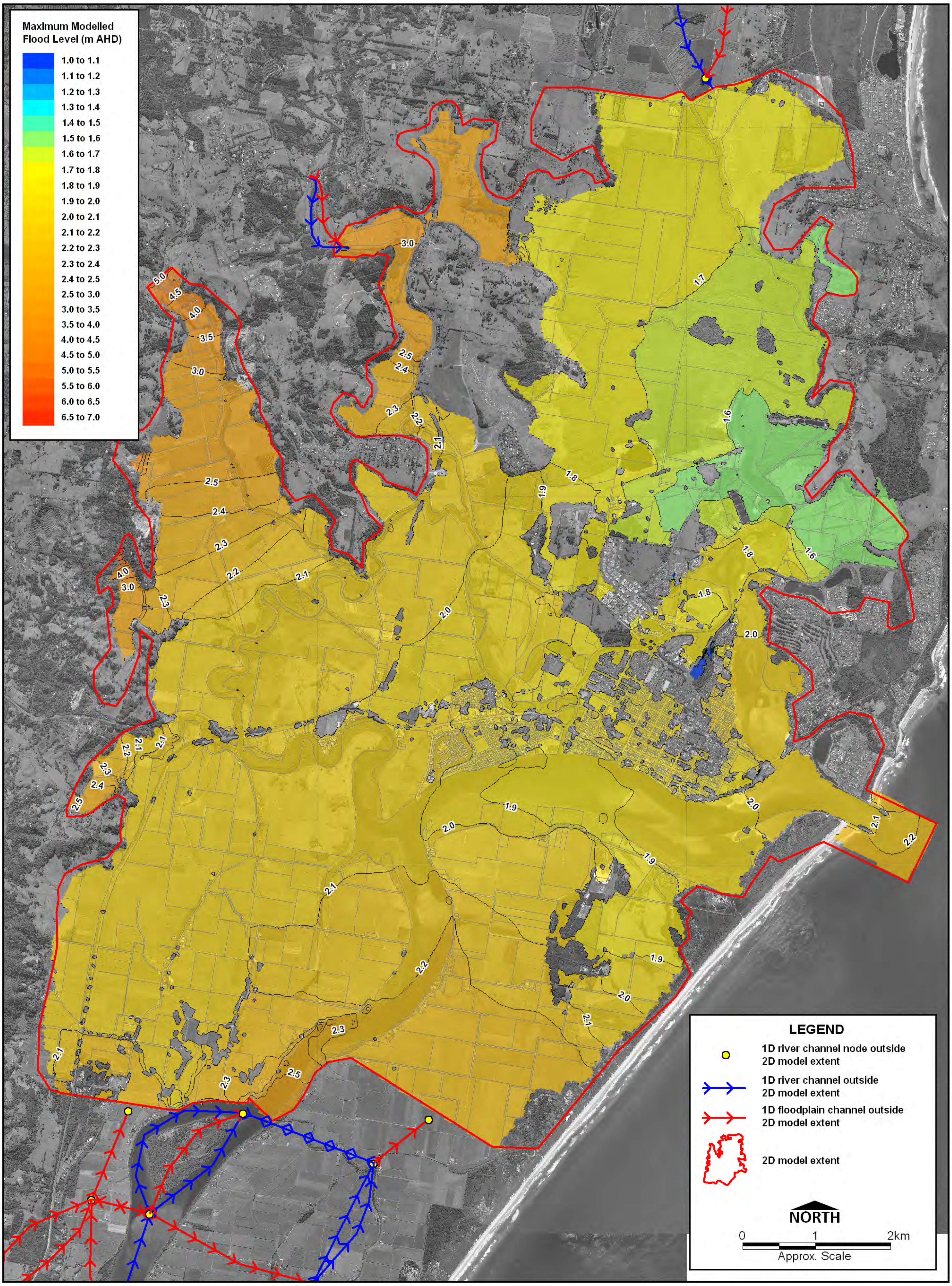


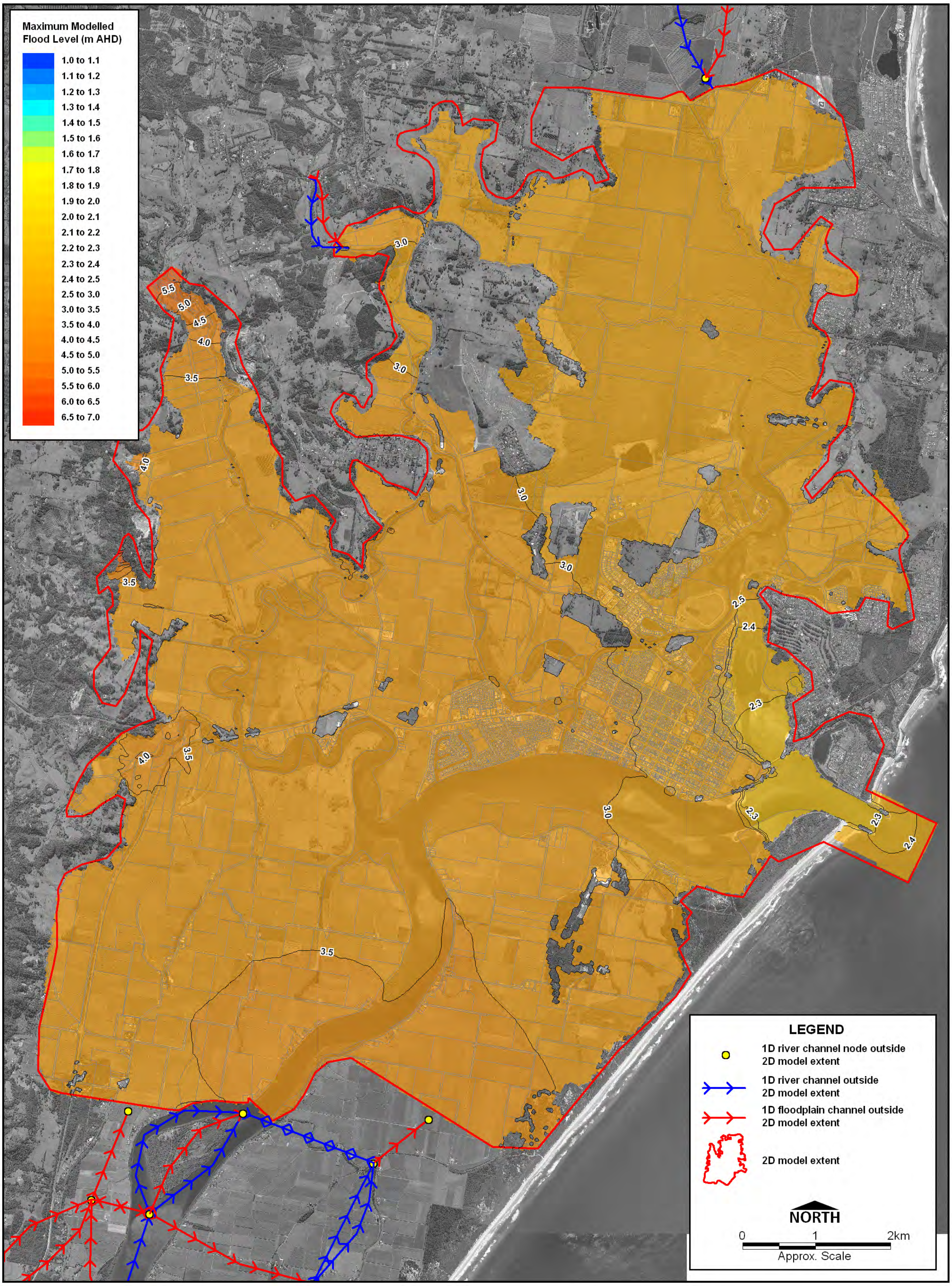
Base Case Peak Flood Levels (mAHD) - 20 Year ARI **Figure 8-13**



Base Case Peak Flood Levels (mAHD) - 50 Year ARI **Figure 8-14**



Base Case Peak Flood Levels (mAHD) - 100 Year ARI **Figure 8-15**



Base Case Peak Flood Levels (mAHD) - 500 Year ARI

Figure 8-16

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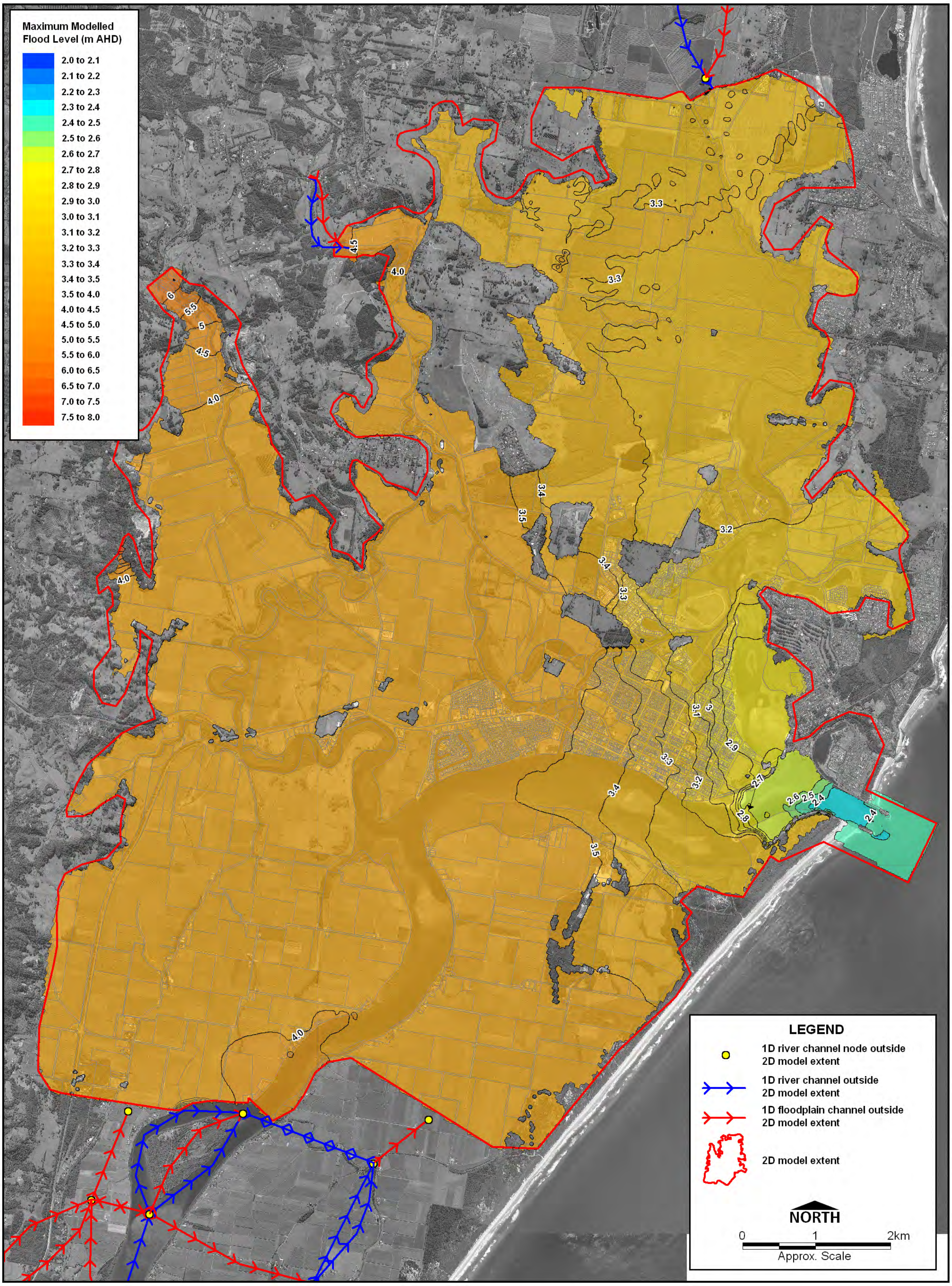

Base Case Peak Flood Levels (mAHD) - PMF Event

Figure 8-17

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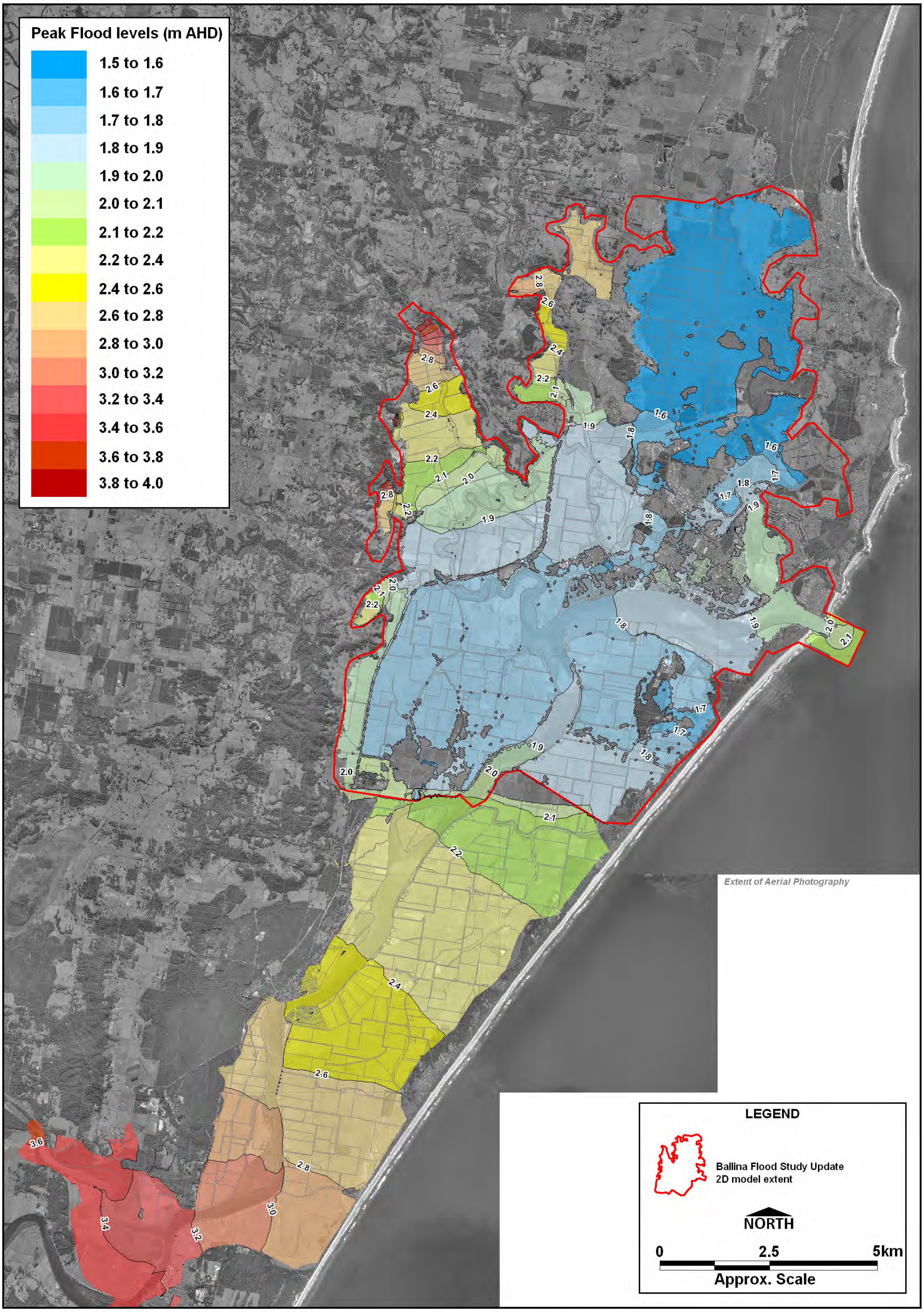
BMT WBM



Peak Flood Levels to be used for
Minimum Fill Level Policy (m AHD) - 50 Year ARI

Figure 8-18

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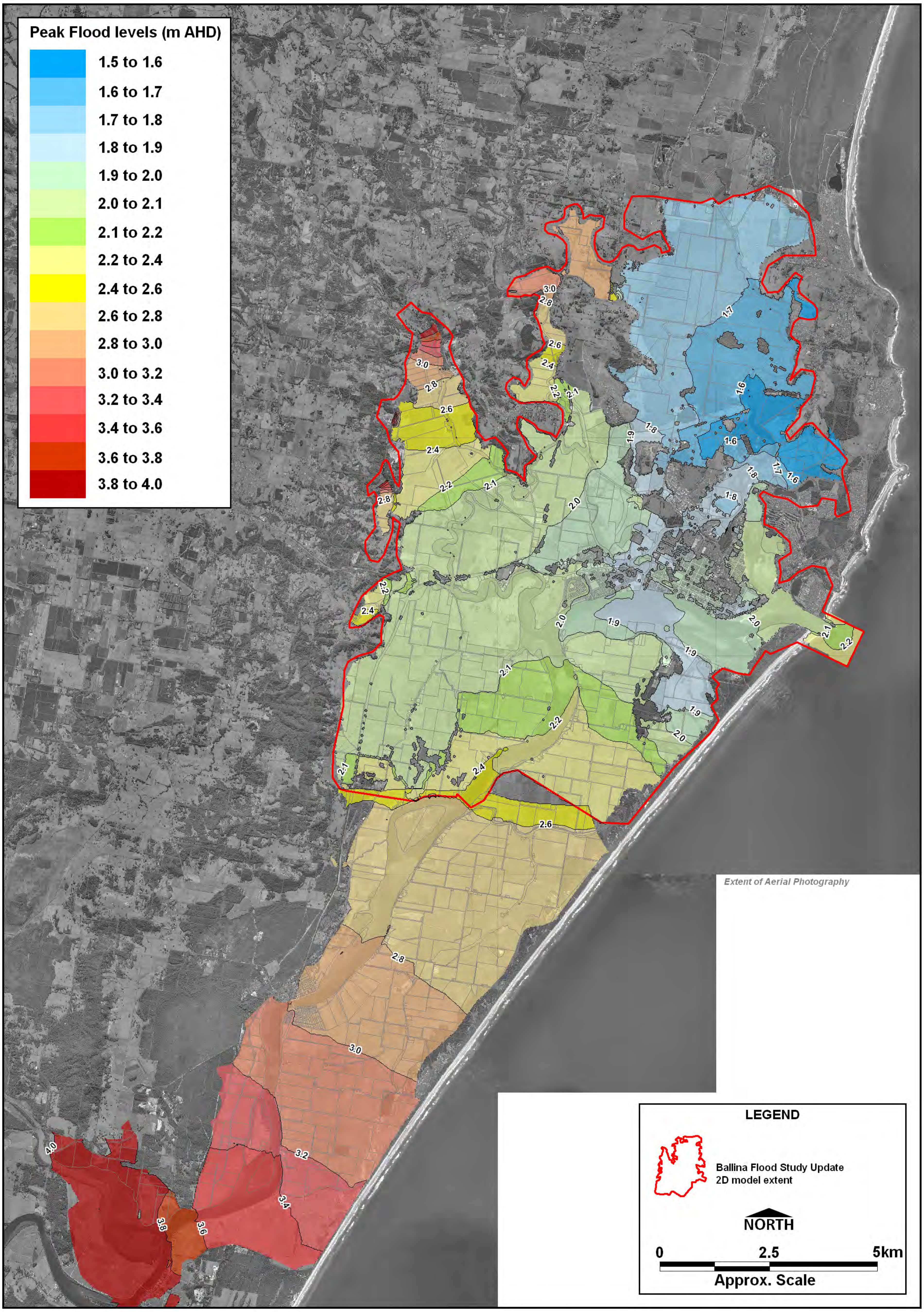

Peak Flood Levels to be used for Minimum Fill Level Policy (m AHD) - 100 Year ARI

Figure 8-19

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BMT WBM

9 CONCLUDING COMMENTS AND RECOMMENDATIONS

Updating the 1997 one-dimensional hydraulic model of the Ballina region, downstream of Pimlico Island, into a two-dimensional model has provided a greater understanding of the complex flooding behaviour of the Richmond River and local creeks. The model has demonstrated the dynamic nature of local flooding.

The Community Reference Group have been involved throughout the flood study update process and have made a valuable contribution to the project.

The flood model has been calibrated to three historical flood events, providing confidence in the ability of the model to accurately represent the flooding behaviour of the catchment. The calibrated model has then been used as a design tool to apply a series of design floods to facilitate local planning processes.

All currently planned public infrastructure works and zoned urban development has been applied to the model, and the consequent impacts on flooding assessed. A series of measures have been investigated to mitigate the adverse impacts of the above future development. Some of the measures investigated have been discarded due to their limited flood mitigation benefit, whilst others have been adopted as part of the local flood mitigation strategy. Although not formally adopted as part of the flood mitigation strategy, various measures that have been investigated are recommended for further investigation. Table 9-1 summarises the mitigation measures that are required or recommended for further investigation. Also included in Table 9-1 is the development that will trigger the requirement for each mitigation measure.

Table 9-1 Mitigation Measures Required / Recommended for Further Investigation

Mitigation Measure	Required / Recommended	Comments	Trigger for Timing of Mitigation Measure
Cumbalum Floodway and Culverts	Required	The floodway and culverts at Cumbalum are essential to ensure impacts in upper Emigrant Creek are minimised	Construction of the Ballina Heights development and Cumbalum Way
Gallans Road Cycleway	Further Investigation Required	It is recommended that mitigation strategies for the cycleway are investigated further	Further Investigation Required
Waste Management Centre Floodway	Required	This floodway is essential to maintain connectivity of the floodplain	Construction of the Waste Management Centre
Riveroaks Floodway	Required	This floodway is essential to mitigate the impacts of the development	Construction of the Riveroaks development
Pacific Highway Culverts east of Teven Road intersection	Required	These culverts include a floodway link to the Emigrant Creek floodplain to the north	Filling of the floodplain to the east of the Ballina Bypass and construction of the Ballina Western Arterial
Enlargement of the Pacific Highway bridge over Emigrant Creek	Further Investigation Required	It is recommended that the RTA investigate this option as part of the Pacific Highway upgrade projects	Further Investigation Required

The mitigation strategy has been developed ensuring that peak flood levels do not increase by more than 50mm during any flood event up to and including the 100 year ARI event. These impacts are defined by comparing with 2005 catchment conditions.

The Ballina flood model, including the aforementioned development and mitigation strategy, is referred to as the 'Base Case' flood model. This Base Case model will be used by Council to assist future strategic planning and rezoning decisions and to ensure that appropriate flood mitigation strategies are developed and implemented. The 50mm maximum flood impact criterion shall apply on a cumulative basis, i.e. the combined impact of all future development will not increase peak flood levels by more than 50mm.

Development of a two-dimensional flood model of the floodplain has provided a more detailed representation of local flooding and thus, peak flood levels. As part of this flood study update, a review of Council's minimum fill level policy has also been undertaken. The revised 100 year ARI flood levels have been used to amend the currently published minimum fill level plan. It is recommended that the revised plan is adopted and applied to all future development. In addition, an amendment to Council's freeboard policy is recommended to ensure consistency with the recommendations of the NSW Floodplain Development Manual (2005). This will increase the freeboard requirements for residential development from 300mm to 500mm.

Completion of the Ballina Flood Study Update is the first stage of the development of the Ballina Floodplain Risk Management Study and Plan. The recommendations within this report should be addressed and included in the final risk management plan.

10 REFERENCES

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APPENDIX A: DATA COLLECTION

A.1 Introduction

Various data are required to assess flood behaviour. Data has been collated for the Ballina Flood Study Update including:

- historic flood and land use data;
- past reports, flood behaviour in general, major flow paths, peak flood levels, flood damage, flow velocities, rate of rise of flood waters, travel time;
- rainfall records and projections of future rainfall characteristics;
- waterway openings to existing flood structures;
- topography; and
- relevant climate change data (presented separately in Appendix C).

A.2 Topographic Data

Quality, high resolution terrain information is required to define the drainage characteristics and provide the basis for the floodplain mapping. This was identified as a deficiency in available data in the briefing phase of this project. As part of this study, Council commissioned QASCO Pty Ltd to collect and compile this data via photogrammetry. The survey brief called for extents from Ross Lane in the north to Pimlico Island in the south. The following points summarise the data provided by QASCO Pty Ltd.

- Aerial photography at +/-0.2m vertical accuracy
- Date of Photography: 28th October 2004
- Flying Height: 1580 metres A.S.L.
- Date of Compilation: April 2005
- The topographic data from aerial photography is at a scale of 1:10,000. It is suitable for the generation of contours with a vertical interval of no less than 1.0 metres
- The accuracy of certain identified areas is of unreliable accuracy due to obstructions of some description (e.g. vegetation or shadow)
- Horizontal Co-ordinates are based on M.G.A. Zone 56
- Vertical Datum is based on AHD

Bathymetric data was provided by DNR in February 2005 for the creeks and the Richmond River. The bathymetric, or hydrographic survey, consist of depth soundings between the river or creek banks and was collected for this project under DNR's Estuary Program in late September 2004. The extent of the survey was:

- 5 km of North Creek from the entrance;
- 12km of the Richmond River from the entrance (approximately to Pimlico); and
- Maguires Creek, Emigrant Creek and North Creek Canal.

The brief for the hydrographic survey requested the survey in the Richmond River be based on 20m tracking lines and 10m survey points along these lines resulting in an approximate 20m x 10m triangulation.

In North Creek, survey cross-sections were required to be taken at increments ranging from 25m to 100m depending on the uniformity of the creek. Generally, all areas that were accessible by a boat were surveyed.

BMT WBM compiled all data into a civil design package (priority of layers for photogrammetry provided by QASCO Pty Ltd) to create a Triangulated Irregular Network (TIN) and subsequently the DEM on a 2.5m grid.

Refer to Figure A-1 for extents of the hydrographic survey.

A.3 Structure Data

All structure data (bridges, culverts and floodgates) was taken from the 1997 Ballina Floodplain Management Study's ESTRY model.

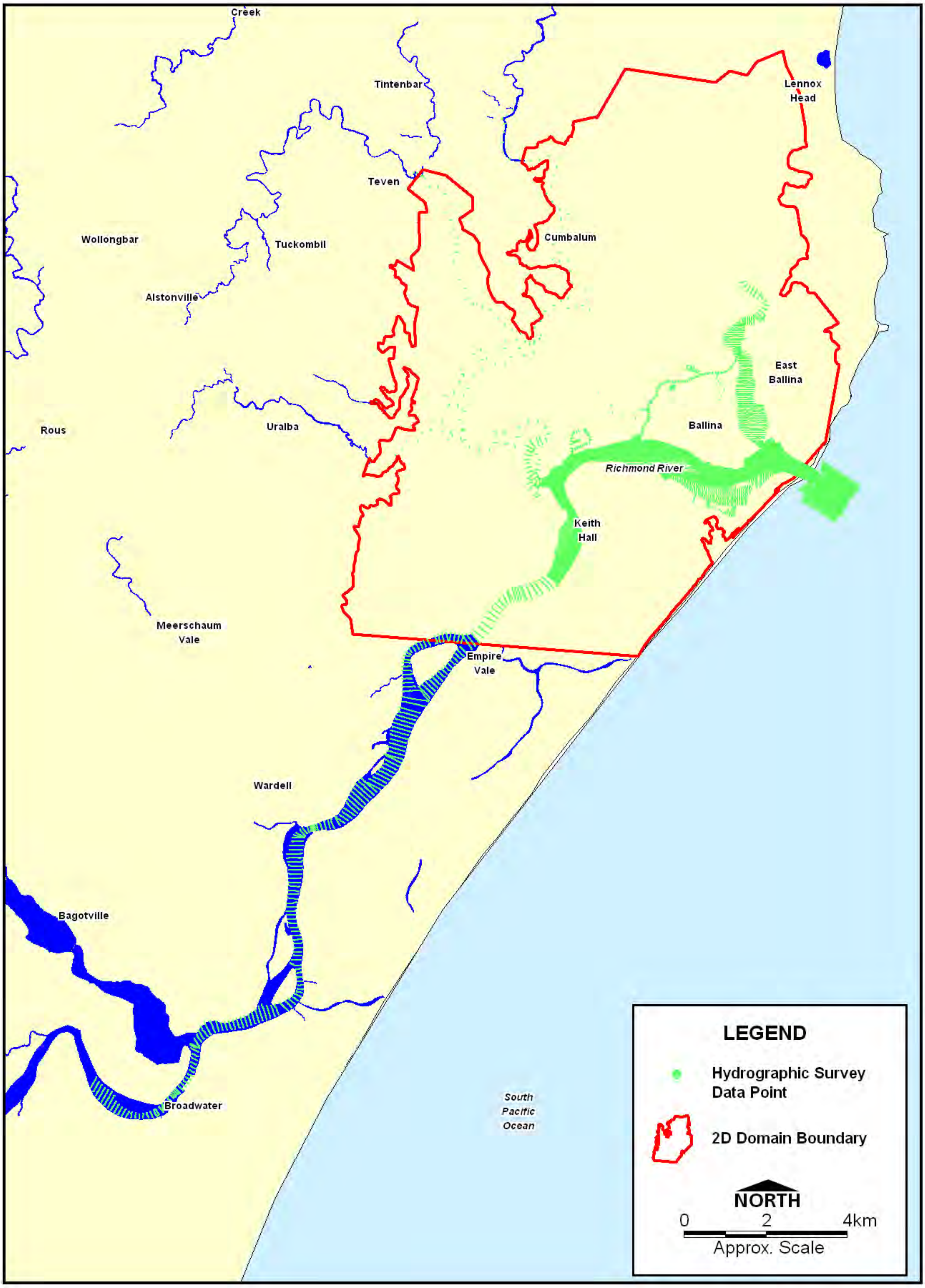
A.4 Rainfall Data

The Water Resources Station Catalogue (http://www.bom.gov.au/hydro/wrsc) provides a database of rainfall stations operated by the State and Territory Water Agencies, regional water authorities, major urban water authorities and the Bureau of Meteorology within the region.

The Bureau of Meteorology (BOM) administers numerous daily rainfall stations and Automatic Weather Stations (AWS). Ballina Airport AWS was installed in 1995. Manly Hydraulics Laboratory (MHL) also have pluviograph recorders installed post 1983. Alstonville Tropical Fruit Research Station (Station No. 058131) has been in operation since February 1963 and is currently operated by the Department of Primary Industries. The Water Resources Station Catalogue does not include pluviograph recorders maintained by MHL at Lake Ainsworth, Main Arm, Huonbrook, Myocum and Cudgera (and previously at Wollongbar and Empire Vale).

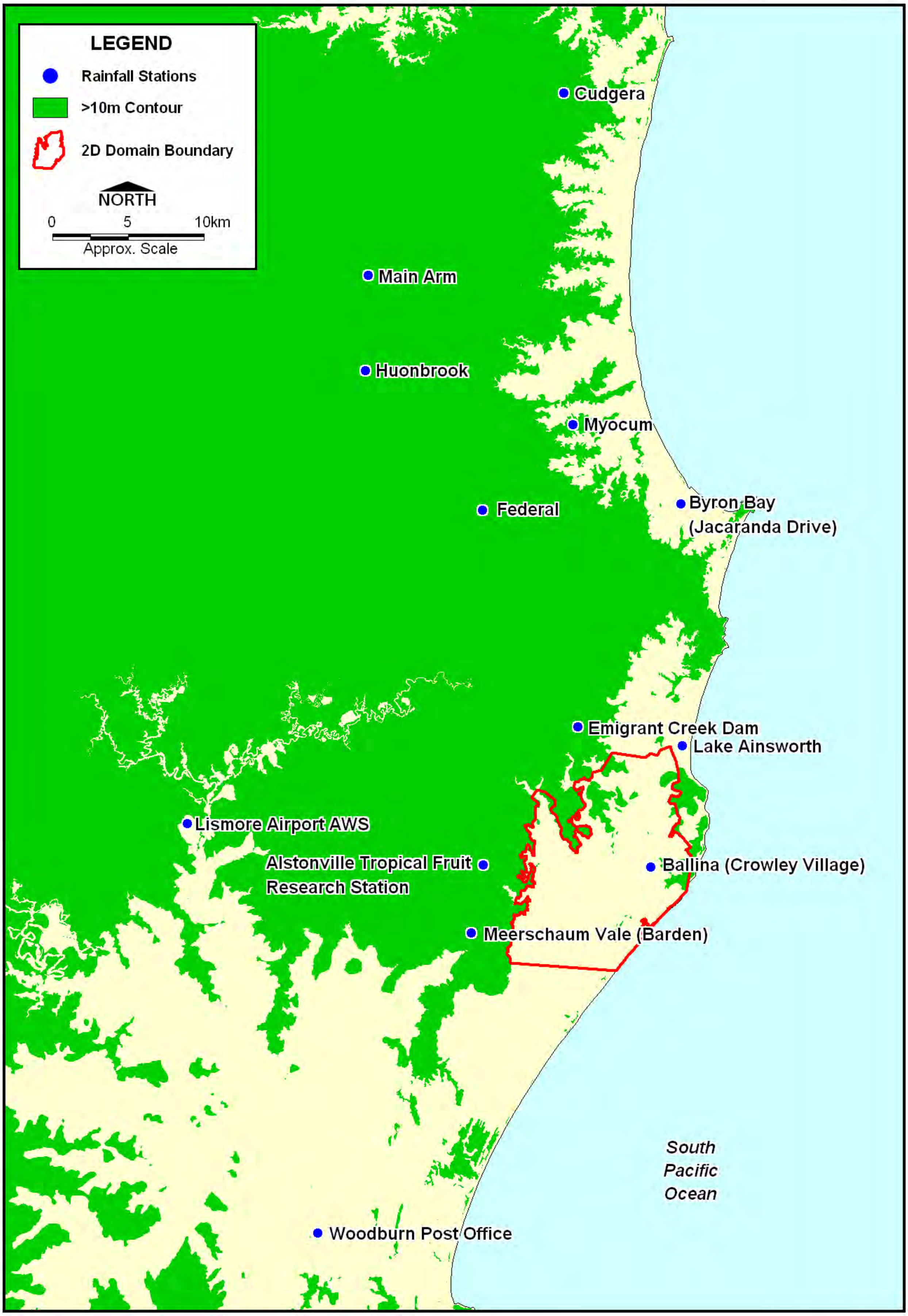
Rainfall data from the AWS (Lismore, Ballina) can be retrieved hourly. Rainfall data from the pluviograph recorders maintained by MHL can be retrieved on the quarter hour. Rainfall data from Alstonville Tropical Fruit Research Station is available at 6 minute increments.

The location of 13 northern New South Wales' gauges is shown on Figure A-2.



Hydrographic Surveys-September 2004

Figure A-1



Rainfall Station Locations

Figure A-2

A.4.1 1974 and 1976 Rainfall Events

No additional rainfall data was collected for the March 1974 and February 1976 events. Their temporal patterns were obtained from recorded data at the Alstonville Tropical Fruit Research Station and Federal P.O. Their spatial pattern (or areal rainfall distribution) was determined from total event rainfalls at the two continuous stations (Federal P.O. and Alstonville Tropical Fruit Research Station) plus daily stations at Byron Bay, Ballina (Crowley Village), and Wardell. Rainfalls at Broadwater Sugar Mill and Bangalow Motel were also used for the 1974 distribution. These stations closed in December 1975.

A.4.2 June 2005 Rainfall Event

The period of rainfall data collected for this event was from 28th June 2005 to 1st July 2005 inclusive. Rainfall in the month of June at Alstonville Tropical Fruit Research Station was also collected to determine antecedent moisture in the catchment.

Hourly rainfall information for the period was provided for Alstonville Tropical Fruit Research Station by the District Horticulturist, Alstonville Horticultural Institute, NSW Department of Primary Industries (via the Council).

Daily rainfall data for the following stations was provided by the Bureau of Meteorology's NSW Climate & Consultancy Section.

- Alstonville (58131),
- Ballina: Crowley Village (58001),
- Meerschaum Vale: Barden (58135),
- Byron Bay: Jacaranda Drive (58007),
- Woodburn Post Office (58061).

Hourly rainfall totals for Lismore AWS (station number 58214) and Ballina AWS (58198) were also provided by the BOM.

BOM maintenance staff advised that the Ballina AWS rain gauge stopped operating at 00:00 AEST on the 30th June 2005, possibly because of being submerged by floodwaters. The gauge was repaired and calibrated on the 5th July 2005

Pluviograph data was provided by MHL's Environmental Data Programs for Lake Ainsworth, Main Arm, Huonbrook, Myocum and Cudgera.

Anecdotally (Col Dorey Pers Comm. 12th June 2006), Tony Gilding at Phillips Road reported emptying his 10 inch rain gauge twice in the one 24hr period in the June 2005 flood.

Table B-1 was provided by the Bureau of Meteorology as part of the RTA's Tintenbar to Ewingsdale Pacific Highway Upgrade Project. The data is for Alstonville Tropical Fruit Research Station (058131) pluviograph data at 6 minute intervals.

Table A-1 Analysis of Rainfall at Alstonville Tropical Fruit Research Station—June 2005 (Source: BOM, Sept 2005)

Period (min)	Peak Rainfall	Ending Date	Ending Time	Intensity (mm/hr)
5	7.7	29th	20:27	92.4
6	8.8	29th	20:27	88.0
12	14.7	29th	20:36	73.5
18	22.8	29th	20:38	76.0
30	27.6	29th	20:44	55.2
60	36.5	30th	9:35	36.5
120	54.5	30th	10:25	27.3
180	68.9	30th	10:30	23.0
360	93.5	30th	10:18	15.6
720	159.7	30th	10:25	13.3
1440	274.1	30th	12:07	11.4
2880	362.2	30th	13:16	7.5
4320	415.5	30th	12:47	5.8

The Federal P.O. gauge was closed in March 1998 and hence was not used for this event. Broadwater Sugar Mill and Bangalow Motel have also been closed for some time.

Daily rainfall totals at the available 13 rain gauges for the June 2005 event are shown on Figure A-3. Since the Ballina Airport AWS rain gauge did not function after 29th June it does not provide a complete record of rainfall during this event. This data shows that the highest rainfall totals were recorded on 30th June 2005 with the highest daily total recorded at Cudgera of 464.5mm. The daily rainfall totals at Lake Ainsworth and Alstonville on 30th June were 224mm and 256mm respectively.

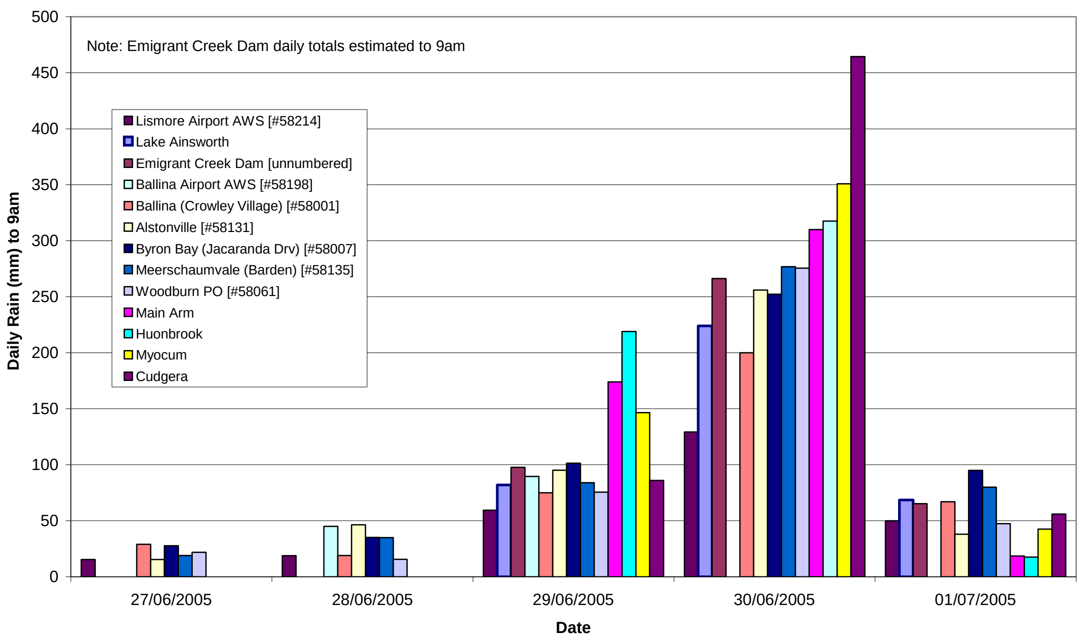


Figure A-3 Daily Rainfall Totals at Northern NSW Gauges—June 2005

The Lake Ainsworth and Alstonville Tropical Fruit Research Station rain gauges were used to define the temporal pattern of the June 2005 storm. These are plotted in Figure A-4. The temporal pattern for Ballina Airport AWS is also presented on the same figure to illustrate that Ballina rainfalls were similar in size and pattern to those recorded at Lake Ainsworth prior to failure of the gauge. This provides confidence in using the Lake Ainsworth record for the North Creek catchment.

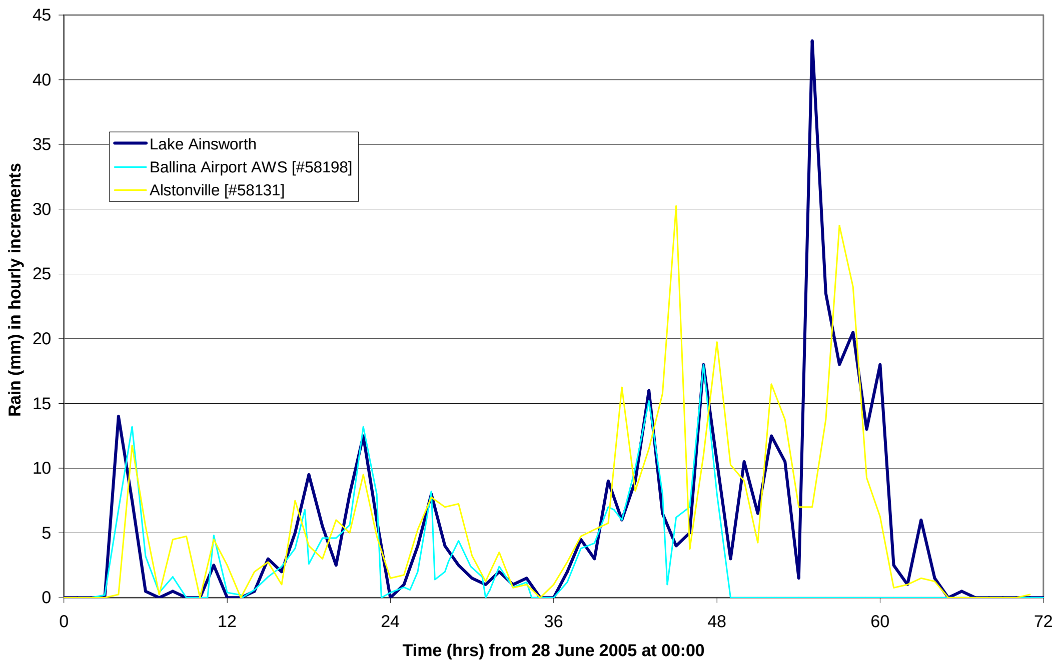


Figure A-4 Historical Temporal Pattern—June 2005

A.5 Resident Survey

BMT WBM welcomed the opportunity to seek new historical flood data from the community as this activity was not part of the previous study's brief. Any reliable historical flood data is highly beneficial to validating the computer modelling.

BMT WBM prepared a questionnaire for Council distribution, seeking knowledge of flooding from the community. A copy of the questionnaire is provided as Appendix B.

BMT WBM undertook a review of responses and produced a database for storing the questionnaire information. Many historical flood points were made available as part of this process. Council utilised their in-house survey team to collect level information for these points.

A.6 Peak Flood Level Data across the Floodplain

A.6.1 March 1974 Flood Event

All recorded flood levels for the 1974 event were determined during the resident survey conducted in 2005. Previously there were no records. The total number of calibration points is seven.

A.6.2 February 1976 Flood Event

Floodplain levels for the 1976 event came from two sources: from the 2005 resident survey and previous studies. The total number of calibration points is eight, with one being outside the model extent.

Council recently uncovered survey record of observed flood silt marks on the abutments of the Teven Rd 'twin bridges' to bring the total records for this event to 10. Some wave action may have influenced the silt marks. The recorded levels are shown in Table A-2.

Table A-2 Observed Levels at Teven Road Bridges—February 1976

Bridge	Recorded Flood Peak (mAHD)
Maguires Creek	2.11
Emigrant Creek	1.89

A.6.3 June 2005 Flood Event

All recorded levels are from June 2005 resident survey, totalling 15 recorded flood levels. Other anecdotal evidence is available.

A.7 Ocean Tide Levels

Tidal anomalies which produce water levels higher than the predicted tides are of vital importance to flood and coastal studies. The actual ocean tide levels are necessary to provide a consistent approach to flood studies by defining the tailwater conditions.

Ballina tide gauge is one of Manly Hydraulic Laboratory's (MHL) NSW Ocean Tide Data Recording Sites. A recorder has been deployed since 1986 and is located at the breakwater. This site has been chosen for minimal effects of near-shore influences, (such as river flows, wave setup and attenuation / amplification due to shallow inshore waters). The water level recorder is a high precision recording instrument for determining water level in the open seas. The total pressure is measured by an ultra precise quartz pressure sensor at regular intervals. The total pressure can then be corrected for water density and atmospheric pressure to determine the water level.

The tide gauge was not deployed in the March 1974 and February 1976 calibration events. For the June 2005 event, the recorded tide levels are shown in Figure A-5.

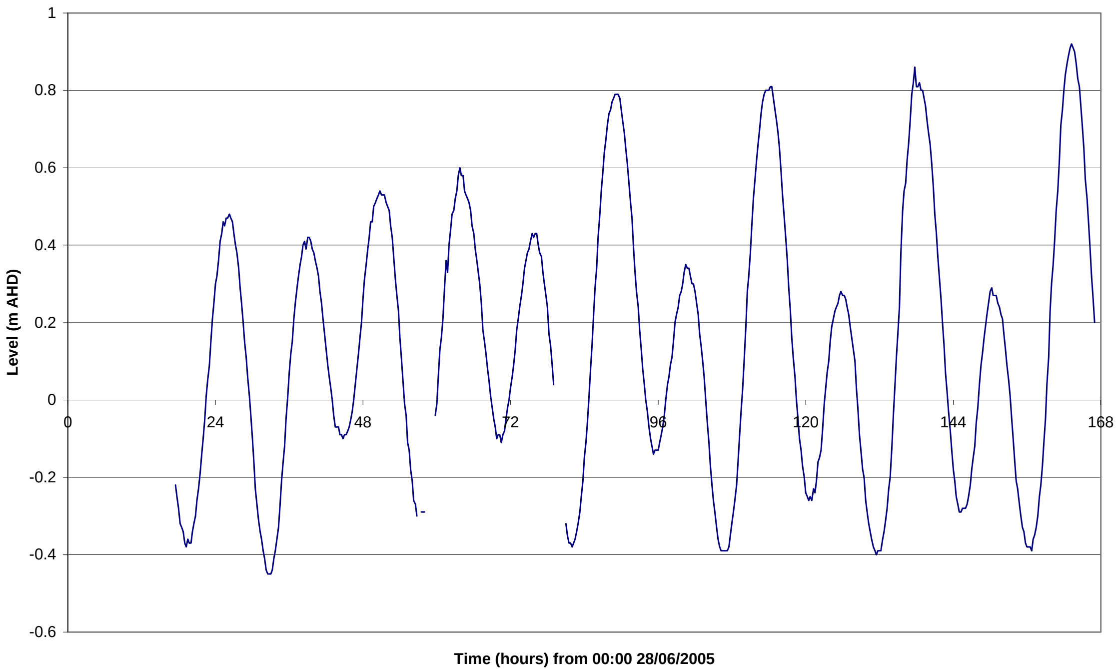


Figure A-5 Recorded Tide at Ballina Tide Gauge—June 2005

A.8 Continuous Stage Recorders - Rivers

Manly Hydraulic Laboratory maintain a network of automatic water level recording stations installed in various coastal river and creeks.

The logging systems consist of the MHL solid state floatwell and pressure recording systems, the Hydromace TRS and 2000 and the Datataker 50 data logger. For the solid state floatwell system, the water level is sensed by a float connected to an optical shaft encoder which is read every 10 seconds for 160 seconds, averaged then stored on the quarter hour Eastern Standard Time. This data is then stored by a solid state recorder which can retain up to a maximum of six months of data. The data is either returned to the Laboratory at the end of this period or downloaded in the field by a portable computer.

Once data has been transferred onto the MHL Alpha Server 1200 computer, a suite of programs runs routines to ensure the data is acceptable for inclusion in the database. At this stage water level data is available for external users. Only hourly water level data is available on-line. The raw data files, which are copied and stored on magnetic tape and optical disk, consist of either the one or fifteen minute files. This data can be loaded onto the computer on request.

A.8.1 Richmond River

None of the automatic water level recorders on the Richmond River were deployed in the March 1974 and February 1976 calibration events.

Missingham Bridge (Ballina BKUP): The sensing device is a Vega 72-1 ultrasonic transducer mounted on the upstream bridge railing. MHL publish this data to RRV Datum/LWOST (which is elsewhere published as –0.861 m conversion to AHD). However, four individual surveys of low water in February 2006 by Ballina Shire Council gave a -1.02 m conversion to AHD. This later datum conversion for this gauge has been adopted in this report. Recorded levels at this gauge in the June 2005 event, as provided by MHL are shown in Figure A-6.

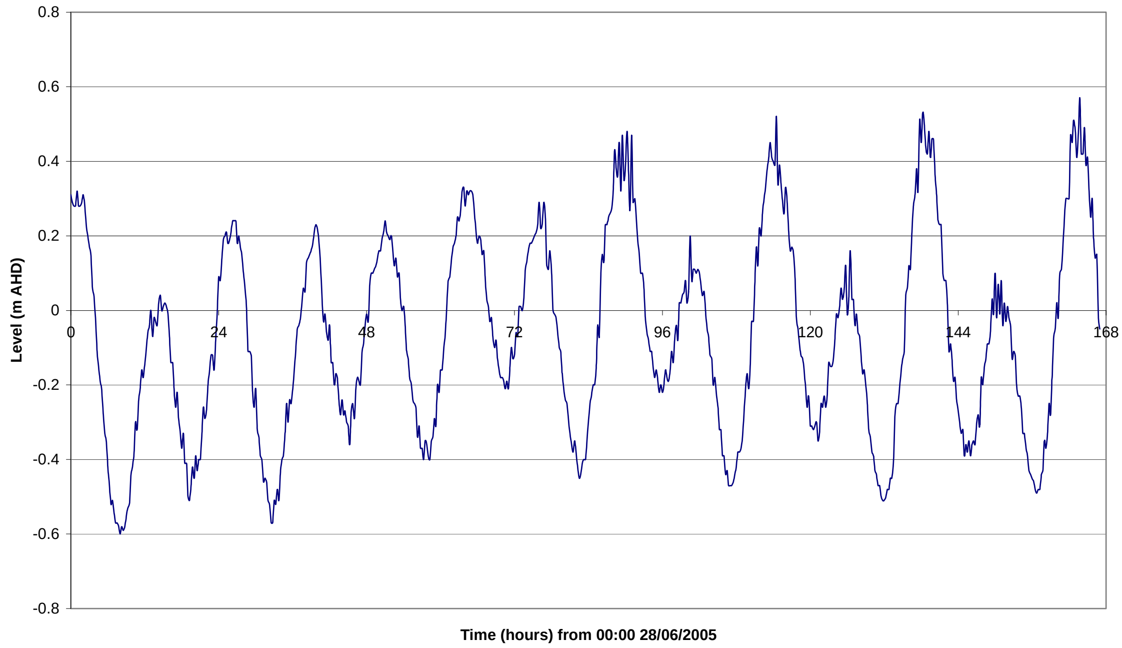


Figure A-6 Recorded Flood Level Hydrograph at Missingham Bridge (Ballina BKUP)—June 2005

Burns Point (A.W.R.C. No. 203461):

The sensing device is a floatwell system with a Hydromace 2000 pressure recorder between the ramps on the town side of Richmond River at the Burns Point Ferry, recording since April 1990. The water level is sensed by a float connected to an optical shaft encoder which is read every 10 seconds for 160 seconds, averaged then stored on the quarter hour Eastern Standard Time. Again, MHL publish this data to RRV Datum/LWOST. However, five individual surveys of low water in February 2006 by Ballina Shire Council gave a –0.78 m conversion to AHD. This later datum conversion for this gauge has been adopted in this report.

Recorded levels at this gauge in the June 2005 event, as provided by MHL are shown in Figure A-7.

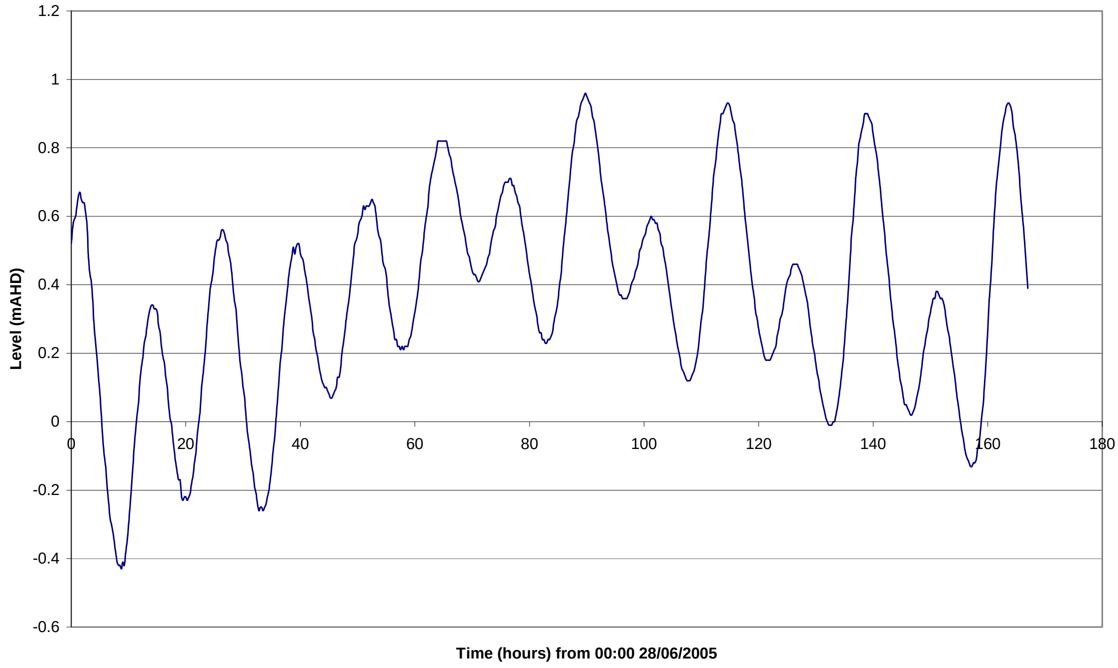


Figure A-7 Recorded Flood Level Hydrograph at Burns Point—June 2005

Wardell:

The recorded flood level at Wardell is shown in Figure A-8. The peak flood level at Wardell was 1.129m AHD which was recorded between 18:30 and 19:30 on 1st July 2005.

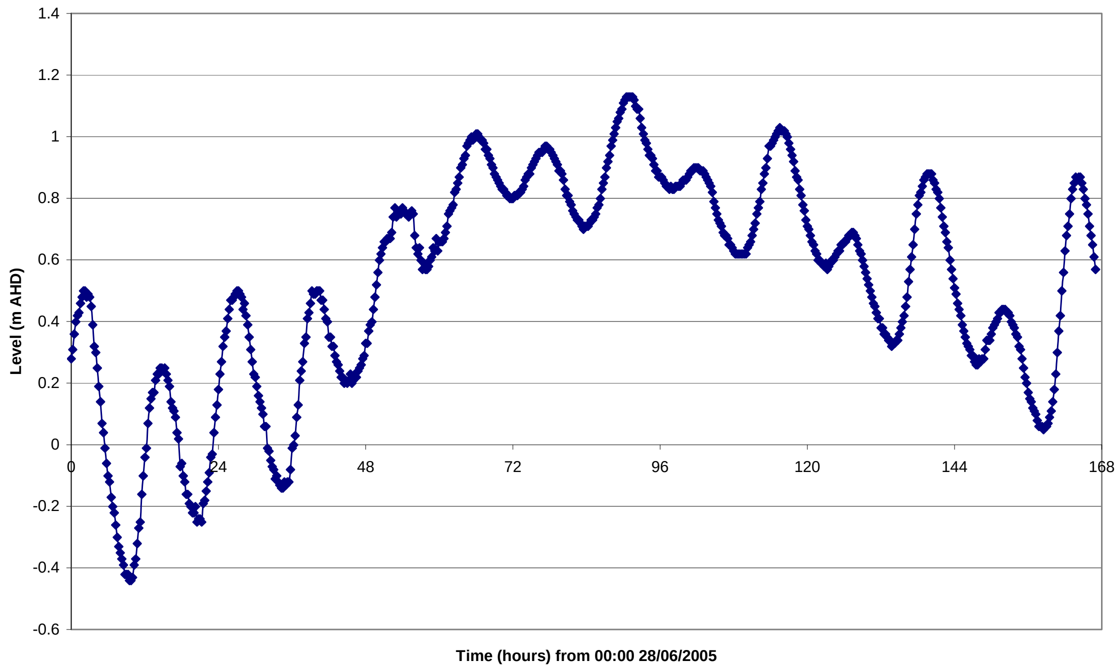


Figure A-8 Recorded Flood Level Hydrograph at Wardell Gauge—June 2005

Woodburn (No. 203412):

The station has been operating since 1985. The recorder type is Hydromace 2000. As this is upstream of the model extent, data here has not been utilised in this study.

A.8.2 Maguires Creek and Emigrant Creek

As there are no operating stream flow stations on either of these creeks except in the headwaters of Emigrant Creek at Knockrow, there is no additional data for this study.

A.9 Aerial Photography

Qualitative analysis of floodplain roughness and land use was undertaken using historical aerial photography and any other available information to attempt to detect any changes that may affect flooding processes.

APPENDIX B: COMMUNITY QUESTIONNAIRE

Ballina Flood Study Update
Can You Help?

Ballina Shire Council is currently updating its 1997 flood study of the lower Richmond River. Council is requesting assistance from the community to provide any historical flood information.

The updated flood study involves new modelling which will be used to estimate flood events and flood risks. The updated flood study will lead to a floodplain management plan which will deal with development on the floodplain and provide advice on flooding and flood emergencies.

Council has engaged WBM Oceanics Australia to assist in the preparation of the updated flood study. WBM Oceanics Australia is a Brisbane based firm of specialist engineers who are experts in undertaking these kinds of studies.

Your recollections of historical floods will provide important information to assist in the investigations. Your help in answering the questions below is appreciated.

Name ……………………………………………………. Date ………………………………………….

Address ………………………………………………….. Telephone Number …………………………..

How long have you lived at this address? ……………………………………………

How long have you lived in the area? ………………………………………………..

In the period of time you have lived in the area:

1. Have you experienced flooding either at your property or another? (If not the address above, please specify the address.)
   Yes No (If no go to Q11)
2. When did the flood occur? _________________
3. Did floodwaters enter any buildings on your property or another? Yes No
4. How deep was the flood water level at the flood peak and when was the flood peak? _____________
5. Are you able to show us how high the flood levels rose? Yes No
   (We may arrange to survey these levels)
6. Do you have any photos/videos of flooding which could be borrowed for copying? Yes No
7. Did any blockages appear to contribute to the flooding? Yes No
   (Please describe)____
8. What was the duration of flooding (state location on property and duration in hours/days)?
9. Do you have any rainfall records? ____
10. Have you experienced or do you know of other floods which have affected the property?
    Yes No

Year	Are you aware of any flood marks?	How high did the flood levels rise?
______________	___________________________	________________________________
______________	___________________________	________________________________

11. Are you aware of any other people who may have knowledge of flooding but no longer reside in the area? Yes No
    How can they be contacted?

Please add any further comments or sketches below.

Thank you for your cooperation.

You have got various options for reply:

1. Post
Ballina Flood Study Update
Ballina Shire Council
PO Box 450
Ballina 2478

2. Deliver
Ballina Shire Council
Cherry St
Ballina

3. Deliver
Ballina Library
River St
Ballina

4. Email
bfsu@ballina.nsw.gov.au

This survey form is also available for viewing on Council's Website: www.ballinacouncil.com.au

Or you may wish to phone if you have questions:
BMT WBM (Free Call) 1800 180 106

APPENDIX C: CLIMATE CHANGE - LITERATURE REVIEW

C.1 Summary

As part of the Ballina Flood Study Update brief, BMT WBM were required to undertake a literature review in order to:

1 determine an appropriate local value for predicted MSL due to climate change; and

2 determine if an increase in intensity and frequency of storm events due to climate change is warranted.

A summary of the review is included in this appendix. Summarising details were presented to Council's Civil Committee and the Community Reference Group on 31st October 2006. The adoption of a 0.2m rise in ocean level has subsequently been adopted for all design flood events. No increase in intensity or frequency of storms was considered necessary.

C.2 Introduction

Current concern with climate change arises from scientific research indicating that the balance of evidence suggests a discernible human influence on global climate. Global warming has the potential to change weather systems, rainfall patterns, wind velocities and, significantly, cause mean sea levels to rise. These factors all can have an impact on the environment within the coastal zone.

A diagram showing the mean sea level evident from 1910 to 2000 at Fort Denison, Sydney Harbour is shown in Figure C-1 below.

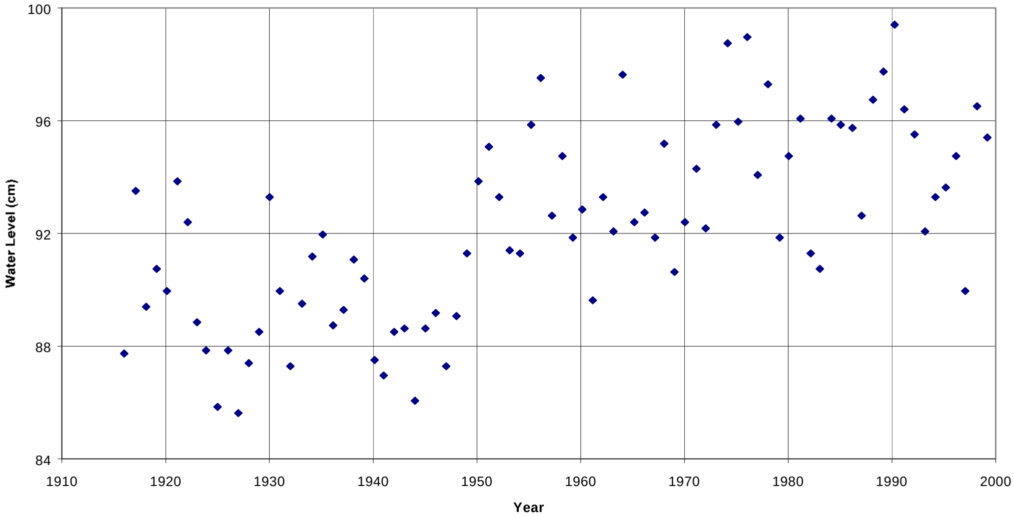


Figure C-1 Historical Annual Mean Sea Levels - Fort Denison

The New South Wales coastline is influenced by the sub-tropics in the north and the mid-latitudes in the south and is therefore affected by weather systems originating from both. During summer months tropical cyclones develop to the north and depressions develop into easterly troughs. Further south and especially in the colder months, low pressure systems such as cut-off lows and east coast lows are a major source of severe weather. These systems are all capable of generating storm surges and severe wave conditions along the coast. Less severe weather conditions can also impact on the wave climatology of the region. For example, sea breezes during the warmer months of the year and anticyclones can cause wind-generated waves from the northeast.

Under conditions of climate change, the atmospheric conditions which drive ocean waves and storm surges may change in frequency and intensity and thereby impact the coastal boundary. In addition to this, rising sea levels will further increase the capacity for waves and storm surges to impact on the coastal zone.

Average sea-level rise due to climate change is a serious threat to coastal regions. Although the magnitudes of future sea-level rise may be relatively small, in combination with a severe storm, it may be enough to expose more vulnerable regions of the coastline to storm surge and waves. Sea-level rise is caused by a number of processes that operate on different spatial scales. On the global scale, contributions to sea-level are expected due to the thermal expansion of oceans, melting of glaciers and ice sheets and changes in the accumulation rates of snow and ice. Regionally, sea levels may be further affected by changes in ocean currents and atmospheric wind regimes, although for the northern NSW coast, regional contributions are expected to be negligible. It is also worth noting that sea-level variations can also occur due to other factors such as geological movements and local effects such as sediment compaction and groundwater removal.

C.3 Literature Review

The following is a summary of a literature review of predicted sea level rises and storm frequency and intensity as they relate to the northern New South Wales coastline, Australia generally and globally. The most authoritative, hence, adopted reference is presented first. Australian references are further divided in to policy documents and local assessment sections.

C.4 Adopted Reference

Intergovernmental Panel on Climate Change (IPCC)[1] *Third Assessment Report (TAR)*, 2001

Summary of relevant issues:

TAR projections of global average sea level rise are given in the following table.

Table C-1 Anticipated Future Sea Level Rise, relative to 1990—TAR 2001

Planning Period (y)	Low (m)	Best Estimate (m)	High (m)
2040	0.03	0.12	0.30
2100	0.09	0.48	0.88

The rise is made up about half by thermal expansion of sea water, about one quarter from melting of glaciers, and a small positive contribution from Greenland ice melt and possibly a negative contribution from snow accumulation over Antarctica. The range is based on General Circulation Modelling (GCM) of 40 possible alternative futures (under families of more Economic, Environmental, Regional or Global) by the Special Report on Emissions Scenarios (SRES), all considered equally sound.

[1] IPCC is considered to be the most authoritative source of scientific judgement

Importantly, this is a downward revision of previous assessments made during a variety of studies.

They also found that global-average sea level rise for the entire 20th century was between 0.1m and 0.2m.

There is no evidence that the nature of El Niño and Southern Oscillation events or the frequency, distribution and intensity of tropical cyclones will change with increasing greenhouse gas concentrations. However, it is likely that any changes in tropical cyclone frequency that do occur due to climate change will be small in comparison to their observed natural variability, which is considerable.

The Report also draws attention to many gaps in information and many uncertainties remaining in the underlying science, highlighting nine broad areas where scientists should direct their attention most urgently:

- Arrest the decline of observational networks in many parts of the world.
- Expand the available observational data to provide long-term records with increased temporal and spatial coverage.
- Better estimate future emissions and concentrations of greenhouse gases and aerosols.
- Understand more completely the dominant processes and feedbacks of the climate system.
- Address more completely the patterns of long-term climate variability.
- Explore more fully the probabilistic character of future climate states by developing multiple ensembles of model calculations.
- Improve the integrated hierarchy of global and regional climate models with emphasis on improving the simulation of regional impacts and extreme weather events.
- Link physical climate-biogeochemical models with models of the human system.
- Accelerate progress in understanding climate change by strengthening the international framework needed to coordinate national and institutional efforts.

C.5 Ballina

WBM Oceanics Australia, Ballina Floodplain Management Study, Report prepared for Ballina Shire Council, Revision 3, December 1997.

Summary of relevant issues:

This report noted predictions for sea level rise associated with thermal expansion of the oceans and some ice melt are between 3 to 10 mm per year. It noted some uncertainty as to the actual magnitude and rate of rise of sea level, which has led to various scenarios being adopted. They are based on the range of model results available. Tabulated sea level rise values for 50 and 100 year planning periods are presented in Table C-2.

Table C-2 Anticipated Future Sea Level Rise, relative to 1997—Ballina Floodplain Management Study[2]

Planning Period (y)	Low (m)	Best Estimate (m)	High (m)
50	0.13	0.26	0.49
100	0.29	0.61	1.00

For sensitivity testing, a 50 year planning interval and a best estimate rise in ocean level of 0.26 m was applied, giving a peak 100 year storm tide level in the ocean of 2.26 mAHD.

No account was taken of any potential changes to storm frequency and intensity.

This report concluded that it is probably impractical to impose additional margins on design fill levels and freeboard allowances whilst there is still significant uncertainty in predicted climate changes and likely sea level rises.

***Richmond River Estuary Processes Study*, Final Report, Jan 2006, For Richmond River County Council**

Summary of relevant issues:

The rise in mean water level will mean that the there will generally be a slightly greater depth of water in the estuary and the tide would be expected to propagate further up the estuary perhaps changing salinity gradings.

WBM Oceanics Australia (Oct 2003). *Ballina Shire Coastline Hazard Definition Study*. Final report prepared for Ballina Shire Council.

Summary of relevant issues:

This study assessed the peak storm tide levels and wave set-up components for the open coast areas for various planning periods and probabilities of occurrence, based on the available wave data and storm tide statistics derived for the Gold Coast region (James Cook University, 1977). For this purpose, peak wave setup is taken as 15% of the significant wave height for the recurrence interval considered. Wave runup is only considered on the open coast. The results are outlined in Table C-3.

[2] No reference source for these figures was provided in the BFMS, however they may have come from the Institution of Engineers, National Committee on Coastal and Ocean Engineering recommendations.

Table C-3 Storm Tide and Wave Setup Levels for Ballina Coast Region

Planning Period	Storm Tide and Wave Setup Levels for Recurrence Intervals Shown					
	1 in 20 years		1 in 50 years		1 in 100 years	
Total water level	Storm Tide Level (mAHD)	Wave Setup Level (mAHD)	Storm Tide Level (mAHD)	Wave Setup Level (mAHD)	Storm Tide Level (mAHD)	Wave Setup Level (mAHD)
Immediate	1.24	2.24	1.30	2.39	1.35	2.51
50 Years	1.44	2.44	1.50	2.59	1.55	2.71
100 Years	1.74	2.74	1.80	2.89	1.85	3.01

The increase in level for the different planning periods is related to predicted increases in mean sea level associated with the enhanced Greenhouse Effect.

WBM, 2005, *Ballina Coastline Interim Measures and Action Plan*, prepared for Ballina Shire Council, Feb 2005

Summary of relevant issues:

Current projections estimate a maximum rise in sea level of 0.9m by the year 2100 (compared to 1990 levels). Table C-4 presents the latest low, mid (best), and high estimates of global mean sea level rise from IPCC (1996) for the years 2020, 2050 and 2100, relative to 1990.

Table C-4 Anticipated Future Sea Level Rise (metres), relative to 1990—IPCC 1996

Year	Low	Best Estimate	High
2020	0.05	0.10	0.20
2050	0.10	0.20	0.40
2100	0.15	0.50	0.95

The likely impact of these predicted sea level rises would be a general rise in the mean water level in the ocean and the estuary and shoreline recession on the coast.

Higher sea levels will translate to higher typical water levels within the Richmond River estuary. Low lying lands (including assets such as roads, parks, buildings etc) may become inundated by tides, while flood levels in the lower estuary will increase. Impacts on estuarine ecology could include either the landward migration of mangroves and salt marshes, unless inhibited by existing development, in which case, these habitats would be lost.

The rise in mean water level will mean that the there will generally be a greater depth of water in the estuary and the tide would be expected to propagate further up the estuary changing salinity gradings. This elevated water level and increased salinity in upper reaches will impact on the ecology of these areas.

The shoreline recession would be most evident on the coastline where wave action involves sediment movement to a depth of about 15m and current estimates of shoreline recession due to sea level rise are in the order of 10-25m. The impact will be less in the lower estuary where wave action is minor and is expected to be in the order of 1-5m.

C.6 Northern NSW – Policy Documents

Australian Government, Department of the Environment and Heritage *NSW Coastline Management Manual,* Appendix B12 Climate Change, Sept 1990

Summary of relevant issues:

Sea level rise of between 0.5 and 1.5m by the year 2100 has been adopted by one technical committee (NAS, 1987). Sea level rise to the year 2050 of between 7 and 67cm (best estimate range 24 to 38cm) has been projected by others using box diffusion models of ocean warming which was undertaken at the University of East Anglia (Commonwealth Group of Experts, 1989).

In coastal areas, the most discussed potential hazard of the postulated warming known as the Greenhouse Effect, is the scenario of rising in sea level. However, climate change may alter wind and wave climates, both of which may produce a realignment of the coast. The impact of any sea level rise would then be exacerbated by the accompanying foreshore erosion.

Table C-2 illustrates "Scenario A" of sea level scenarios developed by the United Nations Environmental Program, Intergovernmental Panel on Climate Change (UNEP-IPCC, 1990). "Scenario A" is based on no limitation of greenhouse gas production, which is considered the most realistic option to choose for planning purposes at this time.

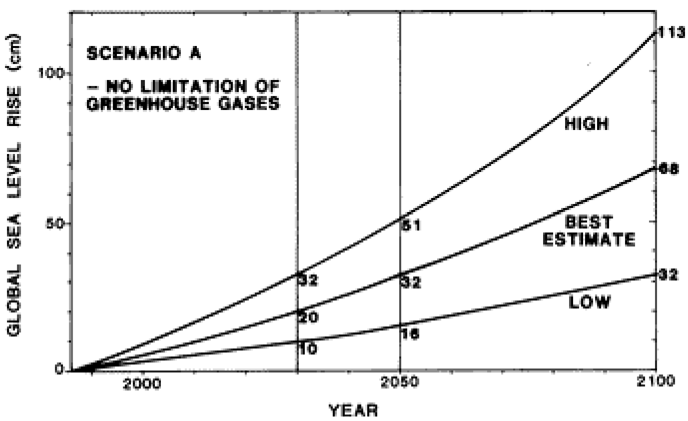


Figure C-2 Sea Level Scenario A (UNEP/IPCC, 1990)

As the IPCC Working Group report is the most recent and it accounts for the views of the international scientific community, it is considered that Figure C-2 illustrates the currently available "best estimate" of sea level scenarios.

It can be suggested that mean sea level off the New South Wales coast has been increasing at an average value of about 0.5mm per year over the last 100 years. Before a more definite conclusion can be drawn, the reason for the distinct change in sea level behaviour over the last two sub-periods would need to be determined.

Some scenarios suggest that the severity and frequency of storm events may increase. This would be caused by a southward movement of the cyclone belt, i.e. more of the NSW coast would become susceptible to cyclones, and by the increased storm activity associated with greater temperature gradients in the temperate zone.

Rainfall intensity may similarly increase in some areas, resulting in higher flood levels and increased scour at river, creek and lagoon entrances and at stormwater outlets.

In the light of the present uncertainty, an adaptive approach towards planning and design in the coastal zone is necessary. This approach should be sufficiently flexible or "robust" to be able to cater for a range of possible outcomes.

C.7 Northern NSW – Site Specific Assessments

McInnes, K. L., and Hubbert, G. D. (2001). The impact of eastern Australian cut-off lows on coastal sea level. *Meteorological Applications*, 8 (2): 229-244.

Summary of relevant issues:

A study into the weather conditions associated with sea-level anomalies along the NSW coast, has indicated that cut-off low events are a major influence. The sea-level anomalies were typically no greater than half a metre and, because of the relatively narrow continental shelf, were likely to consist of a storm surge and wave set-up component. Despite the low amplitudes of the anomalies, their typically long duration, combined with the fact that the accompanying weather system is often responsible for intense rainfall, suggests that the elevated sea levels and run-off could combine to exacerbate coastal flooding. Three events were chosen for more detailed investigation using an atmospheric model and a storm surge model. Storm surge simulations were found to underestimate the amplitude of the measured sea level increase by up to 50%, although wave set-up at the coast could easily account for the remainder of the anomaly. The timing of the modelled peak sea-level anomaly was found to be in relatively poor agreement with observations. Further investigation suggests that the timing errors were most likely related to differences between the modelled atmospheric conditions used to force the storm-surge model and observed atmospheric conditions.

Generally, it was found that the greatest precipitation occurred in the region of onshore winds to the south of the low, whereas the storm surge was found to coincide with the region of southerly or coast parallel winds in both the model and the observations. The impact of elevated sea-surface temperatures (SST's) on the intensity of the atmospheric storm and the associated coastal impacts due to rainfall and storm surge intensity changes were investigated. An increase in storm surge from zero to almost 50% was found depending on case and coastal location. The greatest wind speed and hence storm surge increases were found to occur to the north of about 33°S whereas the greatest rainfall increases due to the warmer SST's were found to occur south of about 31°S. This result suggests that there may be an increased likelihood of overlap between storm surge and extreme rainfall run-off in central NSW coastal regions as a result of Greenhouse warming, with an associated increased threat of coastal flooding events.

The estimation of climatic change effects is made using numerical simulation of the earth's climate system. Such models are extremely complex and extensive and, while there has been considerable improvement over the past decade, the results of such simulations still only provide indicative scenarios rather than definitive predictions. Despite the uncertainty, there is a strong indication that climate change is likely to cause significant change in sea level. Increased sea level can result in inundation, shoreline recession, and changes to the coastal environment.

Nova: Science in the news, *Getting into hot water – global warming and rising sea levels*, Published by the Australian Academy of Science

Summary of relevant issues:

CSIRO researchers believe that damage costs associated with coastal flooding would more than double in southern Queensland and northern New South Wales if sea levels were to rise by 40 centimetres.

WBM (Sept 2001) *Tugun Bypass Environmental Impact Statement: Technical Paper No. 7 Flooding & Hydrological Assessment* prepared for PPK Environment and Infrastructure

Summary of relevant issues:

Gold Coast City Council has adopted an allowance of 0.3m for future sea level rise (Betts, 1999). This is based on the 'best estimate' for 2070 of IPCC (1996). Based on this estimate, an allowance of 0.3m should be made for future sea level rise. There was no allowance for future sea level rise in the derivation of the ocean levels for the Tweed River flood assessments as it was derived prior to an understanding of the issue.

However, the peak ocean level used in the simulation of the 100 year ARI Tweed River flood is 2.6 mAHD. This level is based on the occurrence of a 100 year ARI storm surge (ie. wind setup and barometric setup) with wave setup occurring at the peak of a mean spring tide. The peak ocean level was part of coastal assessments carried out in the 1980's. It is apparent from more recent storm surge estimations in the region that these earlier assessments were somewhat conservative. By way of comparison, the 100 year ARI ocean level used for the flood assessments of the Richmond River (some 60km to the south of the Tweed River) was 2.0 mAHD (Lawson and Treloar, 1994).

Hence, the peak ocean level used in the simulation of the 100 year ARI Tweed River flood:

- is probably over estimated by up to 0.6m (based on other areas);
- should include an allowance of at least 0.3m for future sea level rise.

On this basis, it is concluded that the ocean levels used in the simulation of Tweed River floods may result in an over-estimate of flood levels by approximately 0.3m.

In order to define peak flood levels for rare flood events (ie. those greater than 100 years ARI), it was recognised that the peak levels resulting from Tweed River flooding of the study area are dictated by the peak ocean level. Hence, an assessment of the peak ocean levels derived for the Gold Coast area by the Queensland Beach Protection Authority was used. Based on these studies (Blain, Bremner and Williams, 1985), the peak ocean levels were derived assuming:

- ➢ a storm surge resulting from a tropical cyclone (1.4 mAHD for 500y ARI and 1.5 mAHD for 2000 y ARI)
- ➢ wave set-up of 0.7m (refer Fig 6.1 of Blain, Bremner and Williams, 1985)

- greenhouse sea-level rise of 0.3m.

CSIRO Divisions of Atmospheric Research and Marine Research (Walsh, KJE, Jackett, DR, McDougall, TJ, and Pittock, AB), *Global Warming and Sea Level Rise on the Gold Coast*, Report prepared for the Gold Coast City Council, April 1998

Summary of relevant issues:

There are significant uncertainties regarding predictions of sea level relating dually to the future amount of greenhouse gases in the atmosphere and the ability of models to predict their impacts.

Global sea level rise in the next few decades is expected to come from several main components:

1. thermal expansion of the oceans due to warming, accounting for approximately 60%;
2. melting of glaciers and small ice sheets, about 30%; and
3. changes in the total amounts of snow and ice in larger masses (ie Antartica), the balance 10%.

Global mean sea level is expected to rise by 5-25 cm by the year 2030, and 10-40 cm by 2050 with mid-range estimates of 12 cm and 20 cm respectively.

Possible large local effects caused by land subsidence and groundwater extraction were not considered in this study. Other local effects such as seasonal variations caused by El Nino can be discounted for southern Queensland. Geological rebound from the last Ice Age ice is included but is small. An uncertainty factor is added to account for possible geographic variations in rise caused by winds and ocean current changes, the science of which remains in a preliminary state.

Gold Coast region sea level rise estimates are, relative to sea level at 1990:

1. Between 2 and 34cm with a central estimate of 11cm by 2030
2. Between 3 and 58cm with a central estimate of 18cm by 2050

Ipswich City Council in conjunction with Sinclair Knight Merz. (2000) *Brisbane - Bremer River System Flood Study*, Ipswich Rivers Improvement Trust

Summary of relevant issues:

This was a comprehensive flood study covering the urbanised areas of Ipswich City. The Brisbane River is tidally affected as far as the Bremer River with a range of 2.8 m at Ipswich. The model studies also considered the influence of tide and storm surge levels on predicted flood levels. Combining the 100 year ARI flood and 100 year storm surge tailwater condition with an enhanced greenhouse allowance of 300 mm for sea level rise produced a maximum increase of 80 mm in flood heights near Ipswich.

***Coastal Wetland Habitat Dynamics in Selected New South Wales Estuaries*, K.M. Wilton**

Summary of relevant issues:

Due to their sensitivity to a local tidal regime, it has been suggested that inter-tidal saline coastal wetlands are a physiographic, or ecological, indicator of changes in mean sea level. This study was aimed at proving or disproving this suggestion along the New South Wales coast for the last 60 or 70 years. It concluded no correlation between contemporary mean-sea level rise and mangrove incursion of the salt marsh habitat at the study sites, or with rainfall patterns at a decadal scale.

It was impossible to collect mean-sea level data for each of the individual estuaries assessed in this study since for most of them only tidal plane analyses were available for the last 10 to 15 years (from 1998). Hence, National rates were used as shown in the following table.

Table C-5 Reported Sea Level Rises in Australia

Location	Rate of Sea Level Rise (mm/yr)	Years
Newcastle	2.0	1926 – 1982
Sydney (Fort Denison)	0.7	1897 – 1983
Sydney (Fort Denison)	0.54	1886 – 1988
Sydney (Fort Denison)[3]	0.86	1915 – 1998
Port Adelaide	2.5	1882 – 1976
Adelaide (Outer Harbour)	2.9	50 years prior to 1989

Mean sea level may be super-elevated when various factors combine, such as the combination of spring high-water tide with a storm off the coast during the stages of the El Nino Southern Oscillation and the Pacific Decadal Oscillation.

C.8 Other Australian - Policy Documents

Australian Greenhouse Office, Department of the Environment and Heritage *Climate Change Impacts and Risk Management: A Guide for Business and Government*, Prepared by Broadleaf Capital International Marsden Jacob Associates, 2006

Summary of relevant issues:

Shows how the Australian and New Zealand Risk Management Standard, AS/NZS 4360:2004 can be extended to include climate change.

The planning horizon suggested for this Guide is, in the first instance, a period of approximately 25 years hence. This coincides with the strategic planning horizon of many organisations and also with the investment period for many long-lived assets. Users of the Guide may however, choose to adopt an even longer-term focus - for example, climate scenarios can be constructed for 50 and even 100 years into the future using information that is easy to access.

Australian Greenhouse Office, Department of the Environment and Heritage *Climate change scenarios for initial assessment of risk in accordance with risk management guidance*, Prepared by CSIRO, May 2006

Summary of relevant issues:

[3] By National Tidal Facility , saying records prior to 1915 are unreliable.

This publication presents climate change scenarios for risk assessment to accompany the above *Climate Change Impacts and Risk Management: A Guide for Business and Government*. These scenarios have been developed by CSIRO for the Australian region using current best understanding of climate change and are designed specifically for use in the process of the initial strategic assessment of risks arising from climate change.

Scenarios for 2030 in each of ten regions are presented as changes relative to 1990, since 1990 is the reference year used by the IPCC. The scenarios represent changes in average climatic conditions. The conditions of any individual year will continue to be strongly affected by natural climatic variability and cannot be predicted. For each region, two scenarios are presented for each climate variable: (i) a low global warming scenario (0.54˚C by 2030) which assumes the lowest SRES emission scenario and lowest climate sensitivity and (ii) a high global warming scenario (1.24˚C by 2030) which assumes the highest SRES emission scenario and highest climate sensitivity.

Scenarios for two regions are reproduced here as the location of Ballina, whilst in the larger NSW is close to the smaller South East Queensland region.

Change in climate for New South Wales by 2030, relative to 1990[a]

NSW is likely to become **warmer**, with more **hot days** and fewer cold nights. For example, the number of days above 35°C could average 4-7 in Sydney (now 3), 6-14 in Canberra (now 5) and 47-66 in Cobar (now 41), while the number of days below 0°C could average 35-57 in Canberra (now 62)[1]. **Increased peak summer energy demand** for cooling is likely, with reduced energy demand in winter for heating[2].

Warming and population growth may increase annual heat-related deaths in those aged over 65, e.g. from 14 deaths at present in Canberra to 37-41 by 2020 and 62-92 by 2050, and from 176 deaths at present in Sydney to 364-417 by 2020 and 717-1312 by 2050[3]. Higher temperatures may also contribute to the spread of vector-borne, water-borne and food-borne diseases.

Water resources are likely to be **further stressed** due to projected growth in demand and climate-driven changes in supply for irrigation, cities, industry and environmental flows. Little change in annual rainfall with higher evaporative demand would lead to a tendency for **less run-off** into rivers, e.g. 0% to -15% in the Macquarie Basin[4], -21% to +5% in the Namoi-Peel catchment[5], ±15% in Allyn River at Halton and -25% to +15% in Belar Creek at Warkton[6], -8% in Wollomombi River at Coninside, -15% in Wallumburrawang Creek at Bearbug, and -7% in Little River at Obley[7], and decreases of up to 20% in the ACT's Cotter and Queanbeyan catchments[8]. Run-off may decrease 10 to 25% by 2050 across the Murray-Darling Basin[9].

Droughts are likely to become **more frequent and more severe**, with **greater fire risk**, e.g. by 2020, the number of days with very high or extreme fire danger could average 13-14 in Richmond (now 11.5), 26-29 in Canberra (now 23), and 53-57 in Wagga (now 50)[10].

A **10-40% reduction in snow cover** is likely by 2020[11], with impacts on ski resorts and alpine ecosystems.

Controlled experiments have shown grain yield increases under elevated atmospheric carbon dioxide concentrations. However, it is not known whether this will translate to field conditions in Australia due to water and nutrient limitations and elevated temperatures.

Low to moderate warming may also **help plant growth** especially **frost sensitive crops** such as wheat, but more hot days and a decline in rainfall or irrigation could reduce yields. Warmer winters can **reduce the yield of stone fruits** that require winter chilling and livestock would be adversely affected by greater heat stress[12].

In forestry, the CO_2 benefits may be offset by decreased rainfall, increased bushfires and changes in pests[13].

In cities, changes in average climate and sea-level will affect building design, standards and performance, energy and water demand, and coastal planning[14]. Increases in extreme weather events are likely to lead to **increased flash flooding**, strains on sewerage and drainage systems, greater insurance losses, possible black-outs, and **challenges for emergency services**.

1. Suppiah *et al.* 2006;
2. Howden and Crimp 2001;
3. McMichael *et al.* 2003;
4. Jones and Page 2001;
5. O'Neil *et al.* 2003; Howe *et al.* 2005;
6. Chiew and McMahon 2002;.
7. Chiew *et al.* 2003;
8. Bates *et al.* 2003;
9. Beare and Heaney 2002;
10. Hennessy *et al.* 2006;
11. Hennessy *et al.* 2003;.
12. Howden *et al.* 2003;.
13. Howden *et al.* 1999;
14. PIA 2004.

a. These scenarios should not be used in detailed impact assessments (consult CSIRO for model specific scenarios);

Feature		Low Global Warming Scenario		High Global Warming Scenario	
		Estimate of Change	Uncertainty	Estimate of Change	Uncertainty
Annual average temperature		+0.6°C	±0.2°C	+1.3°C	±0.6°C
Average sea level		+3cm		+17cm	
Annual average rainfall		0%	±6.5%	0%	±15%
Seasonal average rainfall	Summer	+1.5%	±8%	+3.5%	±18.5%
	Autumn	+1.5%	±8%	+3.5%	±18.5%
	Winter	-3%	±6.5%	-7.5%	±15%
	Spring	-3%	±6.5%	-7.5%	±15%
Annual average potential evaporation		+2.4%	±1.9%	+5.6%	±4.4%
Annual average number of hot days (>35°C)		+1 day		+25 days	
Annual average number of cold nights (<0°C)		-5 day		-30 days	
Annual average number of very high and extreme forest fire danger days[b]		+1 day		+10 days	
Extreme daily rainfall intensity (1 in 20 year event)[c]		0%		+6% (east) -5% (west)	
Carbon dioxide concentration		+73ppm		+102ppm	

b. % changes for forest fire danger are for 2020 (changes for 2030 are not available);
c. Results for 1 in 20 year event were unavailable.

Change in climate for South-eastern Queensland by 2030, relative to 1990[a]

South-east Queensland is likely to become **warmer**, with more **hot days** and fewer cold nights. For example, the number of days above 35°C could average 3-6 in Brisbane (now 3) and 76-106 in Charleville (now 65), while the number of days below 0°C in Charleville could average 2-9 in (now 13)[1]. **Increased peak summer energy demand** for cooling is likely, with reduced energy demand in winter for heating[2].

Warming and population growth may increase annual heat-related deaths in those aged over 65, e.g. from 134 deaths at present in Brisbane to 165-189 by 2020 and 776-1368 by 2050[3]. Higher temperatures may also contribute to the spread of vector-borne, water-borne and food-borne diseases.

Water resources are likely to be **further stressed** due to projected growth in demand and climate-driven changes in supply for irrigation, cities, industry and environmental flows. A **decline in annual rainfall** with higher evaporative demand would lead to a tendency for **less run-off** into rivers. **Droughts** are likely to become **more frequent and more severe**, with greater fire risk[4].

Controlled experiments have shown grain yield increases under elevated atmospheric carbon dioxide concentrations. However, it is not known whether this will translate to field conditions in Australia due to water and nutrient limitations and elevated temperatures.

Low to moderate warming may also **help plant growth** especially **frost sensitive crops** such as wheat, but more hot days and a decline in rainfall or irrigation could reduce yields. Warmer winters can **reduce the yield of stone fruits** that require winter chilling and livestock would be adversely affected by greater heat stress[5].

In forestry, the CO_2 benefits may be offset by decreased rainfall, increased bushfires and changes in pests[6].

In cities, changes in average climate and sea-level will affect building design, standards and performance, energy and water demand, and coastal planning[7]. Increases in extreme weather events are likely to lead to **increased flash flooding**, strains on sewerage and drainage systems, greater insurance losses, possible black-outs, and **challenges for emergency services**.

1. Suppiah *et al.* 2006;
2. Howden and Crimp 2001;
3. McMichael *et al.* 2003;
4. Hennessy *et al.* 2006;
5. Howden *et al.* 2003;.
6. Howden *et al.* 1999;
7. PIA 2004.

a. These scenarios should not be used in detailed impact assessments (consult CSIRO for model specific scenarios);

Feature	Low Global Warming Scenario		High Global Warming Scenario	
	Estimate of Change	Uncertainty	Estimate of Change	Uncertainty
Annual average temperature	+0.6°C	±0.2°C	+1.3°C	±0.6°C
Average sea level	+3cm		+17cm	
Annual average rainfall	-1.5%	±5%	-3.5%	±11%
Seasonal average rainfall Summer	0%	±6.5%	0%	±15%
Autumn	-3%	±6.5%	-7.5%	±15%
Winter	-3%	±6.5%	-7.5%	±15%
Spring	-3%	±6.5%	-7.5%	±15%
Annual average potential evaporation	+2.4%	±1.9%	+5.6%	±4.4%
Annual average number of hot days (>35°C)	0		+5 days (near coast) +50 days (inland)	
Annual average number of cold nights (<0°C)	0		-5 days	
Annual average number of very high and extreme forest fire danger days[b]	N/A		N/A	
Extreme daily rainfall intensity (1 in 20 year event)[c]	0%		30%	
Carbon dioxide concentration	+73ppm		+102ppm	

b. Results not available;
c. Results for 2040 (changes for 2030 not available).

Standards Australia, *Australian Standard: Guidelines for the design of maritime structures*, AS 4997—2005

Summary of relevant issues:

This standard adopts the following future sea level rise, based on the mid-scenario from IPCC (2001). Important to note is that the standard does not ask for the construction of the deck of the facility at a higher level but may include options to raise the heights of restraining piles on floating structures at a later time or installing substructure of adequate strength to permit future topping slabs on non-floating structures.

Table C-6 Allowance for Sea Level Rise, AS 4997—2005

Design Life	Sea Level Rise (m)
25 years	0.1
50 years	0.2
100 years	0.4

Australian Greenhouse Office, Edited by Barry Pittock, *Climate Change: An Australian Guide to the Science and Potential Impacts*, Commonwealth of Australia, 2003

Summary of relevant issues:

It is largely based on, and consistent with, the TAR published in 2001. However, this guide has been substantially updated with relevant summaries of the latest international and Australian observations, scientific developments, and studies regarding the impacts of, and adaptation to climate change in Australia.

Whilst this book is essentially The Australian and New Zealand chapter in the Working Group Volume II part of the TAR (IPCC, 2001), the book includes more substantial edited abstracts from numerous more recent Australian reports and papers.

The negative contribution from Antarctica to global sea-level rise predictions is especially uncertain, with recent events on the Antarctic Peninsula raising the possibility of an earlier positive contribution from the West Antarctic Ice Sheet (WAIS).

Based on the SRES scenarios used by the IPCC, and regional changes in climate simulated by nine climate models, projected changes in eastern Australia (excluding south-eastern) show either that there could be an increase or decrease in rainfall at a given locality. When rainfall changes are combined with increases in potential evaporation, a general decrease in available soil moisture is projected across Australia, with droughts likely to become more severe. Most regions would experience an increase in the intensity of heavy rain events.

Further research is necessary to reduce the uncertainties, better establish probabilities, and identify the most cost-effective adaptation and mitigation options and strategies, which in most cases need to be location- and sector-specific.

Models agree on the qualitative conclusion that the range of regional variation in sea level change is comparable to the global average sea level rise, although nearly all models project greater than average rise in the Arctic Ocean and less than average rise in the Southern Ocean.

Church *et al.* (2003) compares model projections with observations from tide gauge records and the TOPEX/POSEIDEN satellite altimeter. They conclude that the best estimate of mean sea level rise globally for the period 1950 to 2000 is about 1.8 to 1.9 ± 0.2 mm per year, and that sea level rise is greatest (about 3 mm per year) in the eastern equatorial Pacific and western equatorial Indian Ocean. Observed rates of rise are smallest (about 1 mm per year) in the western equatorial Pacific and eastern Indian Ocean, particularly the north-west coast of Australia. Regional variations in the rate of sea level rise are weaker for much of the rest of the global oceans. Further, land movements, both isostatic and tectonic, will continue through the 21st century at rates that are unaffected by climate change. It can be expected that by 2100 many regions currently experiencing relative sea level fall will instead have a rising relative sea level. Lastly, extreme high water levels will occur with increasing frequency as a result of mean sea level rise. Their frequency may be further increased if storms become more frequent or severe as a result of climate change.

Projections of local sea level rise and its impacts thus need to be quite location-specific.

Recent invasions of warm temperate rainforest species to higher elevations in northern New South Wales have also been documented (Read and Hill, 1985). At present it is unclear whether this migration is a response to recent warming or whether the vegetation is still responding to the major climate changes following the last glacial maximum.

If cyclones were to travel further polewards (Walsh and Katzfey, 2000), they would be more likely to impact on coastal regions in the south-west of western Australia, southern Queensland, and the northern New South Wales coastal region. The locations of tropical cyclone genesis in the region are correlated with ENSO (Evans and Allan, 1992; Basher and Zheng, 1995), so any change in the mean state of the tropical Pacific may affect the risk of tropical cyclone occurrence in particular locations.

Explosively developing cyclones, which include severe east coast lows off the New South Wales coast, have been found by Lim and Simmonds (2002) to have a statistically significant increasing trend in the period 1979–99. These lows cause high winds, storm surges and heavy rainfalls along the New South Wales coast.

The average rise in sea level in the Australia/New Zealand region over the past 50 years is about 20 mm per decade (Rintoul et al., 1996; Salinger et al., 1996), The State of the Environment Report (2001, p.25) estimates the rise around the Australian coast as 12 to 16 cm over the last 100 years.

The landward transgression of mangroves into saltmarsh environments in the estuaries of Queensland, New South Wales, Victoria and South Australia over the past five decades is a widespread trend, with saltmarsh losses ranging up to 80% (Saintilan and Williams, 1999). While direct human disturbance is undoubtedly a factor in these trends (e.g., revegetation of areas cleared for agriculture, increases in nutrient levels and sedimentation), increases in rainfall and altered tidal regimes have also been implicated (Saintilan and Williams, 1999).

Institution of Engineers, Australia (1991). *Guidelines for Responding to the Effects of Climatic Change in Coastal Engineering Design*. Prepared by the National Committee on Coastal and Ocean Engineering.

Summary of relevant issues:

The Institution of Engineers, Australia, National Committee on Coastal and Ocean Engineering recommends that the possible impact of climate change associated with the 'Greenhouse Effect' should be included in the design process. Further, a robust design philosophy should be adopted which examines the consequences of failure and if this is significant and/or the design life is long, this robustness ensures that the design can either cope with or be adapted to the climate change.

The Committee recommends that the IPCC values be used for planning and design.

***Impacts of Climate Change on Australia, Coastal communities and infrastructure, Chapter 4 Climate Impact and Responses* Australian Government, Bureau of Meteorology**

Summary of relevant issues:

Climate models suggest a future decrease in the number of storm centres over southern Australia but an increase in their intensity (CSIRO, 2002). By 2050, sea level may rise 0.1 to 0.4 metres and tropical cyclone intensity around Cairns in northern Queensland could increase by up to 20%.

The Queensland Government, the Bureau of Meteorology and other agencies are undertaking a major project to look at the threat from storm tide flooding resulting from tropical cyclones, to improve the capability for real-time forecasts of storm tide heights, wave climate and flooding. They recommend allowance should be made for the estimated rise in sea level due to the enhanced greenhouse effect and a 10- 20% increase in the maximum intensity of tropical cyclones.

Allen Consulting Group, *Climate Change, Risk and Vulnerability, Promoting an efficient adaptation response in Australia*, Final Report, March 2005, Report to the Australian Greenhouse Office, Department of the Environment and Heritage

Summary of relevant issues:

The report takes a risk management approach to identifying the sectors and regions that might have the highest priority for adaptation planning. It is important to consider how effectively key systems will respond to climate change in coming years, and the development of policies that align the direction and extent of adaptation actions with social objectives and values.

This report explores the risks to Australia from the impacts of climate change over the next 30 to 50 years. Within this, an analysis of comparative risks will be important for identifying priorities for adaptation action and planning.

Applying a range of GCMs to Australia for the range of global emissions scenarios generated by the Intergovernmental Panel on Climate Change (IPCC) for its Third Assessment Report, CSIRO has identified a number of possible outcomes:

- an increase in annual national average temperatures of between 0.4° and 2.0°C by 2030 and of between 1.0° and 6.0°C by 2070 — with significantly larger changes in some regions by each date;
- more heatwaves and fewer frosts;
- possibly more frequent El Nino Southern Oscillation (ENSO) events — resulting in a more pronounced cycle of prolonged drought and heavy rains;
- possible reductions in average rainfall and run–off in Southern and much of Eastern Australia with rainfall increases across much of the Tropical North — as much as a further 20 per cent reduction in rainfall in Southwest Australia, and up to a 20 per cent reduction in run–off in the Murray Darling Basin by 2030;
- more severe wind speeds in cyclones, associated with storm surges being progressively amplified by rising sea levels;
- an increase in severe weather events — including storms and high bushfire propensity days; and
- a change in ocean currents, possibly affecting our coastal waters, towards the end of this period.

Of these possible results, the most likely are for temperature change (including heatwaves and reductions in frosts), sea level rises and increases in cyclonic wind intensity.

"Coastal infrastructure is of particular concern. Higher sea-level and more frequent extreme storm events pose substantial risk to bridges, roads, ports and coastal industry. Rising insurance costs and issues of compensation and appropriate zoning will need to be factored into future coastal planning and management.

Design standards for infrastructure are generally based on historical climate patterns that are relevant to the geographical area in question. For example, commercial building standards in Australia include provisions for the building of structures such that they are protected from surface water from a 1 in 100 year storm — the frequency and severity of which is obviously based on past records."

"For those wishing to adopt a conservative approach to the current greenhouse science it would be prudent to at least reflect on the lower bounds of climate change forecasts as they relate to variables such as temperature, precipitation, sea level rises etc. This should increasingly be considered as 'common ground'.

Prudent strategic preparations for climate change should view these climate change 'minima' as a starting point — planning and action can be continually updated as knowledge improves and uncertainty diminishes."

C.9 Other Australian – Site Specific Assessments

McInnes, K. L., Walsh, K.J.E., Hubbert, G.D., Beer, T. (2003). I*mpact of Sea-Level Rise and Storm Surges on a Coastal Community*. In: *Natural Hazards*, 30: 187 - 207, 2003.

Summary of relevant issues:

A technique to evaluate the risk of storm tides (the combination of a storm surge and tide) under present and enhanced greenhouse conditions has been applied to Cairns on the north-eastern Australian coast. The technique combines a statistical model for cyclone occurrence with a state-of-the-art storm surge inundation model and involves the random generation of a large number of storm tide simulations. The set of simulations constitutes a synthetic record of extreme sea-level events that can be analysed to produce storm tide return periods. The use of a dynamic storm surge model with overland flooding capability means that the spatial extent of flooding is also implicitly modelled. The technique has the advantage that it can be readily be modified to include projected changes to cyclone behaviour due to the enhanced greenhouse effect. Sea-level heights in the current climate for return periods of 50, 100 , 500 and 1000 years have been determined to be 2.0m, 2.3m, 3.0m, and 3.4m respectively. In an enhanced greenhouse climate (around 2050), projected increases in cyclone intensity and mean sea-level see these heights increase to 2.4m, 2.8m, 3.8m, and 4.2m respectively. The average area inundated by events with a return period greater than a 100 years is found to more than double under enhanced greenhouse conditions.

For Cairns, McInnes et al found 10 to 40cm with 20cm mid-range for mean sea level rise but added a further amount for increased storm intensity.

South Australian Coast Protection Board, *No. 26 Coastline | Coastal Erosion, Flooding and Sea Level Rise Standards and Protection Policy*, January 1992, publication can be viewed at http://www.environment.sa.gov.au/coasts/pdfs/no26.pdf

Summary of relevant issues:

The Board recommended an allowance of 0.3m for sea level rise to the year 2050, which is consistent with internationally agreed projections of that time. Projections beyond 2050 are less certain. The best estimates available indicate a possible range of 0.35m to 1.10m by 2100, with a midrange figure of 0.65m.

The water level to be applied for building site and floor levels will usually need to include an allowance for wave effects as well as for storm tides and sea level rise. It may also need to take account of stormwater backed up by high tides, existing or proposed flood control measures.

Under the policy, development which could not reasonably be protected against sea level rise beyond 0.3m, needed to be on higher land or set far enough back from the coast to be safe for a 1 m rise by

2100. This 1.0rn includes a small margin for greater than expected increase and for weather changes that could result in more storm surge and higher tides.

The policy requires floor levels to be at least 0.25m above the design water level (taking into account the above factors). This is intended to provide a small margin of safety and to cover the range of error in the statistical calculation of the extreme tide. An additional allowance may be necessary if the margin of error in the extreme tide calculation exceeds 0.25m, or if wave effects are uncertain.

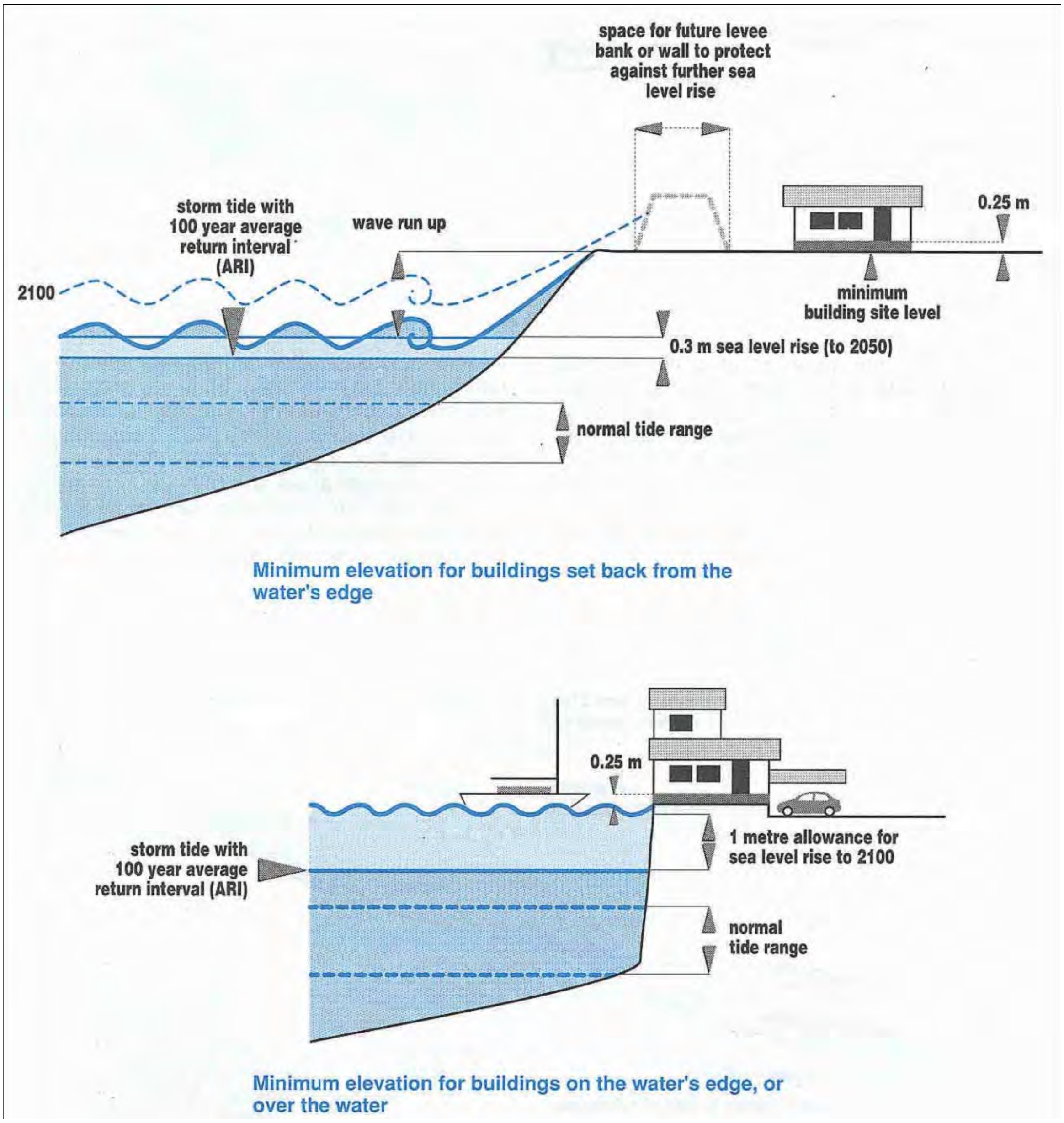


Figure C-3 Allowance for Sea Level Rise—South Australian Coast Protection Board

National Tidal Centre, Bureau of Meteorology, *The Australian Baseline Sea Level Monitoring Project Monthly Data Report, January 2006* prepared under the Australian Greenhouse Science Program for the Australian Greenhouse Office

Summary of relevant issues:

The mission of the project is to monitor changes in sea level around Australia. It involves the operation and maintenance of an array of high-resolution sea level gauges and associated meteorological instruments and management of a quality controlled national database of observations that is made available to the scientific and wider communities. The Baseline Array and a similar array in the South Pacific have been widely acknowledged in the global science community as two of the most accurate and reliable sources for information on sea level and climate change anywhere in the world.

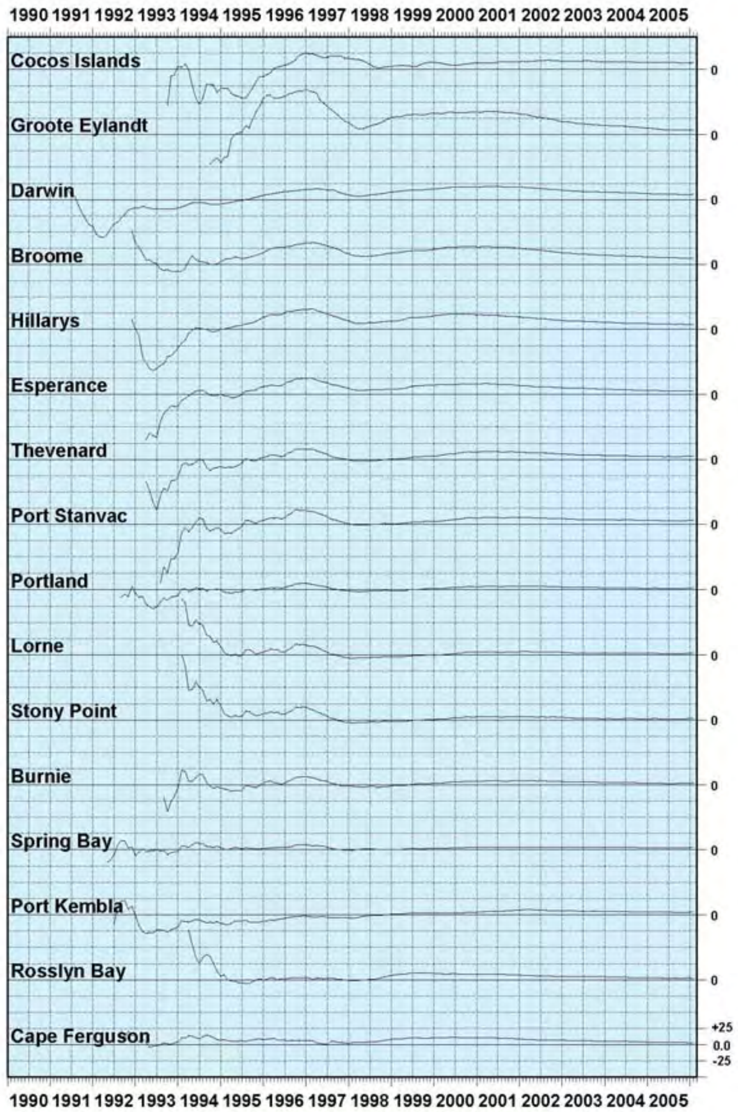


Figure C-4 Sea Level Trends through January 2006 (mm/year)—Australian Baseline Sea Level Monitoring Project

K.L. McInnes, R. Suppiah, P.H.Whetton, K.J.Hennessy and R.N. Jones (March 2003). *Climate change in South Australia, Report on Assessment of Climate Change, Impacts and Possible Adaptation Strategies Relevant to South Australia*, Undertaken for the South Australian Government by the Climate Impact Group, CSIRO Atmospheric Research.

Summary of relevant issues:

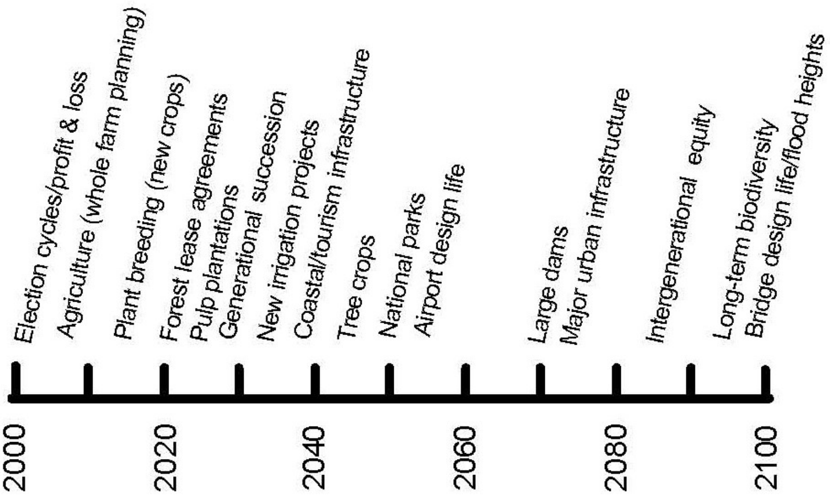


Figure C-5 Planning Horizons Relevant to Climate Risk Assessments

The Queensland State Coastal Management Plan

Summary of relevant issues:

This Plan includes some adaptation measures to deal with the impacts of climate change.

In many temperate urban and rural centres, any increase in severe weather events linked with climate change — bushfires, heavy and sustained rainfall, high winds and in particular cyclones, sustained heatwaves — could cause significant damage.

This is particularly so in inner areas of older cities that have progressively increased population density and hardened surfaces above stormwater infrastructure put in place fifty or more years ago. Demographic changes could exacerbate these effects as they impact both on the volunteer base for emergency services and increase the population at risk.

Adaptation options for urban systems and emergency services would include ensuring that the current study of emergency management priorities and responses being carried out at the Council of Australian Governments' (COAG's) direction, systematically includes the additional risks posed by climate change. Action in this area should build on existing programs and responsibilities. Deliberations under the Australian Government's Disaster Mitigation Australia Package should also be informed by climate change risks. Consideration of the greater risk of heat stress and the ageing of the population might be relevant to thinking on future emergency services needs. Local Government will have an important role to play in designing and delivering adaptation options for urban systems.

National Committee on Coastal and Ocean Engineering 2004, *Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering*, 2004 Update, Engineers Australia: Canberra, p 1.

Summary of relevant issues:

In a recent report on the effects of climate change on building design parameters, the National Committee on Coastal and Ocean Engineering (2004) notes: consideration of the possible impacts of climate change should be included in the design process.

Australian Green Office *Living With Climate Change - An overview of potential climate change impacts on Australia*, Commonwealth of Australia 2002

Summary of relevant issues:

Most models simulate an increase in both extreme hot temperatures and in the frequency of heavy rainfall events with climate change. At a seasonal scale, CSIRO has undertaken regional modelling for south-west New South Wales which suggests that the number of extremely dry springs more than doubles after 2020, as does the number of extremely wet summers.

Projections of future weather extremes with climate change are difficult since global and regional models do not well resolve such events. Nevertheless, there are some indications that climate change could influence the effects of the El Niño Southern Oscillation (ENSO) for Australia’s climate, and the intensity of extreme weather events such as tropical cyclones, drought, and severe storms in some regions. The climate models do not give a consistent indication of future changes in ENSO events. However it is likely that global warming will enhance the drying and drought conditions associated with warm phase (El Niño) events, and enhance intense rainfall and run-off associated with cool phase (La Niña) events.

CSIRO indicates that mid-latitude storms may increase in intensity, and their frequency and location may change as a result of changes in the westerlies and ENSO. Recent decades have seen a reduction in the numbers of mid-latitude storms to the south of Australia, but the intensity of these storms has on average increased. Climate models also indicate a future decrease in the number of storm centres over southern Australia but an increase in their intensity. These changes are likely to affect the coasts in the south-east of the continent that are vulnerable to shifts in wave direction and energy.

Storm systems such as tropical cyclones and mid-latitude storms and their associated cold fronts are the main cause of storm surges. Storm surges in tropical Australia can be several metres in height due to tropical cyclones and a shallow continental shelf. The height of the storm surge depends on the storm intensity, storm size, forward speed, timing relative to the tides, shape of the coast and slower variations such as those due to ENSO. An increased intensity of storm surges is likely with climate change.

Kevin Walsh, Kathleen McInnes and Deborah Abbs, *Sea level rise projections and planning in Australia* in **Coast to Coast 2002, Australia's National Coastal Conference (http://www.coastal.crc.org.au/coast2coast2002/proceedings/Theme3/Sea-level-rise-projections.pdf)**

Summary of relevant issues:

For local planning, ideally a risk assessment methodology may be employed to estimate the risk caused by sea level rise. In many locations, planning thresholds would also have to be considered in the light of possible changes in storm surge climatology due to changes in storm frequency and intensity.

While Table C-1 does represent the best scientific estimate of future sea level rise, these figures are not really adequate for planning purposes. Apart from the fact that there is a wide range of estimates, planners would like a particular value of sea level rise to be associated with a specific probability of occurrence. Some methods have been suggested to do this, based on risk assessment methodologies (e.g. Abbs et al. [2000]; Jones [2001]), but to our knowledge application of these techniques to specific planning in Australia has not yet occurred. It is important to note that the main cause of uncertainty prior to about 2050 is caused by our lack of complete understanding of the processes that cause sea level rise. Because of the thermal inertia of the oceans, there is little difference in the various sea level rise projections before about 2050, after which different rates of warming due to different projections of future greenhouse concentrations cause large differences in sea level rise.

At present, a number of fairly simple (although carefully considered) planning recommendations for sea level rise have been made in Australia. Usually these rely on IPCC projections of global average sea level rise, with an allowance for lateral beach erosion based on Bruun's [1962] rule.

C.10 Global

IPCC *Climate Change 2007: The Physical Science Basis, Summary for Policymakers, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, February 2007

Summary of relevant issues:

The Fourth Assessment Report is not due to be published until later in 2007. However, the above reference has already been published in preparation.

These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth Models of Intermediate Complexity, and a large number of Atmosphere-Ocean Global Circulation Models.

Table C-7 Projected globally averaged sea level rise at the end of the 21st century

Case	Sea Level Rise (m at 2090-2099 relative to 1980-1999)
	Model-based range excluding future rapid dynamical changes in ice flow
B1 scenario	0.18 – 0.38
A1T scenario	0.20 – 0.45
B2 scenario	0.20 – 0.43
A1B scenario	0.21 – 0.48
A2 scenario	0.23 – 0.51
A1FI scenario	0.26 – 0.59

For each scenario, the midpoint of the range in Table C-7 is within 10% of the TAR model average for 2090-2099. The ranges are narrower than in the TAR mainly because of improved information about some uncertainties in the projected contributions.

There is insufficient information in this summary document to give estimates for any future time other than 2090-2099. Table C-8 presents those results. Again, the estimate has reduced from the previous publication.

Table C-8 Anticipated Future Sea Level Rise, relative to 1980-1999—FAR 2007

Planning Period (y)	Low (m)	Best Estimate (m)	High (m)
2040	-	-	-
2090-2099	0.18	0.34	0.59

The full Working Group I report will be available online from May 2007.

<u>Scientific Committee on Problems of the Environment (SCOPE), a committee of the International Council of Scientific Unions (ICSU), 1986</u>

Summary of relevant issues:

This report concluded that if the observed rate of carbon dioxide increase continued, then toward the end of the 21st century a global average sea level rise in the range 20–165 cm could be expected.

<u>Bureau of Meteorology *The Greenhouse Effect and Climate Change*, Undated</u>

Summary of relevant issues:

"Based on analyses of tide-gauge records, global mean sea-level has risen by about 10 to 20 cm over the 20th century. However, in estimating the component of the rise that is attributable to the increased volume of seawater, a major source of uncertainty is the influence of vertical land movements which cannot be isolated in tide gauge measurements. Improved data filtering techniques and greater reliance on the longest-term tide gauge records have led to a high degree of confidence that the volume of seawater has been increasing and causing the sea level to rise within the indicated range. Satellite-based instruments now enable near-global sea-level change measurements, although many years of data will be required before reliable trends can be established. Most of the rise in sea level is related to the thermal expansion of the oceans in response to the rise in global temperature over the last 100 years and the retreat of glaciers."

Sydney (Australia) Morning Herald, *World's Achilles heels: Scientists Identify Potential Runaway Climate Feedbacks*, Oct. 26, 2004

Summary of relevant issues:

"The giant West Antarctic icesheet won't melt in the near future -– the ice is up to a kilometre thick -– but two years ago a vast chunk, the Larsen B iceshelf, broke off the eastern side of the Antarctic peninsula and fragmented into icebergs. In just 35 days, about 3250 square kilometres of ice were lost. The shelf is now roughly 40 per cent of the size at which it had previously stabilised. Some scientists predict that the rest of the sheet could feel the force of global warming quickly. Should the entire sheet melt, it is estimated the sea level around the world would rise by more than six metres."

C.11 Other References

Franks, S.W. and G. Kuczera, G., 2002: Flood frequency analysis: evidence and implications of secular climate variability, New South Wales. *Water Resources Research*, 38, art. no. 1062.

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APPENDIX D: FLOOD FREQUENCY ANALYSIS

D.1 Summary

In April 2005, the DECC requested that BMT WBM undertake a review of the consistency between the flood frequency analysis of the 1997 Ballina Floodplain Management Study, for the upstream boundary of Broadwater, and the rainfall – runoff analysis undertaken for the Mid-Richmond Flood Study.

The review was followed by a revision to the flood frequency analysis involving an amendment to the rating curve at Broadwater. The revised rating curve was based upon the more recent ALS data and additional data determined during consultation with NSW Sugar, MHL and the Broadwater SES. Sensitivity of downstream ocean levels on the rating curve was undertaken.

D.2 Introduction

The design peak water levels at Broadwater have been determined using a flood frequency analysis of recorded peak flood heights at Broadwater. This flood frequency analysis is a re-working of the analysis in the 1997 Ballina Floodplain Management Study. No further recorded data of peaks at Broadwater is available but more recent surveyed data of the channel and floodplain at Broadwater has necessitated the revision of the rating curve used to derive flows from the recorded flood peaks.

This Appendix provides a description of the analysis undertaken and the resulting peak flood levels derived at Broadwater.

D.3 Rating Curve

To convert historical flood levels to flows, a stage-discharge relationship (rating curve) is required. In the absence of a gauged rating curve at the gauge site, a model rating curve has been derived using the TUFLOW / ESTRY Ballina flood model. The model rating curve is required to represent current floodplain conditions.

A wide cross section has been used to represent the total conveyance of the Richmond River system at Broadwater; this includes the main river channel, overflow across the Bagotville Barrage and the floodplain. Airborne Laser Scanning (ALS) data, captured recently for the RTA's Pacific Highway Upgrade Woodburn to Ballina Project, was used for the floodplain section and the 2004 surveyed bathymetry, captured in September 2004 under DECC's Estuary Program for this project, was used for the main Richmond River channel.

Five hypothetical floods were used to derive the stage-discharge relationship with peaks of 1000m^3/s, 2000m^3/s, 3000m^3/s, 4000m^3/s and 4500m^3/s respectively. These flow boundaries at Broadwater were combined with a fixed ocean level of 0 mAHD at the downstream boundary of the flood model. Sensitivity on the fixed ocean level to MHWS (0.6 mAHD) was also undertaken.

As shown in Figure D-1, the rating curves for the Richmond River have rising and falling limbs due to hysteresis. If the flows were determined from a rating curve with hysterisis there would be more than one flow for each stage. Therefore, a representative rating curve has been developed that incorporates characteristics, such as changes to the floodplain with time and hysteresis effects in flow behaviour, into a single rating curve.

In developing the representative rating curve, the historical rating curves were graphed as presented in Figure D-1 and a curve was manually assigned to best represent the historical data. This analysis is concerned only with the relationship between the peak flood level and discharge at Broadwater and not with the whole hydrograph shape. The rating curve was derived from the relationship between peak flood level and discharge for these five hypothetical floods. The representative rating curve is shown, plotted with the other rating curves in Figure D-1. Also plotted are the results of the sensitivity of the downstream boundary condition on the rating curve adopted. The higher downstream boundary condition scenario, results in slightly lower flows for a given river height, with the percentage change decreasing with increasing river height. That is, for floods in the range of the 100 year ARI to rare probabilities, the choice of downstream tailwater level has little influence on the rating flow.

The representative rating curve has then been used to calculate the flows corresponding to the recorded levels at the gauge. Recorded flood heights and associated calculated flows are shown in Table D-1.

Whilst the sensitivity results show a difference in flow for probabilities up to the 100 year ARI, the zero mAHD downstream boundary has been adopted for reasons of consistency with the previous study, as highlighted further in this Appendix.

Figure D-2 shows the stage-discharge relationship from this analysis compared to the relationship from the 1997 Ballina Floodplain Management Study. As shown, the stage-discharge relationship derived in this analysis is different from that used in the previous study. The same recorded level would equate to a lower flow for the full range of floods based on the revised stage-discharge relationship compared to the previous relationship. This is a result of the calculated conveyance being lower for a given stage in the new cross-section used in this analysis compared to the previous case.

It is uncertain whether this change in conveyance is a result of physical changes or data capture techniques. The revised rating curve has been adopted for this study.

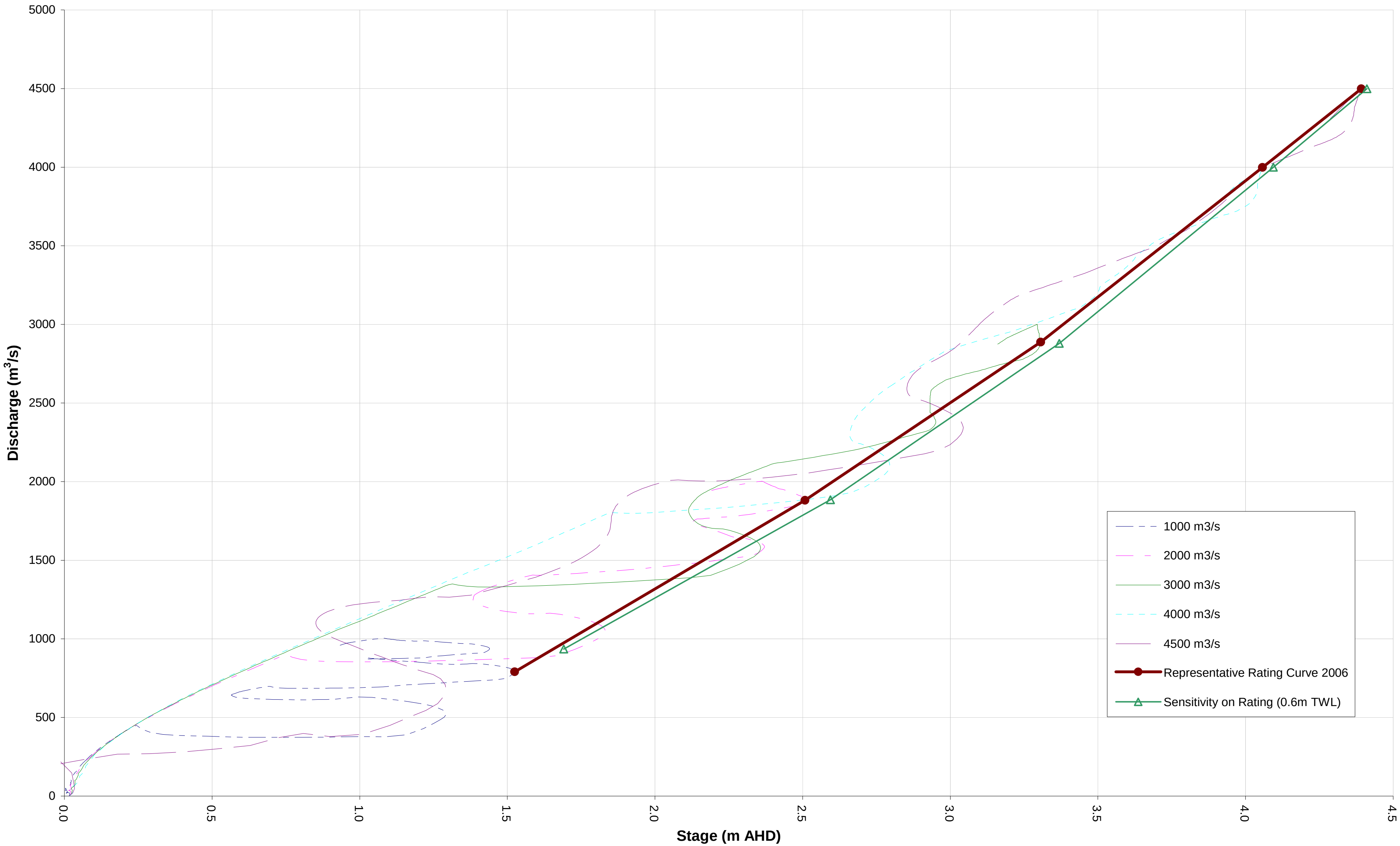


Figure D-1 Representative Rating Curve for the Richmond River at Broadwater Sugar Mill

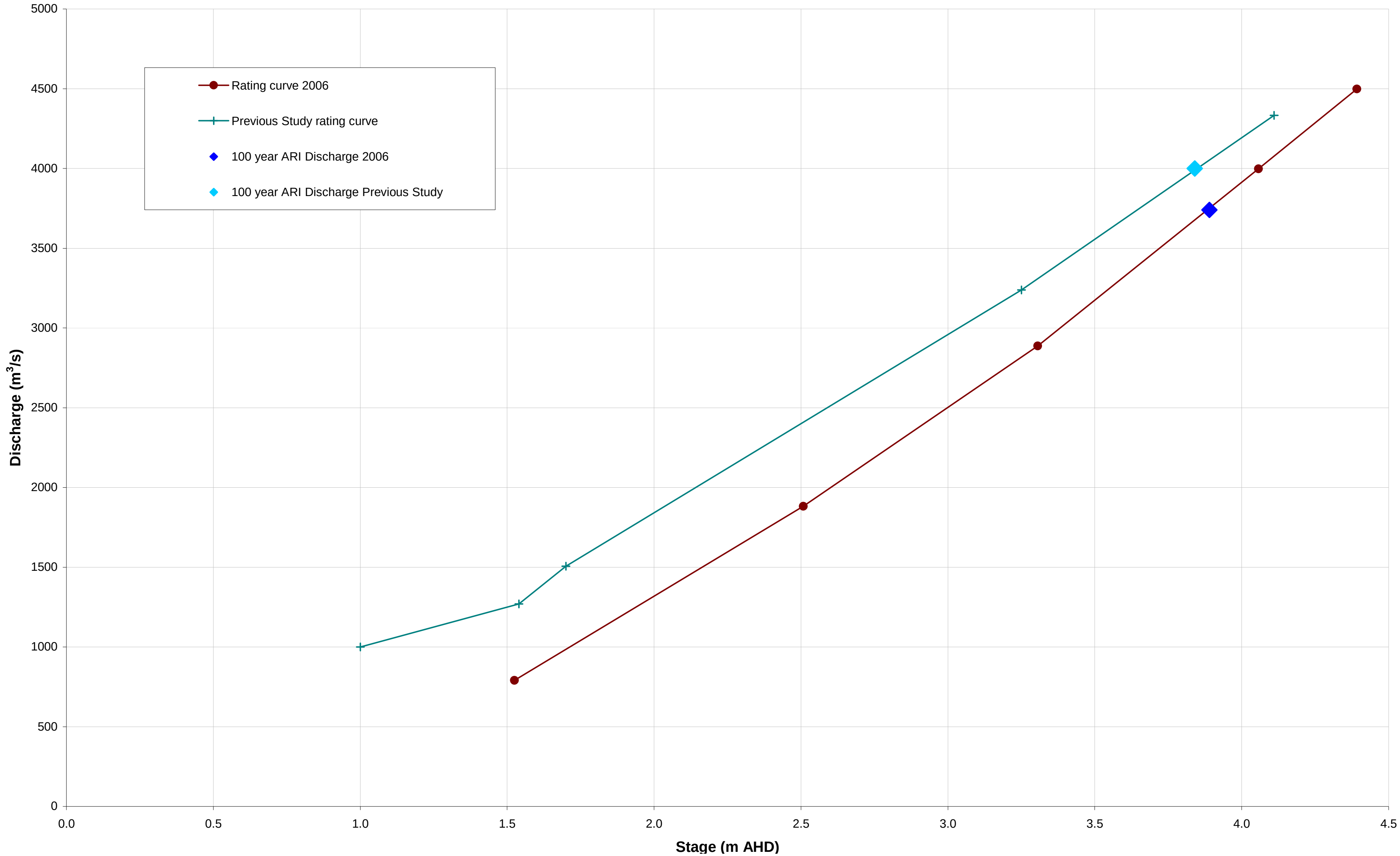


Figure D-2 Stage Discharge Relationship for the Richmond River at Broadwater Sugar Mill

Table D-1 Historical Flood Records at Broadwater (with re-rated flows)

Year	Level	Level	Flow
	m LWD	m AHD	m^3/s
1917	2.64	1.78	1054
1921	2.09	1.23	504
1921	2.59	1.73	1002
1921	2.79	1.93	1214
1928	2.10	1.24	514
1931	2.96	2.10	1402
1937	1.97	1.11	393
1938	2.20	1.34	610
1938	2.16	1.30	571
1938	2.15	1.29	561
1945	3.90	3.04	2544
1946	2.20	1.34	610
1948	2.15	1.29	561
1948	4.15	3.29	2878
1950	2.20	1.34	610
1950	3.30	2.44	1794
1951	2.47	1.61	878
1951	2.14	1.28	552
1953	2.65	1.79	1065
1953	2.22	1.36	629
1954	4.58	3.72	3483
1954	2.54	1.68	950
1955	2.23	1.37	639
1955	2.22	1.36	629
1956	2.93	2.07	1368
1956	2.05	1.19	467
1959	2.03	1.17	448
1959	2.30	1.44	707

Year	Level	Level	Flow
	m LWD	m AHD	m^3/s
1959	2.00	1.14	420
1959	2.10	1.24	514
1962	2.41	1.55	817
1962	3.55	2.69	2097
1963	3.05	2.19	1503
1965	2.50	1.64	908
1967	2.40	1.54	807
1967	3.00	2.14	1447
1971	2.00	1.14	420
1972	2.46	1.60	868
1972	2.41	1.55	817
1974	2.19	1.33	600
1974	4.11	3.25	2823
1974	2.38	1.52	787
1974	2.58	1.72	991
1975	2.49	1.63	898
1976	2.55	1.69	960
1976	2.40	1.54	807
1976	2.38	1.52	787
1978	2.16	1.30	571
1980	2.62	1.76	1033
1984	2.40	1.54	807
1987	2.32	1.46	727
1987	2.56	1.70	970
1988	3.29	2.43	1782
1989	2.80	1.94	1225
1989	2.40	1.54	807

Source :K:\B15219.k.wjs.Ballina\Hydrology\Re-rating Oct2006\FFA_191006.xls

D.4 Flood Frequency Analysis

The Lower Richmond River Flood Study (PWD 1987) published partial duration series from 1917 to 1983 of stage (water level to a local datum) in the Richmond River at Broadwater. Only records above a designated threshold level have been kept. Flood thresholds at Broadwater[1] are listed in Table D-2.

Table D-2 Flood Classification - Broadwater

Flood Classifications					
Minor		Moderate		Major	
Gauge	mAHD	Gauge	mAHD	Gauge	mAHD
2.0	1.14	2.5	1.64	3.0	2.14

Historical flood records at Broadwater are shown in Table D-1, together with the conversion of peak flood levels to flows based on the newly derived rating curve. The peak flood levels used are the same as in the previous study and are derived from the 1987 NSW Public Works report

[1] The SES (Richmond Tweed) are yet to confirm whether this is for the old mill gauge or the new SES gauge.

supplemented after 1980 with records from MHL. Note that the dataset is not purely recorded data. No levels less than approximately 1.25 mAHD were actually recorded. The 1987 Public Works report used correlation diagrams to interpolate values for missing data from records at Woodburn and Wardell. This exercise was undertaken to produce a more complete set for the analysis.

It should be noted that the original gauge at Broadwater which has records to April 1989 was at the Sugar Mill, downstream of the current Richmond River bridge constructed approximately in the year 2000. There is now a gauge upstream at the SES headquarters.

The SES Divisional Controller has advised that there have been no recorded floods above a threshold of 1.80 mAHD since commencement at SES headquarters (personal communication, 31 May 2006). In 2001, a flood peak of 1.66 mAHD was noted.

The period of record has increased to 89 years compared to 73 in the 1997 Ballina Floodplain Management Study.

A flood frequency analysis was undertaken on the flows presented in Table D-1. The Cunane plotting position was used where:

$$PP_m = (m - 0.4) / (N + 0.2)$$

Where m = rank of flood event

N = period of record (89 years to 2005)

The peak flows were plotted against their probability of exceedance calculated using the above formula on log-log axes (refer to Figure D-3).

A complete annual maxima data set should ideally be used for flood frequency analyses. However, since the available series is partial, and no fitting software is available for partial series, two techniques have been undertaken:

1 A distribution has been fitted by hand as shown on Figure D-3. This method is acceptable for interpolation, however, extrapolation is likely to be variable; and

2 The dataset has been transformed to an equivalent annual maxima dataset and the flood frequency analysis undertaken.

For the second method, during years in which there were no recorded flood levels, it was assumed that a large event did not occur and the level for that year is assigned as either:

a. 1.25 mAHD being the lowest actual record during the period to 1980 (520 m^3/s); or

b. 1.80 mAHD being the “no flood” classification reported by the SES (1080 m^3/s).

Table D-3 presents the derived annual maxima series. A sensitivity analysis adopting threshold value for all non-records was also conducted at 1.5 mAHD (750 m^3/s). A further sensitivity analysis assuming values pre-1945 were too sparse to include in the dataset was also conducted.

Table D-3 Historical Flood Records at Broadwater (with re-rated flows)

Year	Flow m^3/s	Year	Flow m^3/s
1917	1054	1962	2097
1918	520	1963	1503
1919	520	1964	520
1920	520	1965	908
1921	1214	1966	520
1922	520	1967	1447
1923	520	1968	520
1924	520	1969	520
1925	520	1970	520
1926	520	1971	420
1927	520	1972	868
1928	514	1973	520
1929	520	1974	2823
1930	520	1975	898
1931	1402	1976	960
1932	520	1977	520
1933	520	1978	571
1934	520	1979	520
1935	520	1980	1033
1936	520	1981	520
1937	393	1982	520
1938	610	1983	520
1939	520	1984	807
1940	520	1985	520
1941	520	1986	520
1942	520	1987	970
1943	520	1988	1782
1944	520	1989	1225
1945	2544	1990	1080
1946	610	1991	1080
1947	520	1992	1080
1948	2878	1993	1080
1949	520	1994	1080
1950	1974	1995	1080
1951	878	1996	1080
1952	520	1997	1080
1953	1065	1998	1080
1954	3483	1999	1080
1955	639	2000	1080
1956	1368	2001	1080
1957	520	2002	1080
1958	520	2003	1080
1959	707	2004	1080
1960	520	2005	1080
1961	520		

Flood frequency analysis techniques used are based on the recommendations from the proposed revision to Book 4 of ARR (2001) by Kuczera & Franks (*Chapter 2 – At-Site Flood Frequency Analysis – Draft (2005)).* The L-Moment fitting method has been used to fit the data to the Generalised Extreme Value (GEV) probability distribution. This has been undertaken using the program HydroFreq 1.0 written by HydroTools Software in Canada. HydroFreq is also able to undertake a Maximum Likelihood fit to a Log Pearson Type III (LPIII) distribution. Results from both the GEV and the LPIII distributions are provided for comparison. The fit through the majority of the data is similar. As the GEV is expected to become the Australian standard, the GEV results are favoured.

Both sensitivity analyses showed a poor correlation between the GEV and LPIII fitting methods. Flows presented in Table D-3 are higher than the sensitivity analyses for the less frequent events, therefore this dataset has been adopted as a conservative measure. It should, however, be noted that the flows are lower in the adopted dataset for the more frequent events. This is considered appropriate given the close fit to the recorded data. Figure D-4 shows both the LPIII and GEV distributions for the data.

The design peak flows derived from this analysis are shown below in Table D-4 and compared to the peak flows used in the 1997 Ballina Floodplain Management Study and the peak flows from the Mid-Richmond Flood Study (WBM, 1999 for the former Richmond River Shire Council).

Table D-4 Comparison of design flows from three studies for a range of flood events at Broadwater

ARI Event	Design flow at Broadwater (m^3/s)				
	Ballina Flood Study Update			Ballina Floodplain Management Study (1997)	Mid-Richmond Flood Study (1999)
	Partial Series Hand Distribution	Annual Series Derived GEV Distribution	Annual Series Derived LPIII Distribution		
5 yr	1100	1060	1070		
10 yr	1650	1410	1460	2150	2080
20 yr	2100	1860	1950	2700	2650
50 yr	2800	2680	2850	3400	
100 yr	3300	3540	3770	4000	3970
500 yr	4600	6810	7210		

The design peak flows from this flood frequency analysis are lower than those calculated in the earlier Ballina Floodplain Management Study (1997) as a result of the change in the stage-discharge relationship. The flows derived in this study are also lower than the design flows from the Mid-Richmond Flood Study, which were derived from catchment rainfall-runoff methods.

For all events studied, the two annual series methods yielded similar flow rates (within 6%). Although the partial series showed close correlation with the annual series for the more frequent events, there is significant difference for the 500 year ARI. This partial series method has therefore not been adopted.

Differences between modelled flows and a flood frequency analysis are expected. Derivation of inflows to a hydraulic model considers complex factors such as temporal patterns and rainfall intensities across the catchment. The FFA, a simplistic approach, considers recorded levels at a gauge at a single location.

The design flows were converted into peak levels at Broadwater using the stage-discharge curve derived in this analysis and compared to the peak levels used in the previous Ballina Floodplain Management Study in Table D-4. This was undertaken using both the GEV and LPIII distribution methods. As expected, due to the lower flow rates, the stage at Broadwater is slightly lower for most design events, than the Ballina Floodplain Management Study (1997).

Design flood levels calculated using the LPIII distribution method are higher than the GEV method, therefore are conservative. Peak levels to be used at Broadwater for the design events up to and including the 100 year ARI event in this flood study have, therefore, been based on the LPIII distribution method as presented in Table D-5. For the 100 year ARI event, the peak level is higher than for the previous study.

Table D-5 Comparison of design peak flood levels at Broadwater in this study and the previous Ballina Floodplain Management Study

	Peak Level (m AHD)				
	Ballina Flood Study Update			Ballina Floodplain Management Study (1997)	Mid Richmond Flood Study (1998)
ARI Event	GEV	LPIII	Estimate		
5 yr	1.79	1.80			
10 yr	2.11	2.15		2.28	2.35
20 yr	2.50	2.57		2.76	2.48
50 yr	3.14	3.27		3.38	
100 yr	3.76	3.92		3.84	3.77
500 yr	5.72	5.93			
10,000 yr			6.30	6.12	
PMF					7.03

For the 10,000 year and PMF events, the LPIII and GEV estimates were not considered likely values. Therefore, an estimate for the 10,000 year peak flood level was used, based upon the findings of the 1997 Ballina Floodplain Management Study and the 1998 Mid Richmond Flood Study.

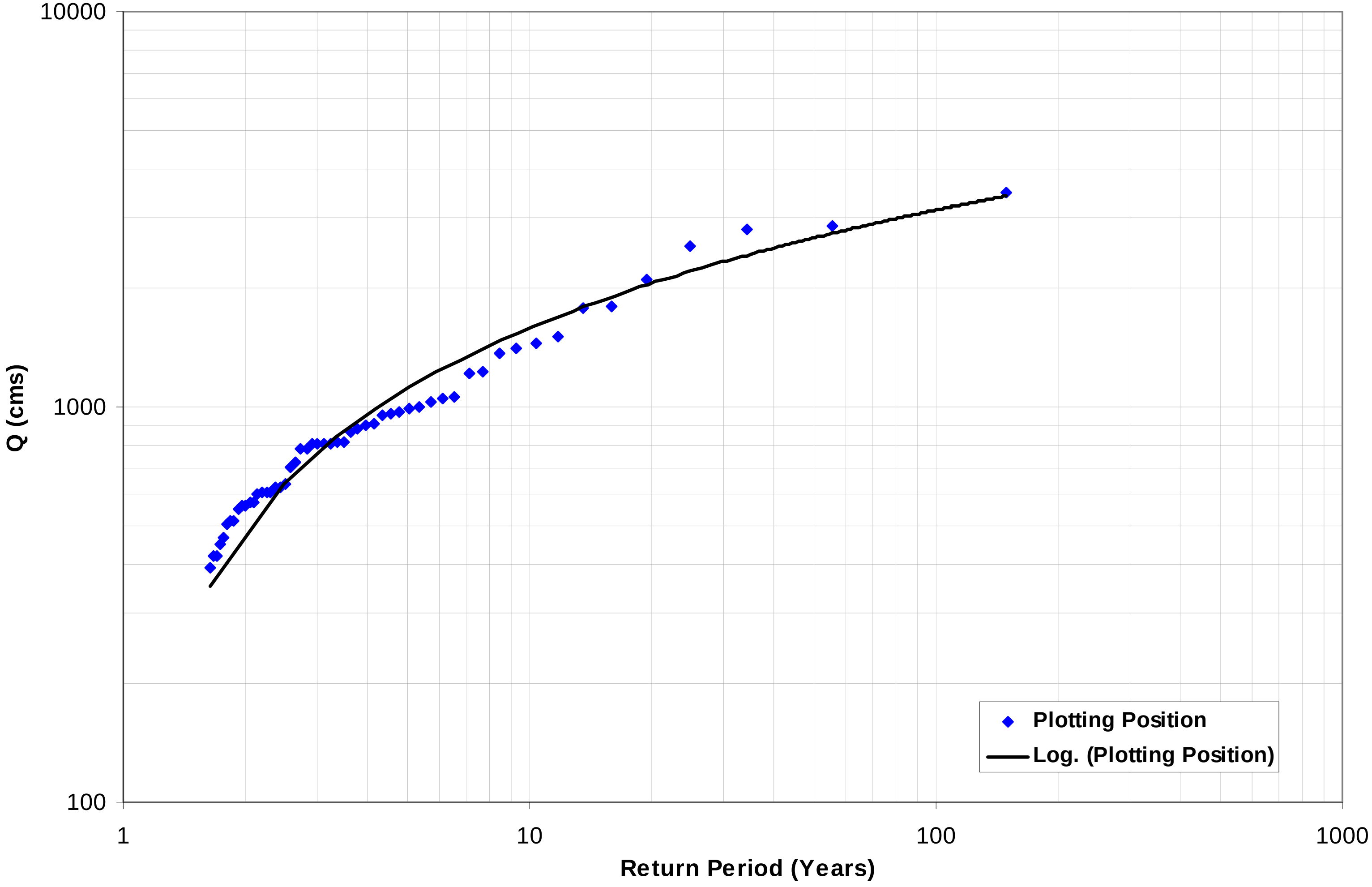


Figure D-3 Hand Calculation of Distribution of Partical Duration Series – Broadwater Sugar Mill

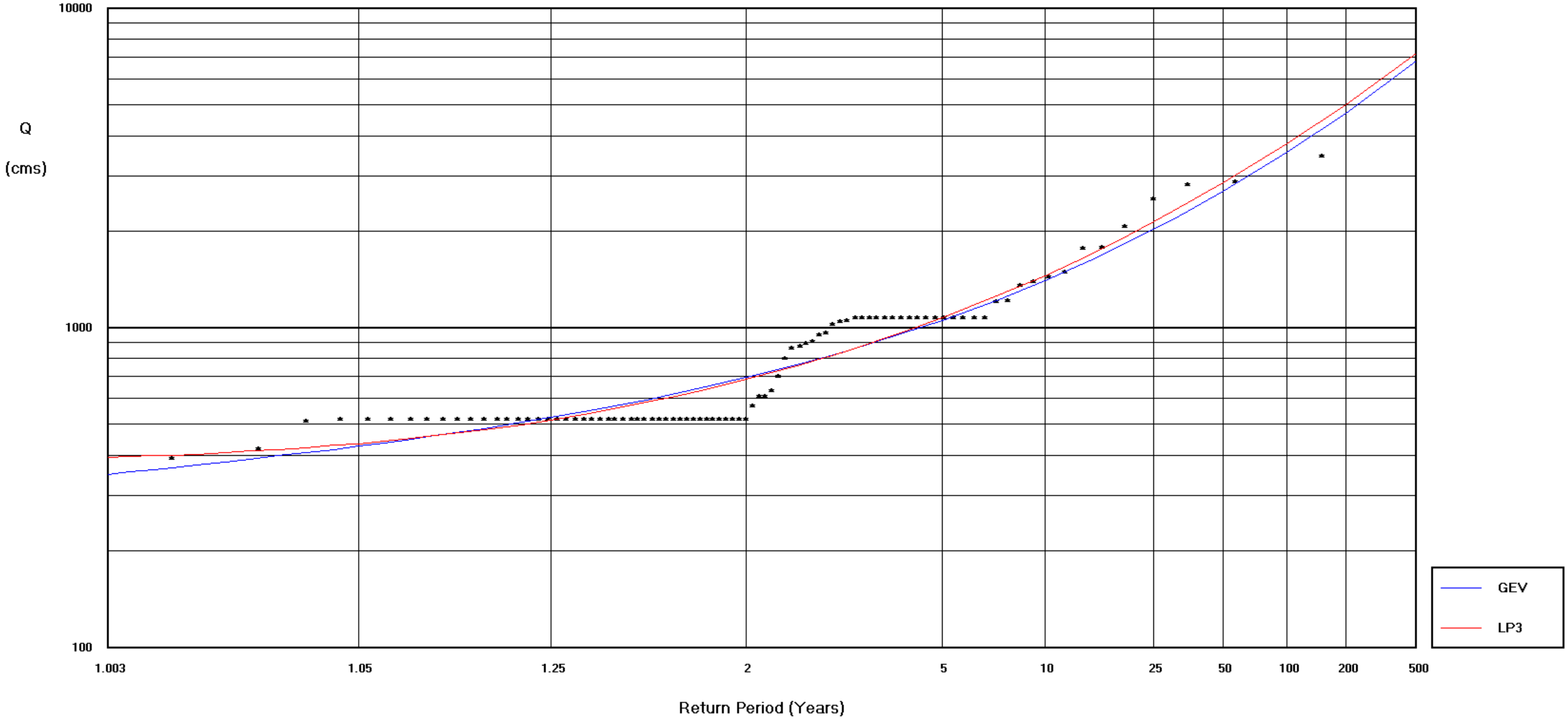


Figure D-4 GEV & LP3 Distributions to Derived Annual Maxima Series – Broadwater Sugar Mill

Note: Asterisks on plot indicate plotting positions of the derived annual maxima series

APPENDIX E: MEETING MINUTES

BALLINA FLOOD STUDY UPDATE - CALIBRATION PRESENTATION

COMMUNITY REFERENCE GROUP

5 SEPTEMBER 2006

Attendees:

Paul Busmanis	Ballina Shire Council	6686-4444
Toong Chin	DNR	6627-0100
Tina O'Connell	WBM	(07) 3831-6744
Katie Bunting	WBM	(07) 3831-6744
Don Cook	Ballina Farmer	6686-2086
Brian Smith	Lennox Heads Residents Assoc.	6687-7176
Jim Spencer	154 Cherry St	6686-7865
Bill Payne	Ardill Payne & Partners	6686-3280
Col Dorey	5 Lewis Place	0427 788-264
Ken Kaehler	Tintenbar	6687-8203
John Hayter	Tintenbar	6687-8378
Gerry Burnage	Ballina SES	6686-3725
Colin Beddoes	201 Deadmans Ck Road	6686-8485

The purpose of this meeting was to present and discuss the calibration flood model prepared for Council by WBM for the Ballina Flood Study Update. This Flood Study is an update of the 1997 Ballina Flood Study and is being revisited for a variety of reasons including technological advances in modeling over the last ten years and the availability of good calibration data from the June 2005 flood. The flood model is being calibrated to the March 1974, February 1976 and June 2005 flood events.

The group was shown a presentation about the flood model and the calibration events and then presented with model results for discussion. The notes below summarise the discussion about some of the key locations:

Sandy Flat Road

- Sandy Flat Road is an important control on flooding to the north of Ballina;
- The calibration modelling results show shallow flow across Sandy Flat Road at the peak of the flood in 1974 but no overtopping of this road in 1976 or 2005; and
- Local residents present at the presentation believe this to be incorrect and that there was no flow over the road in 1974 and 2005 but shallow overtopping in 1976 (*subsequent discussions with said residents revealed they were only in attendance in 1985 during over-road flooding. Local residents have knowledge of what happened in 1974 and 1976)*.

Cumbalum Bridge

John Hayter expressed concern that the road bridge at Cumbalum Road is causing a constriction to flow and as a result flooding upstream of here in 2005 was more prolonged than would be expected for the volume of rain that fell.

Deadmans Creek Road

- There is currently a temporary raised berm on the upstream (northern) side of Deadmans Creek Road at Cumbalum, associated with the development at Ballina Heights; and
- There is local concern that this berm is affecting flood mechanisms in the area and is resulting in greater depths of inundation and longer periods of inundation than previously. Comparing the results of the calibration modelling for the 2005 flood against the 1974 and 1976 flood suggests this is the case.

Koellner Hill

- Residents expressed concern about past filling on this property constricting the natural floodplain of Emigrant Creek and further exacerbating problems upstream.

Gallans Road Cycle Track

- South of Deadmans Creek Road is the Gallans Road cycle track. This cycle track is built over a water main where ground was raised and pipe installed after the 1976 flood. The cycle track is now approximately 1m higher than natural ground level in the area at the head of Roberts Creek and has become a control to flooding here;
- The calibration modelling results suggest that the raising of this track for the water main and then the cycle track has changed flood mechanisms in the area. Prior to this raising there was a flow path for floodwater from Emigrant Creek in an easterly direction across the Ballina Nature Reserve and into North Creek (over and above the low flows heading north via Roberts Creek and then east via Deadmans Creek). Since the raising of this track this flowpath is no longer open and floodwaters from Emigrant Creek are forced southward towards the Pacific Highway and Fishery Creek;
- Local residents present at the meeting were pleased to see the impacts of this raising shown in the model results and accepted that even after the raising there was still some very shallow inundation of this track in the June 2005 flood event.

Confluence of Maguires and Emigrant Creek

- This is a point of conflict between floodwaters from each catchment. A recommendation from the residents was to create an overflow channel for flood relief between the meander downstream of the confluence and Maguires Creek. For the cost to cut this short stretch of channel, greater channel conveyance will result in floods from either catchment being conveyed further downstream earlier.

Fishery Creek

- It was noted by many present that Fishery Creek has become narrower and shallower over the years. In the past this Creek had been navigable in small boats but is no longer so and does not allow for the discharge of floodwaters as it may have in the past. Since the raising of Gallans Road Cycle Track more flow is forced this way but the discharge of floodwater to the Richmond River is impeded by the silting up of Fishery Creek;
- There were suggestions from some present that the Creek should be dredged/re-opened as a flood escape; and

- It was also noted that other creeks in this system are also silting up and that this is a natural process for this area.

Ballina Nature Reserve

- The creeks and drainage channels through the bottom end of the Ballina Nature Reserve are currently silted up to such a degree that they are not flowing. These channels would need regular clearing and maintenance to create a flow route for floodwaters from Newrybar Swamp and could be looked at as a mitigation option for flood relief.

North Creek

- The entrance of this creek has 'sanded up' in recent times. The residents were concerned with the implications of this on flooding.

The members of the Community Reference Group present at the meeting accepted that the flood model was, in general, a good representation of the flooding that occurred in Ballina in 1974, 1976 and 2005.

Other discussion

Members of the Community Reference Group raised concerns over the potential development fill cases currently in consideration for the floodplain (eg Ballina Bypass, Smith Drive). Council and DNR explained the Floodplain Management Process they plan to put in place and how that will take a regional focus on allowable filling and compensatory floodways.

Presentation by Mr. Col Dorey

Col provided an overview of flooding from a Teven Valley/Newrybar Swamp farmer's experience highlighting some of the physical changes/blockages that have resulted in changed and worsened flood characteristics on the floodplain.

He expressed concerns that the new Ballina Bypass needs to alleviate the problems that previous highway construction west of the township has placed on the areas upstream. Also, some alternate solution is required to alleviate the problems caused by the cycleway at the head of Roberts Creek.

BALLINA FLOOD STUDY UPDATE – DESIGN EVENT PRESENTATION

COMMUNITY REFERENCE GROUP

31 OCTOBER 2006

Attendees:

Paul Busmanis	Ballina Shire Council	6686-4444
Tina O'Connell	WBM	(07) 3831-6744
Katie Bunting	WBM	(07) 3831-6744
Don Cook	Ballina Farmer	6686-2086
Brian Smith	Lennox Heads Residents Assoc.	6687-7176
Jim Spencer	Cherry St, Ballina	6686-7865
Bill Payne	Ardill Payne & Partners	6686-3280
Col Dorey	Lewis Place, West Ballina	0427 788-264
Ken Kaehler	Tintenbar	6687-8203
John Hayter	Tintenbar	6687-8378
Gerry Burnage	Ballina SES	6686-3725
Rob Noble	Ballina SES	
Tony Kohlmann	Richmond Tweed SES	
Colin Beddoes	Deadmans Creek Road	6686-8485
Matt Smith	Golf Driving Range, Smith Dve	
John Stevenson	Smith Dve	
Alex McLeay	Waverley	6644-5578
Grant McLennan	(with A.McLeay)	
Steven Smith	LandPartners Pty Ltd	6627-5600

This meeting was the second in a series of meetings designed to discuss the content and outcomes of a flood study for the Richmond River floodplain from Pimlico Island in the south to Ross Lane in the north. It follows on from the first meeting on 5 September 2006, which dealt with the calibration of the flood model to large and recent flooding events.

The purpose of this meeting was to present and discuss the preliminary results of the design event flood modelling prepared for Council by WBM for the Ballina Flood Study Update. This Flood Study is an update of the 1997 Ballina Flood Study and is being revisited for a variety of reasons including technological advances in modeling over the last ten years and the availability of good calibration data from the June 2005 flood. The flood model has been calibrated to the March 1974, February 1976 and June 2005 flood events. The design flood model will be used to predict flood levels and velocities for the 5 year, 20 year, 50 year, 100 year and 500 year Average Recurrence Interval (ARI) design events and the Probable Maximum Flood (PMF). The design flood modelling incorporates Richmond River dominated flooding, local catchment dominated flooding and ocean surge tides.

The group was shown a presentation about the flood model which included a brief review of the calibration events and provided more detail about the design events and was then presented with preliminary model results for discussion of the 50 and 100 year ARI flood events. The notes below summarise the discussion about some of the key locations and concerns of the landowners present:

Ballina Flood Study Update Process

Paul explained that once this Flood Study and flood model has been accepted by Council the next stage in the process would be for Paul to approach Council for funding of the floodplain management component of the study. The floodplain management study would use the design flood model developed by WBM to assess the impacts of pre-approved fill on the floodplain, plus consider Council's Urban Land Release Strategy and infrastructure developments, and to propose solutions where necessary to mitigate these impacts. The Ballina Bypass is one development that comes under the pre-approved fill category to be included in the floodplain management study.

Tina and Paul explained to the meeting that the RTA were undertaking their own flood impact assessment on the proposed bypass design in order to meet their planning constraint of no impacts greater than 50mm in a 100 year ARI event.

Several people present at the meeting expressed concern that the RTA's Ballina Bypass was not in the existing design event modelling presented at this meeting. It was explained that the existing case was to represent conditions as they are today. It was a deliberate decision for Council's model not to have the RTA's bypass included in the existing case. Impacts from the construction of the RTA's bypass is being treated as a development on the floodplain (as a fill scenario) which will be dealt with in the next stage.

Following completion of the floodplain management study the flood model may be used by private developers, through Council, to assess the impact of developments outside Council's current land release strategy. Such assessments would be undertaken against a base case assuming development according to the land release strategy and infrastructure developments including the bypass. The flood model will be a "live" model, continuously maintained to reflect conditions at the time.

Col Dorey and Jim Spencer expressed their wish that Paul should return to Council and secure funding for the floodplain management study in order for this project to continue moving in a positive direction and providing benefit to everyone on the floodplain.

Grant McLennan noted that Ballina Shire Council are actually ahead of some south-east Queensland Councils having a whole of floodplain 2D model for use in a variety of investigations.

The question was asked whether Council's obligation was to maintain the existing situation or to improve the situation based on historical flooding with Council's response being that there was no established formula but that all effects would be put to socially, economically and ecologically justifiable solutions to flooding problems.

Flood Information

Some members of the CRG were concerned that there was not enough information being provided about this flood study and in particular the RTA's Ballina Bypass project, and that not everyone with an interest was being contacted. Paul explained mechanisms available for obtaining more information from the RTA, comprising their website, the "hotline" phone number and upcoming public exhibition. As for membership of this CRG, it was explained that the normal list of community groups and past committee representatives were canvassed as well as newspaper advertising. Several group members suggested that notices in the local newspaper would not have sufficient circulation to get to all the floodplain community.

Climate Change

Tina explained to the meeting that in a development from the previous Floodplain Management Study (1997) the effects of a possible future rise in sea level were being accounted for in this flood study. An additional 0.2m is added to all ocean levels used as the downstream boundary of this flood model. This value of 0.2m has been chosen as a best estimate of the likely rise in sea level over a 50 year period based on an extensive literature review at a national and international level.

No specific comment was provided by the group about the inclusion of a climate change allowance.

Gallans Road Cycle Track

There was further discussion about the impact that the raising of the cycle track at Gallans Road has had on flood mechanisms in this area. Tina explained that the building of the water main along this line after the 1976 flood impacted on flood transfer between the two catchments east and west and that further raising for the cycle track has decreased the quantity of that flood transfer. The results of the design event modelling show this track acting as a significant control on flooding although the track is still overtopped in the 50 year and 100 year ARI results presented at this meeting.

Paul explained that this is one area that could be considered further in the floodplain management study and an area where mitigation may be required.

Deadmans Creek Road

Questions were raised as to the design finish level of Deadmans Creek Road and the provision of flood relief culverts. It was confirmed that the finished level of the road will be no higher than the existing Pacific Highway at this point. The timetable for this work has not been set, however it is likely that the road will be at its finished level some time in 2007. Further work on culvert sizing and use of the road as a floodway with a sag point for larger events is required at this location. Ardill Payne & Partners will work with WBM to finalise a design here.

John Hayter expressed concern that “a couple of culverts” would not mitigate the large scale and ongoing blockages on the floodplain in this vicinity which have caused increased flooding upstream, including through his property to Tintenbar village. Those blockages not only include the road “berm” and subdivision fill, but also the RTA trial pad, filling on Koellner’s Steel Fabrication Shed property and the Cumbalum Bridge.

Cumbalum Bridge

John Hayter expressed his concern that the road bridge across Emigrant Creek at Cumbalum (Koellner Road/Cumbalum Road) including it’s reduced span and fill approaches is causing a constriction in flow and resulting in more prolonged flooding than previously experienced at locations upstream. John also expressed frustration that his submissions to Council regarding this issue appear to have been ignored.

Teven Road

Col Dorey asked if the model accounted for the levee upstream of the Barlow cane farm on Teven Road. Tina showed this levee in the DEM and showed it acting as a control early in the 100 year ARI flood event, eventually drowned by overtopping flows at the peak.

Sandy Flat Culverts

The results of the preliminary design flood modelling in the Sandy Flat area were discussed, in particular with regards to the existing culverts underneath the Pacific Highway. The model results shown indicate a significant constriction of flow at this point. John Hayter believes that the constriction of flow at these culverts is another factor contributing to the prolonged inundation of his land. Bill Payne suggested that increasing the capacity of these culverts is one mitigation measure that should be considered in the floodplain management study.

Other modelled event

Members of the group still felt that landowners would still benefit from a model run put forward at the first group meeting but not yet considered. This model run was to apply the historical rainfall and flood flow of the 1976 flood to existing floodplain conditions. This would answer "what would happen today with all the filling to the floodplain if the meteorologic conditions of the worst flood in memory were to reoccur". Tina's suggestion that this can be seen in the 50 year and 100 year mapped results were not agreed with.

Council will discuss this proposed additional case with WBM.

Other discussion

John Hayter described his anxiety that discussion at this meeting and others tends to focus on impacts downstream of Deadmans Creek Road. He strongly believes that development in the Emigrant valley, such as the Cumbalum bridge, Koellner hill and the RTA test pad have all contributed to worsening the effects of flooding for landowners higher up in the valley, such as himself.

Don Cook and others at the meeting suggested that re-opening Fisheries Creek and Roberts Creek to reestablish former flow paths should be considered as possible measures in the floodplain management study

Tina explained how the roughness of the floodplain was taken into account in the hydrological and hydraulic modelling undertaken by WBM and that a sensitivity test would be carried out to view the impacts on flood level of fully grown sugar cane compared to freshly harvested land.

Future meetings

Assuming funding is provided for the next stage of the project, being the investigation of approved filling scenarios, the next meeting of the CRG will be held to present the results of these scenarios and to discuss possible mitigation solutions.

MINUTES FOR MEETING 3

ATTENDEES:	Paul Busmanis (PB) – Ballina Shire Council (BSC) Toong Chin (TC) – Department of Natural Resources (DNR) Tina O'Connell (TO) – WBM Pty Ltd (WBM) Ben Caddis (BC) - WBM Pty Ltd Colin Beddoes (CB) – 21 Deadmans Creek Road Don Cook (DC) – Ballina Col Dorey (CD) – Ballina John Hayter (JH) – Tintenbar Ken Kaehler (KK) – Tintenbar Alex McLeay (AMcL) – Waverley Stephen Smith (SS)
APOLOGIES:	Jim Spencer
DATE:	14 March 2007
SUBJECT:	**Ballina Flood Study Community Reference Group Meeting 3** **Base Case modelling and possible mitigation options**

The meeting was opened at 7:30pm by Paul Busmanis. PB started by thanking the attendees for their involvement and ongoing contribution to the project.

PB introduced TC, TO & BC.

CD questioned whether the bypass referred to on Page 2 Paragraph 3 (Minutes of CRG Meeting 2) was the RTA's Ballina Bypass. Answer - Yes.

Minutes of CRG Meeting 2 will be amended.

PB proceeded to give a summary of the project history, current status and reasons for the CRG Meeting 3.

TO delivered presentation of the Base Case modelling. Throughout the presentation, numerous issues were raised and discussed. For clarity, the key issues have been sorted into geographic location as follows:

- Deadmans Creek Road and North Emigrant Creek
- Emigrant Creek between Maguires Creek and Duck Creek
- Emigrant Creek downstream of Duck Creek
- Fishery Creek, Little Fishery Creek and The Canal
- Bicentennial Gardens, Gallans Road Cycleway and Roberts Creek
- North Creek
- General Matters

Note that the order of items below does not correspond to the order that each item was raised.

DEADMANS CREEK ROAD AND NORTH EMIGRANT CREEK	
ISSUES RAISED / DISCUSSION	**ACTIONS**
THE REMOVAL OF THE DEADMANS CREEK ROAD BERM WAS DISCUSSED WITH VARIOUS MEMBERS. JH ENQUIRED WHY ROAD NEEDED TO BE PRE-LOADED. TO EXPLAINED THAT LOCAL SOIL CONDITIONS REQUIRED THIS METHOD OF CONSTRUCTION.	
JH STATED THAT BSC ARE SLOW TO RESPOND TO THE CONCERNS AND REQUIREMENTS OF THE FARMING COMMUNITY. FARMERS ARE SUBJECT TO ADDITIONAL RISK AND DESERVE COMPENSATION.	
CB STATED THAT THE DEADMANS CREEK ROAD BERM WAS NOT BEING REMOVED, TO RESTORE ORIGINAL CATCHMENT TOPOGRAPHY, JUST THAT IT WAS BEING REDUCED TO THE HEIGHT OF THE PROPOSED ROAD. BSC AND WBM AGREED THAT FURTHER INVESTIGATION WAS REQUIRED FOR THIS AREA TO REDUCE CURRENT AND FUTURE IMPACTS.	BSC AND WBM TO UNDERTAKE FURTHER INVESTIGATION TO REDUCE IMPACTS IN NORTH EMIGRANT CREEK.
CB ADVISED THAT THE LAND BETWEEN THE EXISTING PACIFIC HIGHWAY AND THE PROPOSED FILL FOR CUMBALUM WAY IS BELOW THE LEVEL OF EMIGRANT CREEK AND IS OFTEN INUNDATED BY 1M OF WATER. CB RAISED THAT USE OF THIS LAND FOR RECREATIONAL FACILITIES WOULD REQUIRE SUBSTANTIAL FILL. TO ADVISED THAT NATURAL WATERCOURSE IS TO ROBERTS CREEK. BSC AND WBM TO INVESTIGATE FURTHER, AS CURRENT STUDY HAS KEPT RECREATION AREAS TO MINIMAL FILL.	BSC AND WBM ARE TO INVESTIGATE CURRENT APPROVALS AND DEVELOP A STRATEGY TO REDUCE IMPACTS IN NORTH EMIGRANT CREEK.

EMIGRANT CREEK BETWEEN MAGUIRES CREEK AND DUCK CREEK	
ISSUES RAISED / DISCUSSION	**ACTIONS**
AMCL ENQUIRED WHETHER VELOCITIES HAD BEEN CONSIDERED IN THE VICINITY OF BARLOWS PROPERTY. TO ADVISED THAT VELOCITIES HAD BEEN MAPPED AS PART OF PREVIOUS DESIGN CASE MODELLING INCLUDING HIGH HAZARD AREAS.	
CD & AMCL RAISED THE POTENTIAL MITIGATION OPTION OF LOWERING THE EXISTING LEVEES BOTH ALONGSIDE TEVEN ROAD NORTH OF B&B TIMBERS AND ALONG BARLOWS ROAD, POSSIBLY LOWERING AND WIDENING THE FLOODWAY THAT IS ALREADY PART OF THIS LEVEE.	RTA CURRENTLY COLLECTING SURVEY OF THESE TWO LEVEES. WBM TO INVESTIGATE THEIR POTENTIAL LOWERING.
AMCL ENQUIRED WHETHER THE 13 CULVERT BOXES BETWEEN BRUXNER HIGHWAY AND TEVEN ROAD AS PART OF BALLINA BYPASS HAD BEEN INCLUDED IN MODELLING. TO RECONFIRMED THAT MODELLING WAS BASED ON CURRENT RTA DESIGN, THEREFORE INCLUDES CULVERTS AND EXISTING DISCHARGES.	
CD RAISED THAT TEVEN VALLEY FARMERS WOULD LIKE THE PROPOSED BALLINA BYPASS BRIDGE CROSSING OF EMIGRANT CREEK (ADJACENT DUCK CREEK) ENLARGED. BSC AND WBM AGREED IT WAS A WORTHWHILE OPTION TO CONSIDER. PB ADVISED THAT BSC HAVE THE OPPORTUNITY TO RESPOND TO THE PUBLIC EXHIBITION OF THE CURRENT RTA BALLINA BYPASS PROPOSAL. HOWEVER, EARLY FEEDBACK TO RTA WILL BE PROVIDED.	BSC TO PROVIDE A FORMAL RESPONSE TO RTA REGARDING THE EMIGRANT CREEK BRIDGE. WBM TO MODEL AN INCREASED OPENING.

CD REQUESTED THAT WBM PROVIDE DETAILS OF THE DIFFERENCE IN FLOOD LEVELS EITHER SIDE OF THE EXISTING PACIFIC HIGHWAY ON THE EASTERN BANK OF THE EXISTING EMIGRANT CREEK BRIDGE AND ON THE WESTERN BANK OF THE EXISTING DUCK CREEK BRIDGE FOR THE NEXT CRG MEETING (FOR CALIBRATION EVENTS).	WBM TO PROVIDE.
AMCL RAISED WHETHER THE BALLINA - BOOYONG HISTORICAL RAILWAY HAD BEEN INCLUDED IN THE MODEL. TO CONFIRMED IT HAS.	
AMCL RAISED CONCERN REGARDING THE BANK STABILISATION THAT HAS BEEN PLACED FOR THE NEW BRIDGE ABUTMENT AT THE CONFLUENCE OF EMIGRANT CREEK AND MAGUIRES CREEK. AMCL STATED THAT THE ROCK HAS SLUMPED INTO THE WATERCOURSE AND IS CONSTRICTING FLOW. PB ADVISED THAT THE SITE HAD BEEN SURVEYED AND THAT THE MODEL REPRESENTED THE CURRENT WATERCOURSE CROSS SECTION. APPROVALS FOR THE BANK STABILISATION WORK WAS OBTAINED, IN ACCORDANCE WITH ORIGINAL PROJECT APPROVAL.	
AMCL SUGGESTED THAT COUNCIL REVIEW THE CONDITIONS OF APPROVAL FOR THE RTA'S BALLINA BYPASS. AMCL ENQUIRED WHY THE TRIANGULAR SHAPED LAND (WEST OF WEST BALLINA AND EAST OF TEVEN ROAD) WAS SHOWN AS BEING FILLED. PB ADVISED THAT THE LAND IS A REMNANT PARCEL OF LAND BETWEEN OLD RTA BYPASS ROUTE AND EXISTING PACIFIC HIGHWAY . THIS PRESENTATION IS WORK IN PROGRESS AND THE CURRENT WESTERN ARTERIAL ROUTE DISSECTS THIS LAND, BOUNDARIES WILL BE TIDIED UP FOR FUTURE PRESENTATIONS.	

EMIGRANT CREEK DOWNSTREAM OF DUCK CREEK

ISSUES RAISED / DISCUSSION	ACTIONS
DISCUSSION WAS HELD REGARDING THE FLOODING OF PROPERTIES IN SMITH DRIVE. AMCL ADVISED THAT THIS AREA WAS NOT FLOODED IN THE 1976 FLOOD CONTRARY TO WBM MODELLING RESULTS AND OPINION OF CD.	
CD RAISED THAT THE OPTION 1 CULVERTS WERE POORLY LOCATED AS THE TEVEN ROAD/PACIFIC HIGHWAY INTERSECTION IS HIGHER THAN THE SURROUNDING ROADS. HISTORICALLY, THE SECTION OF PACIFIC HIGHWAY EAST OF HERE, WITHSTANDS MORE FLOOD OVERFLOWS.	

FISHERY CREEK, LITTLE FISHERY CREEK AND THE CANAL

ISSUES RAISED / DISCUSSION	ACTIONS
DC RAISED THAT CURRENTLY LITTLE FISHERY CREEK RUNS THROUGH THE PROPOSED RIVER OAKS DEVELOPMENT SITE. AS PART OF DA FROM 2002, A RELIEF DRAIN (APPROX. 3-4M WIDE AT BASE IN A 7M RESERVE) WAS CONSTRUCTED FROM THE WESTERN END OF RIVER OAKS TO THE CANAL AROUND THE TREATMENT WORKS. BSC AND WBM AGREED IT SHOULD BE INVESTIGATED AND BE INCLUDED IN THE BASE CASE MODEL.	BSC AND WBM TO INVESTIGATE RELIEF DRAIN AND INCLUDE IN MODEL.
DC RAISED THAT MITIGATION OPTION 4 (FLOODWAY 3) WAS THROUGH THE HIGH GROUND IN THAT AREA. BC ADVISED THAT THE PLAN IS JUST SCHEMATIC AND CURRENT MODELLING IS A CRUDE LOOK AT PROVIDING AN ALTERNATIVE ROUTE FOR LITTLE FISHERY CREEK FLOW TO THE CANAL. BC ADVISED THAT EXACT ALIGNMENTS WOULD BE CONSIDERED DURING FUTURE DETAILED INVESTIGATION.	AS ABOVE.
DC ENQUIRED WHETHER THE WESTERN BALLINA ARTERIAL (COLLOQUIALLY REFERRED TO AS THE "MINI-BYPASS") HAS BEEN APPROVED. PB ADVISED THAT COUNCIL HAVE NOT FINALISED THE CURRENT ALIGNMENT,. PB ADVISED THAT THE ROAD PROJECT WAS STILL SUBJECT TO AN EIS. WHAT IS IN THE BASE CASE MODEL IS COUNCIL'S MOST UP-TO-DATE CONSENSUS ON WHAT IS PLANNED FOR THIS BYPASS.	

BICENTENNIAL GARDENS, GALLANS ROAD CYCLEWAY AND ROBERTS CREEK	
ISSUES RAISED / DISCUSSION	**ACTIONS**
CB noted that there is an existing excavated channel (approx. 3m deep by 3m wide) between the sand quarry at the north of the airport and North Creek. The channel is blocked at the western end and does not contribute to draining flood waters from the area. There is a natural watercourse to the north of the man-made drain as well. CB suggested that as part of the scheme for alleviating flooding in North Emigrant Creek, the recommissioning of this channel may be beneficial. It was generally agreed that this was a good idea.	BSC & WBM to investigate.
CB asked how Options 5 and 6 were causing a reduction in impact in Roberts Creek. BC noted that it was an example of the sensitivity of the catchment. TO added that it is also likely to be due to the transition between 2 contour bands, therefore not a significant change.	

NORTH CREEK	
ISSUES RAISED / DISCUSSION	**ACTIONS**
SS noted that the road connection between North Creek Road and Angels Beach Drive is currently under review and may not be required. PB advised that traffic modelling was currently being updated and the report was due soon.	WBM to review base case should Council change the planned infrastructure here

GENERAL MATTERS	
ISSUES RAISED / DISCUSSION	**ACTIONS**
The source dominance of catchment flooding was discussed in detail, with particular interest paid to ocean level rise due to climate change.	
AMcL and CD discussed the ranking of the 1976 storm event. The 1976 storm event is considered to be between 1:50 to 1:100 year. The assessment has changed due to update of historical data.	
TO presented that current modelling of a 200mm rise in ocean levels over the 50 year planning horizon, has now been shown to be conservative, according to the 4^{th} Assessment Report by the IPCC. PB issued a copy of the IPCC summary report (Feb 2007) to all interested attendees.	
Various members disagreed that flooding of certain parts of the catchment was due to the dominant event indicated on the plan presented.	
WBM and BSC highlighted that the plan presented was a combination of design events that does not necessarily resemble any previous floods within the catchment. It was noted that this was a 'worst case scenario' event used for the design event modelling.	

CB ENQUIRED WHETHER THE BASE CASE MODEL IS TO BE ACCEPTED BY THE COMMUNITY, REGARDLESS OF PAST CATCHMENT WORKS AND PLANNING DECISIONS. A DISCUSSION FOLLOWED WHEREBY PB ADVISED THAT THIS CURRENT PHASE OF THE WORKS IS LOOKING AT MITIGATING IMPACTS OF FUTURE DEVELOPMENT, RATHER THAN COMPENSATING FOR PREVIOUS DEVELOPMENT AND INFRASTRUCTURE. HOWEVER, BSC AND WBM NOTED THAT OPTIONS ARE BEING INVESTIGATED TO ADDRESS ISSUES RELATED TO DEADMANS CREEK ROAD AND CONSEQUENT IMPACTS. CD WANTS THE BASE CASE TO NOT JUST LIMIT CUMULATIVE IMPACT TO 50MM BUT TO IMPROVE ON EXISTING FLOODPLAIN CONDITIONS. EXISTING FLOODPLAIN CONDITIONS ARE NOT ACCEPTABLE TO THE CRG AND SHOULD NOT BE THE BASIS FOR IMPACT ASSESSMENT. THE MITIGATION OPTIONS PUT FORWARD IN THIS STUDY SHOULD ADDRESS PRE-EXISTING FLOODING PROBLEMS INCLUDING THE LEVEE EFFECT THAT THE EXISTING PACIFIC HIGHWAY BETWEEN BRUXNER HIGHWAY AND WEST BALLINA EXPERIENCED IN PAST FLOODS.	
CD NOTED THAT DURATION OF INUNDATION WAS AN IMPORTANT CONSIDERATION (AS LONG INUNDATION TIMES MAY LEAD TO OXIDISATION, GRASS KILL, AND BLACKWATER EVENTS).	
AMCL SOUGHT CLARIFICATION REGARDING THE TERMINOLOGY USED FOR FLOODWAYS AND FLOODPLAINS. TO ADVISED THAT A FLOODWAY WAS AN EXCAVATED CHANNEL USED FOR CONVEYANCE OF FLOODWATERS. TO SUGGESTED REFERRING TO THE FLOODWAYS AS EXCAVATED CHANNELS.	
PB ADVISED THAT NO DEVELOPMENT SHOULD OCCUR WITHIN A FLOODWAY. TO NOTED THAT A FLOODWAY WAS LIKELY TO BE A HIGH HAZARD ZONE WITH DEEPER AND FASTER MOVING WATER.	
AMCL ASKED ABOUT THE HAZARD MAPPING. TO STATED THAT HAZARD MAPPING HAD BEEN UNDERTAKEN AS PART OF THE DESIGN EVENT MODELLING PREVIOUSLY PRESENTED. WBM MAY NEED TO UNDERTAKE LOCALISED HAZARD MAPPING FOR ENDS OF FLOODWAYS EVENTUALLY ADOPTED AS PART OF THE MANAGEMENT PLAN.	
CB ENQUIRED WHETHER VEGETATION HAD BEEN CONSIDERED IN ANY OF THE MITIGATION OPTIONS. TO ADVISED THAT THIS WAS A 'FIRST PASS' TO DETERMINE WHICH OPTIONS WARRANTED FURTHER INVESTIGATION, WITH AN ASSUMPTION OF GRASSED SWALES. VEGETATION AND OTHER CONSIDERATIONS WOULD BE INVESTIGATED DURING FUTURE DETAILED INVESTIGATION.	
AMCL STATED THAT THE BALLINA BYPASS REPORT IS INCORRECT AND THAT THERE'S A DISCREPANCY BETWEEN REPORTED AND ACTUAL FLOODING. TO RESPONDED THAT AMCL'S COPY OF THE BALLINA BYPASS REPORT WAS A VERY EARLY VERSION THAT WAS ONLY ISSUED TO HYDER AND THE RTA AND HAS SINCE PROGRESSED. TO HIGHLIGHTED THAT AMCL'S COPY WAS NOT A PUBLISHED DOCUMENT. TO ALSO STATED THAT THE BALLINA BYPASS WAS A SEPARATE PROJECT TO THAT BEING DISCUSSED AT THIS MEETING.	
A FEW MEMBERS EXPRESSED AN INTEREST TO RUN THE 1974 / 1976 FLOOD THROUGH THE EXISTING CATCHMENT (2007 CONDITIONS) TO DEMONSTRATE HOW THE CATCHMENT HAS CHANGED. TO ADVISED THAT A MAP COMPARING THE EXTENTS (AREA) OF FLOODS MODELLED (1974, 1976, 2005, 20 YEAR ARI AND 100 YEAR ARI) COULD BE PRODUCED (MODELLED RESULTS ONLY NOT RECORDED EXTENTS) THAT MAY ASSIST CRG MEMBERS TO DIFFERENTIATE THE FLOOD SIZES.	BSC & WBM TO CONSIDER
CB RAISED THAT THE MODELLING SHOULD BE COMPARING 1976 CATCHMENT CONDITIONS TO PRESENT, AND THAT THE 1976 FLOOD SHOULD BE MODELLED. PB AND TO ADVISED THAT THIS CURRENT STUDY IS LOOKING AT FUTURE DEVELOPMENT ON THE CATCHMENT AND THAT THE 100 YEAR DESIGN STORM IS A MORE EXTREME EVENT THAN THE 1976 EVENT.	

It was agreed by all that further mitigation options were to be investigated with particular emphasis placed on the Deadmans Creek Road and North Emigrant Creek areas.

It was also agreed that a further CRG Meeting would be held following the modelling and issue of the Draft report.

Paul Busmanis closed the meeting at 11:00pm.

MINUTES Ballina Flood Study Update Project – Community Reference Group 4

ATTENDEES: Paul Busmanis (PB) - Ballina Shire Council

Toong Chin (TC) - Department of Environment and Climate Change

Ben Caddis (BC) - BMT WBM Pty Ltd

Colin Beddoes (CB) - Deadmans Creek Road

Bob Boyes (BB) - Teven

Don Cook (DC) - Ballina

Col Dorey (CD) - Ballina

Ken Kaehler (KK) - Tintenbar

Alex McLeay (AM) - "Waverley"

Stephen Smith (SS) - Landpartners

Paul Snellgrove (PS) - Ardill Payne & Partners

APOLOGIES: Brian Smith - Lennox Head

DATE: 25 June 2007

The meeting was opened at 6.30pm by Paul Busmanis. PB thanked attendees for their attendance, interest, and contribution to the project.

BC provided presentation to the meeting showing progress of the flood study work by WBM.

Previous Minutes	
ISSUES RAISED / DISCUSSION	**ACTIONS**
AM asked whether velocities would be shown	Velocity maps and hazard maps
	will be available
DC asked whether the drain along the Woods/Cook boundary was included	Yes. It is noted a small pipe is at the outlet.
Emigrant Creek between Maguires Creek and Duck Creek	
ISSUES RAISED / DISCUSSION	**ACTIONS**
AM Asked why the cross section showing flood levels across the Pacific Highway at West Ballina (at his property) was chosen. Shows flooding on his land, but no cattle have drowned, and no flooding occurs on his land. BC cross section chosen was random, but other sections (max and min can be checked.	BC to check max and min cross sections
CD restated that the cross section confirms that the RTA Highway is a barrier. There is opportunity to correct mistakes (building up of highway) which contributed to 1976 flood paths. What are flood levels without	

the highway? PB flood model will show combined mitigation measures i.e. necessary openings and floodways.	
AM commented there is little value in assessing flood levels without the existing RTA West Ballina highway, as the highway is unlikely to change.	
AM asked whether land north of the current Riverbend development has been filled or will be filled? PB not aware of any filling beyond existing development consent.	
AM asked whether the flood model included the RTA plans for the Smith Drive roundabout? BC not included. PB was aware that planning was being done to "fit" a roundabout and it would be included when complete/available.	BC update model when data available.
BB asked whether bridges in Teven Valley are considered? PB new bridges have wider openings than current bridges.	
AM asked what has been provided for bridging and openings in the Western Arterial? PB a concept design has been completed by consultants (SKM) and this is currently in the flood model. Any changes to the concept design, as a result of this flood study, will need to be included in the road design.	
AM indicated that farmers get affected by floods smaller than the 1:100 year flood, i.e. 1:20 year, and this needs to be considered. BC smaller floods will be assessed as part of the study.	
AM indicated that velocities are affected by tides, and also culverts are tidal. Therefore important to look at this, and smaller flood events. (e.g. Teven Road culverts).	
AM requested definition of floodway, there is some confusion about what defines a floodway. TC there are 3 "hydraulic" categories in defining floodwaters, being floodways, flood storages and flood fringes. Floodways can be man made or natural and are usually defined by their hazard (i.e. velocity and depth). The study can define floodways.	
Deadmans Creek Road and North Emigrant Creek	
ISSUES RAISED / DISCUSSION	**ACTIONS**
CD asked the consequences of removing the bike track, would flood flow paths change? BC flow paths would change.	
CD has the power line road been considered in the model? BC No PB recent access track has not been picked up.	
CB & CD asked why modifications to the cycle track has not been considered in the mitigation measures? BC indicated that changes to the cycle track do not assist in the 1:100 assessments. There may be impacts for lesser floods and this will be investigated.	Assess changes to cycle track for smaller floods.
DC asked why the connection from Emigrant Creek to Fishery Creek did not provide a flood mitigation option? BC said there was small benefit to flood improvement.	TC suggested further Investigation of this option.
CB & CD commented that floodways shown for Cumbalum development (adjacent and parallel to highway) did not consider flow path south of	BC to provide further information/ assessment.

Deadmans Creek road (i.e. need to connect to Roberts Creek)	
General Matters	
ISSUES RAISED / DISCUSSION	**ACTIONS**
DC noted the floodplain is complex. Water floods lower parts and fills, and then drains in another direction.	
CD asked about the model and RTA's comparison between 1D and 2D modelling and >200 mm discrepancy. BC new modelling techniques and new survey etc. leads to improvement with better information.	
AM asked about the assessment of tide versus storm surge. Storm surge has much greater impact. BC the normal tidal cycle is included in the model and storm surge is added when considering raised ocean levels.	
CD & AM queried information being provided by RTA regarding flooding. PB explained that the RTA model for the Ballina Bypass has been included in the BSC flood model, along with other development scenarios applicable to BSC. The outcomes and outputs will therefore be different to the RTA.	
CD questioned the base case model not being good enough. That is, it did not rectify the build-up of the West Ballina Pacific Highway or the constriction at Emigrant Creek, which was shown to be the problem in the 1976 flood.	

PB the new modelling was re-looking at the whole picture, as it is now and what is proposed for the future. Mitigation measures need to be provided to reduce flood impacts. The comparisons between the 1976 flood and the base case will be made.	BC prepare flood maps.

MINUTES FROM MEETING 5

ATTENDEES:	Paul Busmanis (PB) – Ballina Shire Council (BSC) Toong Chin (TC) – Department of Environment & Climate Change (DECC) Ben Caddis (BC) - WBM Pty Ltd David Anderson (DA) - Cumbalum Colin Beddoes (CB) – Deadmans Creek Road Don Cook (DC) – Ballina Col Dorey (CD) – Ballina John Hayter (JH) – Tintenbar Ken Kaehler (KK) – Tintenbar Serge Killingbeck (SK) - Ballina Environment Society John Hayter (JH) - Tintenbar Peter Moodie (PM) - Ardill Payne & Partners Steven Smith (SS) - Landpartners Pty Ltd Terry Woods (TW) - Ballina
APOLOGIES:	
DATE:	16 August 2007
SUBJECT:	**Ballina Flood Study Update Community Reference Group Meeting 5** **Base Case modelling and possible mitigation options**

The meeting was opened at 6:40pm by Paul Busmanis. PB thanked the attendees for their continued interest and contribution toward the project.

BC provided a presentation to the meeting showing progress of the flood study work.

Previous minutes - no comment.

Note that the order of items below does not correspond to the order that each item was raised.

EMIGRANT CREEK BETWEEN MAGUIRES CREEK AND DUCK CREEK	
ISSUES RAISED / DISCUSSION	**ACTIONS**
CD restated that the reconstruction of the Pacific Highway by the RTA in the 1960's (east of Emigrant Creek, West Ballina) is a flood barrier and should not be there. Emigrant Creek bridge should be fixed (widened).	
The flood events of the 70's, being 1:20 yr and/or 1:50 yr events, caused major flooding. A repeat of these events with current development would be worse.	
WBM will model improvements (widening) of Emigrant Creek bridge for inclusion in the study report.	WBM
CD said further that the Pacific Highway should be lowered. Existing flood modelling shows the benefit of this due to the difference in water levels north and south of the highway.	

DEADMAN'S CREEK ROAD AND NORTH EMIGRANT CREEK	
ISSUES RAISED / DISCUSSION	**ACTIONS**
CD questioned the RTA's Ballina Bypass having a 300 m flood relief opening and the Cumbalum Way having a 90 m opening (culverts).	

BC EXPLAINED THAT ALTHOUGH THE CUMBALUM FLOOD RELIEF BRIDGE ON THE PROPOSED RTA BALLINA BYPASS HAS A WIDER OPENING, THE RTA'S CUMBALUM SERVICE ROAD IS RESTRICTING FLOW, HENCE, CONTROLLING FLOW THROUGH THE AREA. THE FLOW OVER THE CUMBALUM SERVICE ROAD IS WIDER, BUT SHALLOWER THAN THROUGH THE DEADMANS CREEK ROAD CULVERTS. ADDITIONALLY, THE FLOW THROUGH THE CULVERTS HAS A HIGHER VELOCITY AND THERE IS ALSO FLOW ACROSS THE PROPOSED CUMBALUM WAY. THEREFORE, A COMPARISON OF JUST THE WIDTH OF OPENINGS IS NOT AN APPROPRIATE COMPARISON.	
CD QUESTIONED THE FLOW CAPACITY ACROSS DEADMAN'S CREEK ROAD BECAUSE OF THE FILLING FURTHER EAST, ALONG THE FOOTHILLS AND THE CHANNEL OF THE OLD ROBERTS CREEK.	
CB SAID THERE WAS A NEED TO MAKE THE SITUATION BETTER AND NOT JUST DEAL WITH WHAT WE HAVE. CB WAS DISSATISFIED WITH THE LACK OF ACTION AND RESPONSE TO THE IMPACTS OF THE CUMBALUM (BALLINA HEIGHTS) DEVELOPMENT. CB SAID THERE WAS A NEED TO GO BACK TO ORIGINAL CONDITIONS AS A BASE, NOT THE RECENT DEVELOPMENT.	
PB EXPLAINED THAT THE PURPOSE OF THE MODEL WAS TO ALSO LOOK TO THE FUTURE AND TO MAKE SURE FLOOD PLANNING ACCOMMODATED FUTURE DEVELOPMENT.	
DA SAID THAT THE PROPOSED DEVELOPMENT AT CUMBALUM (FILLING OF PART OF EMIGRANT CREEK VALLEY) SHOULD HAVE BEEN ADDRESSED PRIOR TO NOW.	
PB EXPLAINED THAT EARLY 1D FLOOD MODELLING WAS DONE, HOWEVER IT IS NOW BEING UPDATED TO THE 2D MODELLING WHICH IS BEING DONE BY THIS STUDY. THE DESIGNS FOR THE DEVELOPMENT ALSO CHANGE.	
JH SAID THE PRIORITY WAS FOR LOCAL FLOOD WATERS TO GET TO THE OCEAN BY THE MOST DIRECT ROUTE, BEFORE THE UPSTREAM RICHMOND RIVER FLOOD WATERS ARRIVE AT BALLINA.	
DC SAID THE CUMBALUM DEVELOPMENT, WITH NEW HOUSING, WAS CONTRIBUTING TO INCREASED RUN OFF.	
CB SAID HE BELIEVES THAT A 40% INCREASE IN RUN OFF OCCURS AND PROPOSED INFILTRATION IS INEFFECTIVE.	

FISHERY CREEK, LITTLE FISHERY CREEK AND THE CANAL

ISSUES RAISED / DISCUSSION	ACTIONS
TW SAID THE FLOODWAY SHOWN ADJACENT RIVEROAKS WAS NOT NECESSARY. THE LAY OF THE LAND INDICATED ONLY A SMALL AREA OF LAND NEEDED TO BE DRAINED, AND THE FLOODWAY WAS OVERSIZED. EXTENDING THE FLOODWAY NORTH ONTO HIS LAND WON'T HAPPEN.	
PB EXPLAINED THE FLOOD MODEL WAS BEING USED TO SHOW NECESSARY FLOOD ESCAPE ROUTES FOR THE 1:100 YEAR EVENT. THE FLOODWAY WAS NOT ADDRESSING LOCAL DRAINAGE.	
TW ASKED ABOUT THE DREDGING / CLEARING OF FISHERY CREEK. BC SAID THAT MODELLING SHOWED THAT MINOR IMPROVEMENTS WERE ACHIEVED BUT OVERALL THE EFFECTIVENESS OF THE DREDGING OPTION WAS MINIMAL.	

CYCLEWAY

ISSUES RAISED / DISCUSSION	ACTIONS

BC EXPLAINED THAT THE MODEL WAS USED TO DO AN ASSESSMENT OF IMPROVING THE EAST - WEST DRAINAGE WHICH CROSSES THE CYCLEWAY ROUTE. AN OPENING (EQUIVALENT TO 25 METRES OF CULVERS) COMBINED WITH LOWERING THE CYCLEWAY BY UP TO 300MM SHOWED BENEFITS IN REDUCING FLOOD HEIGHTS TO THE WEST, BUT INCREASING FLOOD HEIGHTS TO THE EAST. THIS WILL BE RECORDED IN THE FLOOD STUDY REPORT AS AN OPTION WHICH SHOWS MERIT BUT NEEDS INVESTIGATION TO DETERMINE FEASIBLE OPTIONS. (NEED TO CHECK SERVICE LOCATIONS ETC).	
DC SAID THE HEIGHTS OF THE CYCLEWAY AND THE HIGHWAY WERE CRITICAL IN ASSESSING THIS OPTION.	

DREDGING

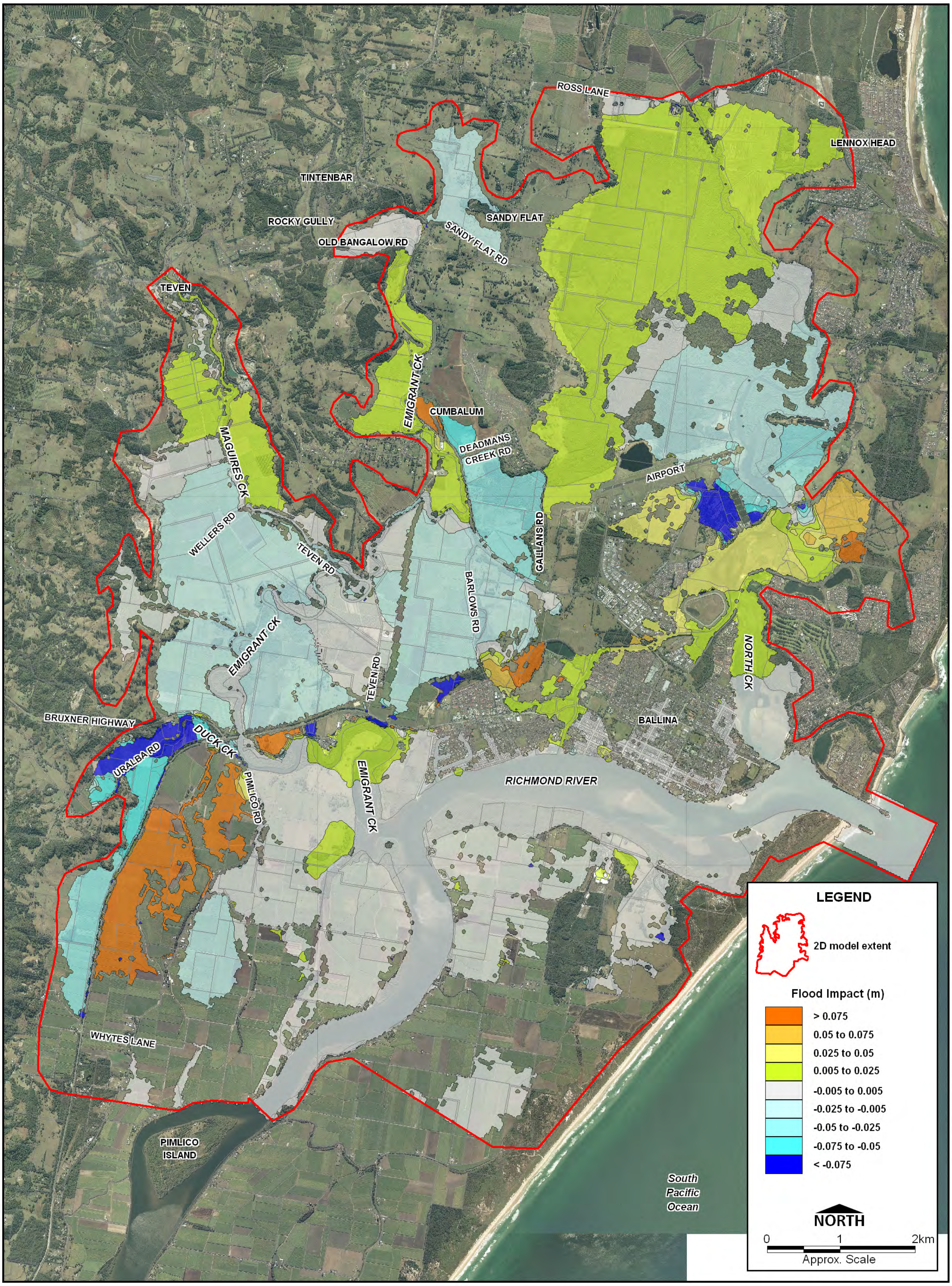
ISSUES RAISED / DISCUSSION	ACTIONS
BC PRESENTED INFORMATION REGARDING A FLOOD MITIGATION OPTION WHICH DEALT WITH DREDGING PARTS OF THE RICHMOND RIVER AND NORTH CREEK. (THIS OPTION WAS REQUESTED FOR INVESTIGATION BY COUNCIL'S CIVIL COMMITTEE). THE RESULTS SHOWED THAT FLOODING WORSENED IN AND AROUND BALLINA ISLAND WHEN A STORM / SURGE (CYCLONE CONDITION) WAS ASSESSED. BC EXPLAINED THAT THE OPTION HAD NOT BEEN ADOPTED AS PART OF THE MITIGATION STRATYEGY.	

GENERAL MATTERS

ISSUES RAISED / DISCUSSION	ACTIONS
CD ASKED ABOUT THE ROLES AND RESPONSIBILITIES OF LOCAL GOVERNMENT AND STATE GOVERNMENT WITH RESPECT TO ACTION OR INACTION ABOUT FLOODING AND OUTCOMES OF FLOOD STUDIES.	
TC EXPLAINED THE NSW STATE GOVERNMENT ROLE AND THE REQUIREMENT OF COUNCIL'S TO FOLLOW THE STEPS IN THE FLOODPLAIN DEVELOPMENT MANUAL. THIS STUDY AND THE CONSULTATION WITH THE CRG IS PART OF THE PROCESS (STEPS).	
PB EXPLAINED THAT MOST OF THE FLOOD STUDY UPDATE HAS BEEN COMPLETED AND IT WAS UNLIKELY THAT ANOTHER CRG WOULD BE HELD PRIOR TO THE PUBLIC EXHIBITION OF THE REPORT. ALL GROUP MEMBERS ARE ENCOURAGED TO COMMENT ON THE FLOOD STUDY UPDATE WHEN ON PUBLIC EXHIBITION. THE CRG WILL HOWEVER CONTINUE TO FOLLOW-UP ON THE FLOOD STUDY UPDATE AND WITH FURTHER STEPS OF THE PROCESS IE MANAGEMENT STUDY AND MANAGEMENT PLAN.	

Paul Busmanis closed the meeting at 9:00pm.

APPENDIX F: GALLANS ROAD CYCLEWAY ASSESSMENT FIGURES

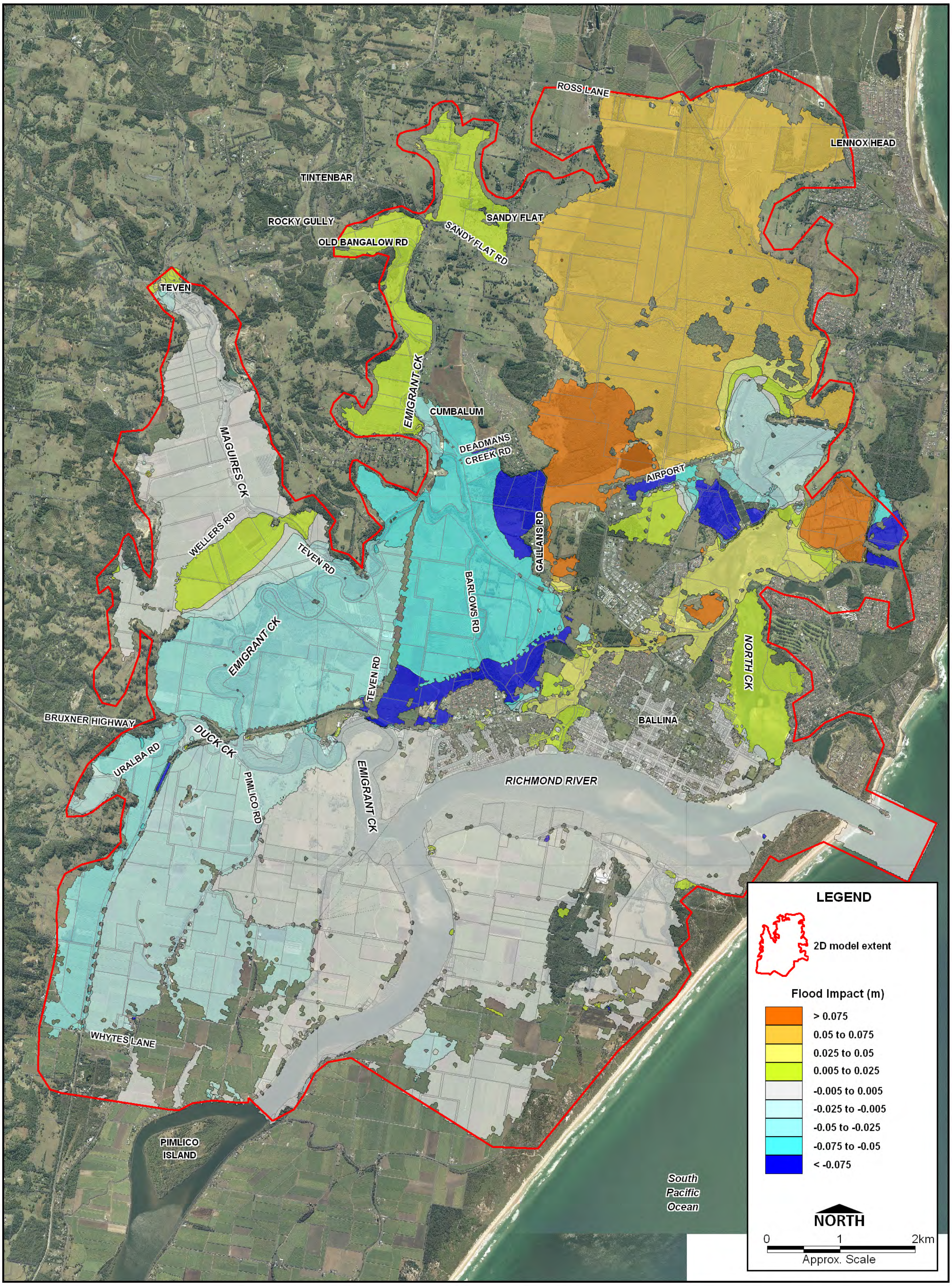


Gallans Road Assessment Impact Results
5 Year ARI Combined Event

Figure F-1

I:\B15219_I_BRH Ballina Flood Study_LEH\DRG\FLD_061_070815_BC_5yABC_cycle_flood_difference.wor

BMT WBM

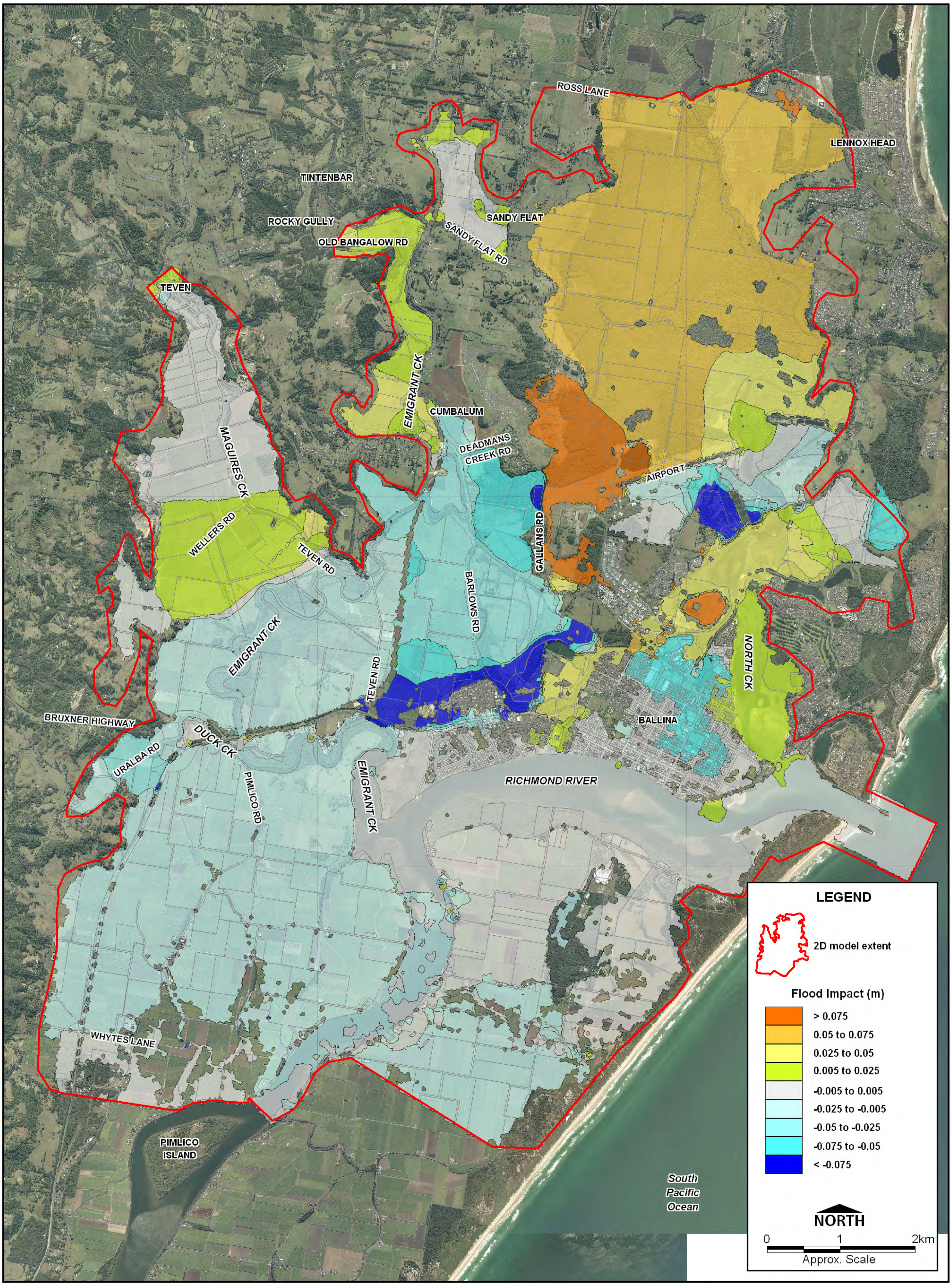


Gallans Road Assessment Impact Results
20 Year ARI Combined Event

Figure F-2

I:\B15219_I_BRH Ballina Flood Study_LEH\DRG\FLD_060_070815_BC_20yABC_cycle_flood_difference.wor

BMT WBM

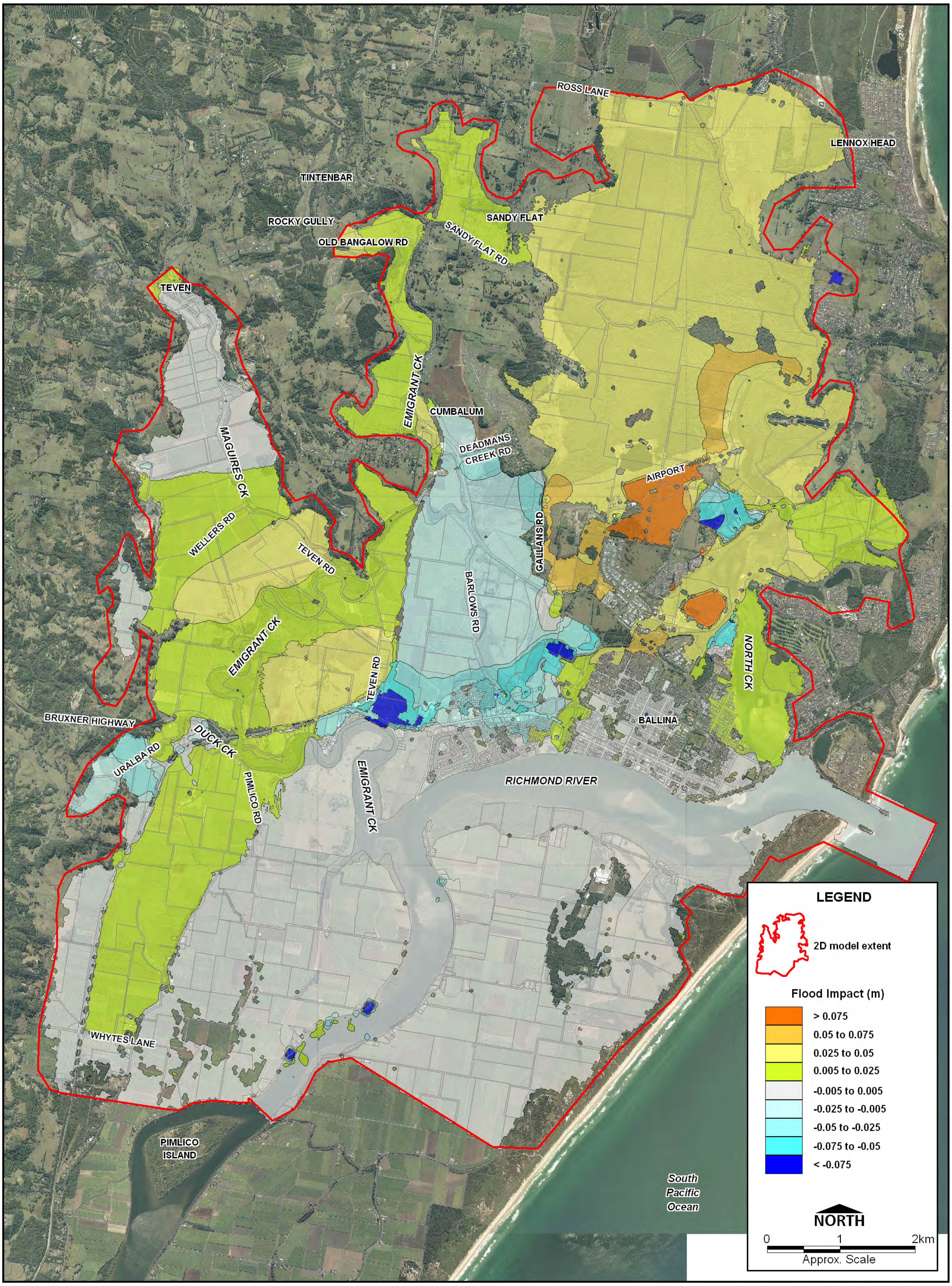


Gallans Road Assessment Impact Results
50 Year ARI Combined Event

Figure F-3

I:\B15219_I_BRH Ballina Flood Study_LEH\DRG\FLD_059_070815_BC_50yABC_cycle_flood_difference.wor

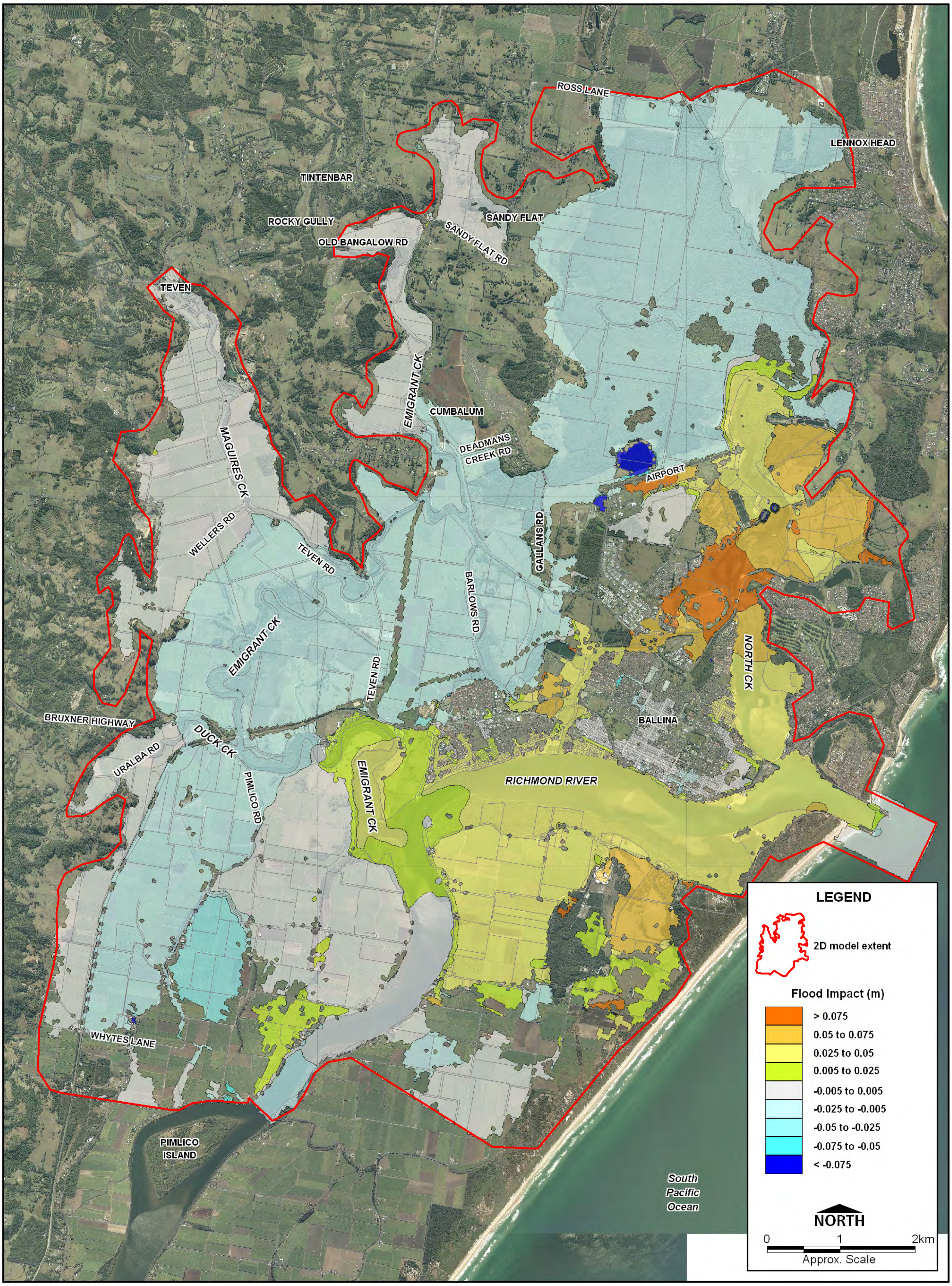
BMT WBM



Gallans Road Assessment Impact Results
100 Year ARI Combined Event

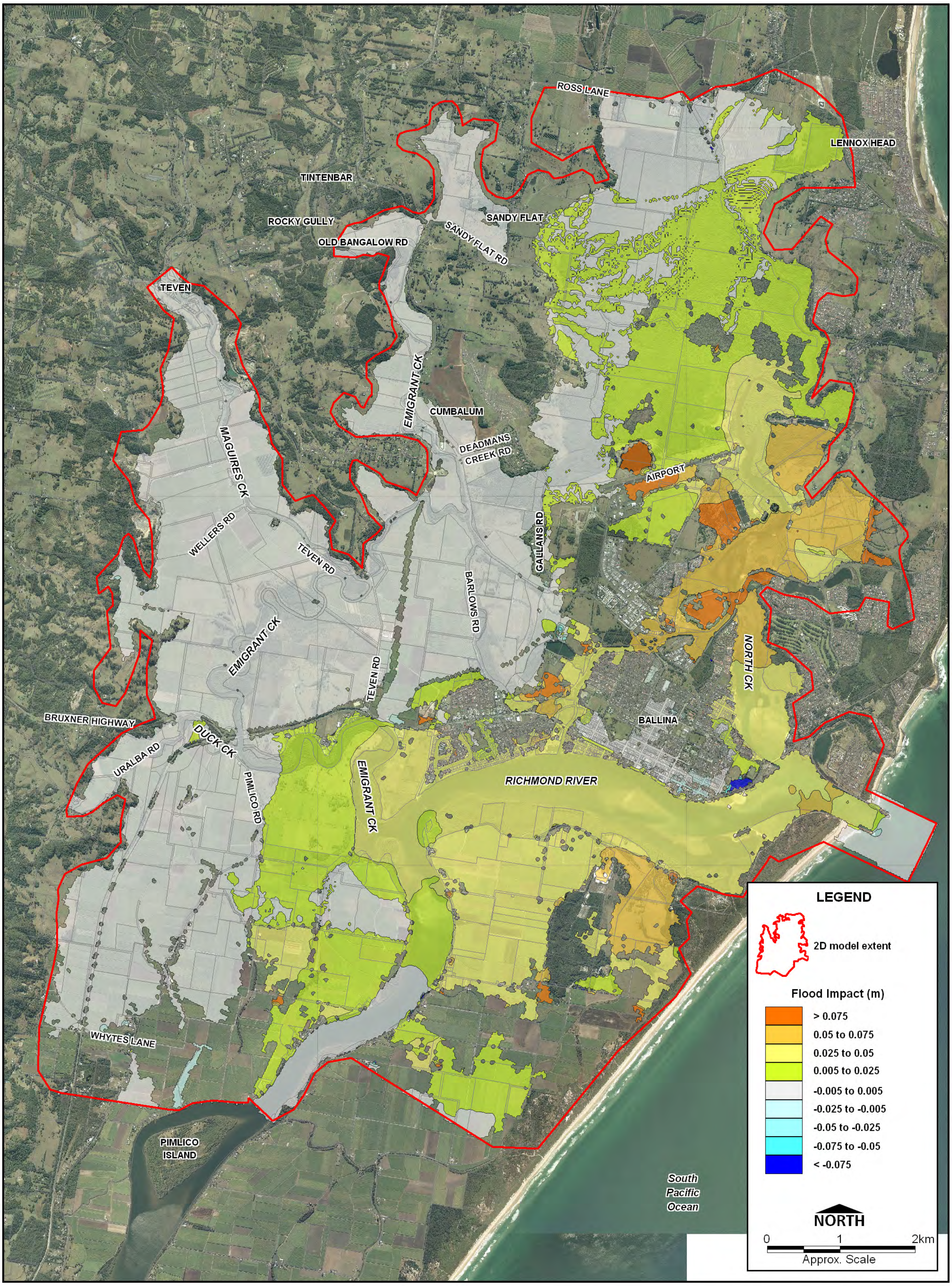
Figure F-4

APPENDIX G: DREDGING ASSESSMENT FIGURES



Dredging Assessment Impact Results
20 Year ARI Local Catchment Dominating Event

Figure G-1

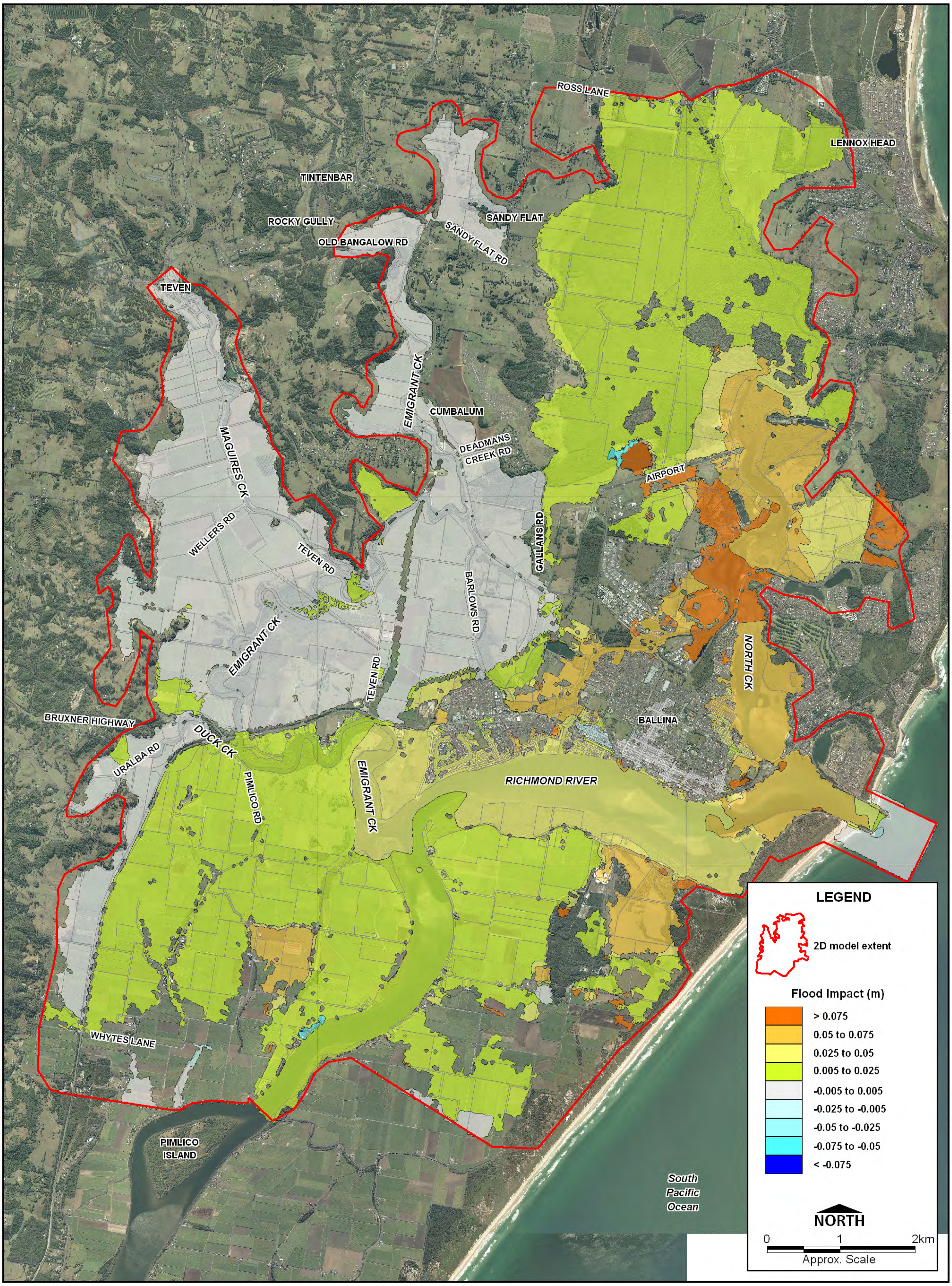


Dredging Assessment Impact Results
20 Year ARI Richmond River Dominating Event

Figure G-2

I:\B15219_I_BRH Ballina Flood Study_LEH\DRG\FLD_046_070809_DA_20yB_flood_difference.wor

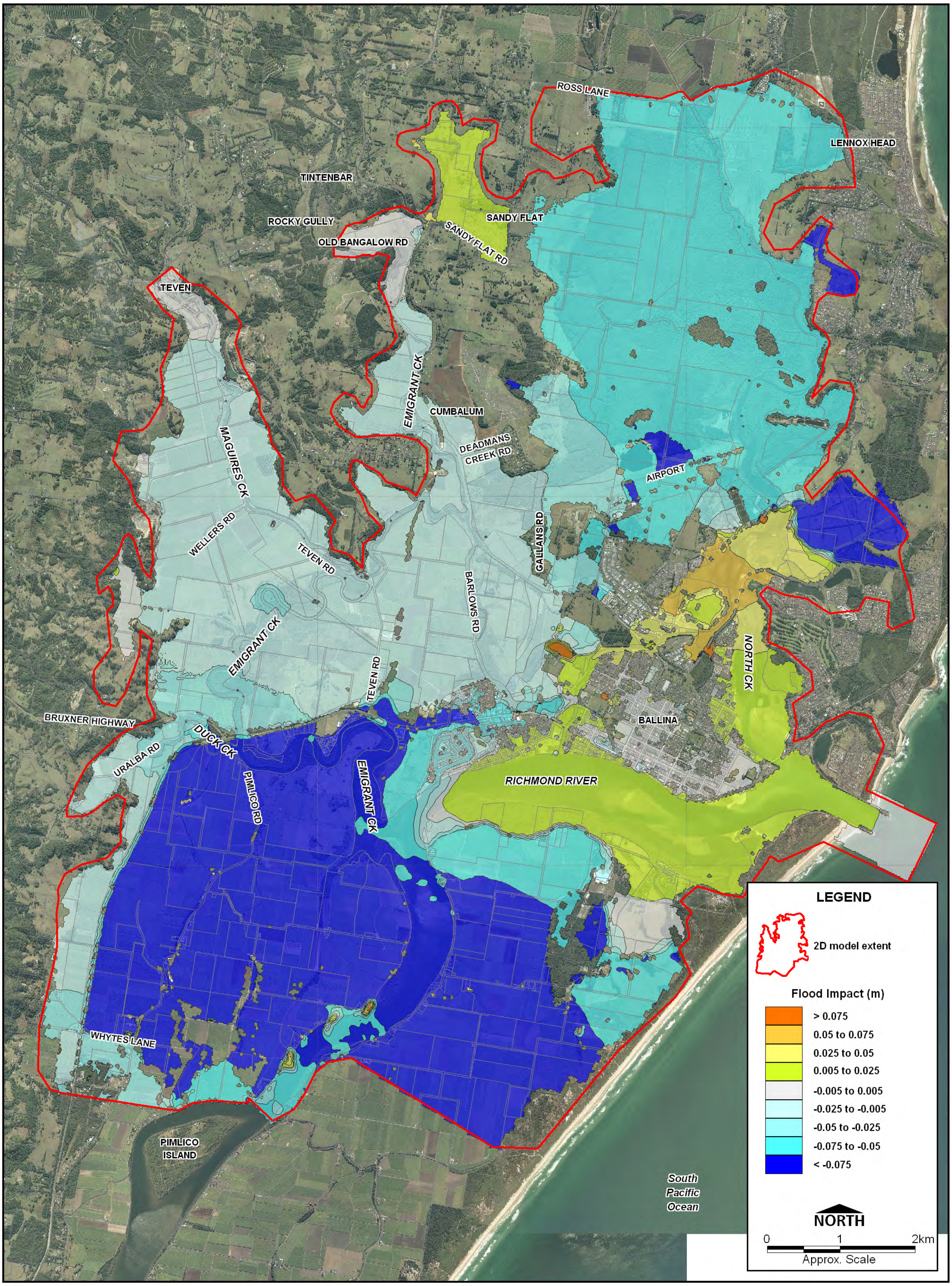
BMT WBM



Dredging Assessment Impact Results
20 Year ARI Ocean Dominating Event

Figure G-3

I:\B15219_I_BRH Ballina Flood Study_LEH\DRG\FLD_047_070809_DA_20yC_flood_difference.wor

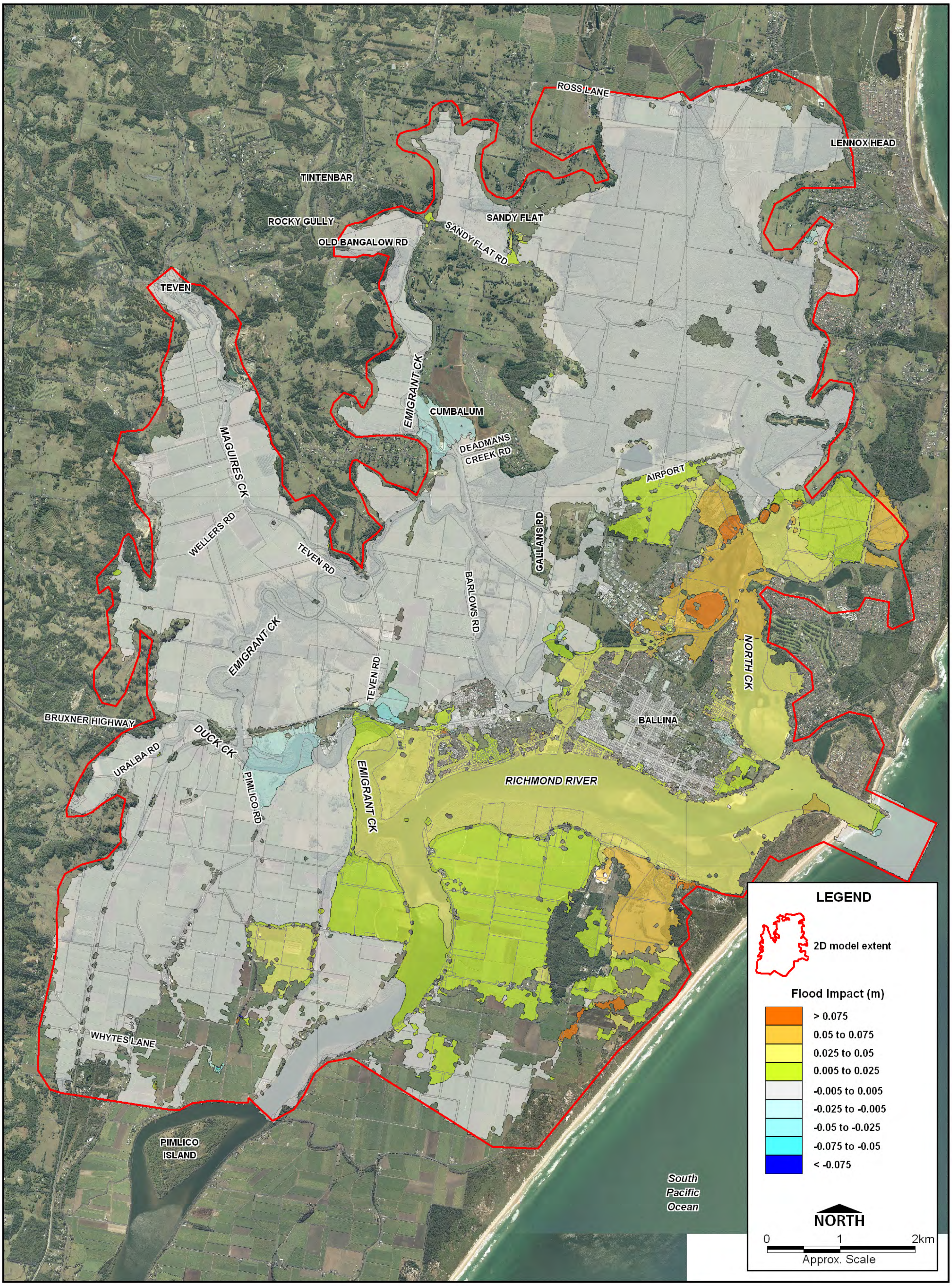


Dredging Assessment Impact Results
100 Year ARI Local Catchment Dominating Event

Figure G-4

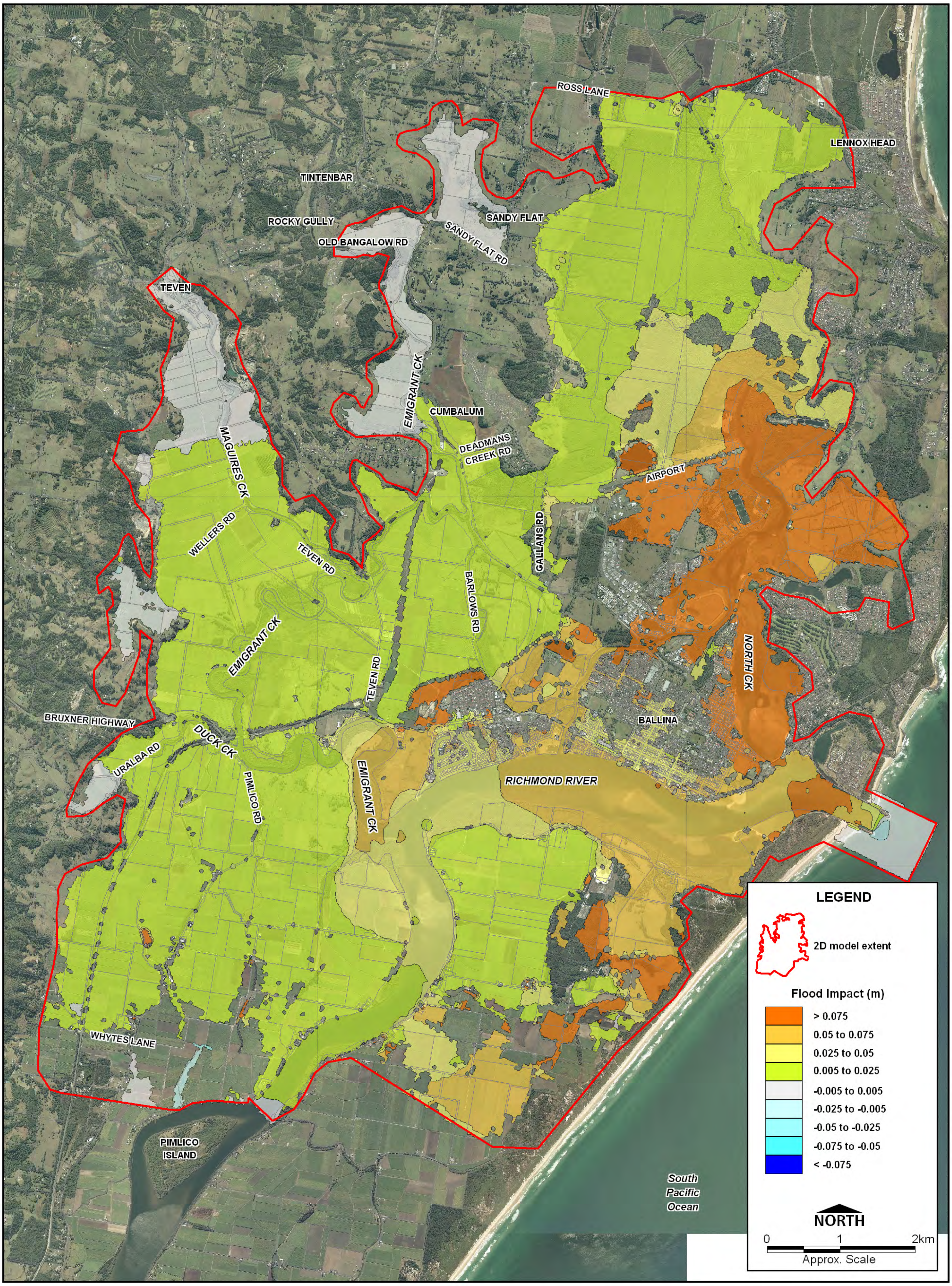
I:\B15219_I_BRH Ballina Flood Study_LEH\DRG\FLD_049_070809_DA_100yA_flood_difference.wor

BMT WBM



Dredging Assessment Impact Results
100 Year ARI Richmond River Dominating Event

Figure G-5



Dredging Assessment Impact Results
100 Year ARI Ocean Dominating Event

Figure G-6

I:\B15219_I_BRH Ballina Flood Study_LEH\DRG\FLD_051_070809_DA_100yC_flood_difference.wor

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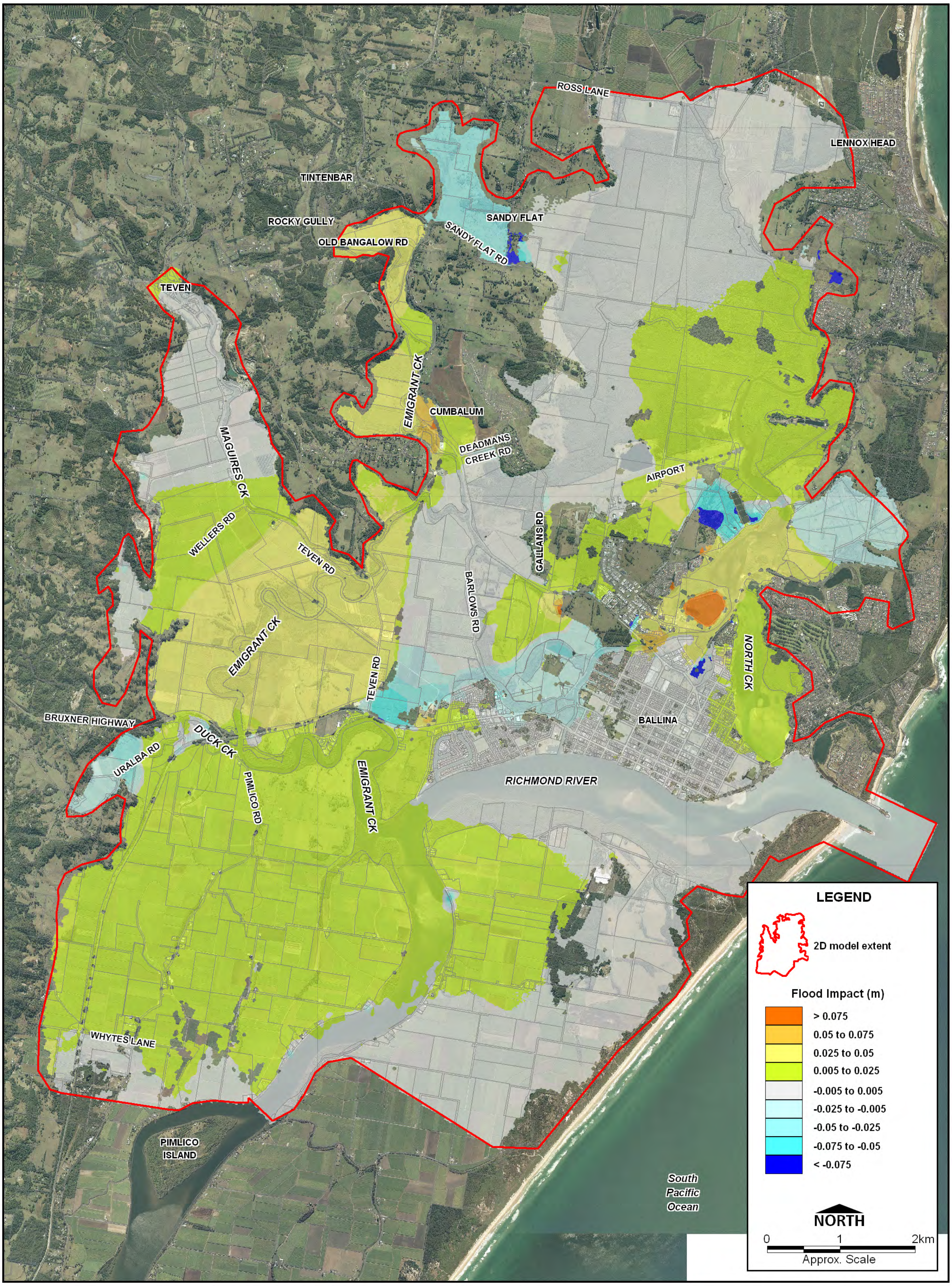
APPENDIX H: WIDENING OF THE PACIFIC HIGHWAY BRIDGE ASSESSMENT FIGURES



Impact Results for 50% Enlargement of Emigrant Creek Bridge
100 Year ARI Combined Event

Figure H-1

I:\B15219_I_BRH Ballina Flood Study_LEH\DRG\FLD_086_071206_BC_100yABC_EmigrantCkBdgEnlargement.wor

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