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BRISBANE WATER FORESHORE FLOOD STUDY

Report Prepared for

Gosford City Council and
Department of Environment and Climate Change

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Cardno (NSW/ACT) Pty Ltd

ABN 95 001 145 035
Level 9, The Forum
203 Pacific Highway
St Leonards NSW 2065
Australia
Telephone: 02 9496 7700
Facsimile: 02 9499 3902
International: +61 2 9496 7700
sydney@cardno.com.au
www.cardno.com.au

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1. INTRODUCTION

1.1 NSW Flood Prone Land Policy

Gosford City Council (GCC) is responsible for local planning and land management in the Brisbane Waterway foreshore area and proposes to develop a floodplain risk management plan in accordance with the NSW Flood Prone Land Policy for the foreshore of Brisbane Water.

The State Government's (Department of Environment and Climate Change, DECC) Flood Policy is directed at providing solutions to existing flooding problems in developed areas and ensuring that new developments are compatible with the flood hazard and do not create additional flooding problems in other areas. Under the Flood Policy the management of flood prone land remains the responsibility of local government with the State Government subsidising flood mitigation works and measures to alleviate existing problems and providing specialist technical support to assist councils to discharge their floodplain management responsibilities.

The State Government's Floodplain Development Manual (2005) has been prepared to assist councils in formulating management plans through the Floodplain Risk Management Process as outlined in ***Section 2*** of the Manual. ***Appendix C*** of the Manual outlines the application of the Process in a series of stages as presented below: -

1. Establish a Floodplain Risk Management Committee
2. Data Collection
3. Flood Study
4. Floodplain Risk Management Study
5. Floodplain Risk Management Plan
6. Plan Implementation
7. Review of Plan

The brief developed by GCC and DECC was to undertake the work necessary for Stage 3 - Flood Study, for the Brisbane Water estuary from Half Tide Rocks in the south to Gosford City in the north, see Figures 1.1 and 1.2. Note that the related catchment areas extend well beyond the waterway itself and that the outcomes of this study relate to the specific foreshore of Brisbane Water and not to the tributary creeks.

Following a request for tenders Gosford City Council and the Department of Environment and Climate Change commissioned Cardno Lawson Treloar (CLT) to undertake this study.

This report describes the study approach, data and modelling systems applied to this study together with the outcomes of the analyses.

1.2 Background

The Brisbane Water waterway is the most notable geographic feature of the Gosford region and is situated on the Central Coast about 50km north of the Sydney Harbour Bridge. The waterway is a tidal estuary and its locality is shown on Figure 1.2. Half Tide Rocks can be considered as the entrance to Brisbane Water (see Figure 2.1).

Topographically, Gosford (like most of the Central Coast) is formed of ridges and valleys largely vegetated with forest and bush. The eastern part of Gosford faces the Tasman Sea with a number of coastal lagoons along the shoreline. As can be expected from such topography, there are numerous small catchments that drain into the Brisbane Water waterway via small creeks. Narara and Erina are the two major creeks draining large catchment areas to the north and northeast of Brisbane Water, respectively, with many smaller creeks such as Kincumber Creek having locally important influences.

Most of the urban development on land directly fronting Brisbane Water occurred during the middle part of the last century. Many such developments were placed on low-lying marshlands and swamps filled just enough to build subdivisions. Now, almost all such developments face numerous flooding and drainage issues due to their flatness and being very close to high tide level in Brisbane Water. Almost all the low-lying areas in foreshore towns like Davistown, Empire Bay, Ettalong, Umina, and Woy Woy are affected by potential water level rises in Brisbane Water as a result of Greenhouse related climate change.

In order to manage flooding and tidal inundation risks in such areas, Council has prepared numerous floodplain management plans for the tributaries of Brisbane Water in accordance with the NSW Government's Floodplain Risk Management Process. To date the technical investigations or flood studies underlying these plans have assumed 1.95mAHD as the 1% AEP flood level in Brisbane Water. This level is based on the observed levels in Brisbane Water during the 1974 ocean storm event and has been used as the basis for planning levels in management areas, (Department of Public Works, 1976).

Council is now undertaking an investigation to establish more reliable estimates of the 1% AEP flood level throughout Brisbane Water in order to base its planning controls on more reliable data. This study has investigated all possible natural mechanisms that can impact on water levels in Brisbane Water, as well as the effects of man-made structures, such as culverts and the Main Northern Railway bridges across the entrances to Fagans and Pheagans Bays. Generally, the outcomes of this study will also provide realistic downstream boundary conditions for individual creek studies.

Locally generated winds and wind waves also cause water levels in Brisbane Water to rise substantially at the shorelines as a result of wind set-up and wave run-up (there being very little wave set-up arising from these short period waves). Hence this study has identified areas around the Brisbane Water foreshore that may not only be subject to flooding from increased Brisbane Water levels, but are also subject to the impact of wave run-up.

Ocean swell also causes a wave set-up that develops within Broken Bay where waves begin to break and propagates upstream past Ettalong into Brisbane Water. This phenomenon occurred in May 1974 and caused the highest recorded water levels in the waterway. Hence it was important also to consider ocean storms with their magnitude and spatial variation in wave set-up throughout the estuary. In this context joint occurrence between severe ocean storms and high rainfall over the whole catchment was not considered very likely and severe ocean storms were simulated without including runoff, similar to the May 1974 storm.

Additionally, especially within Broken Bay and on the Gosford Broadwater, local wind setup has been considered. At Ettalong itself, the more frequent elevated water levels may be caused by such processes as coastal trapped waves and much of that information is embodied within the long term data from the Fort Denison tide gauge.

Finally, although rare, tsunamis have been recorded in the central coast region of Australia and it was important to present the available data for completeness. Although not recorded in Brisbane Water, the highest tsunami wave (trough to crest) recorded at Fort Denison was 0.8m in May 1960 and was caused by an earthquake in Chile (Bureau of Meteorology, 1998). A similar but lower wave would have propagated into Brisbane Water.

This Brisbane Water Foreshore Flood Study (BWFFS) has defined flood behaviour in Brisbane Water for various design events taking into account rainfall runoff from the whole catchment, elevated ocean levels and local winds (waves and wind set-up), as well as discussing other processes.

1.3 Council's Floodplain Risk Management Committee

Gosford City Council has set up a Floodplain Risk Management Committee (the Committee or FRMC) in accordance with the New South Wales Government's Floodplain Development Manual - April 2005 (The Manual). The Committee includes a Councillor representative and officials from Council, Department of Environment and Climate Change (DECC), State Emergency Service (SES), NSW Department of Primary Industries - DoPI (formerly NSW Fisheries), Central Coast Law Society, Central Coast Real Estate Institute and also from local Community organisations. The FRMC assists Council in the development and implementation of floodplain risk management plans and will be involved in the management/implementation of this study.

The Technical Sub-Committee (TSC) of FRMC comprises of officials from Council and DECC, and focuses on technical, administrative and financial (grant funding) matters for projects like this one. The FRMC has a key role in steering the overall direction of this project and has been involved in the review of the study results made available throughout the study duration.

1.4 Objectives

The main objective of this study has been to determine water levels in Brisbane Water for the full range of flood and ocean events that can occur due to the various natural physical processes, taking joint occurrence issues into account to some extent. The flooding behaviour can be influenced, either separately, or by a combination of, catchment rainfall runoff flooding, rainfall directly onto Brisbane Water, elevated ocean levels, local winds and, to a minor extent, the condition of the ocean entrance channel near Ettalong.

The study has been undertaken in two parts. Part 1 provides design still-water flood levels and the wind-wave climates in Brisbane Water in consistent, average recurrence interval (ARI) terms. Part 2 combines design Brisbane Water flood levels with specific local bathymetric information and details of specific foreshore structures to estimate the potential elevated design flood levels due to wind set-up and wave run-up at any location around the Brisbane Water foreshore. This involved the selection of five types of edge-treatment (each with two wall crest levels) at each general location and the estimation of wave run-up height at each ARI, see Section 8 and Appendix J. In many residential areas it is possible that re-development will seek to change existing edge-treatments. Hence the selected range will provide a basis for Development Application approvals and conditions. The effect on wave run-up of distance inland from the edge of Brisbane Water has been considered also.

Where the floodplains on the Brisbane Water foreshore are developed, the developments and their occupants may be at risk from both catchment floods in creeks as well as inundation from elevated water levels in Brisbane Water.

The outcomes from this study include: -

- **Public Participation:** Community consultation is highly important in the whole process leading to the development of a sustainable floodplain risk management plan and is an essential component of the flood study. An information leaflet and questionnaire were prepared and delivered to residents, whose properties were considered to be lower than 2.5m AHD (see Figure 4.2) and potentially at risk of inundation.

- **Brisbane Water Design Foreshore Flood Levels:** This Study has determined design still water levels and flood extents for a full range of flood events for existing catchment conditions. All contributing physical processes of wind, rain, waves and tide were considered. Cardno Lawson Treloar, as part of the Brisbane Water Estuary Processes

Study, have set up and calibrated hydrologic and hydrodynamic models of the catchment and waterway, respectively, as well as fine grid wave models of sub-regions of the waterway. This calibration process involved some months of work and hence having these models 'ready-to-go' helped the study schedule.

- **Hydraulic and Hazard Categorisation:** To achieve effective and responsible floodplain risk management, the Brisbane Water floodplain was divided into areas that reflect the different hydraulic impacts of development activity on flood behaviour and the hazard impact of flooding on development and people.

- **Floodplain Risk Management Measures:** This study forms the basis for a future Brisbane Water Foreshore Flood Risk Management Study and Plan, where detailed assessment of flooding risk management measures and a damages assessment will be undertaken for all urban settlements along the foreshore of Brisbane Water. Cardno Lawson Treloar have undertaken many Floodplain Risk Management Plans and undertook this study keeping those future needs in mind.

2. STUDY AREA

The study area comprises Brisbane Water and the corresponding catchment area that drains into Brisbane Water, see Figure 2.1. The entrance (opening) to the sea at Half Tide Rocks was considered to be the downstream extent of the study area.

The catchment area is shown also on Figure 2.1 and the extent of the study area for which hydraulic analysis was required included Brisbane Water and the foreshore areas affected as the water level in Brisbane Water rises. The extent of the upstream and downstream boundaries for the hydraulic modelling was agreed between Council and Cardno Lawson Treloar prior to the commencement of the study and following a joint site reconnaissance of the study area in May 2006. Note that the downstream boundary of the Brisbane Water Delft3D model extends well seaward of Broken Bay. This is important so that ocean swell effects, which contribute to elevated levels in the waterway, could be included in a physically realistic manner. Some extent of the downstream reaches of Narara and Erina Creeks was included also; these two creeks provide some of the larger flood flows to Brisbane Water and hence realistic introduction of those flows to the system helped to develop realistic local area levels. This was especially the case for Narara Creek which discharges to Fagans Bay, the natural entrance of which is partially closed by the Main Northern Railway causeway.

Cardno Lawson Treloar have a verified MIKE-11 model of the Hawkesbury River, Pittwater and Brisbane Water areas. This tool is important for developing suitable tidal boundaries for the more complex model of Brisbane Water, but which excludes the Hawkesbury River and Pittwater, yet requires realistic boundary information for those waterways.

3. STUDY APPROACH

The investigations were undertaken as a progressive series of tasks as outlined below.

3.1 Compilation and Review of Available Information

Cardno Lawson Treloar compiled and reviewed all information that is pertinent to the Study. A preliminary list of available data and previous reports was provided with Council's study Brief. Cardno Lawson Treloar contacted relevant authorities and other sources for the purposes of data compilation [for example: Council, Department of Commerce (Manly Hydraulics Laboratory), DNR, Bureau of Meteorology, local SES, local newspapers and historical societies]. Nevertheless, Cardno Lawson Treloar held most of the available information, including tidal record data at all the available monitoring sites within the waterway.

Site reconnaissance was undertaken in the company of Council and DECC officers on the 9th May 2006 to develop an appreciation of all significant factors and works that may affect flood behaviour. This site inspection provided an opportunity to discuss the project with Council's officers and for them to advise Cardno Lawson Treloar of some specific issues and their histories.

Figure 3.1 shows a small local flooding control structure at Empire Bay (upper) and another site at Davistown on the Cockle Channel (lower). The Empire Bay site can be affected by very high tides - possibly a spring tide and some meteorological forcing (now reduced as a result of the one-way flood-gate on the seaward side of the drainage pipe), and the Davistown site was inundated during the May 1974 ocean storm event.

3.2 Acquisition of Additional Data

Historical flood behaviour and other relevant information relating to past events help to assist in the set-up and calibration of the numerical models utilised in this study. A resident survey of historical flooding experience was prepared and distributed to residents who were identified to be potentially affected by foreshore flooding. These responses were then collated and summarised for incorporation into the study.

Further to the available topographic and bathymetric data provided by GCC, accurate definition of levels of low-lying areas such as Davistown, Empire Bay and Woy Woy was required. To this end, Cardno Lawson Treloar, with the direction of Council, commissioned ground survey in the required areas.

3.3 Design Event Modelling for Existing Conditions

A number of types of water level investigation have been undertaken. They include: -

- Analyses of recorded water level data,
- Hindcast investigations of the May 1974 storm event, and
- Simulation of both catchment flood and ocean storm events with selected approximate return periods (that is, from 5 to 200 years average recurrence Interval (ARI) events, plus the Probable Maximum Flood (PMF) and the equivalent ocean storm, taken to be described by estimated 10,000-years ARI storm elevated ocean level, wind and wave parameters.

The calibrated hydrodynamic model developed for this study was coupled with a whole of Brisbane Water SWAN wave model to allow the simultaneous simulation and interaction of hydrodynamic (tide and wind forcing) and wave processes (included as spatially and temporally varying radiation stress fields and manifested as spatially and temporally varying wave set-up) throughout the estuary.

For the purposes of this study, the design Brisbane Water flood level investigations included the 0.5% AEP, 1% AEP, 2% AEP, 5% AEP, 10% AEP and 20% AEP catchment flood events and the PMF event.

The calibrated hydraulic model and underlying DTM were modified to represent accurately the existing catchment and floodplain conditions.

Design event input to the hydrologic and hydraulic models included:-

- Design rainfalls according to the current version of Australian Rainfall & Runoff (1998)
- Downstream boundary conditions
- Inputs such as catchment losses, starting water levels etc., as appropriate, were established.

The modelling of design flood events was undertaken for a range of storm durations to ensure that the critical events were identified. Sensitivity analyses were also undertaken to assess the effects that varying model parameter values and design inputs would have on the results, including the sensitivity of the downstream ocean boundaries on design flood levels.

Where feasible, the modelling results were checked using alternative methods. For example, checking of peak flow estimates by an alternative hydrological method, such as the Rational Method (AR&R, 1998).

There is no clear delineation between Brisbane Water and the creeks that discharge to it. For the purposes of this study it is understood that the results of this study are not applicable beyond the entrances to these creeks. It is possible that this study will lead to changed downstream water level boundaries for future creek flood studies. This study does not include re-assessment of those creek flood studies. However, where flooding extends into low-lying areas such as Davistown, flooding beyond the 'banks of the estuary has been addressed.

3.4 Greenhouse Induced Sea Level Rise

The potential impact of a greenhouse induced sea level rise on the design flood levels for one sea level rise scenario, being the 100-years planning period, together with the 100-years ARI design flood event was investigated. Recent publications by CSIRO (1998, 2007) and IPCC (2001, 2007) and AGSO (2000) were considered for this task.

Any 'permanent' rise in mean sea level (MSL) will propagate fully into Brisbane Water, and apart from some minor change in water-way conveyance and over-bank storage associated with this permanent water level rise, design flood levels presented in this report would be increased by an equivalent amount, as described Section 6.8.

3.5 Wind Wave Run-Up

Locally generated wind wave run-up can cause inundation on many foreshore properties, and may be the major component of water level in some cases, other than the astronomical tide. The likely wind elevated design flood levels along the entire foreshore of the Brisbane Water waterway were determined for the 5% AEP, 1% AEP and PMF flood events. Wave run-up calculations were undertaken in general terms using typical cross sections and generic formulae corresponding to those cross sections, see Section 8 and Appendix J, and in terms of the R_2 parameter. Only 2% of wave run-up heights exceed this value and R_2 is a commonly adopted design parameter. Site visits helped to establish a comprehensive list of typical cross sections to categorise the entire foreshore of the Brisbane Water waterway into an appropriate number of typical cross sections, based also on Brisbane Water regions.

The wave run-up information has been prepared in a manner that will assist Council with future calculations of actual wave run-up levels at any location along the Brisbane Water foreshore for development assessment and flood planning purposes, given the actual edge treatment.

3.6 Hydraulic Categories and Provisional Hazard Mapping

Based on existing conditions: -

- Flood extent and provisional flood hazard mapping based on the velocity-depth criteria defined in the Floodplain Development Manual (2005) were undertaken.
- The hydraulic categories (namely flood fringe, flood storage and floodway areas) were defined. The model results and relevant post-processing using available guidelines and methods (such as reported in Howells et al, 2003) provided this information.

Extent mapping was undertaken for three peak design flood events namely the 5% AEP, 1% AEP and the PMF and hazard and hydraulic categories presented for the 1%AEP event.

3.7 Public Participation and Community Consultation

An effective community consultation program was undertaken concurrently with all stages of the study and included:-

- preparation of brochures and questionnaires to advertise the study and to request input from residents
- public notices in local newspapers to seek public participation
- community consultation to obtain both input and feedback from the public
- direct contact with local community groups to promote flood awareness and encourage community involvement in the study
- a presentation of the draft final flood study results to a meeting of the Full Council.

From 18th January to the 15th February 2008 the draft report was placed on public exhibition at Council institutions and on its website. From this display, comments and submissions were invited. Three submissions were received and are addressed in detail within Appendix L. Where appropriate, relevant findings and information have been included in the final report.

4. DATA COMPILATION

A range of data items were required to set up, calibrate and operate the hydrological, hydrodynamic and wave models used in this study.

4.1 Compilation and Review of Available Data

4.1.1 GCC Information

A range of data items were provided by GCC. They related to previous reports, topographic (catchment wide DEM) and bathymetric data, and cadastral plans in electronic form.

4.1.2 Bathymetric Data

This data was obtained from a number of sources, namely: -

- Chart AUS 204
- Survey on north-east side of St Hubert's Island, August, 2004, Hydrographic Surveys
- 1992 Public Works hydro-survey extending from Wagstaff Point to Gosford. This is the most recent overall hydro-graphic survey of the estuary
- Chart 83042 – Broken Bay. 1989 seabed survey undertaken by NSW Public Works.
- Some cross-sectional data for Narara and Erina Creeks, thereby allowing parts of the downstream reaches of these waterways to be described in the overall hydrodynamic model developed for this study

This data was digitised to provide a digital terrain model (DTM) extending from the 200m depth contour offshore to the Gosford shoreline and throughout the estuary.

4.1.3 Meteorological Data

The long term Sydney Airport anemometer data, described in more detail in Section 7, has been analysed in terms of peak event wind speeds using the Extreme Value Type 1 distribution, see Appendix A. Only independent (>24 hours apart) records were included in that analysis. Results are presented in Tables 4.1 and 4.2. Those wind speeds were used to undertake local wind set-up analyses, see Section 6.6 and local-sea wave analyses, see Section 7.3.

Table 4.1 Wind Speeds (m/s) by Octant

Octant	Gust Speeds		10 min Average Speeds		3 hour Average Speeds	
	100 yr ARI	20 yr ARI	100 yr ARI	20 yr ARI	100 yr ARI	20 yr ARI
N	28.4	26.1	19.3	17.8	18.5	17.0
NE	23.8	22.9	18.3	17.6	17.6	16.9
E	25.7	22.8	19.8	17.5	19.0	16.8
SE	28.2	25.6	21.7	19.7	20.8	18.9
S	42.1	38.3	31.7	28.8	30.4	27.6
SW	35.1	31.9	25.6	23.3	24.6	22.4
W	38.3	35.0	26.6	24.3	25.5	23.3
NW	33.9	31.3	21.3	21.3	22.1	20.4

Table 4.1 also includes wind gust speed - generally 2-second gusts. These results are general and do not include any shoreline terrain correction factors. Additional information is presented in Table 4.2.

Table 4.2 Wind Speeds (m/s) at Selected ARI - 10 Minute Average Speeds

Octant	Average Recurrence Interval (years)					
	5	10	20	50	100	1000
N	16.4	17.1	17.8	18.7	19.3	23.5
NE	17.0	17.3	17.6	18.0	18.3	20.3
E	15.4	16.5	17.5	18.8	19.8	26.3
SE	17.9	18.8	19.7	20.8	21.7	27.4
S	26.2	27.5	28.8	30.5	31.7	39.9
SW	21.2	22.3	23.3	24.6	25.6	32.1
W	22.2	23.3	24.3	25.6	26.6	33.1
NW	19.4	19.9	21.3	20.9	21.3	24.1

4.1.4 Water Level Data

This data came in a range of forms and from a range of sources. Principal amongst these was the extensive gauging study undertaken by Manly Hydraulics Laboratory, (MHL, 2004).

Water level data was collected from five permanent sites - one in Middle Harbour and four in Brisbane Water, (2, 9, 10 and 22) and seven temporary sites (4, 6, 11, 14, 16, 18 and 20), see Figure 4.1, were established at other strategic locations within the estuary for a period of approximately twelve weeks.

This water level data was used for two aspects of this study. The first was to provide time series data for numerical hydrodynamic model calibration. That data was provided by MHL in digital form. The second was to provide descriptions of the spatial variations of tidal ranges and tidal planes. That data is reproduced in Appendix B.

Predicted tidal levels and recorded water levels at hourly intervals for Fort Denison, Sydney, were provided by the National Tidal Centre for the May 1974 storm event. Records of indicative peak water levels that were observed in Brisbane Water for that event, other than in isolated locations such as Fagans Bay, remain as the highest recorded water levels in Brisbane Water – Public Works, 1976. These levels have been converted from Standard Datum to AHD.

A second, ocean-water level event that lead to unusually high water levels in Brisbane Water occurred in April 1990 (Department of Public Works, 1991). It arose from a very large low pressure system over the Tasman Sea, but neither significant rainfall nor wave action occurred at that time in the Broken Bay region. A level of 1.4m AHD was recorded in Sydney Harbour, being the third highest recorded water level since 1914. The effects propagated well into Brisbane Water with tidal anomalies up to 0.4m occurring. Peak observed water levels were:-

• Ettalong	1.20m AHD at 2200 27/04/1990
• Koolewong	1.09m AHD at 0000 28/04/1990
• Wharf St, Gosford	1.02m AHD at 0000 28/04/1990

These higher water levels would have caused a temporary increase in influx of ocean water and subsequent outflow. Generally, the highest water levels in Brisbane Water itself, leaving aside local flooding issues in creeks and stormwater flow areas, are caused by ocean storm systems, with little accompanying rainfall.

Water level data was collected at Koolewong by MHL on behalf of Gosford City Council between 1993 and 2003 at 15 minute intervals. It has been analysed and plotted in terms of probability of exceedance. Water level data for a number of sites around Brisbane Water was recorded between February and April 2004, including Koolewong and Ettalong (MHL, 2004). Data for Middle Harbour was also available for this period. This data was analysed also on a probability of exceedence basis.

Water level records from Koolewong and Ettalong were provided by MHL in digital form - up to ten years at Koolewong, but only three months at Ettalong (February to April, 2004).

Tidal constant data for the offshore region of the Brisbane Water hydrodynamic model was taken from Australian National Tide Tables (2006).

4.1.5 Discharge Data

MHL (2004) also report on discharge measurements taken at a number of strategic locations using Acoustic Doppler Current Profiler (ADCP) instruments, see Figure 4.1. These instruments record current speeds and directions along selected transects across the waterway and through the water column. Typical vertical resolution is in bins of 0.5m. Integration of speed and direction leads to an estimate of discharge. Taking records through the tide cycle leads to an irregular time series of discharge data that can be used for model calibration.

Generally, discharge data is more reliable than current data taken from one location because it enables the tidal prism upstream of the cross-section (transect) to be quantified. A single measurement point on a cross-section does not describe the speed (and direction) variation across the section; where, in some circumstances, reverse flow may occur over some part of the cross-section.

ADCP's do not record data from the top and bottom 10 to 15% of the water column. This is a consequence of their acoustic beam structure. Account of this characteristic is included in the calculation of discharge.

4.1.6 Wave Data

Both sea and swell are important in different regions of Brisbane Water. Local sea is the more widely occurring of the two throughout the estuary, being most important in the wide expanse of the Gosford Broadwater. On a minor-scale, local sea is important in the region north-east of St Hubert's Island to the Cockle Channel, for example, whereas inshore propagating severe ocean-storm swell is important at Ettalong, especially on high tide when larger waves can propagate over the Ettalong Point shoal more effectively.

MHL have collected wave data (height, period and direction) since March 1992 from their Long Reef Waverider buoy site. That data was available to this study for the purpose of describing ocean waves at the boundary of the overall Brisbane Water wave modelling system.

4.2 Acquisition of Additional Data

4.2.1 Flood Data

A resident survey was conducted to determine historical flood behaviour, obtain flood levels, photographs and other relevant information of past events to assist in setting up the hydraulic models and their calibration. This task included preparation and distribution of an Info-Pack consisting of a brochure and an appropriately worded questionnaire to residents, property owners and other interested individuals/groups. A covering letter was prepared to accompany the info-packs, explaining the objectives and likely outcomes of the study and informing the public about the study process and projected outcomes. This task included contacting/interviewing those questionnaire respondents who were willing to provide further, useful information. Additionally, an advertisement was prepared by Cardno Lawson

Treloar and placed in relevant newspapers to advise interested residents how they could join in the consultation process. The newspaper advertisement and distributed info-pack and survey are presented in Appendix C.

Overall, 6,000 surveys were delivered/posted, see Figure 4.2 for locations. These locations were identified as properties having land below the 2.5mAHD contour and likely to be affected by foreshore flooding.

In all 701 responses were received; however, many addressed unrelated issues or local catchment flooding. Only 34 were considered specifically useful for this study and they are also shown in Figure 4.2. Following the completion of this task, Cardno Lawson Treloar reviewed the public responses and prepared summary tables including each response. A summary of the relevant responses is included in Appendix C, the full catalogue of responses was supplied to Council in electronic form.

4.2.2 Survey Data

Council provided topographic information available at 2m contour intervals in digital format for the urban part and 5m contour lines for the entire Gosford LGA, including the Brisbane Water foreshore area.

High resolution Aerial Photography suitable for reliable flood modelling and mapping were also made available for the project.

Bathymetric data for Brisbane Water itself was also available from the on-going Brisbane Water Estuary Possesses Study as detailed in Council's brief.

Following preliminary assessments of the PMF Brisbane Water flood, it was determined that more detailed ground survey was required to describe the low-lying areas near Saratoga, Davistown and Woy Woy that lie under the 2mAHD contour and hence not defined well by Council's contour data.

Johnson Partners undertook this work in February and March 2007, including the survey of thirty flood levels identified from the resident survey responses. The ground survey was needed to identify the levels of the Cockle Channel top-of-bank, see Figure 3.1, and land immediately landward, for example, otherwise no reliable flood extent could be described.

Figure 4.3 shows the section lines along which the survey was undertaken, results of which were provided to Council for inclusion in their databases.

5. HYDROLOGY

Rainfall-runoff processes for the Brisbane Water Catchment were modelled using the RAFTS (WP Software, 2000, version 6.5) hydrological modelling package. A hydrological model for the entire Brisbane Water catchment was developed to provide inflow hydrographs for the Brisbane Water hydrodynamic model. Details of the hydrological modelling and model outputs are provided in this section of the report.

5.1 General

The following catchment attributes were considered in the hydrological analysis of the catchment:-

- rainfall intensity-frequency-duration (IFD) relationships
- slopes and overland flow paths, and
- land use (pervious/impervious area, initial/continuing rainfall loss rates and catchment roughness).

The state of the catchment development at the time of aerial survey was considered to be the existing state of the catchment and adopted for the hydrological analysis. The aerial survey was undertaken in the year 2005.

5.2 Establishment of the Hydrological Model

Based on topographic features and land-use patterns, the catchment was divided into 126 sub-catchments. Topographic data for the Brisbane Water catchment was based on digital 2m contour data provided by Council. Land-use patterns were based on aerial photography (2005) and land-use zoning information supplied by Council.

The sub-catchment layout is shown in Figure 5.1; details of the model parameters for these sub-catchments are provided in Appendix D.

The percent impervious for each land-use type was determined from site reconnaissance and the assessment of aerial photography. For residential areas, it was found that for the majority of residential areas a value of 40% was appropriate. Some residential areas, such as Woy Woy, were identified as having higher density residential and assigned a 50% impervious area value, with lower density residential areas, such as Hardys Bay, assigned a 25% impervious area value. Similar considerations were used to assess the percentage impervious for the commercial/industrial land use. The percent impervious values/range of values adopted for each land use type is given in Table 5.1.

In addition to the division of sub-catchments based on land-use, sub-catchments within major urban areas were split to simulate the fast and slow responses typically observed in highly urbanised catchments. This dual response is due to the large proportion of impervious areas in urban regions, which are usually associated with a stormwater drainage system that conveys runoff efficiently from the catchment area delivering the fast response. The slow response is derived from the pervious area within the catchment, for example, open spaces and property lawns, as well as from catchment storage areas.

The catchment roughness parameter was determined from previous experience in accordance with the guidelines presented in the RAFTS manual. The catchment roughness adopted for each land use type is given in Table 5.1.

Table 5.1 RAFTS Land Use Parameters

Land-Use Type	Percent Impervious (%)	Catchment Roughness
Forest	5	0.100
Rural	10	0.070
Residential	25-50	0.025
Commercial/ Industrial	70-90	0.020
Road	90	0.015

Hydrograph routing lag times to account for flow travel times from different sub-catchments were determined using the method described by Hee (1993). Travel times were modified for flows through culverts or pipes in order to represent the lag created due to ponding behind these structures.

5.3 Model Calibration

As there are no flow-gauging stations within the catchment, the hydrological model could not be directly calibrated.

The RAFTS model parameters for the current study were therefore independently derived from past experience in similar catchments and verified against previous studies. The modelled discharges were also checked against rational method calculations.

In addition, the sensitivity of the hydrological model was examined by estimating the sensitivity to a range of key model parameters, as outlined in Section 5.7.

5.4 Model Verification

5.4.1 Erina Creek Verification

Erina Creek has a total catchment area of 32km^2 and is predominately described by forest and rural land use areas.

The *Erina Creek Flood Study Review* was completed by Webb, McKeown and Associates (1991). The report details the hydrologic and hydraulic investigations of the Erina Creek catchment. A number of methods were used to determine the peak design flows; the preferred hydrological model was the WBNM model because it facilitated the calibration of the hydraulic model using an acceptable range of Mannings ‘n’ values.

The 100-years ARI peak flow from the calibrated hydraulic model at Punt Bridge was found to be 270m^3/s, for the critical event duration of 6 hours. This compares well with the peak flow obtained from the RAFTS model in the current study; which was 317m^3/s at Punt Bridge for the 6 hours event. These values are within the accuracy range commonly achieved for hydrological model results.

It was noted by Webb, McKeown and Associates that the 6 and 9 hours duration events produced similar peak flows for the catchment. However, the 6 hours event was chosen as the critical one because, when both events were entered into the hydraulic model, the 6 hours event produced the highest water levels. RAFTS modelling in the current study also produced similar peak flows for the 9 hours and 6 hours events with the 9 hours event having the larger peak discharge.

5.4.2 Narara Creek Verification

Narara Creek has an area of approximately 47km^2 that is located in the north-western region of the Brisbane Water estuary. The land uses within the catchment are a mixture of residential, commercial, forested and open spaces.

In a previous study (Lawson and Treloar, 1999), a MIKE-11 hydraulic model was developed for the Narara Creek catchment. The model was calibrated to known flood levels within the lower Narara Creek area.

Table 5.2 presents a comparison of peak flows at the catchment outlet at Fagans Bay for the 100, 20 and 5-years ARI design events. Peak flows from the RAFTS model compare well with results from the MIKE-11 model and are within 20% of the reported values.

Table 5.2 Comparison of MIKE-11 and RAFTS Peak Flows - Narara Creek Discharge

Model	Duration	100-Years ARI Peak Flow (m^3/s)	20-Years ARI Peak Flow (m^3/s)	5-Years ARI Peak Flow (m^3/s)
Mike11	6hr	468	334	227
RAFTS	6hr	497	351	230
RAFTS	9hr	480	356	247

The critical duration for the MIKE-11 modelling was found to be the 6-hours event; in the RAFTS modelling the 6-hours and 9-hours events produced similar peak flows with the 9-hours event having the higher peak flow for the 20-years and 5-years ARI events.

5.4.3 Rational Method Calculations

The probabilistic Rational Method was used to estimate the design peak discharges for three selected catchments within Brisbane Water. The method adopted for these calculations was derived for eastern New South Wales and is presented in AR & R (1998). The selected catchments were:-

- Narara Creek
- Erina Creek
- Kincumber Creek

The design peak flows comparison is presented in Table 5.3.

Table 5.3 Comparison of Rational Method Calculations and RAFTS Modelled Flows

Model	Catchment	100-Years ARI Peak Flow (m^3/s)	20-Years ARI Peak Flow (m^3/s)	5-Years ARI Peak Flow (m^3/s)
Rational Method (1999)	Narara Creek	440	280	170
	Erina Creek	330	210	125
	Kincumber Creek	70	45	27
RAFTS (6-hours Duration)	Narara Creek	497	351	230
	Erina Creek	317	227	151
	Kincumber Creek	62	47	33

5.5 Design Rainfall

A uniform areal distribution of the design storm rainfall has been assumed in the hydrological analysis. Design rainfall depths and temporal patterns resulting from the design storms of the 100, 50, 20, 5 and 2-years ARI events were developed using the standard techniques provided in AR & R (1998). These depths were estimated using Intensity Frequency Duration (IFD) relationships. The IFD parameters derived from AR & R (1998) for the Brisbane Water catchment are presented in Table 5.4.

Table 5.4 Design IFD Parameters for Brisbane Water

Parameter	Value
2-Years ARI 1-hour Intensity	37.40 mm/hr
2-Years ARI 12-hours Intensity	8.50 mm/hr
2-Years ARI 72-hours Intensity	2.80 mm/hr
50-Years ARI 1-hours Intensity	76.20 mm/hr
50-Years ARI 12-hours Intensity	17.90 mm/hr
50-Years ARI 72-hours Intensity	5.90 mm/hr
Skew	0.0
F_2	4.3
F_{50}	15.9
Temporal Pattern Zone	1

The Probable Maximum Precipitation (PMP) was estimated using the publication ‘Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method’, (Hydrometeorological Advisory Services, June 2003) recommended by the Bureau of Meteorology. Catchment specific values used in the calculation of the PMP are provided in Table 5.5. The recommended ellipse isohyets for the spatial distribution of the PMP are shown overlying the catchment area in Figure 5.2. The Brisbane Water catchment is entirely contained within the 6th PMP ring (Ring F). Because only one PMP value can be applied to each sub-catchment, the representative rainfall was chosen to be the ring in which the majority of the catchment area was contained.

Table 5.5 PMP Calculation Values

Parameter	Value
Moisture Adjustment Factor	0.71
Elevation Adjustment Factor	1.00
Percentage Rough	100%
Area Enclosed A (km^2)	2.6
Area Enclosed B (km^2)	16.0
Area Enclosed C (km^2)	65.0
Area Enclosed D (km^2)	128.9
Area Enclosed E (km^2)	172.5
Area Enclosed F (km^2)	190.7

Table 5.6 presents the estimated design storm rainfall intensities for the full range of storm events and durations of interest, as calculated using the IFD curves and PMP methods described.

Table 5.6 Design Rainfall Intensities (mm/h)

Duration	2-Years ARI	5-Years ARI	20-Years ARI	50-Years ARI	100-Years ARI	PMP (Ring A)
15-min	77	99	128	150	167	659
30-min	55	71	93	109	121	477
45-min	44.0	57	75	89	99	402
1-hours	37.4	48.9	65	76	85	350
1.5-hours	29.6	38.7	51	61	68	301
2-hours	24.9	32.7	43.3	51	57	264
3-hours	19.5	25.7	34.1	40.4	45.2	213
6-hours	12.9	17.0	22.6	26.9	30.1	142
9-hours	10.1	13.4	17.8	21.2	23.8	-
12-hours	8.50	11.3	15.1	17.9	20.1	-
24-hours	5.64	7.49	10.0	11.9	13.4	-
36-hours	4.40	5.85	7.84	9.33	10.5	-

5.6 Design Flow

The estimated design rainfalls were applied to the hydrological model in order to predict design runoff hydrographs. Design rainfall losses were adopted in accordance with AR & R (1999) guidelines. Table 5.7 below describes the initial and continuing loss scenarios utilised for the different land-use types.

Table 5.7 Design Rainfall Losses Used in RAFTS

Land-Use Type	Initial Loss (mm)	Continuing Loss (mm/hr)
Forest	20	5
Rural	10	2.5
Residential	5	2.5
Commercial/ Industrial	1	1
Road	1	0

For PMP estimates, an initial loss of 1mm and no continuing rainfall losses were assumed as per the recommendations of AR & R (1999).

Design discharge hydrographs were obtained for the 3, 6, 9, and 12-hours storm durations and supplied to the Delft3D hydrodynamic model. At all discharge locations along the Brisbane Water foreshore, hydrographs from the RAFTS model were created and were used as input hydrographs to the Delft3D model of the estuary. The output locations from the RAFTS model are shown in Figure 5.3. Appendix E presents the peak flows for all the discharge locations along the Brisbane Water foreshore.

5.7 Model Sensitivity

The sensitivity of the hydrological model to key model parameters was investigated to demonstrate the range of uncertainty in the model results for the 100-years ARI 6-hours design event. The RAFTS model parameters investigated in this sensitivity analysis were:-

- Catchment roughness – increased/decreased by 20%
- Rainfall losses (Initial and Continuing Losses) – increased/decreased by 20%
- Percentage impervious – increased/decreased by 20%

The peak flows from the sensitivity analysis are included in Appendix E for comparison with the adopted design flows.

6. HYDRODYNAMIC PROCESSES

The dominant water level forcing phenomenon in Brisbane Water is the astronomical tide. However, the highest recorded water levels in the estuary occurred during the severe ocean storm of May 1974 (Department of Public Works, 1976), though levels may be higher in Fagans Bay in a severe creek flood because of the constriction caused by the Main Northern Railway causeway.

The following analyses were directed towards the definition of flood planning levels throughout the estuary and the development of realistic risk-based downstream boundary water levels to be applied to creek flood-studies.

Note that planning levels, in general, must be formed from envelopes of estuary water levels near creek mouths and water levels formed from individual creek flood studies themselves at selected ARI. Flood planning levels may include wave run-up also.

The definition of planning levels is discussed in Section 8.

Numerical modelling was applied to the investigation of local area wind set-up and to local area wave hindcasting. Those models are described below. Results of the numerical modelling were extracted from all simulations at 119 locations along the Brisbane Water foreshore. The locations of these output locations can be seen in Figure 6.1.

6.1 Hydrodynamic Model

Planning level investigations required application of a high level model capable of simulating a range of processes – wind field, wave, flood flows and tidal forcing. These simulations were undertaken using the Delft3D modelling system.

The Delft3D modelling system has been applied to water level and wave investigations at many international locations, as well as within Australia by Cardno Lawson Treloar including the Brisbane Water Estuary Processes Study (in publication). Other sites include Port Botany (Sydney), Cairns Navy Base (Queensland), New Caledonia and Exmouth Gulf in Western Australia, for example.

The Delft3D modelling system includes wind, pressure, tide, discharges and wave forcing, three-dimensional currents, stratification, sediment transport and water quality descriptions and is capable of using irregular rectilinear or curvilinear coordinates.

Delft3D is comprised of several modules that provide the facility to undertake a range of studies. All studies generally begin with the Delft3D-FLOW module. From Delft3D-FLOW, details such as velocities, water levels, density, salinity, vertical eddy viscosity and vertical eddy diffusivity can be provided as inputs to the other modules. The wave module works interactively with the FLOW module through a common communications file.

6.1.1 Hydrodynamic Numerical Scheme

The Delft3D FLOW module is based on the robust numerical finite-difference scheme developed by G. S. Stelling (1984) of the Delft Technical University in The Netherlands. Since its inception the Stelling Scheme has had considerable development and review by Stelling and others.

The Delft3D Stelling Scheme arranges modelled variables on a horizontal staggered Arakawa C-grid. The water level points (pressure points) are designated in the centre of a continuity cell and the velocity components are perpendicular to the grid cell faces. Finite difference staggered grids have several advantages including:-

- Boundary conditions can be implemented in the scheme in a rather simple way
- It is possible to use a smaller number of discrete state variables, in comparison with discretisations on non-staggered grids, to obtain the same accuracy
- Staggered grids minimise spatial oscillations in the water levels.

Delft3D can be operated in 2D (vertically averaged) or 3D mode. In 3D mode, the model uses the σ-coordinate system first introduced by N. Phillips in 1957 for atmospheric models. The σ-coordinate system is a variable layer-thickness modelling system, meaning that over the entire computational area, irrespective of the local water depth, the number of layers is constant. As a result, a smooth representation of the bathymetry is obtained. Also, as opposed to fixed vertical grid size 3D models, the full definition of the 3D layering system is maintained into the shallow waters and until the computational point is dried.

Horizontal solution is undertaken using the Alternating Direction Implicit (ADI) method of Leendertse for shallow water equations. In the vertical direction (in 3D mode) a fully implicit time integration method is also applied.

Vertical turbulence closure in Delft3D is based on the eddy viscosity concept.

6.1.2 Wetting and Drying of Floodable Areas

Many nearshore areas include shallow intertidal areas and Brisbane Water includes floodable shoreline areas; consequently Delft3D includes a robust and efficient wetting and drying algorithm for handling this process.

6.1.3 Conservation of Mass

Problems with conservation of mass, such as a ‘leaking mesh’ do not occur within the Delft3D system.

However, whilst the Delft3D scheme is unconditionally stable, inexperienced use of Delft3D, as with most modelling packages, can result in potential mass imbalances.

Potential causes of mass imbalance and other inaccuracies include:-

- Inappropriately large setting of the wetting/drying algorithm and unrefined inter-tidal grid definition
- Inappropriate bathymetric and boundary definition causing steep gradients
- Inappropriate time step selection (i.e. lack of observation of the scheme’s allowable Courant Number condition) for simulation.

6.2 Model Set Up

Initially a single model domain of Brisbane Water, developed for the Estuary Processes Study, was utilised. For application to this study the existing model was extended over low-lying foreshore areas and included topographic data from Council’s contour information and the ground survey described in Section 4.2.2. The model layout can be seen in Figure 6.2, which shows that the model extends offshore to a depth of approximately 70m AHD and features water level boundaries offshore and along the boundaries with the Hawkesbury River and Pittwater. A calibrated MIKE-11 model of the Hawkesbury River system, including Brisbane Water and Pittwater, has been used to determine concurrent water level time series estimates for Pittwater and the Hawkesbury River boundaries during selected offshore water level conditions. Wave input in the form of radiation stress fields is applied also to this grid following parallel wave simulations, see Section 7.

The model has a curvilinear grid with variable horizontal resolution. Offshore areas have a grid resolution in the order of 100m x 100m, while areas inside Brisbane Water, where steep hydrodynamic gradients exist, have horizontal grid cells in the order of 10m x 10m.

Model calibration increases confidence that the model system provides a realistic description of the estuarine and flooding processes described by it in complex forcing conditions – for example, current speeds (process) caused by a spring tide (forcing condition). Brisbane Water is a complex hydraulic system featuring: -

- Several branches, some of which are interconnected,
- Generally shallow (water depths < 10m),
- Significant mangrove and intertidal areas,
- Mobile sand shoals, and a
- Significant hydraulic control at 'The Rip'.

The calibration of the Delft3D hydrodynamic model was initially undertaken as part of the Estuary Processes Study and involved two main stages. The first stage involved calibrating the water levels by adjusting the bed friction factor. The second stage of the calibration was to ensure that the discharges through sections of the model agreed with available flow data. Discharge rate is influenced by two key factors: bed friction and the conveyance, which in turn is affected by bed level and cross-sectional area. The discharge calibration ensures that the correct storage is defined in each branch of the model, thereby ensuring reliable velocity descriptions. It is possible to achieve a good water level calibration yet a poor discharge calibration if the correct storage is not provided within the model. The Brisbane Water bathymetric data is reasonably comprehensive; however, important areas such as Kincumber Broadwater and Cockle Channel have large inter-tidal areas that are relatively unsurveyed. During the discharge calibration, bed levels of unsurveyed areas were adjusted to provide the correct storage.

Figure 4.1 presents the locations of the MHL water level and discharge data collection sites. Figures 6.3 and 6.4 present modelled and measured water level time series at a number of MHL sites. The agreement between modelled and measured water levels is very good at all locations.

Figure 6.5 presents modelled and measured discharges at locations along the main branch of Brisbane Water. The calibration is generally very good including across 'The Rip' (Site 5). Figure 6.6 presents modelled and measured discharges across the Woy Woy Channel and near the railway bridge at the entrance to Woy Woy Bay. The calibration at the railway bridge is generally good, although the model underestimates the discharge in Woy Woy channel.

Figure 6.7 presents modelled and measured discharges across Cockle Channel and at the entrance to Kincumber Broadwater. The modelled peak discharge through the Cockle Channel cross-section is of lower magnitude than the measured data; however, the calibration across Humphrey's Channel is very good. There are large inter-tidal areas upstream of the Cockle Channel that are not well surveyed and this lack of detail influences the modelled result.

Overall the calibration in this region of the model is good. Figure 6.8 presents modelled and measured discharge at the entrance to Fagan's Bay and Narara Creek. At these locations, the hydrodynamic calibration is also very good.

The overall hydrodynamic calibration of the model is very good. The region of the model where there is the largest relative difference between the model and measured data is the region near Woy Woy Channel. This area is highly influenced by tidal flow through the surrounding mangrove areas. In this region of the model, the density of survey data is relatively low. Additional survey data of intertidal areas near the Woy Woy Channel could improve the hydrodynamic model performance in this region; however, the additional data would have very little influence on the outcomes of the overall modelling investigations. The overall description of estuarine hydraulics in the Woy Woy region is reproduced well by the Delft3D model.

6.3 Catchment Flood Events

Using the output from the RAFTS hydrological modelling (Section 5), hydrodynamic modelling of the various ARI catchment runoff events was undertaken.

6.3.1 Boundary Conditions

A major consideration in determining peak water levels as a result of catchment flooding within the Brisbane Water Estuary is the downstream boundary condition. Previously, Cardno Lawson Treloar have adopted a boundary water level based on long term recorded data (Fort Denison and Newcastle) and selected a level so that one can be 99% confident that the level will not be exceeded during any flood. This criterion can be adopted when there is little or no correlation between the boundary water levels and rainfall events in the subject catchment, an appropriate assumption for Brisbane Water. Analysis of recorded Fort Denison water level data, in terms of probability of exceedance is provided in Figure 6.9. Inspection of this plot shows that the 1% exceedance level is approximately 1mAHD. To this end, an offshore spring tidal signal that peaked at 1mAHD was utilised for the catchment flood simulations.

Since the adopted boundary condition is a dynamic non-stationary water level signal, consideration of tidal phasing relative to that of the catchment flow hydrographs was required. To undertake this, a series of simulations was completed with PMF catchment flows, where the peak of the tide was shifted both in and out of phase with the peak catchment flow by 3 hours. This phase comparison was undertaken on catchment flows from Erina and Kincumber Creeks, being two of the largest discharges during catchment storm events. Narara Creek, while draining the largest catchment area, was not appropriate for this investigation as the presence of the Main Northern Railway causeway across the entrance to Fagans Bay acts as a hydraulic control, and thus is the predominant influence on flood levels within that area of the estuary. Three simulations were competed as follows:-

- The catchment flow peaks (at Brisbane Water) in phase with the peak offshore water level,
- The catchment flow peaks (at Brisbane Water) 3 hours before the peak offshore water level, and;
- The catchment flow peaks (at Brisbane Water) 3 hours after the peak offshore water level.

A comparison of the resulting water levels at four locations across the estuary is provided in Figure 6.10. From these investigations it was concluded that the peak flood levels within the estuary as a result of catchment flooding are observed when the peak of the offshore tidal signal is in phase with the peak of the major catchment flows entering the estuary. All design catchment events were therefore completed using the in-phase boundary conditions.

6.3.2 Catchment Flood Results

Hydraulic modelling of the design catchment storm events was undertaken using the calibrated Delft3D modelling system. As part of the model system, 69 discharge locations were utilised to distribute the individual catchment flows in a spatially realistic manner along the foreshore of the estuary. These locations can be seen in Figure 5.3. Each ARI design event was run for the 3, 6 and 9-hours rainfall durations.

Peak water level results from each of the design events, being the 5, 10, 20, 50, 100 and 200-years ARI events, as well as the PMF event, can be seen in Appendix F, Table F1. As was detailed previously in Section 5, the critical duration for the major catchment flows is approximately 9-hours, and hence the hydraulic modelling results show that the peak water levels within the estuary are associated with this critical duration.

6.4 Ocean Storm Events

As identified by historical records and the community consultation undertaken as part of this study, ocean storm events and extreme tidal levels are the predominant cause of foreshore flooding. In order to quantify the nature of these phenomena, both hindcast and hypothesised storm events were simulated using the Delft3D model system. The individual events were based on observed and recorded data from a number of sources, detailed herein.

The design coastal storm conditions for the Central Coast region are East Coast Low (ECL) events for ARI's greater than 10-years. These complex weather systems often originate from a tropical low pressure region and generally move southwards down the NSW coast; but have been known to move northward. They can be particularly damaging to the central-NSW coast because they can form relatively close to the coastline and often generate powerful offshore waves from the east to south-east sector. As a result these waves experience less refraction compared to more southerly weather systems and larger waves can interact with the coastline. They also generate a range of offshore wave directions as they move along the coastline.

ECL events can also generate a storm surge, which can further increase the impact on shoreline areas. It has been observed that ECL can occur frequently when conditions are favourable; that is, they tend to be episodic. This was observed in 1974 when two ECL storms damaged the mid-NSW coast a few weeks apart. More recently the June 2007 period featured several intense ECL events, including the storm that caused extensive damage in the Newcastle region. These two events are discussed below.

6.4.1 Historical Events

6.4.1.1 May 1974

During May 1974 a severe storm event caused elevated water levels along the Central-NSW Coast and water level data was 'recorded' within Brisbane Water (Department of Public Works, 1976). The elevated water levels were caused by a combination of processes, including: -

- A high astronomical tide,
- Inverse barometer effect,
- Wind set-up,
- Wave set-up,
- Possible propagation of coastal trapped waves along the continental shelf, and
- Possible ocean basin processes – such as the el Nino southern oscillation;

the latter two possibly causing the generally persistent elevated ocean level along the NSW coast observed during the month. The May 1974 ocean storm was particularly severe because peak wave conditions coincided near the time of peak astronomical tide in the Gosford and Sydney regions. The impact of the May 1974 event on Brisbane Water is documented in Department of Public Works (1976) and Foster et al (1975). Lord and Kulmar (2000) also discuss this event. The average recurrence interval (ARI) of an event like the May 1974 storm is generally considered to be greater than 100-years in terms of combined wave and elevated water level processes and hence coastal impact. However, the ARI of this storm depends upon the method of assessment (peak wave height/duration/direction), location (open coast/estuarine) and type of impact (inundation/erosion), for example. Where joint occurrence between wave height and water level affects the impact, then the ARI may be much longer than that of peak storm wave height itself.

The May 1974 storm event was simulated using the following boundary conditions: -

- Measured Fort Denison tide (provided by National Tidal Centre),
- Peak wave conditions (Foster et al, 1975): -
  - H_s=9.0m,
  - T_p=16s,
  - Direction = 112.5^{o}TN
- Peak wind conditions: -
  - W_s=27m/s, and
  - Direction = 135^{o}TN,

The recorded Fort Denison water level data for May 1974 was provided by the National Tidal Centre. Wave and wind directions are based on the available synoptic data for the May, 1974 storm - Foster et al (1975).

A simulation using the same parameters was undertaken on a calibrated Sydney Harbour model as well and the modelled water level at Fort Denison determined. This procedure allowed the difference between the boundary tide (Fort Denison measured water level) and modelled Fort Denison water level to be determined. That is, a true ocean tide is not available at Sydney or for offshore Broken Bay. This difference was then subtracted from the Brisbane Water sites model output water level results so that any wave and wind set-up within Sydney Harbour, and already included in the Fort Denison tide gauge record, was removed from the model tidal boundary condition at Broken Bay. Atmospheric pressure effects would be included in the recorded Fort Denison water levels, but for this analysis can be taken to be the same at both sites. Note that these are dynamic simulations in which the ocean water level varies – not a constant water level simulation. Peak wave and wind conditions were ramped-up over a period of 12-hours from background levels of H_s=2m and a wind speed of 0m/s over a period of 12 hours and then maintained at peak conditions for 6 hours before ramping down over a period of 15 hours. Peak wave and wind conditions coincided with peak ocean level conditions.

Note that the wave forcing is applied to the hydrodynamic model as spatially and temporally varying maps of radiation stress – not as a water level added to the storm tide boundary. At the offshore model boundary in about 70m depth wave set-up would be essentially nil. The wave and hydrodynamic models are operated in parallel with 30-minute intervals between wave model computations. Each of those takes the latest water levels and currents from the hydrodynamic model, as well as the offshore wave conditions at the simulation time, and computes the wave field, including wave breaking and current effects on the waves. A radiation stress map is then available for use in the hydrodynamic model and its inclusion in that computation leads to the development of spatially and temporally varying wave set-up that can propagate in a physically realistic manner further into the model domain. The new water level and current field is then used in the next wave field computation - intervals of 30 minutes having been found to be appropriate for changing tide levels and computational efficiency.

A comparison of the observed and simulated water levels within Brisbane Water is shown in Figure 6.11. Observed levels were obtained from both a Public Works survey completed directly after the 1974 event (Department of Public Works, 1976) and the resident survey, described in Section 4.2.1. Simulated levels show good agreement with observed levels. Some anomalies do exist, however. For example, at Point Frederick an observed level of 2.87mAHD is much greater than the model result of 1.71mAHD, which may be due to local flooding and drainage issues that are not able to be addressed or resolved within the estuary wide hydrodynamic model - or a record error.

On the basis of these results the 1974 event is considered to be greater than a 100-years, but less than a 200-years ARI event, which is consistent with commonly accepted treatment of the event. Generally, these results show good agreement with the observed levels and provide confidence that extreme water levels within the estuary caused by ocean storm events can be accurately represented by the model system.

6.4.1.2 June 2007

The June 2007 period featured several intense ECL events, including the storm that caused extensive damage in the Newcastle region. The most severe conditions occurred between the 7th and 12th of June with an intense low pressure system moving south along the east coast causing heavy rainfall and minor flooding to the Brisbane Water area (MHL, 2007). Despite its severe nature, no widespread inundation of low lying areas from estuary waters was reported.

Peak levels along the Brisbane Water foreshore were obtained from MHL for Koolewong (1.12m) and Punt Bridge (1.15m), at the mouth of Erina Creek. When compared to the outcomes of the following sections peak levels within the Brisbane Water Estuary were not extreme and less than those for a 5-years ARI event. This is due to an equivalent 4-years ARI offshore wave height (MHL, 2007) and the coincidence of the peak of the storm with a low tide.

6.4.1.3 Other Events

Estuary levels from other ocean storm events are discussed in Section 4.1.4.

Photographic evidence of one ocean flooding event was captured in October 1994 along the Yattalunga foreshore. Figure 6.12 presents a series of photographs that show the elevated estuary water level and overtopping of the foreshore area by waves. No rainfall was observed during this event.

6.4.2 Design Ocean Storm Events

Simulations for design ARI event conditions were undertaken for 5, 10, 20, 50, 100, 200-years ARI and a PMF event, assumed to be equivalent to a 10,000-years ARI ocean event. The basis for their selection as representing these ARI was the analysed Fort Denison water level data, analyses of long term offshore Botany Bay wave data and Sydney Airport wind data, all in terms of probability of exceedance. Although these events were selected to represent the selected ARI events, the joint probability of all factors contributing to elevated water levels may result in the return period for the combined selected met-ocean parameters being greater, especially in Brisbane Water; even though there is some correlation between these forcing conditions. For the waves and wind, it was assumed that peak conditions must persist for six hours to ensure that water levels could propagate into the estuary. This is because an elevated ocean water level of short duration will not have time to ‘fill’ Brisbane Water - moreover, inspection of historical wave records shows that near-peak wave conditions can persist even longer. Table 6.1 describes the boundary conditions for each simulation. Boundary conditions were developed from the following data sets: -

- Water Levels – Fort Denison (MHL, 1992) Table 53,
- Waves – analysed offshore Port Botany peak storm data, and
- Wind – Mascot 1939-1997 record.

Table 6.1 Ocean Storm Boundary Conditions

ARI (years)	Peak Offshore WL	Peak Wave Conditions			Peak Wind Conditions	
	(mAHD)	H_s (m)	T_p (sec)	Dir (°TN)	Speed (m/s)	Dir (°TN)
5	1.25	7.5	13	112.5	18.9	SE
10	1.3	8	13.5	112.5	20.5	SE
20	1.35	8.5	14	112.5	22	SE
50	1.41	9.1	14.6	112.5	23.9	SE
100	1.46	9.6	15.1	112.5	25.4	SE
200	1.51	10.1	15.6	112.5	26.8	SE
PMF	1.78	12.8	18.3	112.5	35	SE

It is quite possible that other storm scenarios could produce similar peak water levels for each of the design cases, but those selected are typical of the most common very severe ocean storm conditions and are consistent with the meteorology and wave conditions of the May 1974 storm.

As with the May 1974 investigations, the boundary conditions for the design ARI events were applied also to the Sydney Harbour model to remove the wave set-up and wind set-up already included implicitly in the Fort Denison water level result applied to the Brisbane Water model offshore boundary.

Peak water level results at the 119 foreshore locations have been tabulated in Appendix G, Table G1. Table 6.2 summarises the peak water levels for each event at Ettalong, Woy Woy, Koolewong and Gosford.

Table 6.2 Peak Water Levels

ARI (years)	Peak Water Level (mAHD)			
	Ettalong	Koolewong	Gosford	Woy Woy
5	1.36	1.35	1.39	1.3
10	1.41	1.43	1.47	1.37
20	1.47	1.51	1.55	1.43
50	1.53	1.6	1.65	1.52
100	1.59	1.68	1.75	1.59
200	1.65	1.77	1.83	1.66
PMF	1.85	2.11	2.23	1.94

6.5 Tsunami Events

Historically, tsunamis generated from distant sub-sea earthquakes or locally by landslides on the continental shelf have impacted on the mid-NSW coast. For this study site, such events are likely to be very rare with return periods well in excess of 100-years ARI. Geoscience Australia is currently undertaking a study to quantify the tsunami risk for the whole Australia coastline. As yet, there are no coastal planning design guidelines for tsunamis on the NSW coast. The highest recorded (Fort Denison) tsunami (0.8m trough to peak) in this region occurred in 1960 and was caused by an earthquake in Chile. A tsunami of this magnitude is unlikely to have a significant impact along the majority of the Brisbane Water foreshore, especially north of ‘the Rip’.

6.6 Wind Set-up

Wind set-up is the increase in mean water level caused by inter-facial shear between the wind and water leading to a landward flow of water that ‘piles-up’ at the shoreline. In reality the process is more complicated and includes Coriolis forces and 3D flow. Wind set-up is inherently calculated in the ocean storm simulations, described above. For the purposes of wave run-up calculations and the determination of that component of flood planning levels (Section 9), however, the quantification of directional wind set-up was performed through a separate modelling exercise, as well. It may also need to be considered as part of total water levels for catchment flooding.

This investigation was undertaken by running the Delft3D model with the design wind speeds, provided in Section 4.1.3, for eight directional sectors. The application of these wind cases was undertaken over a spring tide cycle and the wind set-up value was calculated as the difference from the peak level for the tide only case. Results of the wind set-up simulations are included in Appendix J and will be discussed further in Section 9.

6.7 Analysis of Water Level Data

Along with available recorded water level data at Koolewong and Ettalong, and design storm simulation results, a Delft3D simulation of 6-weeks of tides (February-March 2006) was undertaken to provide a high frequency of occurrence water level data set for each foreshore location (see Figure 6.1). These datasets formed the basis of extremal analysis extrapolation aimed towards providing a probabilistic description of the water level exceedance at the selected locations around the estuary foreshore; which may be utilised for downstream boundary conditions of local creek flood studies and planning investigations within the estuary. Firstly, validation of the modelled results was required and undertaken at the Koolewong and Ettalong recorded water level sites, which are north and south of ‘The Rip’ hydraulic control, respectively.

6.7.1 Koolewong

Figure 6.13 shows a plot of the Koolewong water level curve (red line and asterisks) based on 10 years of recorded water levels, in terms of probability of exceedance. The figure also includes: -

- Koolewong extreme levels (5 to 200-years ARI and PMF - blue circles) and the May 1974 storm (green box) based on Delft3D simulations, and
- Koolewong levels from the 6-week Delft3D tidal simulation (February-March 2006 – blue asterisks).

For plotting purposes, the probability of exceedance for the ARI extreme levels and the May 1974 peak water levels were based on a duration of half an hour. That is, a 100-years ARI event has a probability of exceedance of 0.5 hours in 100 years, or $5.7\text{x}10^{-5}\%$. Figure

6.13 shows that the simulated extreme water levels which influence flood planning levels at Koolewong are consistent with, but a little higher than, the Koolewong water level probability of exceedance curve based on the 10 years of recorded data. Note that the correct plotting position, in terms of probability of exceedance, of these points is not known exactly; although it is likely that they occur less frequently. The probability of exceedance distribution for the February-March 2006 modelled data is a good match compared with the 10-years dataset for the more frequently occurring water levels.

Nevertheless, there is some difference between the recorded water level data at Koolewong and the results – other than for May 1974, which is consistent. The recorded data are likely to be a little low because of the less stormy period from 1993 to 2003. Note that it does not include the high record of April 1990, see Section 4.1.4.

6.7.2 Ettalong

Ettalong does not have a long term water level record like that for Sydney Harbour, or even a medium-term record (10 years) as there is at Koolewong. The May 1974 storm event indicates that extreme water levels at Ettalong may be higher than those for Sydney Harbour, although this is principally a product of wave set-up, which may occur at Ettalong due to the presence of the sandbars at the entrance to Brisbane Water from Broken Bay.

A probability of exceedance water level curve for Ettalong has been developed by modifying the design water level curve for Sydney Harbour (Fort Denison) (MHL, 1992) to reflect the differences between the sites. Water level data was available for Middle Harbour and Ettalong for the February – April 2004 period. The differences between Middle Harbour and Ettalong were determined for defined probabilities using an interpolation routine. The differences between the Ettalong and Middle Harbour water level probability of exceedance distributions during this period were then applied to the long-term Sydney Harbour water level probability of exceedance distribution. Additionally, note was taken of the extreme ARI simulations.

Figure 6.14 presents an adjusted water level curve for Ettalong based on the Sydney Harbour curve and Brisbane Water model results, including the 6 weeks tidal simulation. The modelled extreme water level ARI storm events are also shown. In general all datasets show good agreement over both the less frequent and more commonly occurring water levels.

6.7.3 Water Level Exceedance Plots

Comparison of the modelled water level data against recorded data at both Koolewong and Ettalong provides confidence that the models provide realistic results that are appropriate for use in the determination of flood planning levels. Furthermore, the results can be used to determine downstream boundary conditions for any local creek flood study that drains to the Brisbane Water estuary. To assist this determination, water level curves, in terms of probability of exceedance, are provided in Appendix H for fourteen locations along the foreshore where major creeks join the estuary. These locations are presented in Figure H1 in Appendix H. The plots include both the 6-weeks of simulated tidal data and the simulated design storm event results.

For the purpose of local creek flood studies the 1% probability of exceedance level, which is the level that one can be 99% confident will not be exceeded during any creek flood event, is a reasonable parameter to be taken for downstream boundary levels. For Narara Creek this level needs to be defined east of the railway causeway and the whole of Fagans Bay modelled. Table 6.3 provides a summary of the 1% probability of exceedance levels for the various foreshore locations shown in Figure H1, Appendix H.

Table 6.3 1% Probability of Exceedance Levels (mAHD) at Selected Foreshore Locations

Site	Foreshore Location	1% PoE Level	1% PoE Level +0.2m MSLR	1% PoE Level +0.9m MSLR
Koolewong	018	0.62	0.82	1.52
Ettalong	005	0.85	1.05	1.75
Ettalong Creek	001	0.93	1.13	1.83
Woy Woy	014	0.68	0.88	1.58
Gosford	024	0.72	0.92	1.62
Point Frederick	026	0.72	0.92	1.62
Erina Creek	029	0.74	0.94	1.64
Saratoga	036	0.72	0.92	1.62
Kincumber creek	049	0.63	0.83	1.53
Bensville	054	0.63	0.83	1.53
Davistown / Empire Bay	059	0.64	0.84	1.54
Rip Bridge	064	0.66	0.86	1.56
Wagstaffe	069	0.85	1.05	1.75
Pretty Beach	071	0.87	1.07	1.77
Narara Creek Entrance	102	0.75	0.95	1.65
Woy Woy Bay	111	0.74	0.94	1.64

6.8 Climate Change

6.8.1 Mean Sea Level Rise

Many scientists believe that global warming of the Earth's atmosphere will lead to a rise in mean sea level. Predictions of global sea level rise due to the Greenhouse effect vary considerably. It is impossible to state conclusively by how much the sea may rise, and no policy yet exists regarding the appropriate provision that should be made in the design of new coastal developments.

Based on a number of global greenhouse models, a guide to future ocean level rises is presented in Table 6.4.

Table 6.4 Predicted Greenhouse Related Mean Sea Level Rises

	Sea Level Rise (m) to Year 2100		
Greenhouse Scenario	Min	Max	Central
ASER (2001)	0.09	0.88	0.48
IPCC (2007)	0.18	0.59	0.34

Other recent investigations undertaken by CSIRO (1998) advise a mean sea level rise of 0.2m over the 50-years period from 1998 for the NSW coastline. Investigation of the Australia State of the Environment Report 2001 web-site advises a mean sea level rise of 0.09m to 0.88m by 2100. Thus there is considerable uncertainty in this parameter estimate.

To account for this uncertainty in the definition of planning levels around the Brisbane Water Foreshore, a range of sea level rise scenarios over a planning period of 100 years were considered. Firstly, the 100-years ARI design storm was re-simulated incorporating a mean sea level rise 0.3m. Results at four locations are shown below in Table 6.5. It can therefore be assumed that a rise in the MSL offshore tidal boundary will result in an equivalent rise of the design levels within the estuary, putting aside small changes in conveyance and storage.

Table 6.5 Peak Water Levels Under Mean Sea Level Rise Scenario – 100-years ARI Event

Scenario	Peak Water Level (mAHD)			
	Ettalong	Koolewong	Gosford	Woy Woy
Present	1.59	1.68	1.75	1.59
100 years planning period (with MSLR = 0.3m)	1.89	1.97	2.03	1.88

Through consultation with council and DECC it was decided to assess flood planning levels under four sea level rise scenarios. These cases included 0.18m, 0.3m, 0.55m and 0.91m rises over a planning period of 100 years. This analysis, as presented in Section 8 and Appendix J, will allow Council to set appropriate planning levels including consideration of the associated risks should upper predictions of sea level rise eventuate.

6.8.2 Storm Intensity and Frequency

There is no current consensus on the impact of climate change on coastal storms in the Central Coast region of NSW. While the IPCC (2007) warns of a potential increase in the frequency and intensity of coastal storms and cyclone events, recent studies, for example CSIRO (2007) and McInnes *et al* (2007), present climate change predictions which indicate both increased and decreased wind speeds along the NSW coast, depending on the model and/or climate change scenario applied.

Brisbane Water is not located in an active tropical cyclone region and even studies which predict the largest increase in the southern extent of the east Australia cyclone region due to climate change processes do not predict cyclones off the Central Coast of NSW within the next 50 to 100 years (CSIRO, 2007).

Of more importance for the NSW central coast is the potential change in ECL event frequency or intensity due to climate change. Current understanding on ECL events is limited, although it is widely believed that the ENSO cycle has a significant influence on the frequency of ECL events. A study of "East Coast Lows" along the Queensland coast identifies that east coast lows have doubled in frequency over the 30years to 2000 (AGSO, 2000), most notably due to the 1970-1980 period of high frequency events, and while it identifies this as significant it also makes the point that this "*appears linked to broader climatic variations*" such as the Southern Oscillation Index.

Climate change models to date have not been able to investigate changes to wind conditions generated by small scale systems such as ECL events. CSIRO (2007) concludes that for ECL events "*model studies do not as yet indicate how the occurrence of east coast low pressure systems may change*".

Due to the lack of consensus related to climate change impacts on the frequency and/or intensity of these events it is appropriate to adopt coastal storm conditions based on the current climatology and historical records.

6.9 Discussion

The results of the hydraulic modelling simulations show that extreme water levels caused by ocean storm events are the predominant driver of extreme water levels within the estuary. A direct comparison of equivalent catchment storm and ocean storm ARI events shows that ocean storm levels exceed those of the catchment storms. This is consistent with historical data and resident surveys. Furthermore, at the peak of a 100-years ARI ocean storm event, the volume of water within the estuary is approximately 128,000,000m^3, while the total run-off during a 100-years ARI - 6 hours catchment storm event is in the order 23,500,000m^3. The effect of this catchment event would therefore not be expected to be of the same significance as the ocean events.

6.10 Hydraulic and Hazard Categorisation

Based on a detailed DEM of the Brisbane Water Estuary foreshore and catchment areas (provided by Council) and the available survey of low-lying areas, flood extents were developed using the results of the hydraulic (oceanic) modelling. These extents are presented in Figures 6.16 A - I for the 20-years ARI, 100-years ARI and PMF events. A key to these extents is provided in Figure 6.15. Levels used to derive these extents are based on the design storm tide level, neglecting wave run-up. Also included in the extent figures is the wave impact zone that delineates the areas that are exposed to wave run-up and overtopping in addition to design water level inundation. While these extents show the general nature of flooding around the foreshore areas, the extents may not be appropriate on a site by site basis. That is, the extents are only as accurate as the survey data on which they are based. Furthermore, local site specific topographic information was neither available nor practical for inclusion into the modelling and mapping systems.

6.10.1 Provisional Flood Hazard

The provisional flood hazard variations of the waterway were defined as per the definition provided in the *Floodplain Development Manual - Figure L2* (NSW Government, 2005), presented as Figure 6.17. The hazards are provisional because they only consider the hydraulic aspects of flood hazard. Using model results the hazard was calculated from the envelope of the velocity - depth results calculated for each discrete time step.

The Floodplain Development Manual (2005) requires that other factors be considered in determining true hazard such as size of flood, effective warning time, flood readiness, rate of rise of floodwaters, depth and velocity of flood waters, duration of flooding, evacuation problems, effective flood access, type of development within the floodplain, complexity of the stream network and the inter-relationship between flows.

High and low hazard areas were defined over the entire foreshore area for the 100-years ARI event and are provided in Figures 6.18 A - I. Figure 6.15 provides the key to the various figures.

6.10.2 Hydraulic Categorisation

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The Floodplain Management Manual (2001) defines flood prone land to fall into one of the following three hydraulic categories:-

- **Floodway -** Areas that convey a significant portion of the flow. These are areas that, even if only partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.

- **Flood Storage -** Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked, would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.

- **Flood Fringe -** Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

Floodways were determined for the 100-years ARI case by considering those model branches that conveyed a significant portion of the total flow. These branches, if blocked or removed, would cause a significant redistribution of the flow. The criteria used to define the floodways are described below.

As a minimum, the floodway was assumed to follow the waterway from bank to bank. In addition, the following depth and velocity criteria were used to define a floodway:-

- Velocity x Depth must be greater than 0.25m^2/s **and** velocity must be greater than 0.25m/s **OR**
- Velocity is greater than 1m/s.

Flood storage was defined as those areas outside the floodway, which if completely filled, would cause peak flood levels to increase by 0.1m and/or would cause peak discharge anywhere to increase by more than 10%. This criterion was applied to the model results as described below.

Previous analysis of flood storage in 1D cross-sections assumed that if the cross-sectional area were reduced so that 10% of the conveyance was lost, the criterion for flood storage would be satisfied. To determine the limits of 10% conveyance in a cross-section, the depth at which 10% of the flow was conveyed was determined. This depth, averaged over several cross-sections, was found to be 0.2m, typically, (Howells et al, 2003). Thus the criteria used to determine a flood storage area were:-

- Depth greater then 0.2m
- Not classified as floodway.

All areas that were not categorised as Floodway or Flood Storage, but still fell within the flood extent, are described as Flood Fringe.

The hydraulic categories for the 100 -years ARI event are provided as plans in Figures 6.19 A - I. The hydraulic categories are based on the envelope of the hydraulic categorisation at each location. The hydraulic categorisation was undertaken for each discrete time step and the envelope of these results presented.

7. WAVE PROCESSES

7.1 Numerical Wave Model

Wave processes in Brisbane Water have been investigated using the SWAN wave model. The SWAN wave model, developed at the Delft University of Technology, includes a full spectral solution for wave propagation, wind input, refraction, shoaling, model boundary wave input, directional spread, bed friction, white-capping and non-linear wave-wave interaction. The model has the capability of resolving curvilinear grids as well as nested grids that allow for large areas to be modelled whilst, providing fine resolution in areas where seabed depths have high spatial variability.

7.2 Model Set Up

Due to the complexity and extent of the waterway system, a series of separate model domains have been developed to cover the whole study area and to allow local sea and swell to be investigated. Swell wave conditions typically affect coastal areas and locations near Ettalong – seaward of about Schnapper Road. The overall Delft3D model grid (Figure 6.2) has been used to propagate swell from deep water into the study area. The grid was truncated at 'The Rip' because swell energy does not propagate past that point.

To account for the complex physiography of the region, a total of five high-resolution domains were defined to investigate local sea inside Brisbane Water. Figure 7.1 describes the extent of all the individual local sea model domains. These wave model layouts mean that there are some shoreline locations that lie within two grid areas. Results were taken from the more appropriate grid (complete fetch definition for a specific wind direction).

Wave propagation was undertaken at a water level of 1.6m AHD, this being analogous to a high storm-tide water level within Brisbane Water, even though this level would be more likely to occur during a severe east coast low ocean storm with onshore winds rather than with northerly winds, for example. Nevertheless, water levels can remain high for some hours as wind direction changes. Wave generation is sensitive to water level in the more shallow areas of Brisbane Water because of the relatively large increase in water depth that high water levels cause.

The same 119 locations along the Brisbane Water foreshore as selected for the hydraulic modelling, see Figure 6.1, were selected for the wave model output. Shoreline locations were generally in a depth of 1m CD, typically. Because local sea periods are relatively short, typically 1 to 3 seconds (T_z), bed friction, does not affect wave propagation to these locations. Wave breaking was important only at the shoreline/shoreline-structures themselves, to be addressed in Section 8.

7.2.1 SWAN Model Calibration

Wave model calibration provides confidence that the model system applied to this investigation will reproduce wave conditions in Brisbane Water reliably. The model has been calibrated for local sea in Botany Bay using the same Sydney airport wind data in depths similar to those used for this study, see Lawson and Treloar (2003). No site specific characteristics required changing and so the SWAN model can be used at this site also with confidence.

7.3 Local Sea Wave Climate

The SWAN wave model was used to develop the wave 'climate' at foreshore locations along the Brisbane Water foreshore study area. This task required the SWAN wave propagation model to be applied to a large range of wind directions from north through south to north-west at 22.5^{o} increments around the clock. Additionally, a range of wind speeds from 2.5 to 25m/s were included, leading to 176 wave modelling cases at a water level of +1.6mAHD – a rare high water level, but not unknown and in the order of the 100-years storm tide level described in Section 6.4. The results of this wave modelling provided a basis for developing 59 years of time series wave data at each foreshore location from the observed wind data at Mascot. This model output provided a long-term time series of wave parameters at each of the foreshore locations in terms of H_s, T_z and direction, together with wind speed and direction.

7.4 Swell Wave Climate

For the swell wave model, a matrix of predefined model simulations was simulated using 22.5^{o} direction intervals (9-directions, north through east to south) and 1s period intervals from 3 to 11s (T_z – 9 wave periods). Time series of swell wave conditions were then prepared by transferring 9 years of recorded offshore directional wave data from Sydney (MHL Long Reef Waverider buoy data) to selected locations within the Ettalong area.

7.5 Detailed Wave Climate

The time series results, for both sea and swell, were then examined to identify peak storm wave heights, which were then analysed using the Extreme Value Type 1 distribution and applying the method of moments to the top 50 wave height results in each directional sector at each selected location. This provided extremal wave conditions for selected average recurrence intervals (ARI) in each directional sector; though generally, swell only has one nearshore direction at each location. Jointly occurring wave period parameters were then determined by correlation analysis.

The results are presented in Appendix I for selected average recurrence intervals (ARI) from 5 to 200 years.

In local-sea wave conditions the largest waves occur in the Broadwater areas of Gosford that are exposed to the south-easterly to south-westerly fetches. Near some protected areas there is little difference between 5-years ARI and 100-years ARI conditions because wave generation is fetch limited.

Near Ettalong, swell wave conditions up to 1m (H_S) are observed. Swell propagation to Ettalong is limited by water depth on the Ettalong Point shoal. Furthermore, swell waves do not penetrate further than Booker Bay, with only very small amounts of wave energy passing Kourung Gourung Point.

Wave periods (T_Z) are generally less than 3 seconds for local sea - 1.5 seconds at 5-years ARI to 2.5 seconds at 100-years ARI. For swell, T_z varies from 8 to 10.5 seconds for 5 to 100-years ARI, typically.

8. DESIGN PLANNING LEVELS

The estimation of design planning levels includes a number of components, which are:-

- Design Still Water Level
  - Storm tide level from ocean modelling scenarios - ocean storm-tide, swell set-up and wind set-up
  - Local sea wave set-up at each site, a function of edge treatment and incident waves
- MSL rise
- Local design wave parameters - wave run-up, a function of edge treatment

Results for each of these components are presented in Appendix J, Tables J1-I3, for specified design events; being the 5, 100-years ARI and PMF events.

8.1 Joint Occurrence

Design water levels for properties located along the foreshore of Brisbane Water will be affected by elevated water levels within the estuary that occur during severe ocean storms, generally from the east-north-east to south sector. Those high water levels may be accompanied by local sea wave activity that then causes local sea wave set-up and run-up; though wave set-up will be minimal because wave periods will be very short. However, the highest storm tide levels in the area will occur during storms that have south to easterly sector winds - not northerly or westerly winds. Swell will only penetrate to the Ettalong area. Therefore, the joint occurrence of the highest water levels and highest local wind-generated waves will be very rare on the westward and northward-facing shorelines of the study area. Hence, the following joint occurrence relationship between local sea waves and the 100-years ARI design storm tide level has been adopted: -

- 100-years ARI storm tide and the greater run-up of coincident 100-years ARI local sea from the ENE-South directions, 100-years swell (at Ettalong) and a boat wave height of 0.5m.

8.2 Storm Tide Level

Design water levels are formed from a number of increments that are described in detail in Section 6.4.

No single estimate of MSL rise has been adopted for this study. There is some uncertainty associated with this parameter, as discussed in Section 6.7, and as such four sea level rise scenarios have been assessed to account for this uncertainty. Sea level rises of 0.18m, 0.3m, 0.55m and 0.91m for a 100-years planning period have been assessed, based on recommendations made by the IPCC (2007) and DECC and through discussion with council. The procedure for defining planning levels (Section 8.6) makes allowance for any value of sea level rise to be included, based on a rise in mean sea level resulting in an equivalent rise in the design storm tide level around the Brisbane Water foreshore (see Section 6.8.1). The assessment was undertaken for each of the four sea level rise scenarios to provide the subsequent management study or plan with sufficient information to adopt an appropriate position in regards to future sea level rise and its inclusion within the flood planning level.

8.3 Wave Set-up

The process of wave set-up refers to the deviation of the mean water level as a result of wave shoaling, breaking and momentum flux conservation as it progresses shoreward across the breaker zone. Goda (2000) provides an approximation of this set-up based on the significant wave height (H_s) or the breaking wave height (H_b) near the shoreline, whichever is smaller. The calculation of wave set-up is implicitly included in the derivation of the water level component for the wave run-up estimations. It is also presented separately, in line with approximations from Goda (2000), within Appendix J, Tables J1 to J3.

Regional wave set-up caused by the shoreward propagating swell has been included in the ocean storm modelling.

8.4 Local Design Wave

Discussion of the derivation of design waves at the 119 foreshore model output locations can be found in Section 7 and results are presented in Appendix I. In defining the planning level, the design wave height, either sea or swell, that provides the greater run-up height is to be used, generally. However, consideration of possible boat waves that may approach the shore when design water levels are present needs attention.

Review of the NSW Maritime (2007) area map shows the presence of both 4 and 8 knots speed restriction and no-wash zones at various locations around the Brisbane Water foreshore. The locations of these restrictions are catalogued in Table 8.1 along with their corresponding output locations. Along these shorelines consideration of boat waves can therefore be ignored. However, outside these areas the foreshore may be subject to wash of larger boats, like ferry services. It is estimated that boat wash from these types of vessels could reach a height of 0.5m with a wave period in the order of 5 seconds. To this end, the wave run-up assessment was undertaken for both the local design wind wave, either sea or swell, and the boat-wash wave of 0.5m with the larger run-up value adopted for each location.

Table 8.1 Navigation Restriction Zones in Brisbane Water Estuary

Navigational Restriction	Location	Output Point
8 knot zone	Ettalong Beach	2 - 5
8 knot , no wash zone	Booker Bay	7 - 9
4 knot, no wash zone	Woy Woy Channel	15 - 17
8 knot zone	West Pt Fredrick	25
no wash zone	Paddys Channel	39
8 knot , no wash zone	Lintern Channel	40 - 41
no wash zone	Cockle Channel/Cockle Bay	42 - 46, 55 - 60, 90 - 93
4 knot, no wash zone	St Huberts Island	61 - 63, 75 - 85
8 knot, no wash zone	Rileys Bay, Hardys Bay and Pretty Beach	67 - 71
4 knot zone	Fagans Bay	94 - 103

8.5 Wave Run-up

Wave run-up and wave overtopping height computations have been based on formulations presented in Coastal Engineering Manual (2002), Shoreline Protection Manual and a Manly Hydraulics Department study (2001). They provide combined wave set-up and run-up heights, without providing a breakdown of the two water level components. None of these publications addresses wave run-up relationships for all shoreline case types that may be encountered in Brisbane Water.

Wave run-up depends upon edge treatment and is irregular in its character. Five idealised edge treatment cases have been addressed in this study – each for two crest levels. They are described below:-

- 1 in 20 natural slope
- 1 in 10 beach face
- 1 in 5 embankment
- 1 in 2 seawall
- Vertical wall

Examples of these edge treatment types that are currently found around the Brisbane Water foreshore are shown in Figures 8.1 and 8.2.

For the first four cases, run-up is in terms of the 2% non-exceedence run-up height. That is, only 2% of run-up waves will be higher. Generally, these edge treatment conditions refer to the shoreline near the level of the 100-years ARI storm tide.

Calculations were undertaken for two edge treatment crest heights, being 1.5mAHD and 2.5mAHD, for each edge treatment type, resulting in 10 overall run-up height calculations at each location. The two selected crest levels are considered to cover the vast majority of foreshore levels around Brisbane Water.

In defining the run-up level, three mechanisms of wave run-up were identified. They included wave run-up without overtopping of the edge treatment crest, wave run-up rising above the edge treatment crest, thereby resulting in wave overtopping and wave overtopping when the design still water level is above the edge treatment crest.

8.5.1 Wave Run-up with No Overtopping

Run-up algorithms on smooth slopes can be found in many published articles and manuals. For the purposes of this study, the de Waal and van der Meer (1992) wave run-up algorithm for smooth slopes, as specified in the Coastal Engineering Manual (2002) has been adopted. The equation for this calculation is presented in Appendix K. It is described as a robust approximation developed using extensive measurements of model run-up events (CEM, 2002). Should the run-up level not exceed the defined crest level, then the planning level is considered to simply be the run-up height on top of the SWL (+freeboard).

The definition of run-up on a vertical wall is quite different, however. For a smooth impermeable, continuous wall the run-up level can be approximated as the wave height above the still water level (SWL), or approximately two times the crest level above the SWL. This is derived from linear wave theory – suitable for short period waves.

8.5.2 Wave Run-up with Overtopping

Once the crest level is reached, the mechanism of run-up is no longer applicable because there is no edge treatment slope to allow the run-up process to continue. In this case overtopping of the crest occurs and a wave is transmitted onto the foreshore area. This transmitted wave can be defined using an algorithm developed by Seelig (1980) as defined in the Shoreline Protection Manual (1984). The equation is presented in Appendix K. The run-up level can then simply be defined as the height of the transmitted wave added to the crest level.

8.5.3 Overtopping when SWL is above the Crest

Should the design SWL be above the foreshore crest level, then waves are able to directly penetrate onto the foreshore areas. Studies undertaken by the Manly Hydraulics Department (2001) define the depth of penetration as half the approaching wave height. This is thought to be a realistic approximation of the wave dynamics and from this the planning level can be defined as the height of the penetrated wave on top of the crest level or water level, whichever is higher. Again, this approximation is defined in Appendix K.

8.6 Flood Planning Levels

The definition of flood planning levels can therefore be undertaken using the following calculation:-

$$PL = DWL + WRH \qquad \text{(eqn. 8.1)}$$

where:

PL - Planning Level
DWL - Design Water Level = Design Storm Tide Level + Local Wind Setup + Mean Sea level rise.
WRH - Wave Run-up Height - based on edge treatment type and wave parameters

both values are presented in Appendix J, Tables J1 to J3, for the specified design return periods.

Tables J4 to J8, in Appendix J, present the calculated run-up levels for the 100-years ARI parameters excluding mean sea level rise (Table J4) and including various predictions of mean sea level rise as described in Section 8.2 (Tables J5 to J8). The maximum calculated value for all 10 foreshore edge treatments has been adopted as the preliminary Flood Planning Level at each site. It is envisaged that should further clarification of the planning level be required, consideration of the type of edge treatment could be undertaken using Appendix J, Table J2.

Note that freeboard may need to be added to these planning levels.

8.6.1 Foreshore Finishes

The magnitude of wave run-up is also dependant on the finish material of the foreshore edge treatment. Generally, the higher the porosity or roughness of the edge treatment the lower the run-up height. The prescribed algorithms for run-up calculations, see above, are for smooth impermeable slopes, an upper limit case. As a basic guide, reduction coefficients are provided, in line with published literature (CEM, 2002) and based on a variety of possible edge treatment types. They are presented in Table 8.2.

It should be noted that these factors are applicable to the run-up height not the combined planning level. Therefore, should such reduction factors be incorporated into the assessment of the FPL, they must be applied to the wave run-up height only, using equation 8.1 together with the values from Appendix J, Table J2 (for the 100-years ARI). The revised formula for calculating the FPL is now:-

$$PL = DWL + (WRH \times RR) \qquad \text{(eqn. 8.2)}$$

where:- *RR* = Surface Reduction Factor - from Table 8.2

Table 8.2 Surface Roughness Reduction Factors

Type of Edge Treatment Surface	Reduction factor for $R_{u2\%}$
Smooth, concrete, asphalt, sand and block/brick revetment	1.0
Grass / vegetated bank	0.90
Modular permeable wall	0.80
Rock structure (1 layer)	0.60
Rock structure (2 layer)	0.55

8.6.2 Inland Reduction in Flood Planning Levels

Where a block slopes upward back from the shoreline edge structure, the FPL will affect only a small part of the block. However, where a block is relatively flat, wave run-up may penetrate some distance inland, but is attenuated by percolation and friction. This landward reduction of wave run-up can not be estimated with great confidence, and has been based on observational experience. For local sea cases it is assumed that wave run-up diminishes to zero at a point 20m inland from the edge structure – swell energy has a greater overland penetration capacity and may be in the order of 40m.

Figure 8.3 shows local sea waves overtopping at the Gosford vertical seawall during the June 2007 storms. This shows that although a significant amount of water overtops the crest of the wall the inundation is limited to an area less than 10m from the crest of the wall. These storms were considered to be in the order of a 5-years ARI event and hence a value of 20m for local sea overtopping under the 100-years ARI design event is considered to be appropriate.

The application of the FPL should therefore be done over this 20m wide area, 40m when considering swell, of the foreshore. Landward of this area, the planning level should be based on the calculated design water level (DWL) for the appropriate foreshore location.

8.6.3 Freeboard

The estimation of all of the components that make up the FPL at each selected location includes some uncertainty, and the degree of uncertainty varies with each water level component. It is greatest for wave run-up; and wave run-up can be the largest water level component.

It is common practice to take some precaution over this uncertainty. In this case, where wave run-up height is greater than or equal to 1.3m, no freeboard allowance has been adopted. Where it is equal to or less than 1m, a freeboard allowance of 0.3m is advised; with varying freeboard magnitude adopted for run-up heights between these delimiting magnitudes in order to provide consistent outcomes in FPL.

The definition of the FPL above has not included a freeboard allowance. It is envisaged that such an allowance would be applied – except where wave run-up height exceeds 1.3m, and would provide a factor of safety over the uncertainty associated with the calculation of the FPL. A freeboard of 0.3m should therefore be applied once the FPL is calculated.

8.6.4 Further Considerations

Should a particular property lie between two of the reported foreshore locations, the location that provides the higher FPL should be adopted. This takes a conservative approach that is in keeping with the floodplain risk management and estuarine management processes, outlined by the NSW Government.

8.6.4.1 Risk Assessment

Design criteria are generally determined on the basis of an average recurrence interval (ARI). In this instance an ARI of 100-years has been adopted. This is a common design risk position for public and private property that is not of a critical nature – such as hospitals and ambulance stations.

Adopting this design ARI leads to the following risk levels: -

Planning Period or Property Life (years)	Probability (%) of Equalling or Exceeding the 100-Years ARI Level
25	22
50	39
75	53

These encounter probabilities indicate that there is a risk of the design water levels being exceeded during a planned functional life of a property that is less than 100 years, even though the 100-years ARI level has been adopted.

9. CONCLUDING REMARKS

This report describes the investigations undertaken to develop Flood Planning Level parameters for the Brisbane Water Foreshore.

It has been found that severe ocean storms cause the highest levels rather than catchment floods of the same ARI or AEP, other than within Fagans Bay, which is affected by Narara Creek and the Main Northern Railway causeway.

The investigations were based on extensive data analysis and calibrated modelling systems, with the outcomes showing considerable consistency between the two data types.

The results provide two sets of data. They are:-

- Flood planning levels for developments along the Brisbane Water foreshore, including wave run-up for five types of edge treatment, two crest levels and roughness parameters
- Downstream boundary water levels that can be used for individual creek flooding studies. This parameter may reasonably be taken to be the 1% exceedance level, which is the level that one can be 99% confident will not be exceeded during any creek flood event. These levels are presented in Table 6.3 for selected foreshore locations. For Narara Creek this level needs to be defined east of the railway causeway and the whole of Fagans Bay modelled.

Uncertainty in future predicted sea level rise has been incorporated in the study through the calculation of flood planning levels under four possible sea level rise scenarios in line with current scientific consensus, the DECC and council.

Following public display three submissions were received. The report has been modified to address the matters raised.

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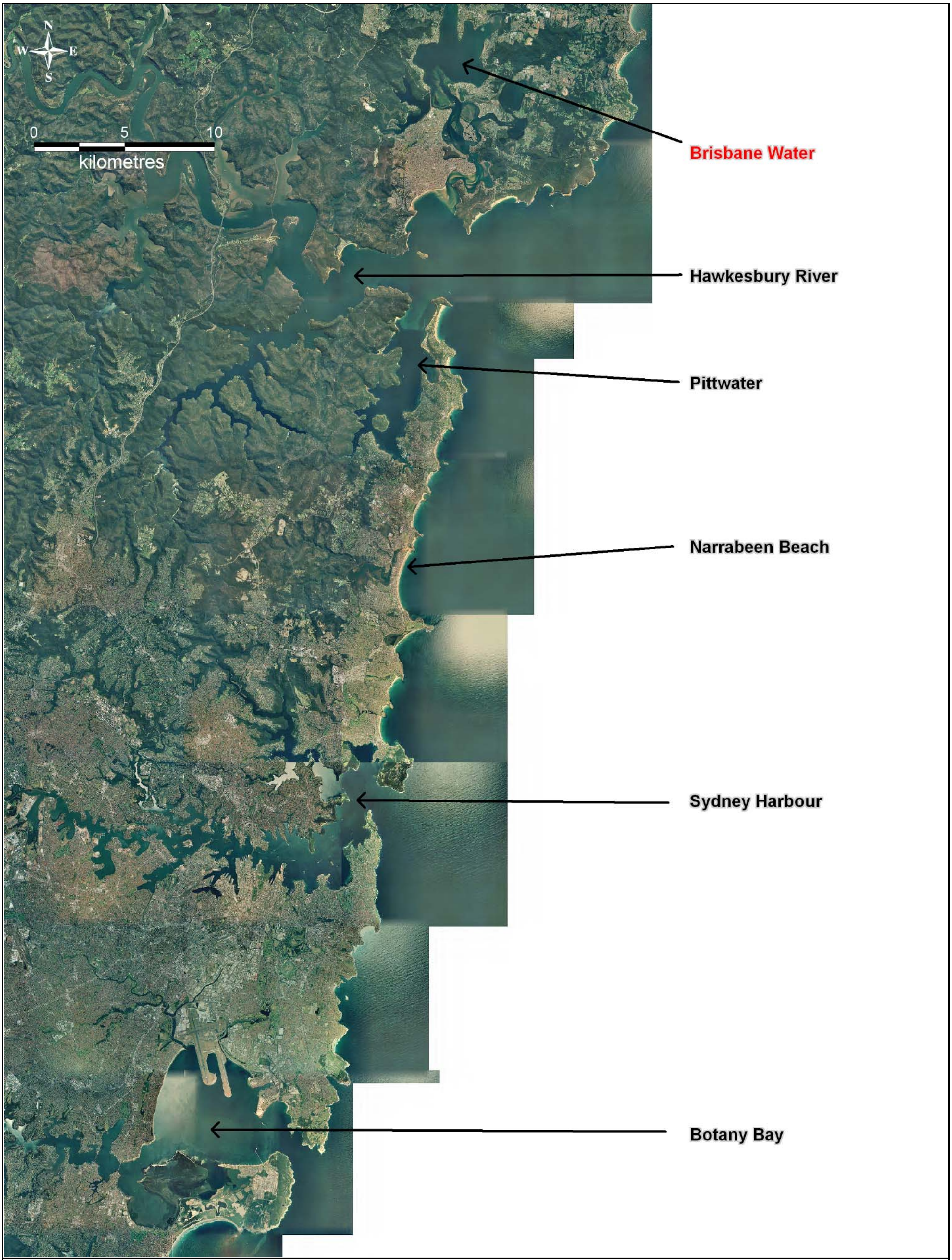
FIGURES



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LOCALITY PLAN

Figure 1.1

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STUDY AREA

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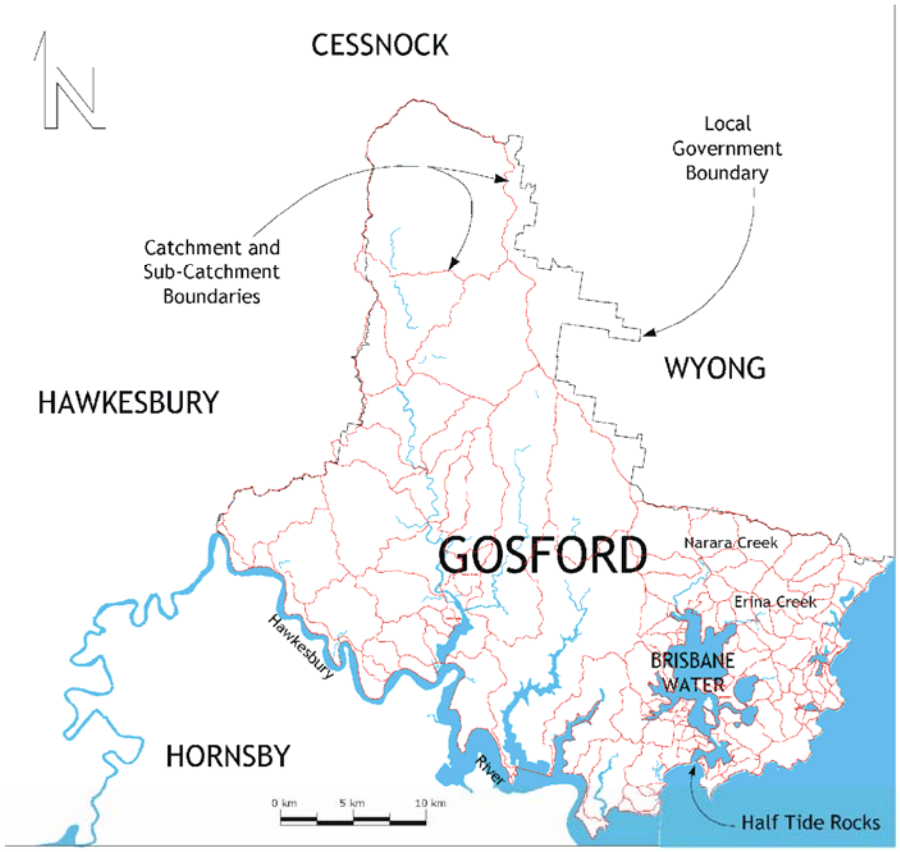
Figure 1.2



Brisbane Water within Gosford City Local Government Area

Brisbane Water Foreshore Flood Study Catchment Area

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Brisbane Water Foreshore Flood Study

BRISBANE WATER CATCHMENT LOCALITY

Figure 2.1

Empire Bay

Davistown

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PHOTOGRAPHS FROM SITE VISIT
UNDETAKEN 9th MAY 2006
Figure 3.1

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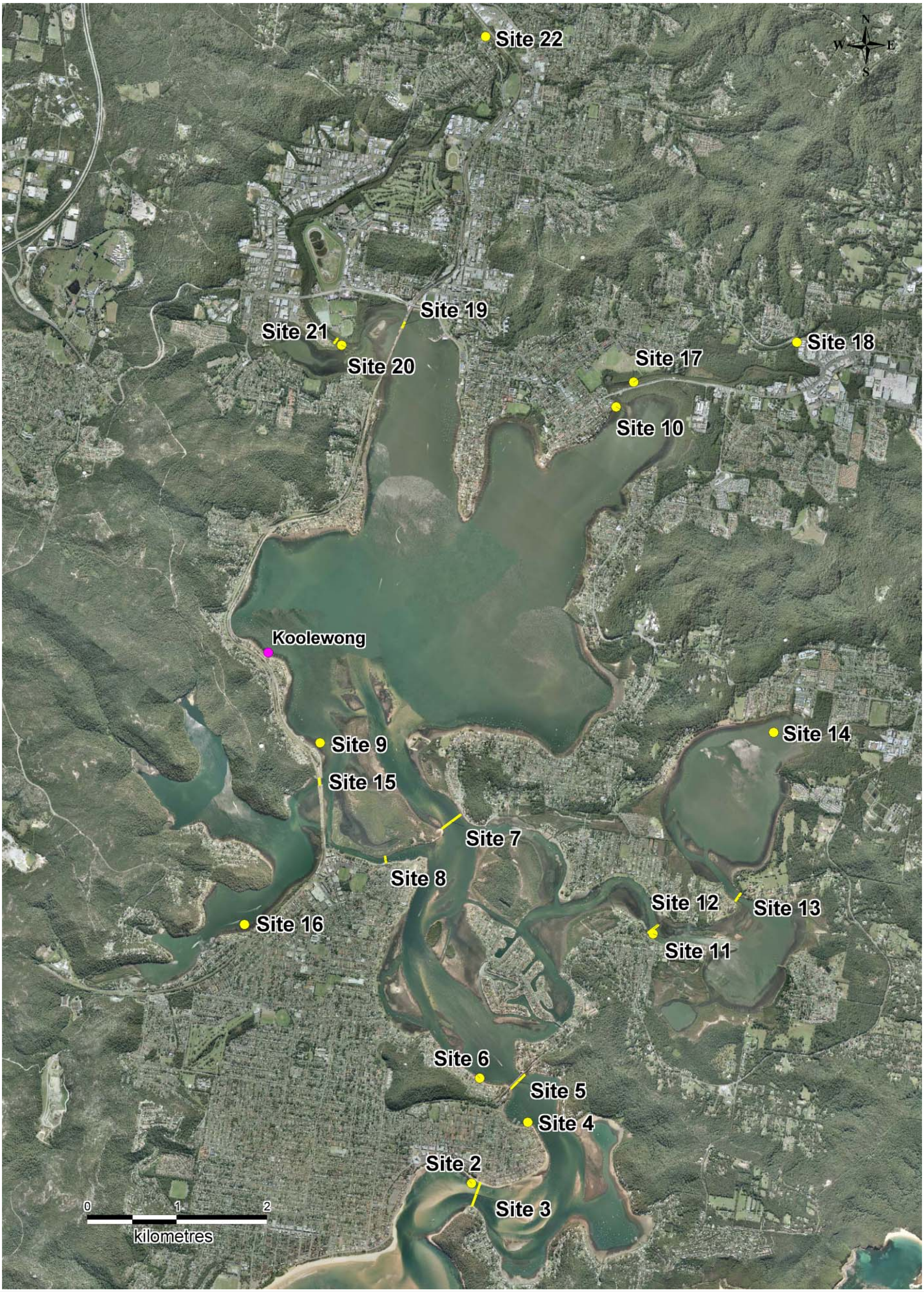

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MHL DATA LOCATIONS

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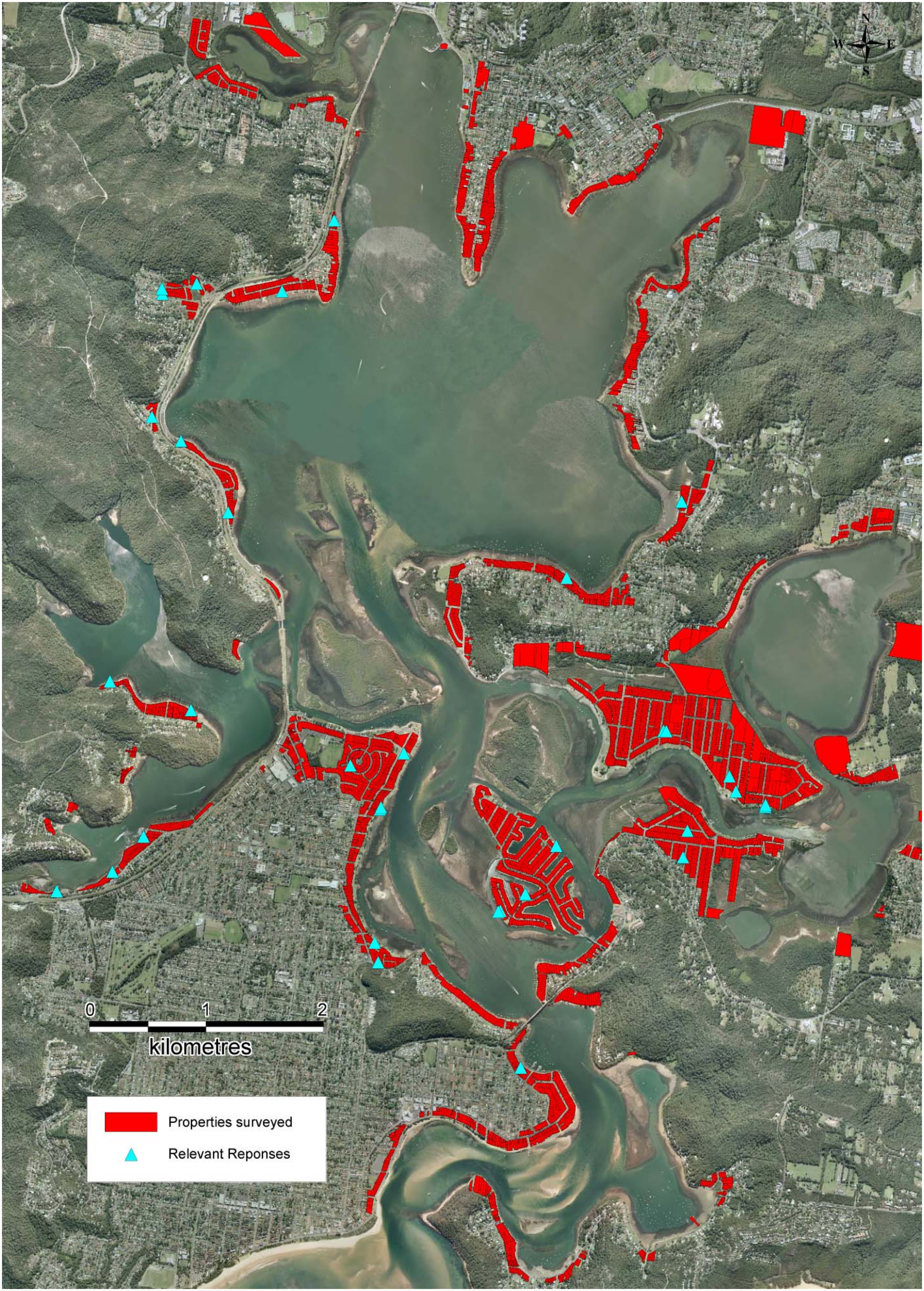
Figure 4.1



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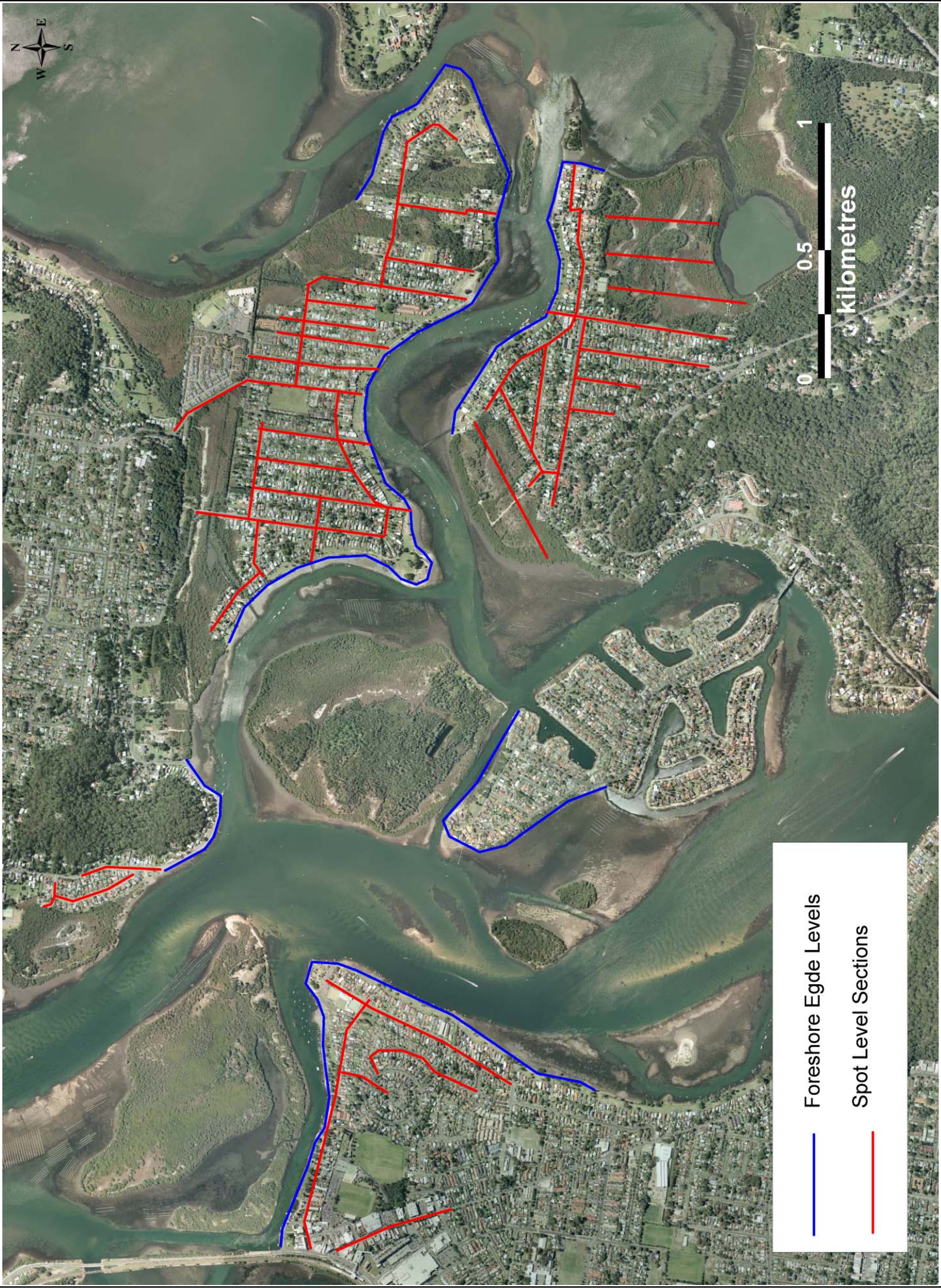
RESIDENT SURVEY LOCATIONS

Figure 4.2



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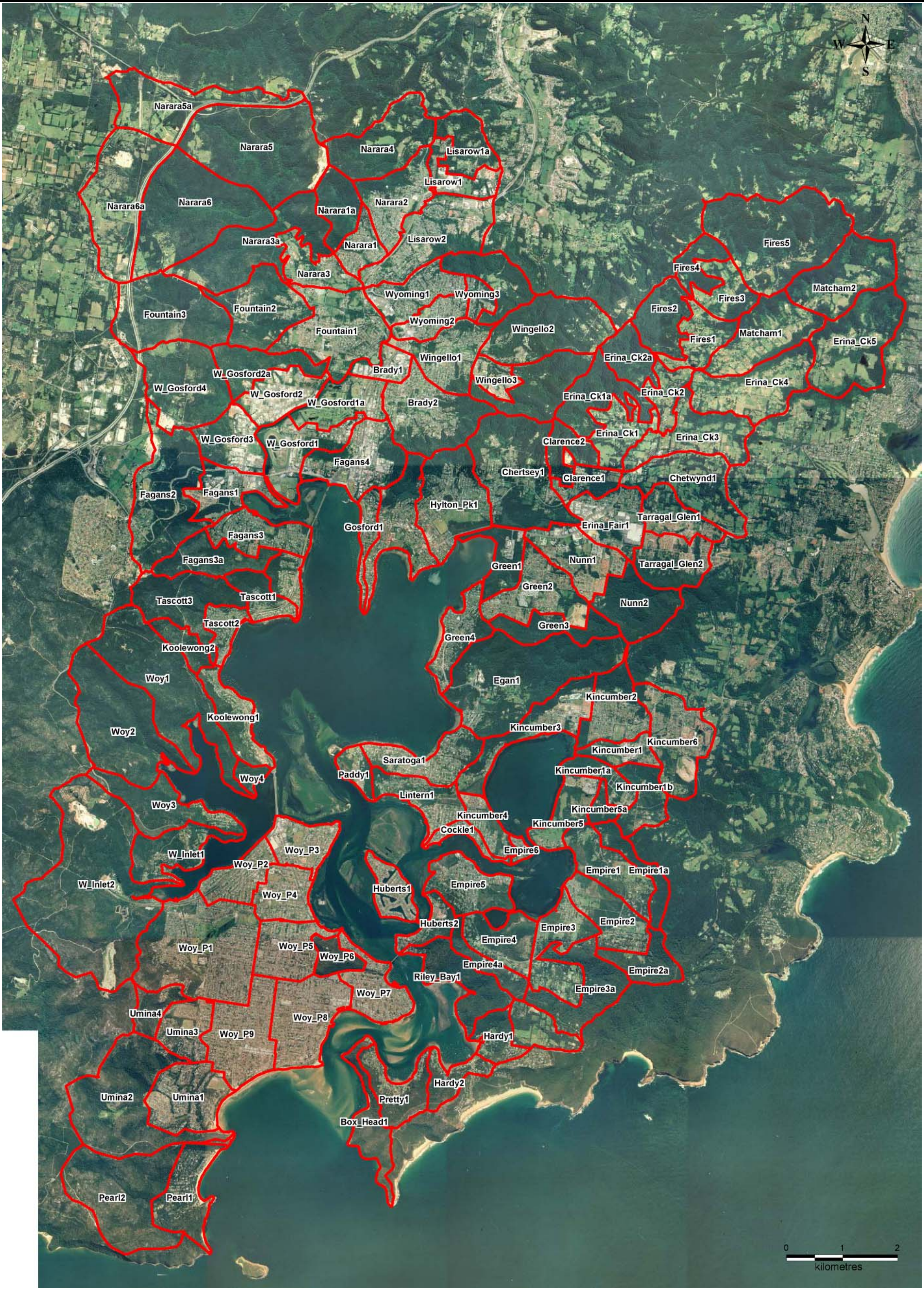
GROUND SURVEY SECTIONS
COMPLETED BY JOHNSON PARTNERS – MARCH 2007
Figure 4.3



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RAFTS CATCHMENT LAYOUT

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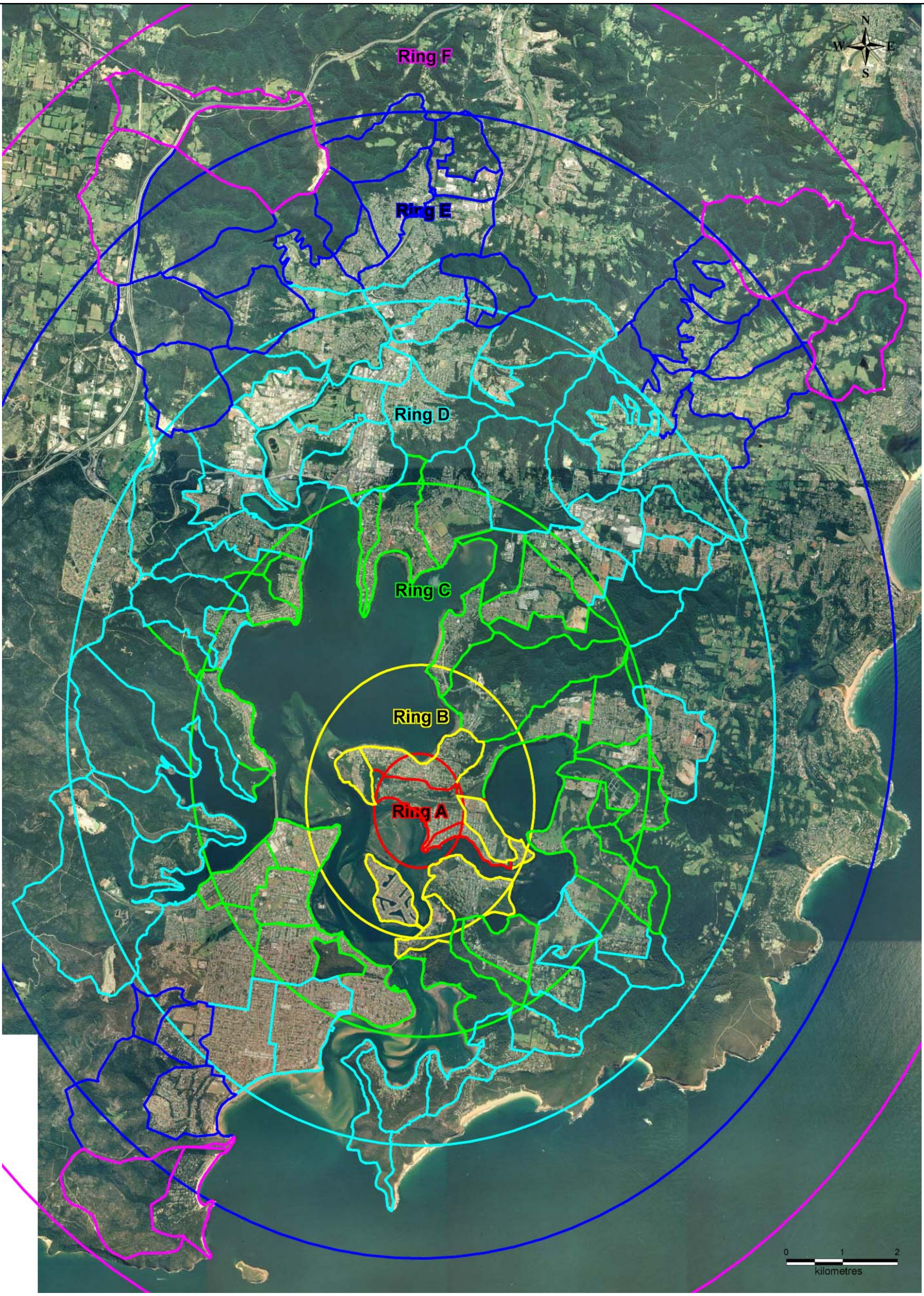
Figure 5.1



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PMP SPATIAL DISTRIBUTION RINGS

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Figure 5.2

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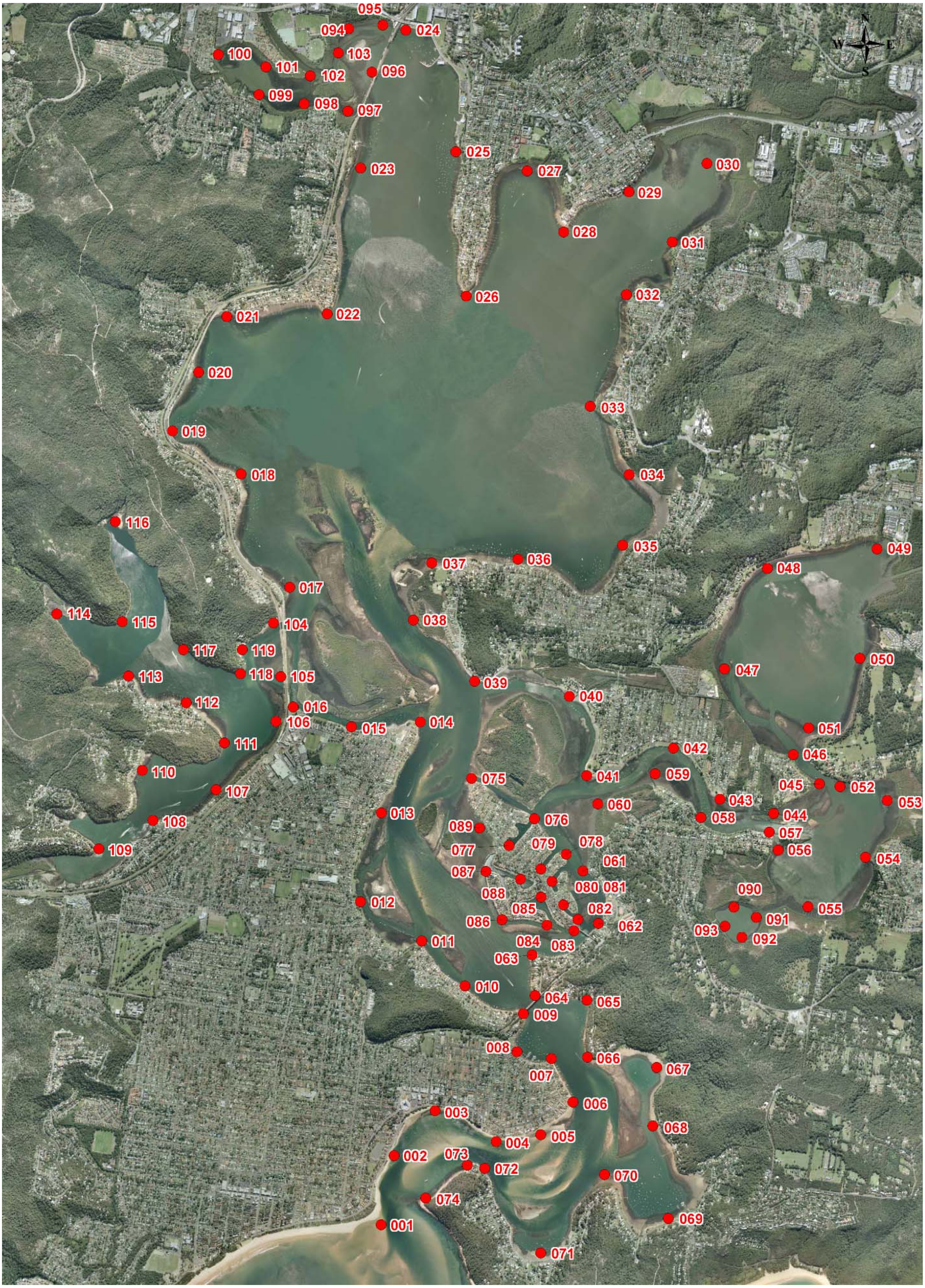
DELFT3D DISCHARGE LOCATIONS FROM RAFTS

Figure 5.3



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FOREShORE OUTPUT LOCATIONS

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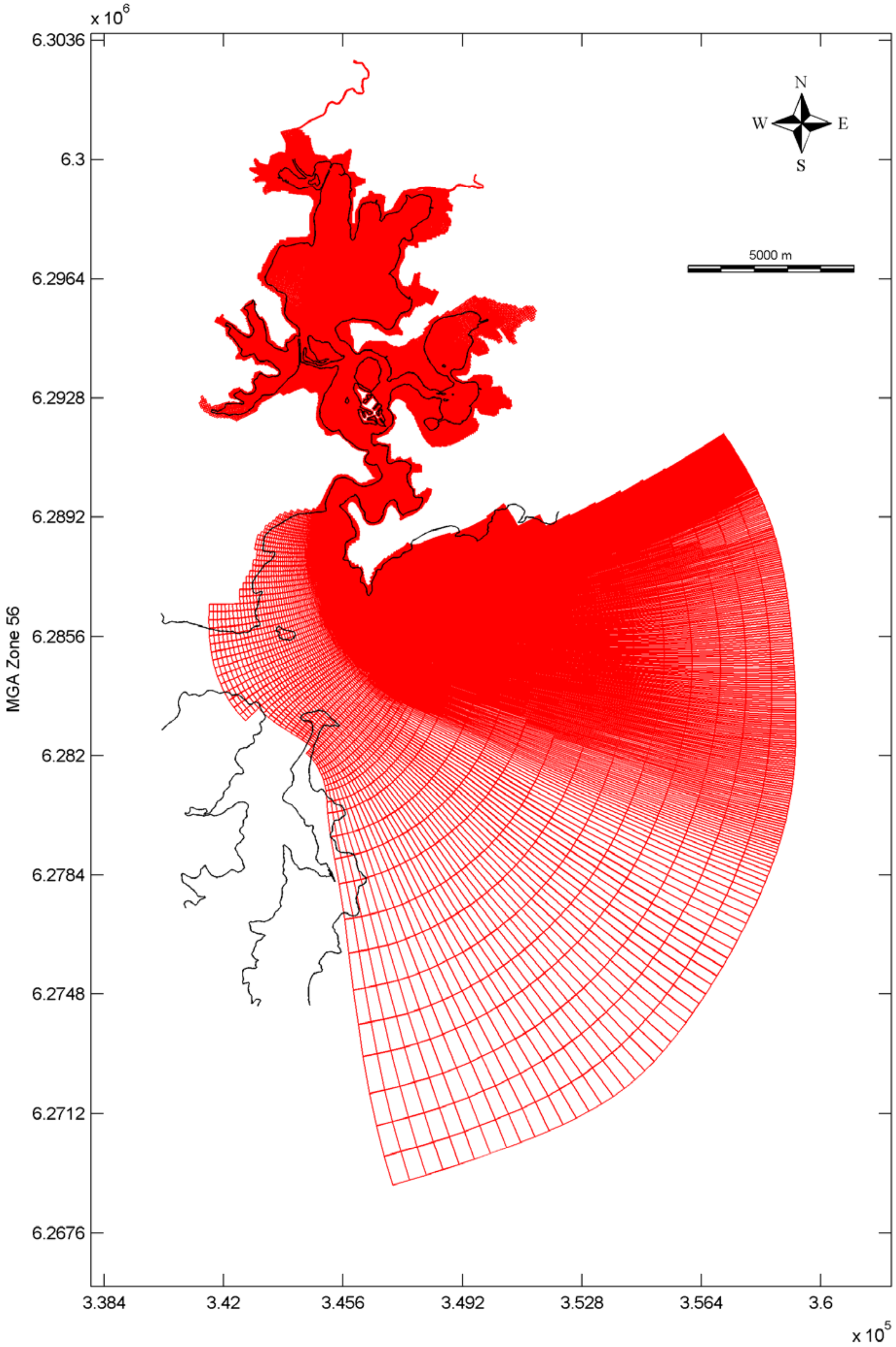
Figure 6.1



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DELFT3D MODEL GRID

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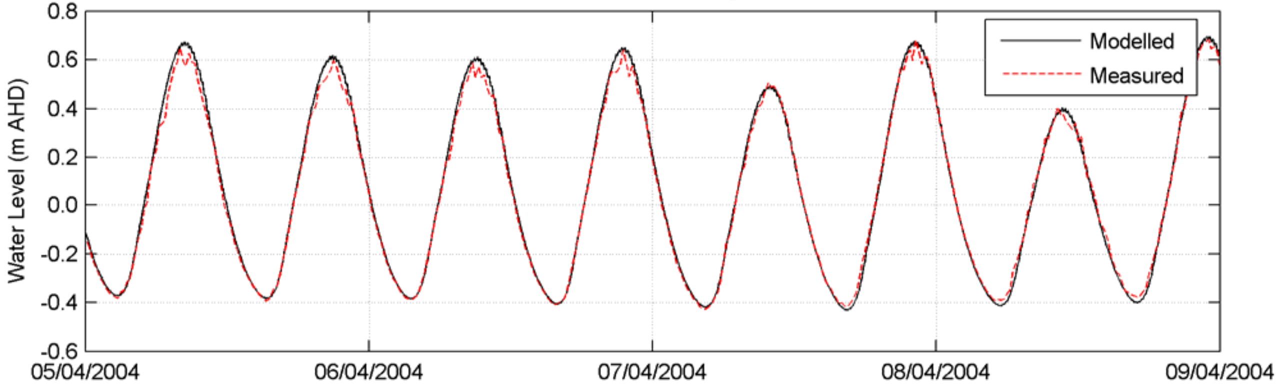
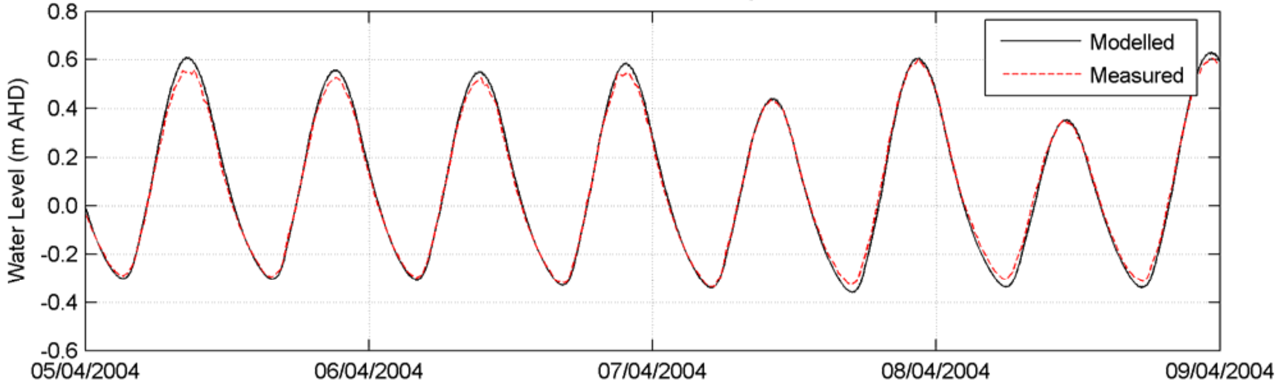
Figure 6.2

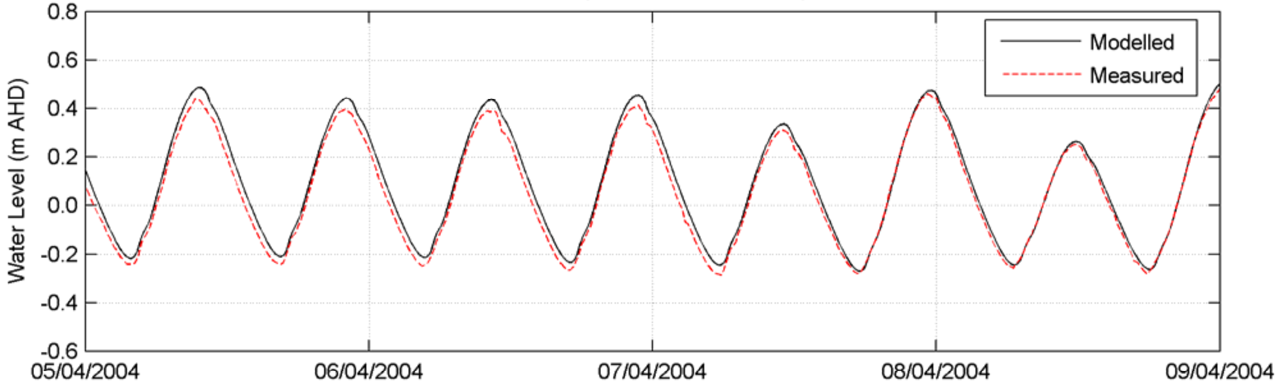
Site 2: Ettalong



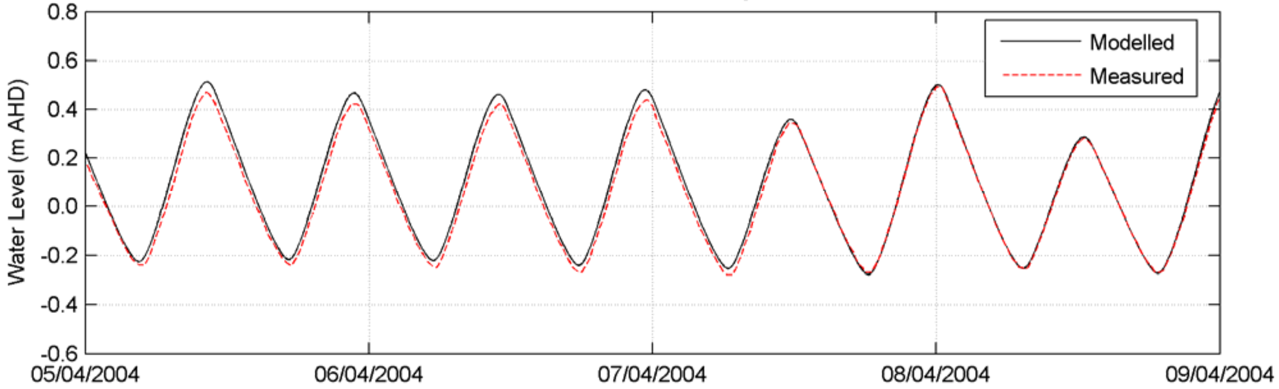
Site 4: Booker Bay



Site 6: Upstream of 'The Rip'



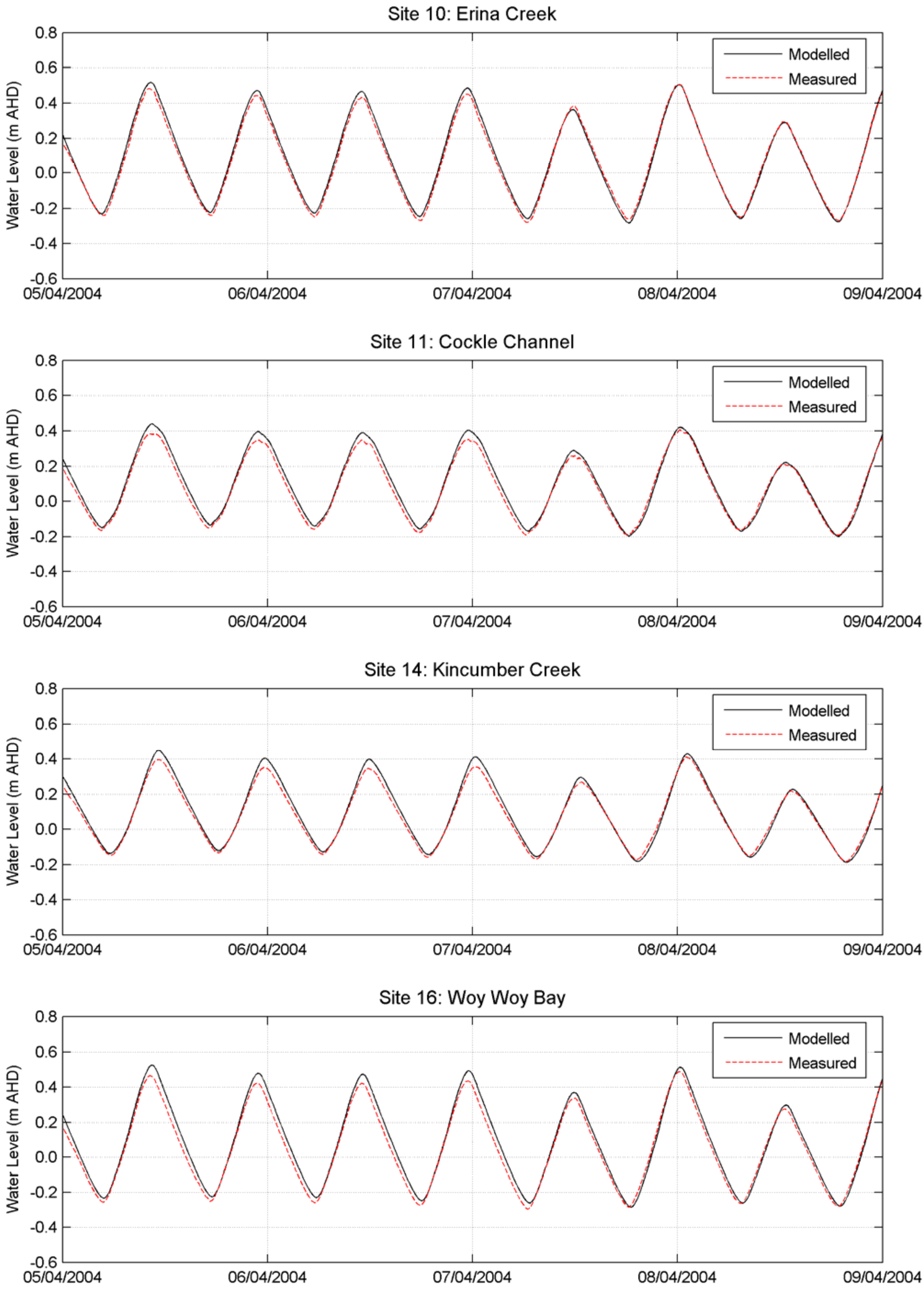
Site 9 Koolewong



Brisbane Water Foreshore Flood Study

WATER LEVEL CALIBRATION

Figure 6.3



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WATER LEVEL CALIBRATION

Figure 6.4

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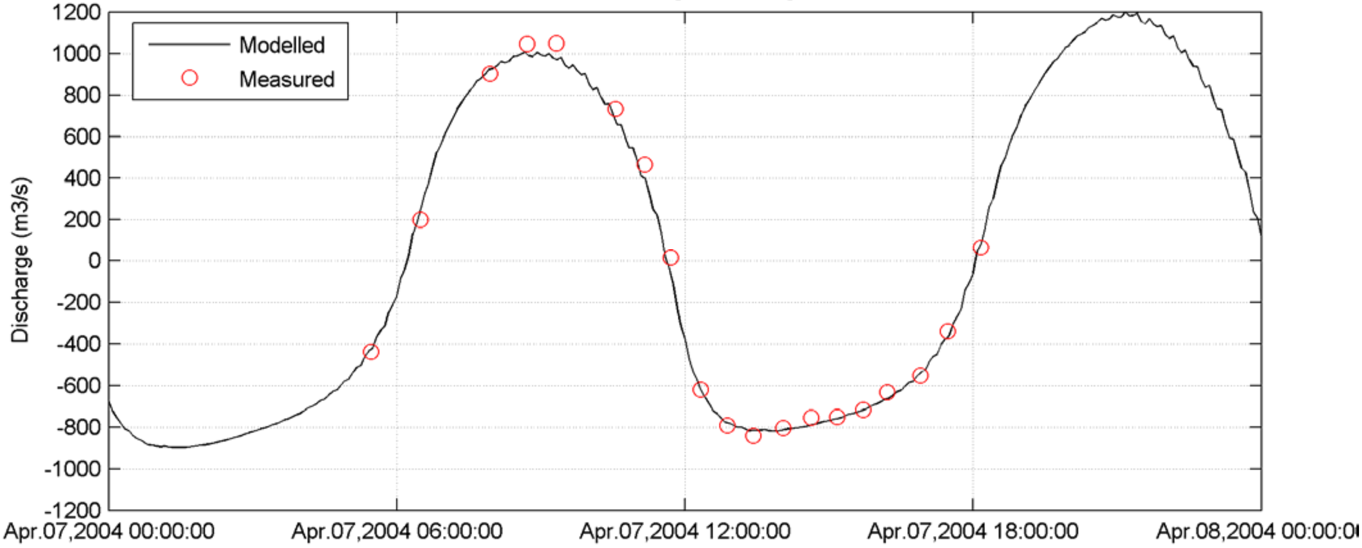
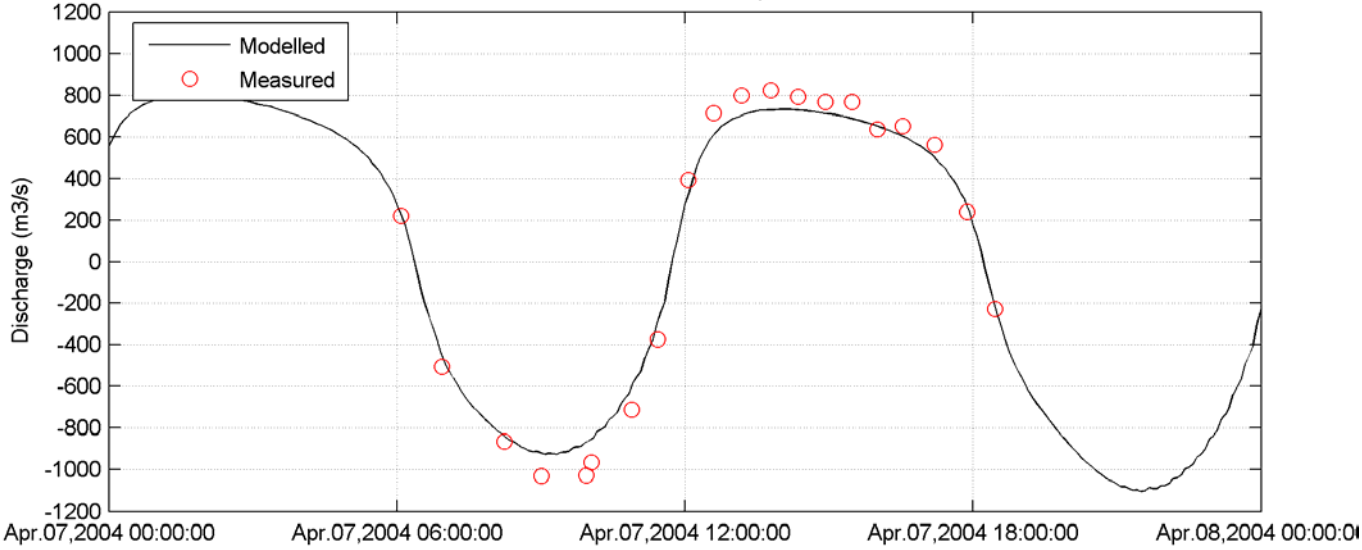
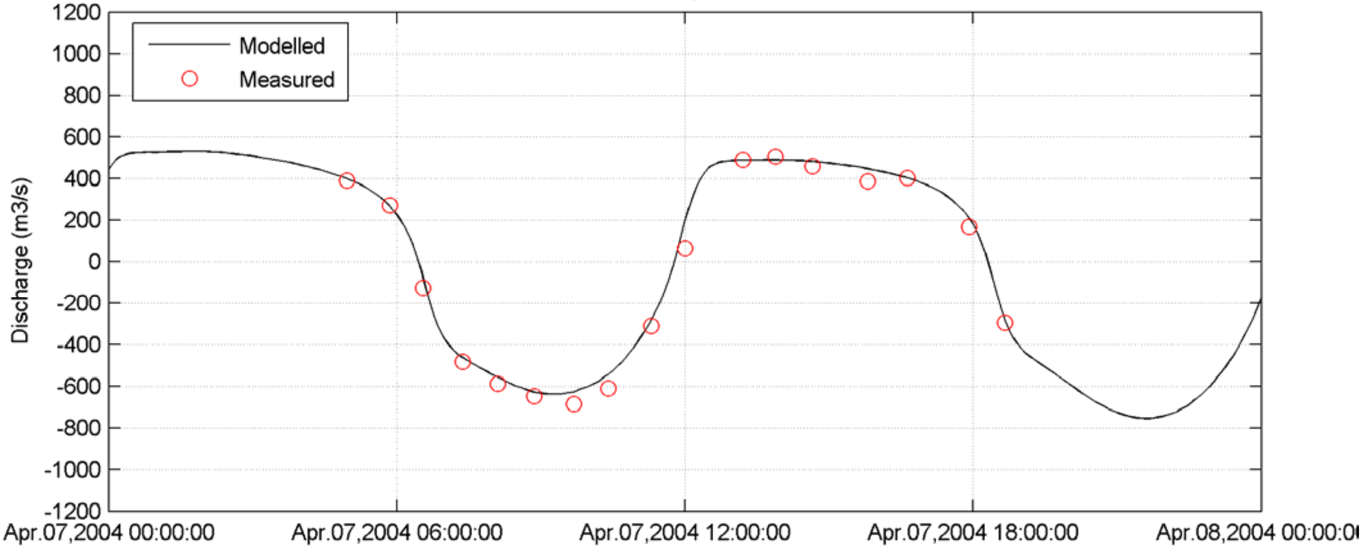

Site 3: Kourung Gourung Point


Site 5: The Rip


Site 7: Paddys Channel

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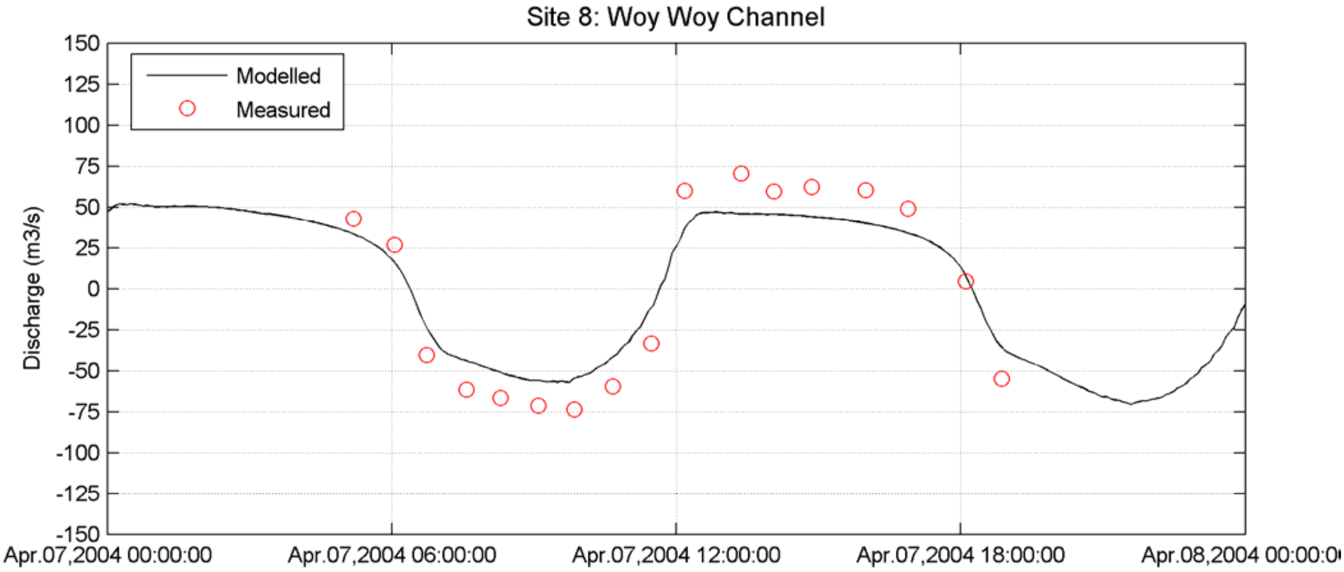
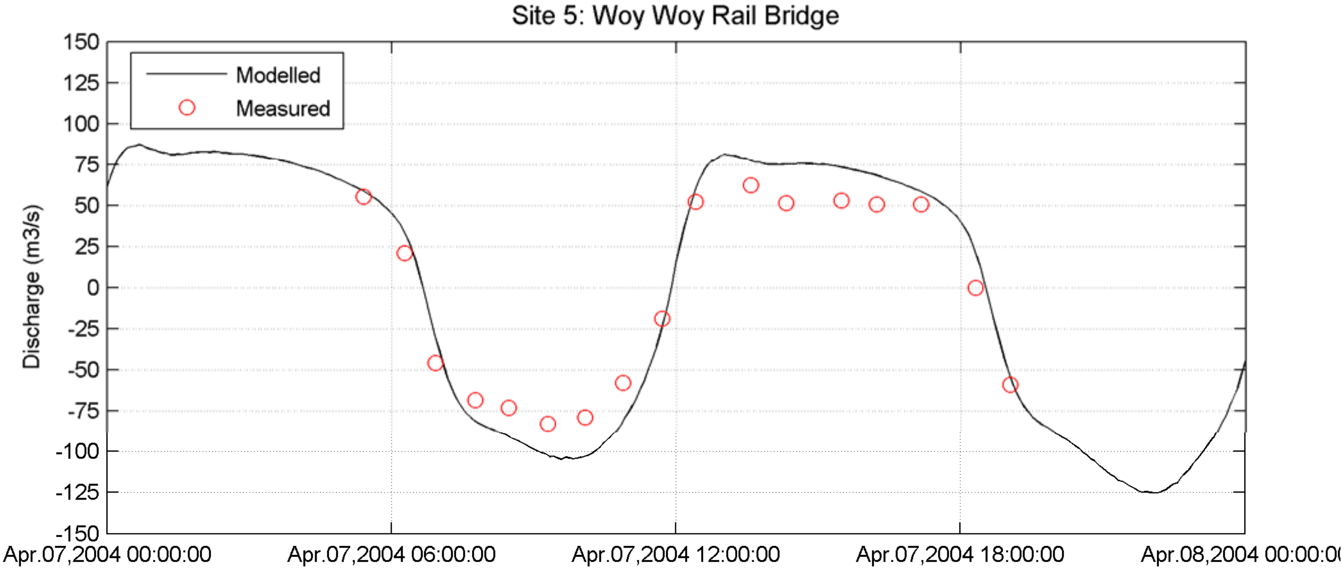
DISCHARGE CALIBRATION

Figure 6.5





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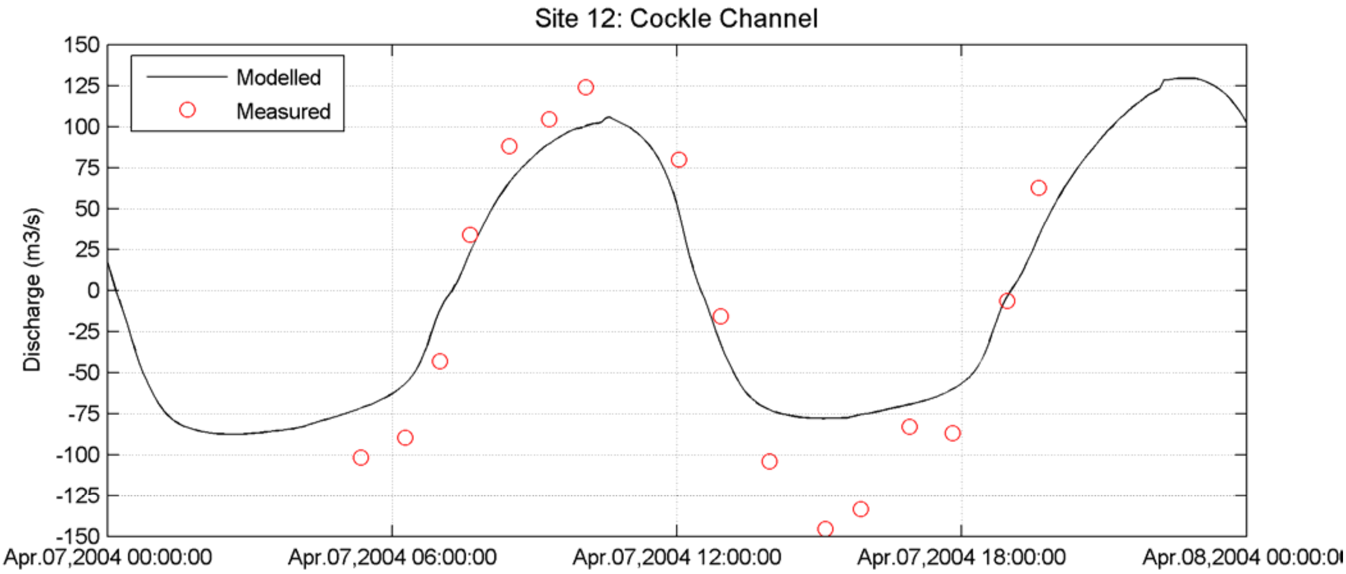
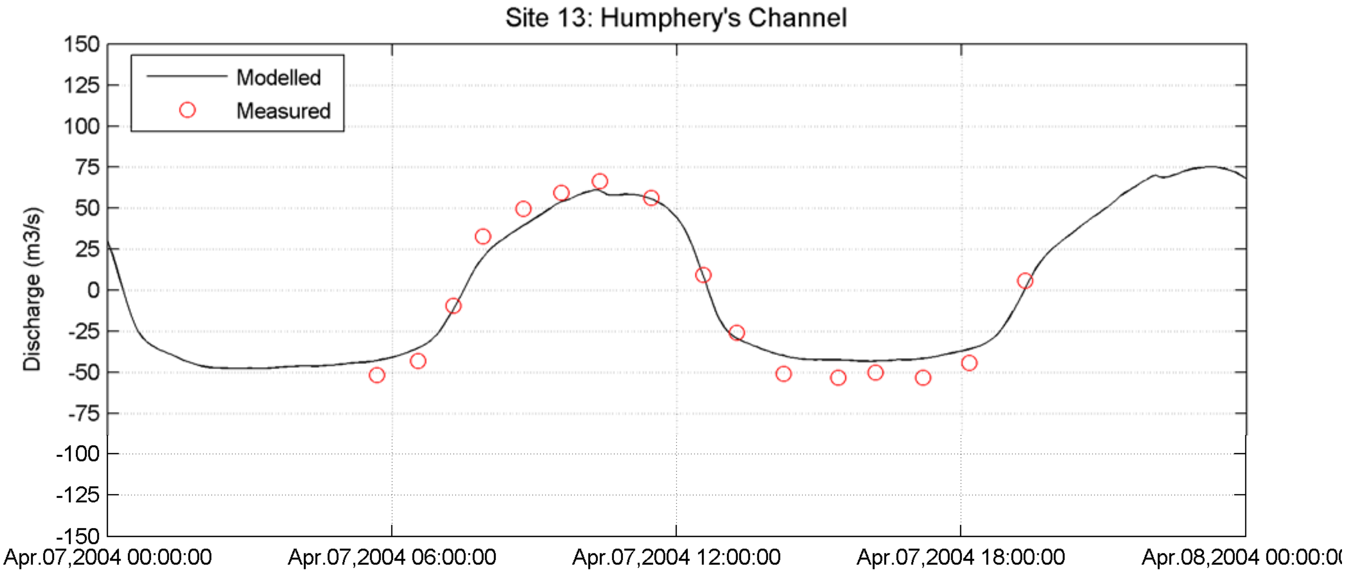
DISCHARGE CALIBRATION

Figure 6.6


Site 12: Cockle Channel


Site 13: Humphery's Channel

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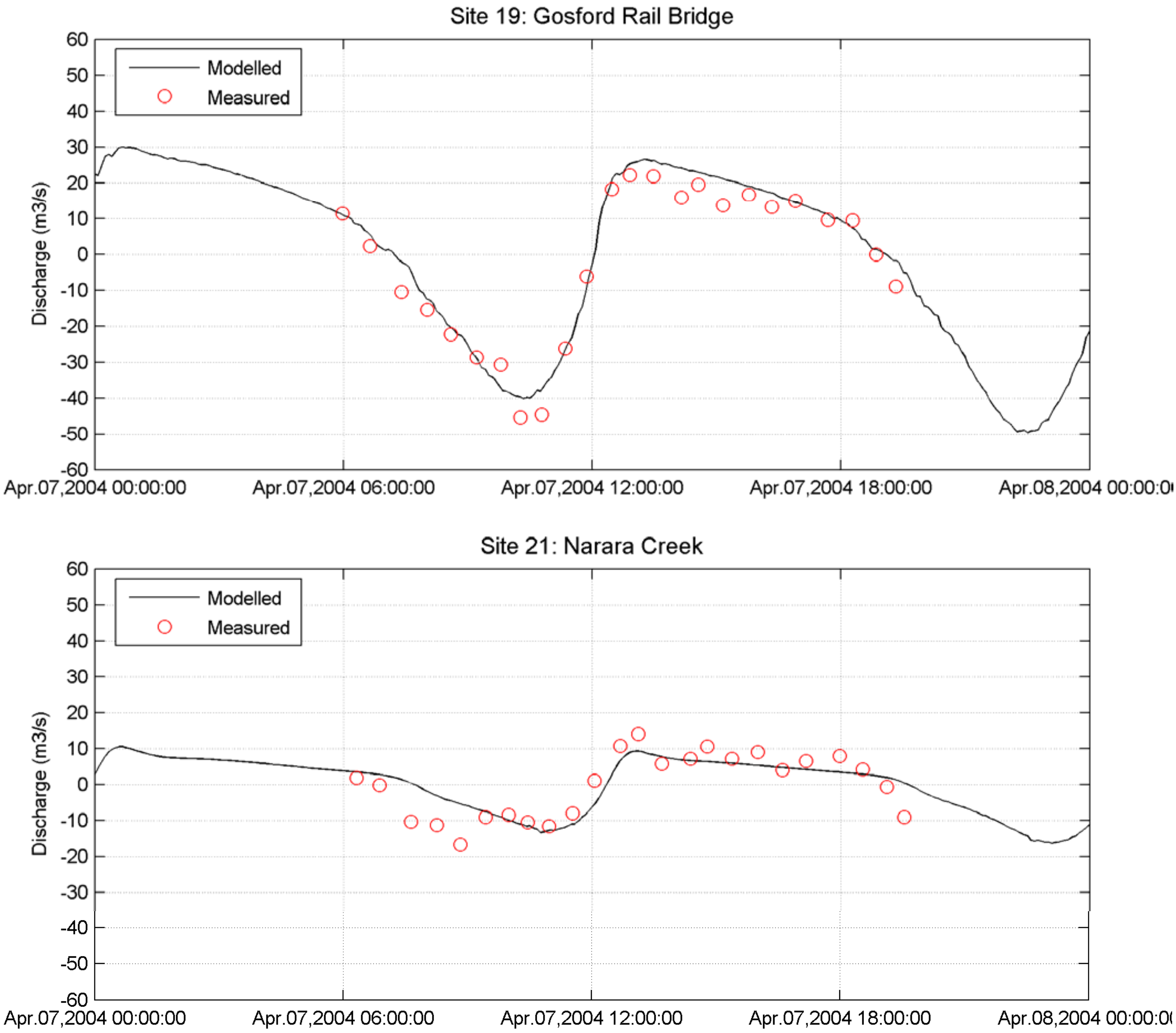
Brisbane Water Foreshore Flood Study

DISCHARGE CALIBRATION

Figure 6.7


Site 19: Gosford Rail Bridge

Site 21: Narara Creek

Brisbane Water Foreshore Flood Study

DISCHARGE CALIBRATION

Figure 6.8

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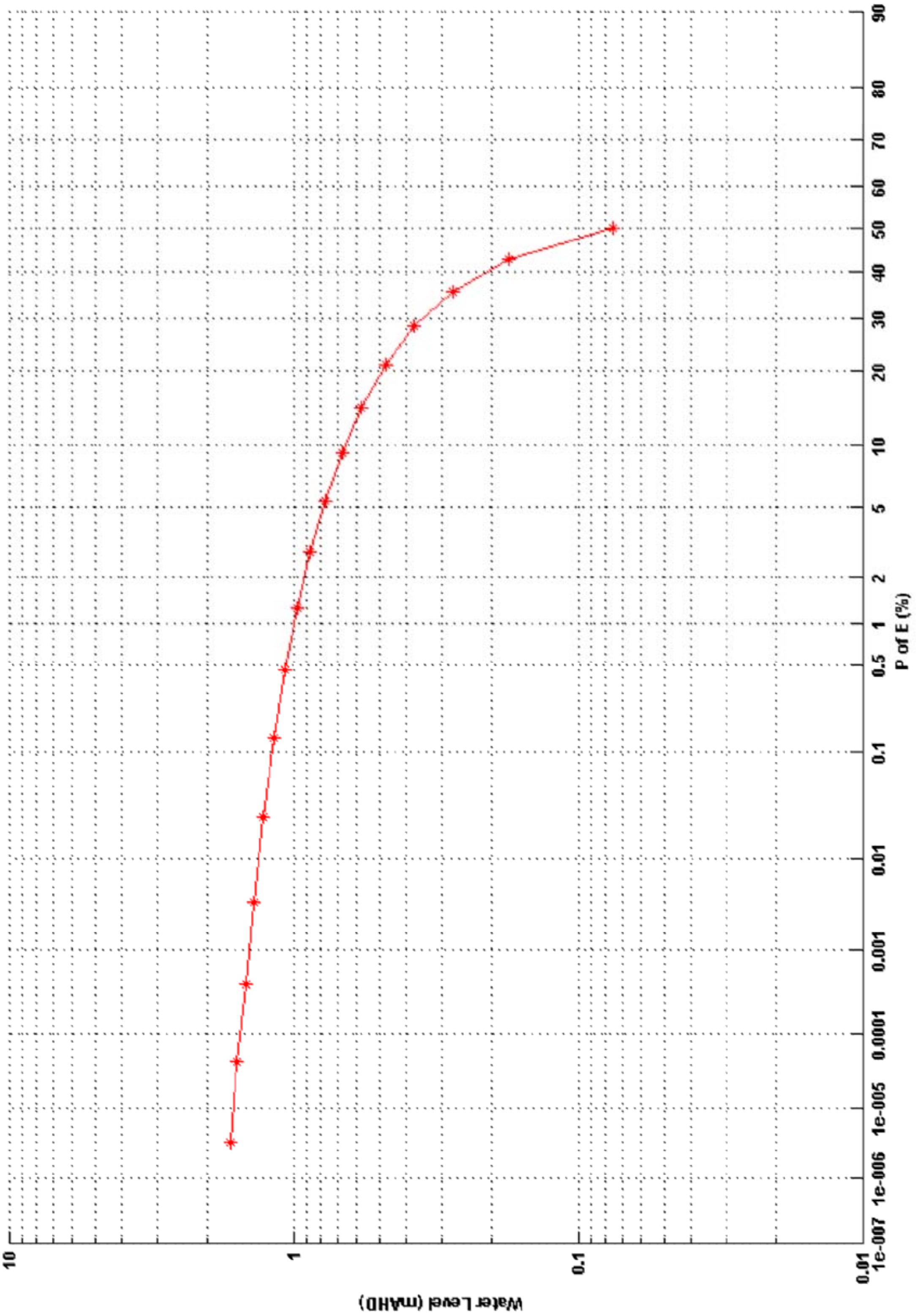
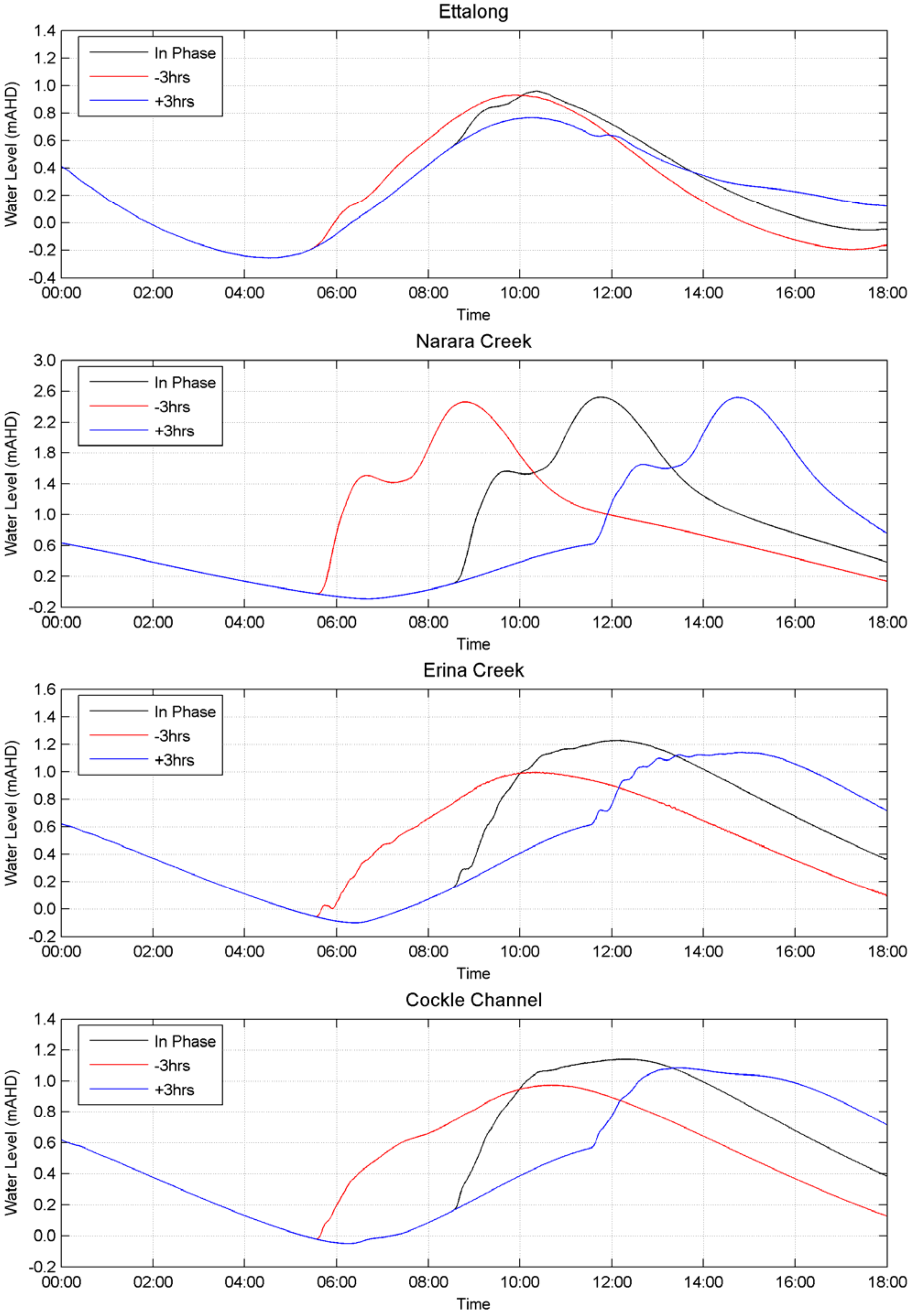


Brisbane Water Foreshore Flood Study

SYDNEY HARBOUR WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE (Adapted from MHL621 Table 53)

Figure 6.9



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CATCHMENT FLOOD LEVEL SENSITIVITY TO TIDAL PHASING

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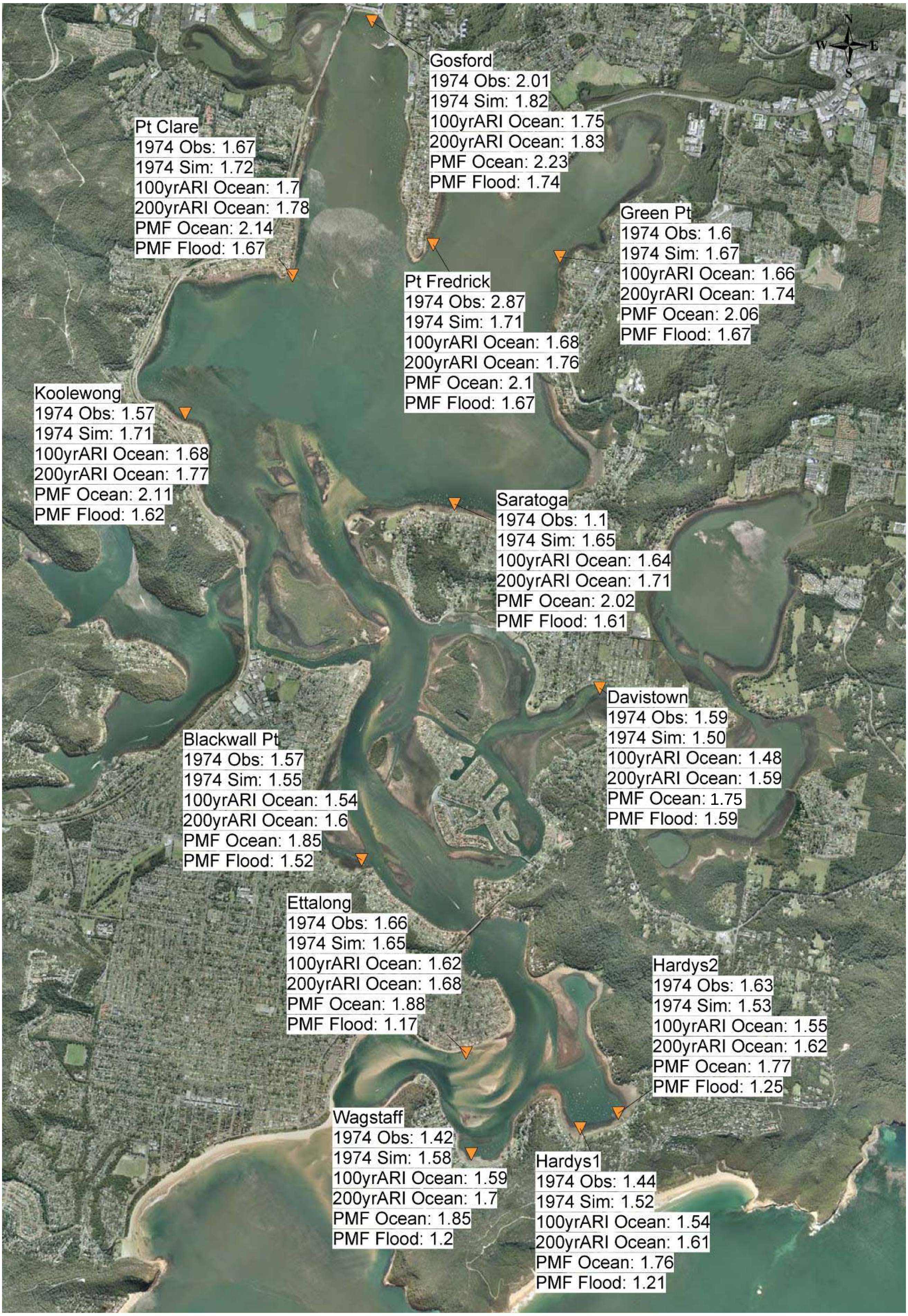
Figure 6.10



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Brisbane Water Foreshore Flood Study

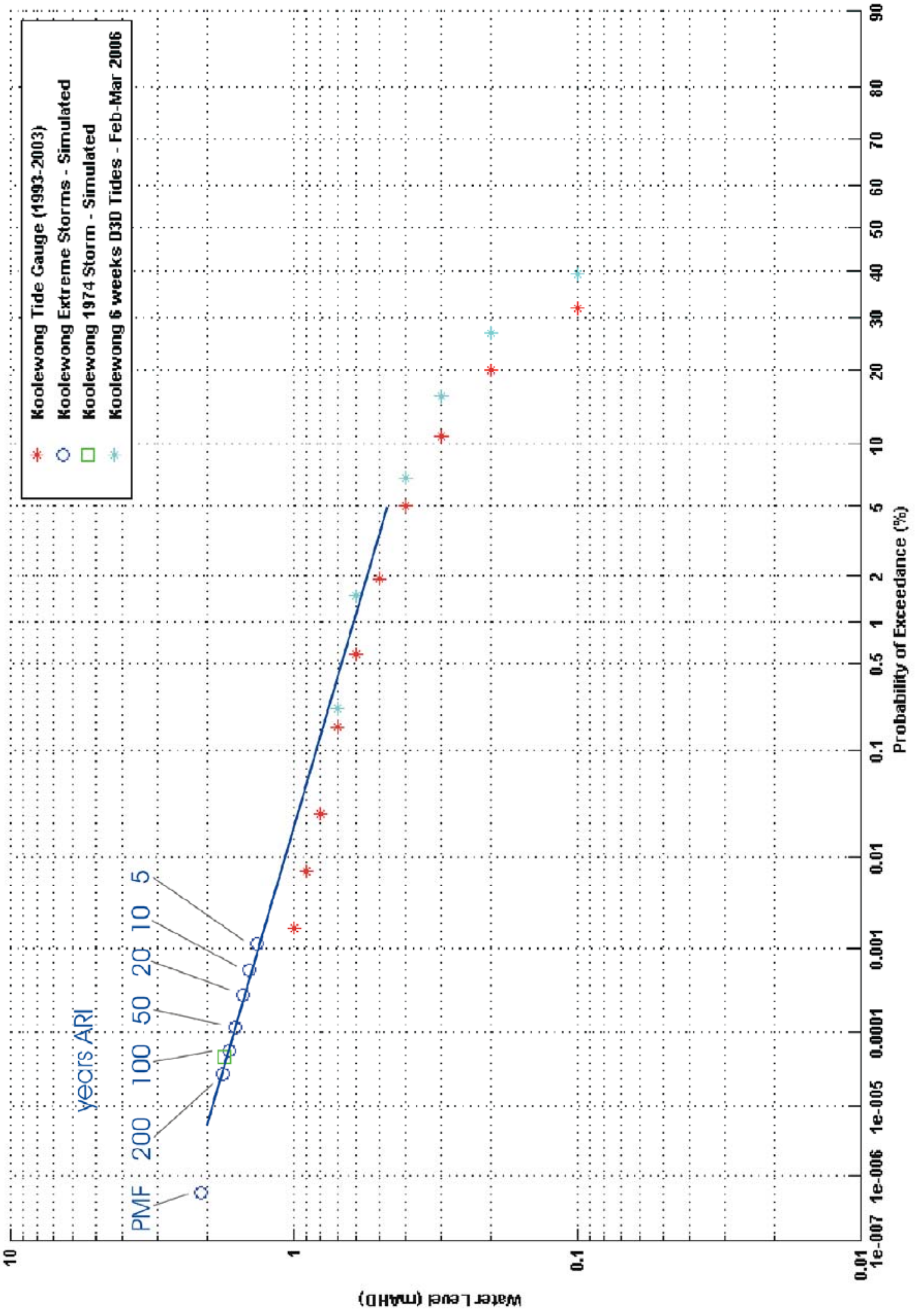
OBSERVED AND SIMULATED WATER LEVELS (mAHD)
MAY 1974 OCEAN STORM EVENT
Figure 6.11

View of Brisbane Water from Yattalunga Foreshore

Foreshore Flooding along Yattalunga Foreshore

Inundation of Forshore at Road Reserve, Mundoora Avenue

YATTALUNGA FORESHORE FLOODING – OCTOBER 1994
Source: J. Angeleri
Figure 6.12



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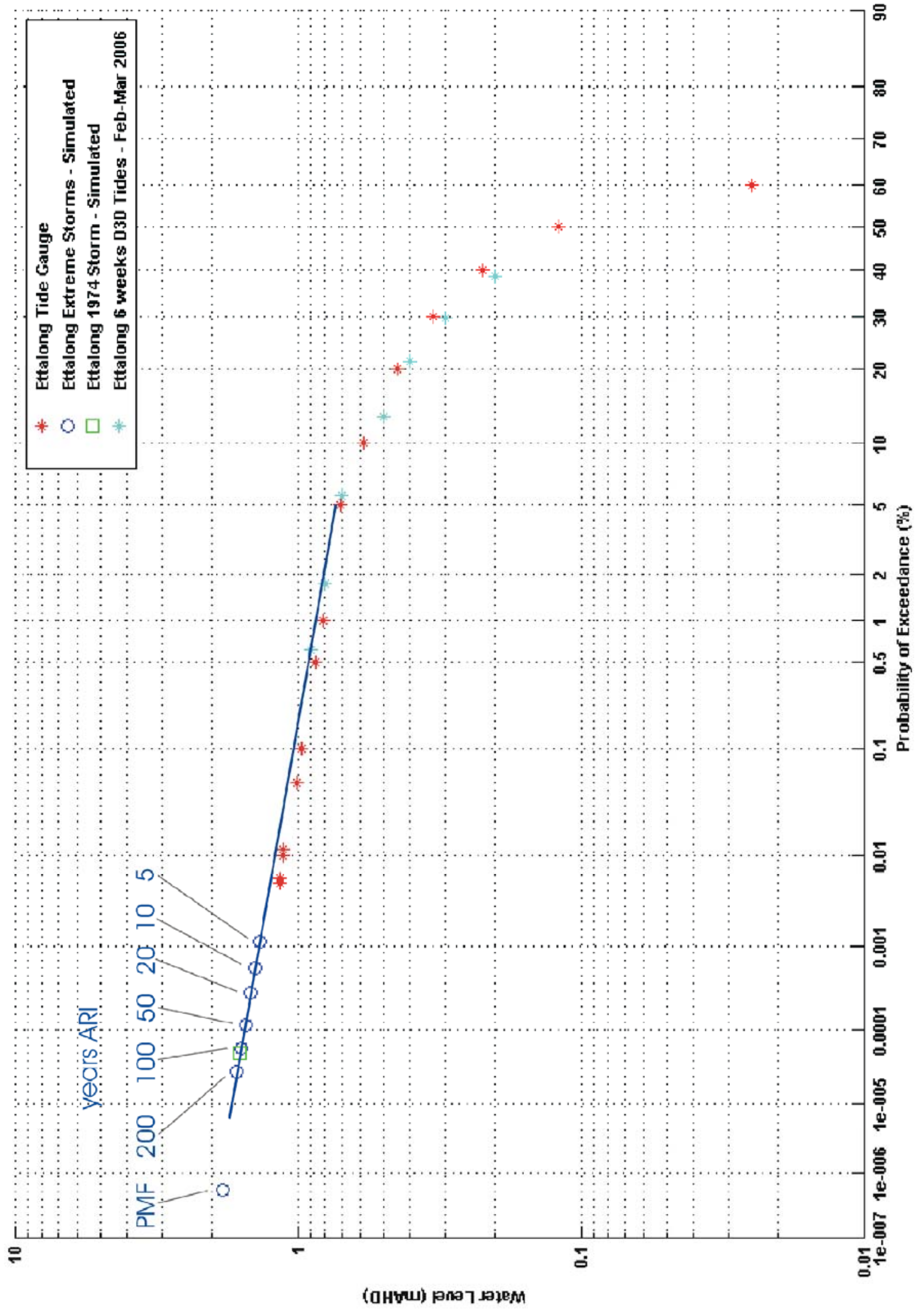
Brisbane Water Foreshore Flood Study

KOOLEWONG WATER LEVEL PROBABILITY OF EXCEEDANCE CURVES

Figure 6.13



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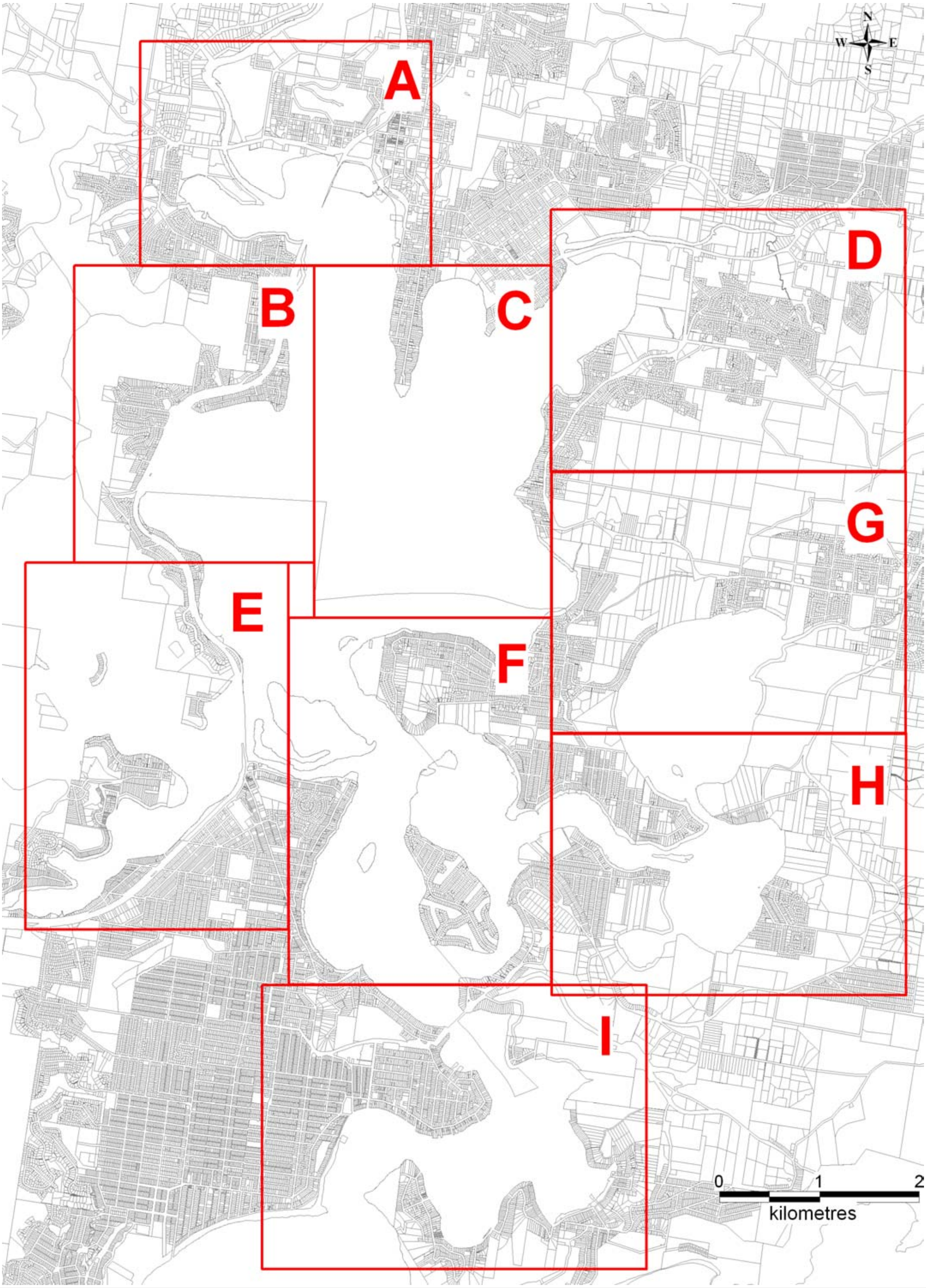
Brisbane Water Foreshore Flood Study

ETTALONG WATER LEVEL PROBABILITY OF EXCEEDANCE CURVES

Figure 6.14



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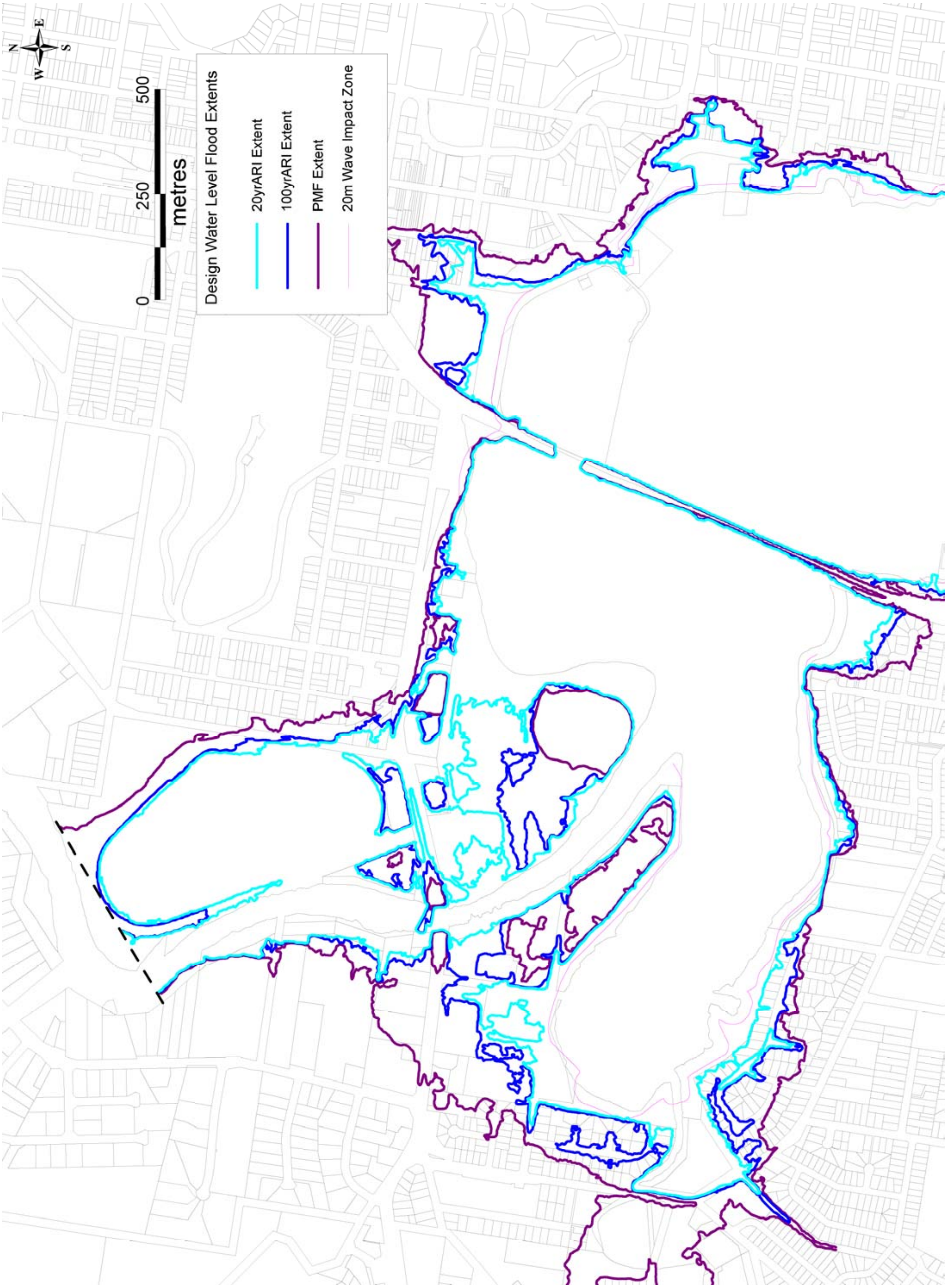
Brisbane Water Foreshore Flood Study

EXTENT MAPPING AREA KEY

Figure 6.15



Brisbane Water Foreshore Flood Study

DESIGN STORM TIDE FLOOD EXTENTS
PLATE A
Figure 6.16A

Cardno
Lawson Treloar

LJ2523/R2353v7 July 2013

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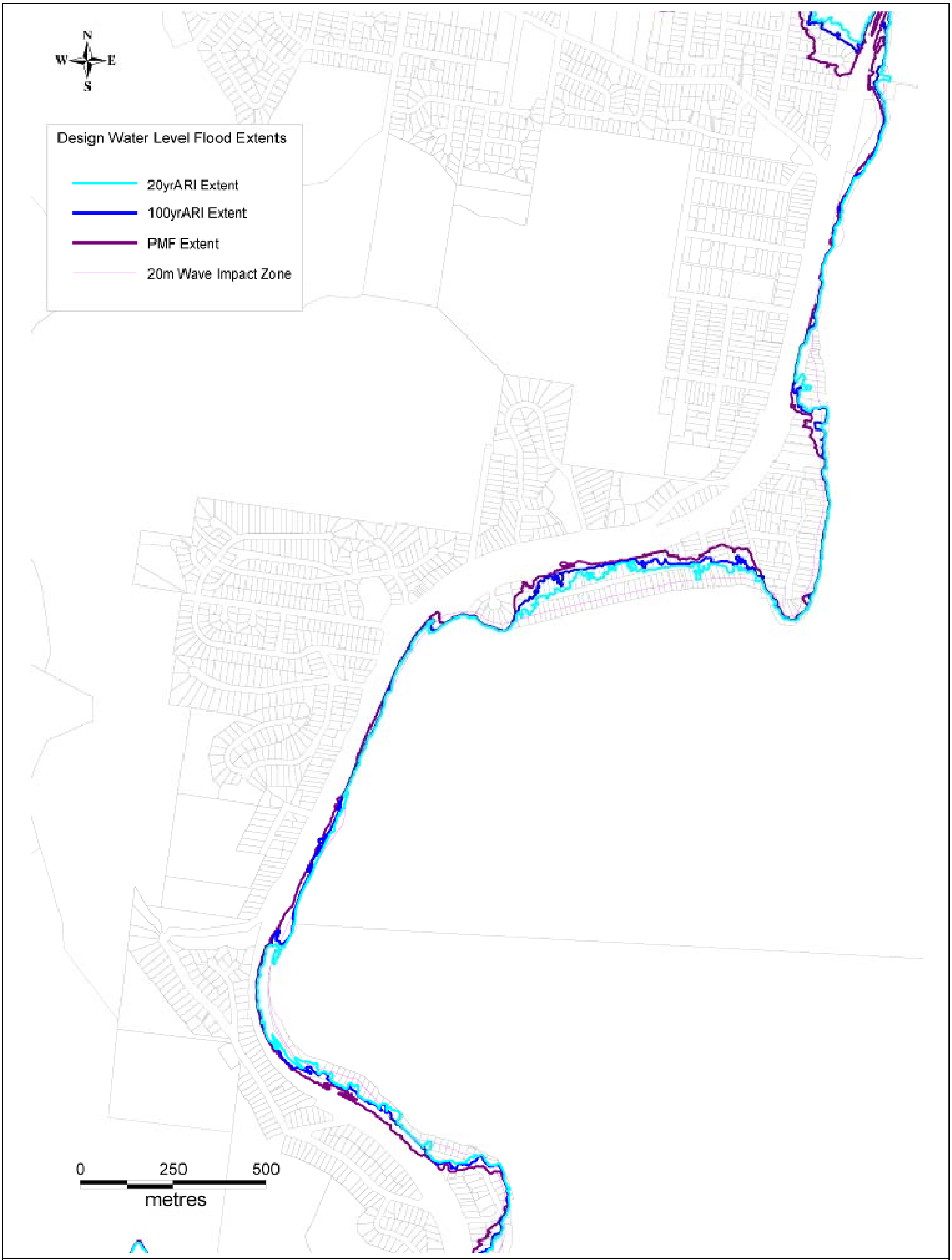

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LJ2523/R2353v7 July 2013

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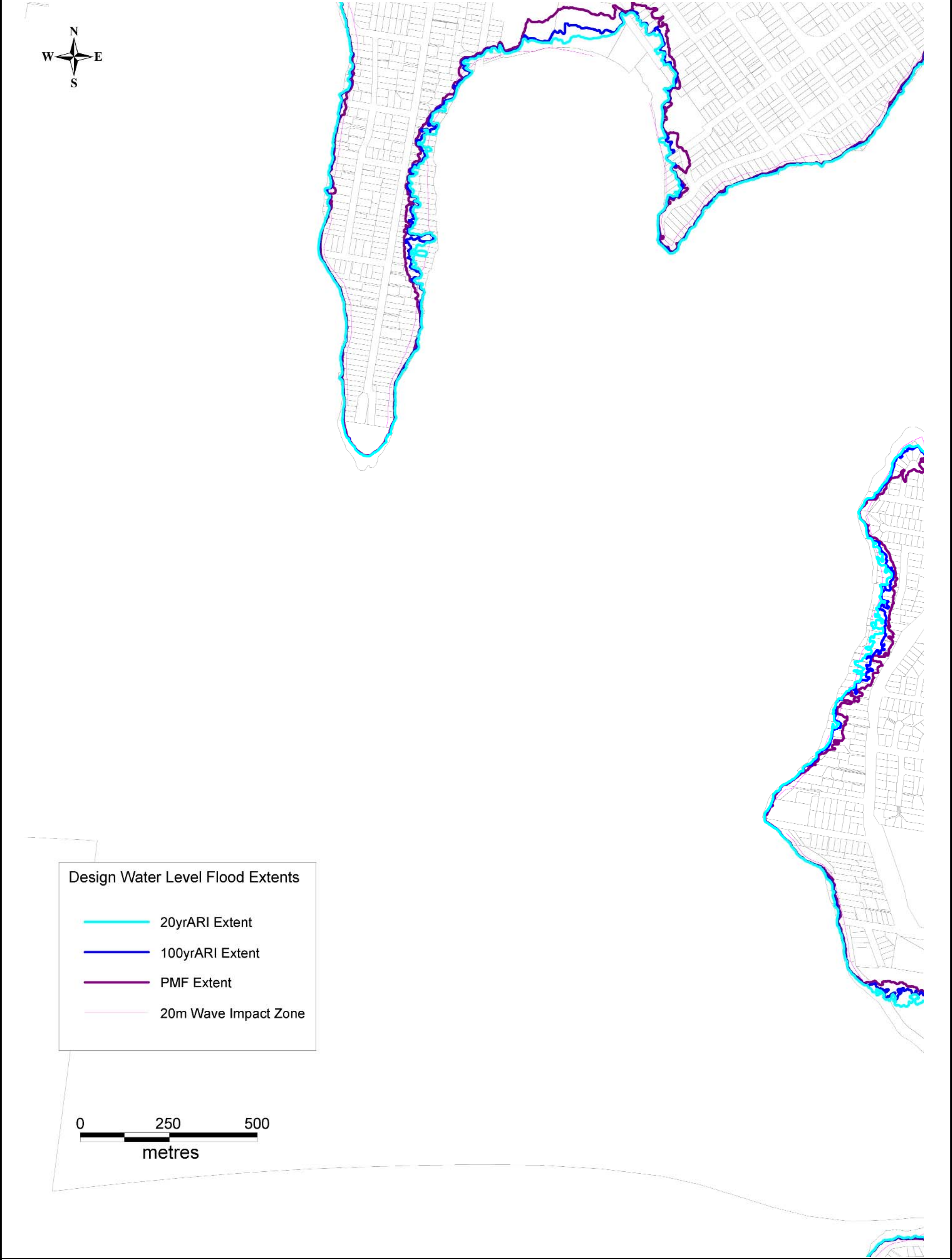
Brisbane Water Foreshore Flood Study

DESIGN STORM TIDE FLOOD EXTENTS
PLATE B
Figure 6.16B



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LJ2523/R2353v7 July 2013

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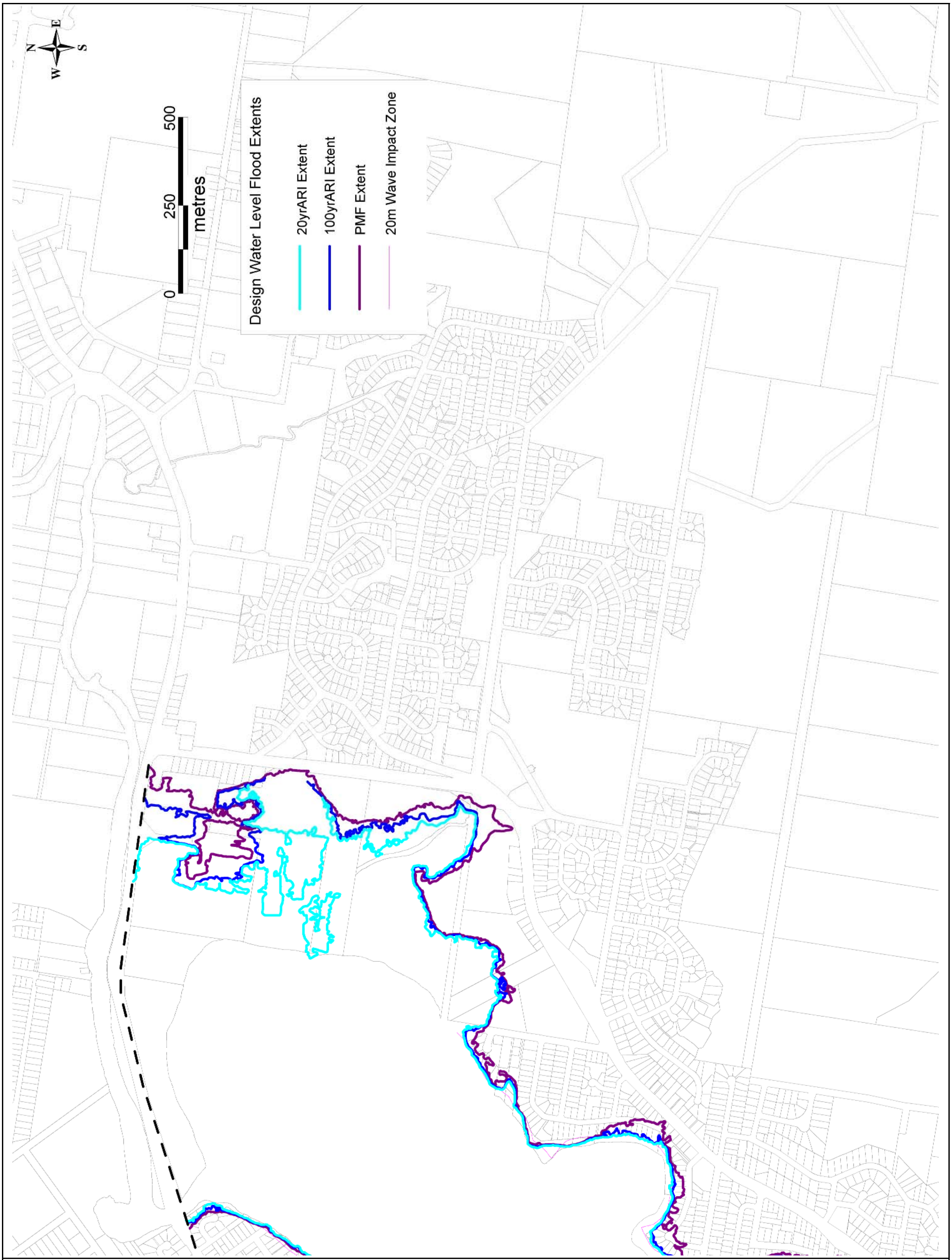
Brisbane Water Foreshore Flood Study

DESIGN STORM TIDE FLOOD EXTENTS

PLATE C

Figure 6.16C



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LJ2523/R2353v7 July 2013

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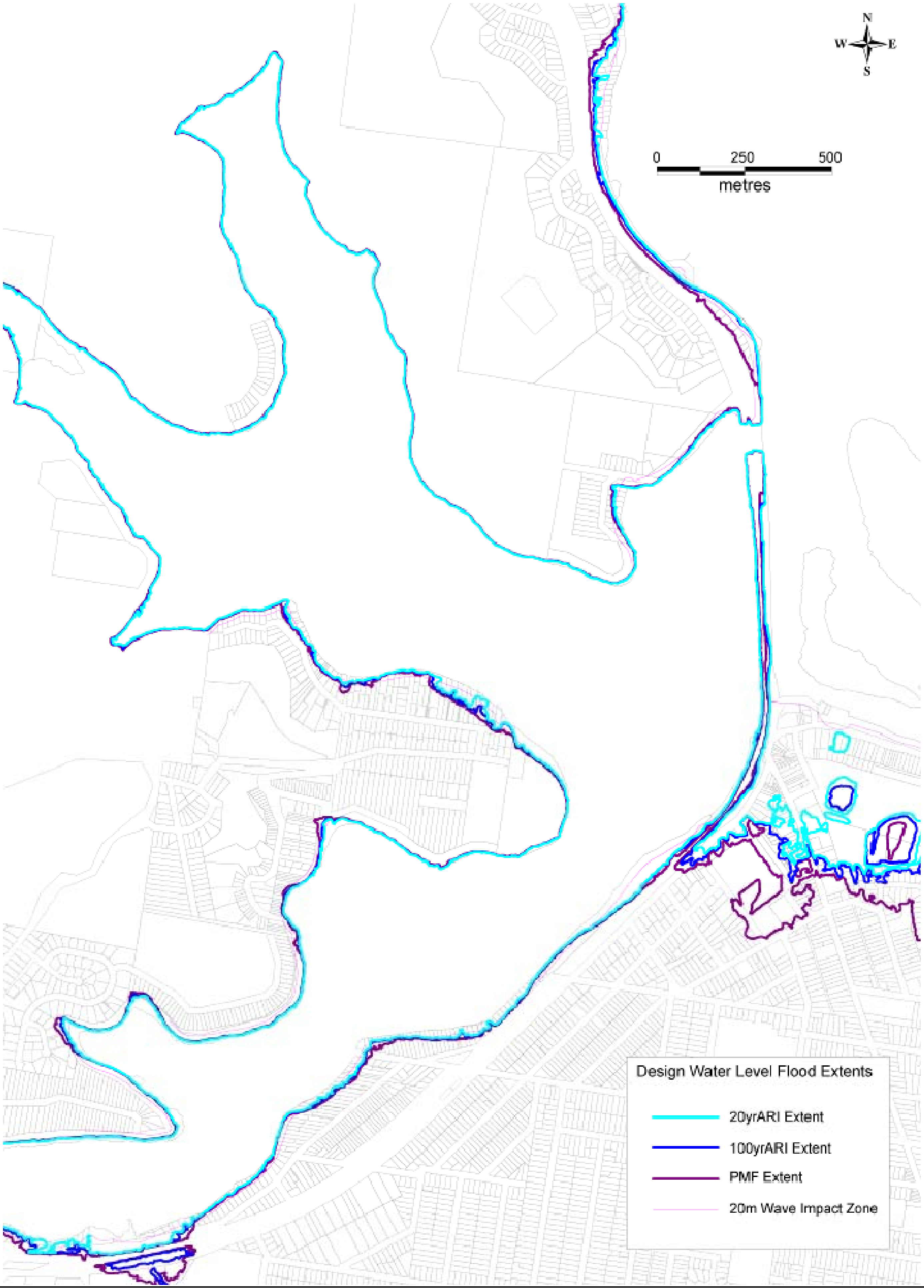
Brisbane Water Foreshore Flood Study

DESIGN STORM TIDE FLOOD EXTENTS
PLATE D
Figure 6.16D



Cardno Lawson Treloar

LJ2523/R2353v7 July 2013

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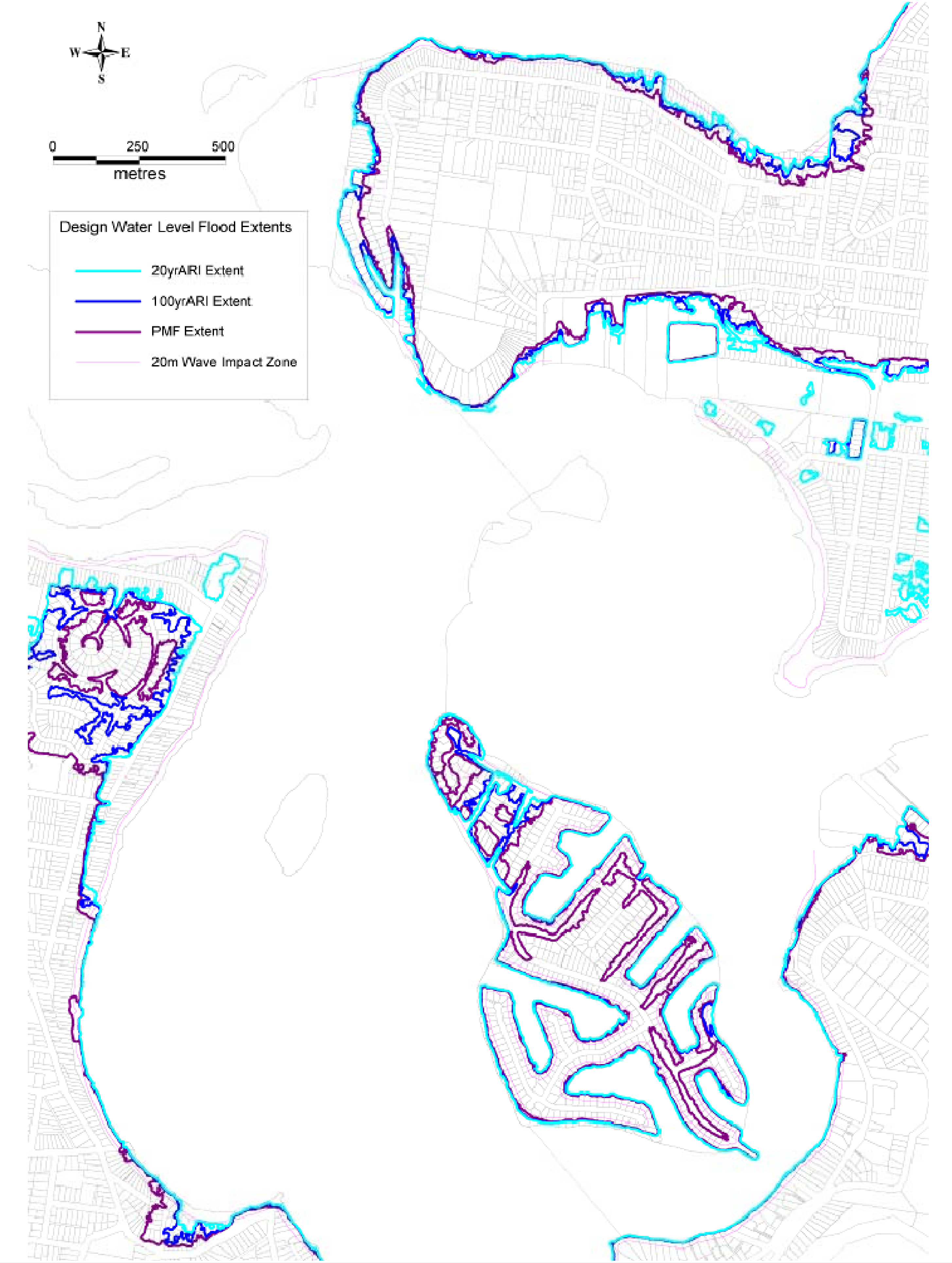
Brisbane Water Foreshore Flood Study

DESIGN STORM TIDE FLOOD EXTENTS

PLATE E

Figure 6.16E



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LJ2523/R2353v7 July 2013

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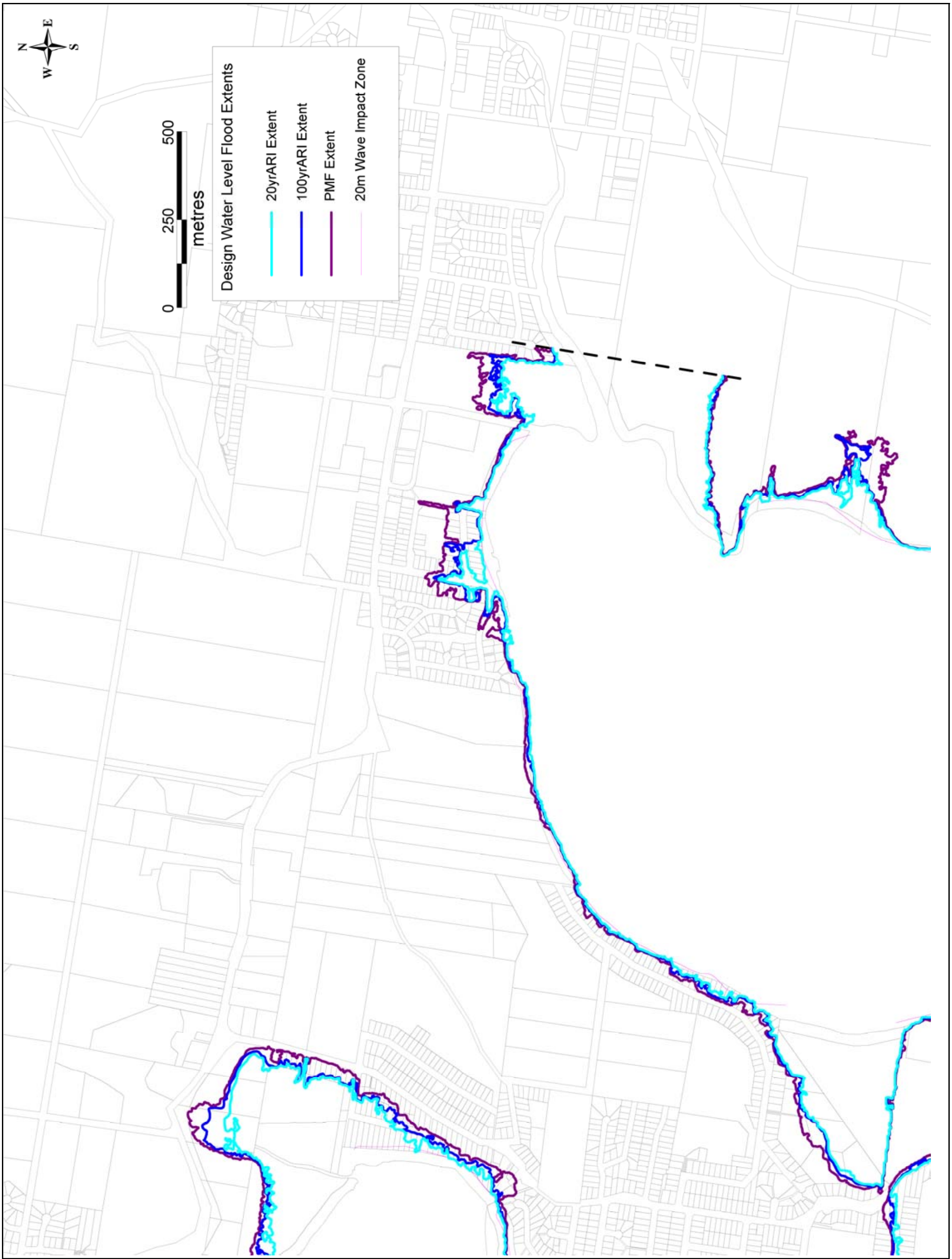
Brisbane Water Foreshore Flood Study

DESIGN STORM TIDE FLOOD EXTENTS

PLATE F

Figure 6.16F



Brisbane Water Foreshore Flood Study

DESIGN STORM TIDE FLOOD EXTENTS
PLATE G
Figure 6.16G

Cardno Lawson Treloar

LJ2523/R2353v7 July 2013

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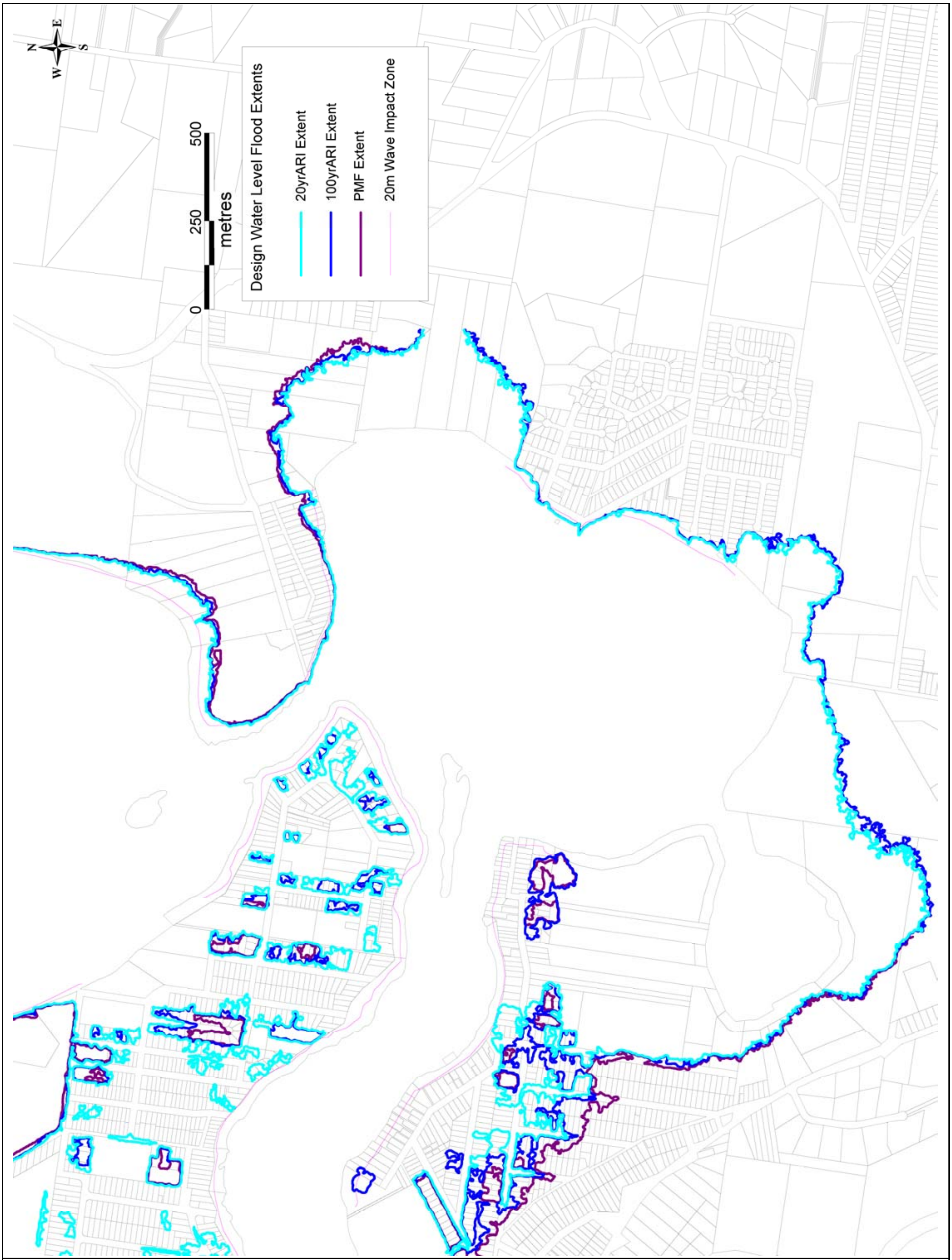

Brisbane Water Foreshore Flood Study

DESIGN STORM TIDE FLOOD EXTENTS

PLATE H

Figure 6.16H

LJ2523/R2353v7 July 2013

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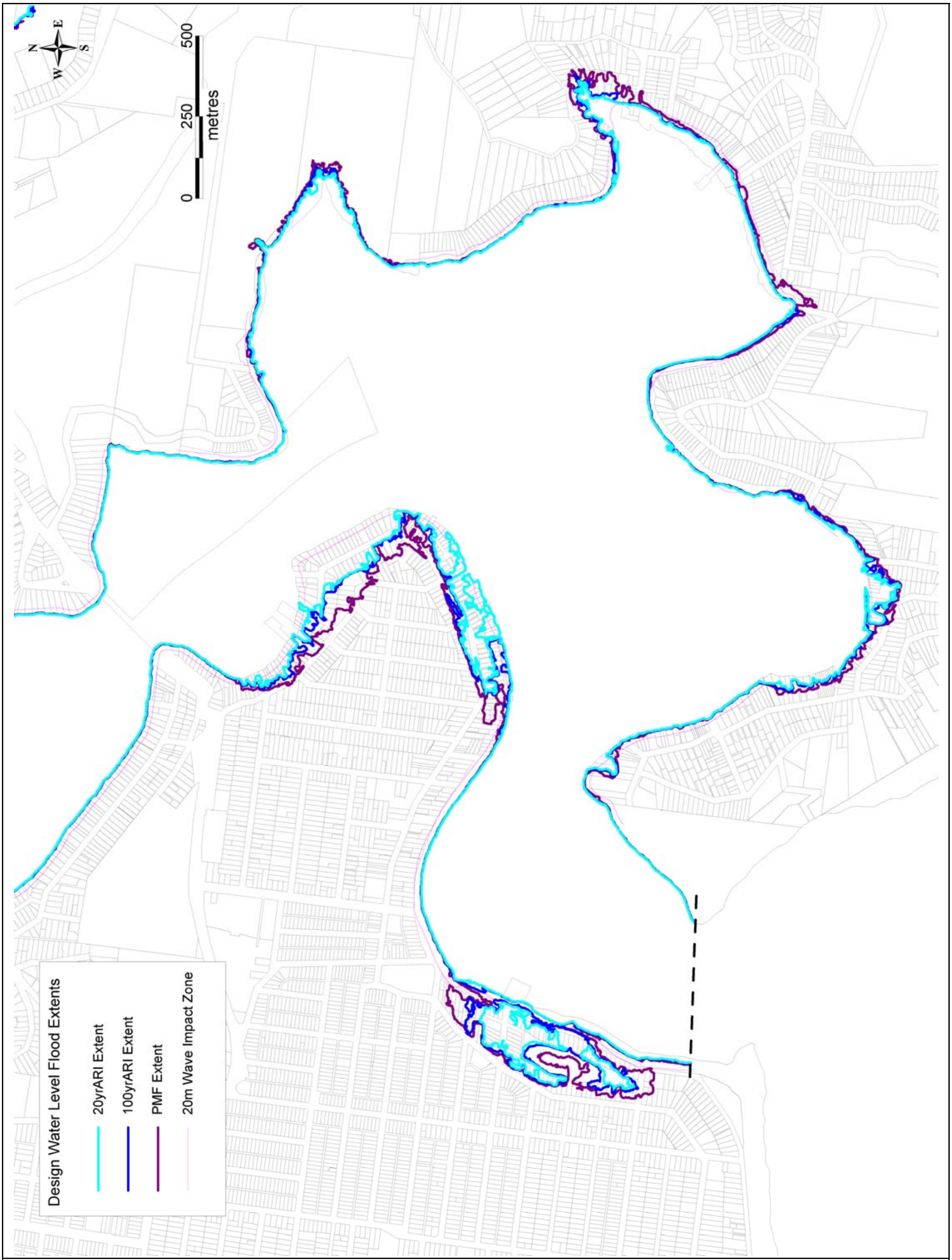

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Lawson Treloar

LJ2523/R2353v7 July 2013

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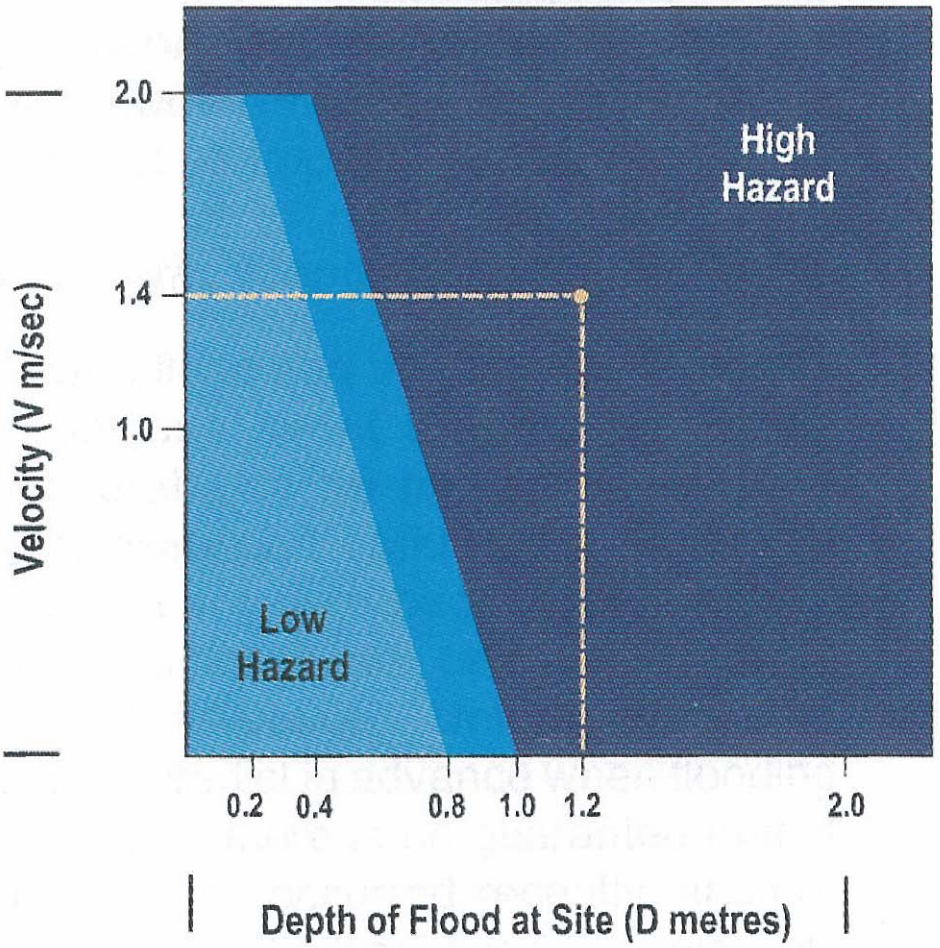
Brisbane Water Foreshore Flood Study

DESIGN STORM TIDE FLOOD EXTENTS
PLATE I
Figure 6.16I



Notes

The degree of hazard may be either -

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

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

Example:

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

Taken from: NSW Floodplain Development Manual (2005)

Brisbane Water Foreshore Flood Study

PROVISIONAL HAZARD DEFINITION GRAPH

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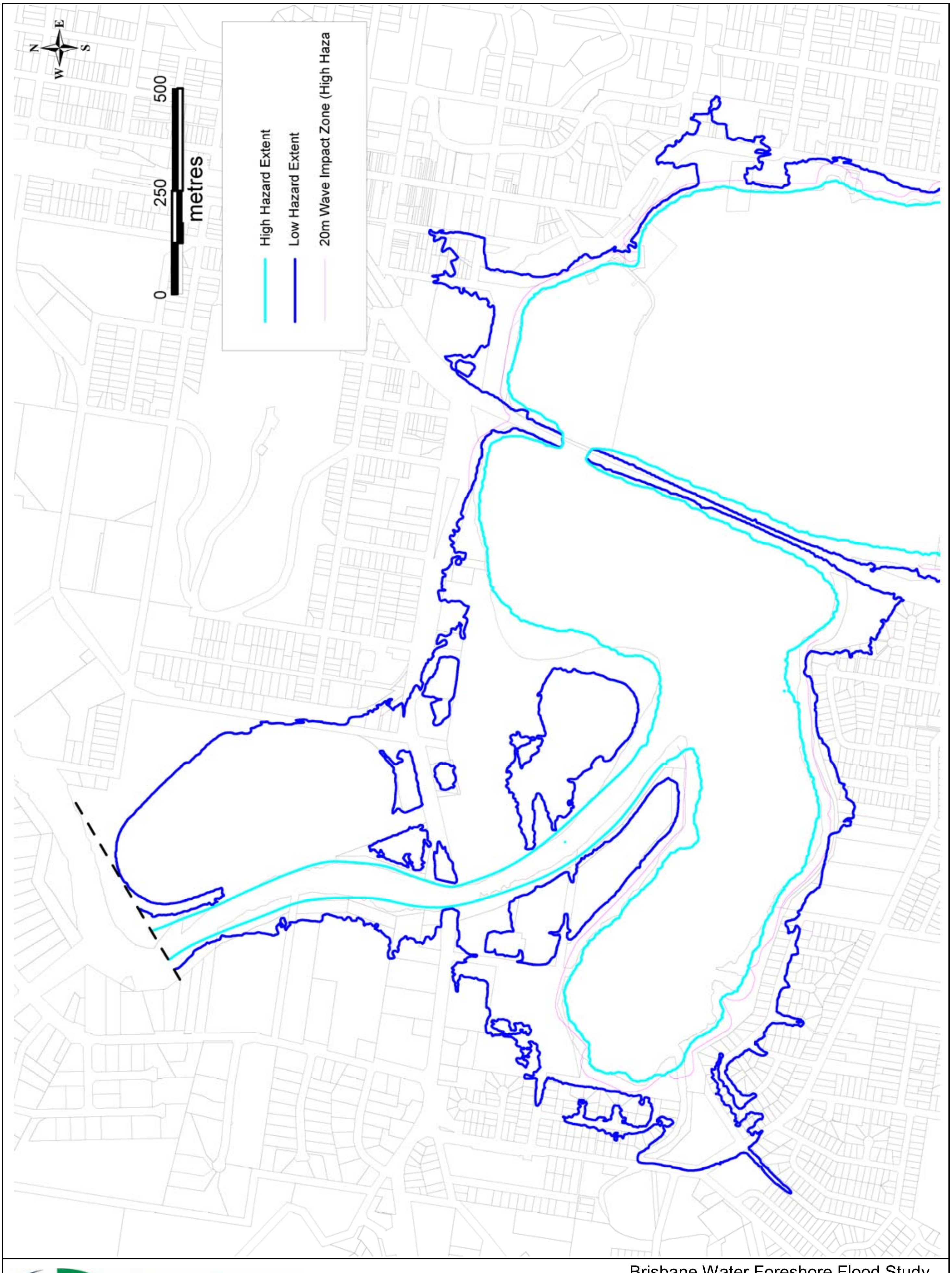
File: J:\CM\LJ2523\Figures\Hazard_Graph.png

Figure 6.17



Cardno
Lawson Treloar

Brisbane Water Foreshore Flood Study

100yrARI PROVISIONAL FLOOD HAZARD EXTENTS
PLATE A
Figure 6.18A

LJ2523/R2353v7 July 2013

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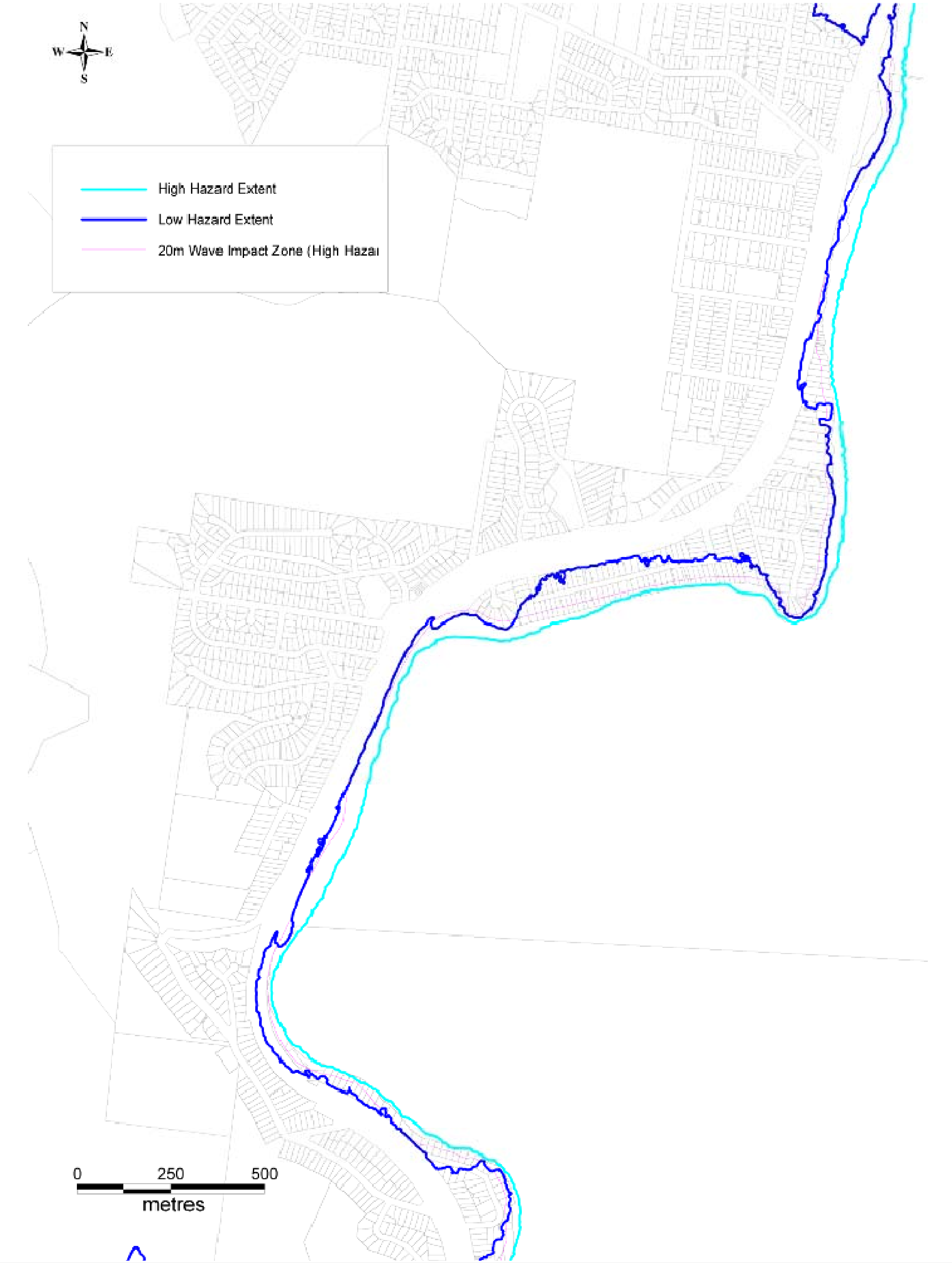


Cardno Lawson Treloar

LJ2523/R2353v7 July 2013

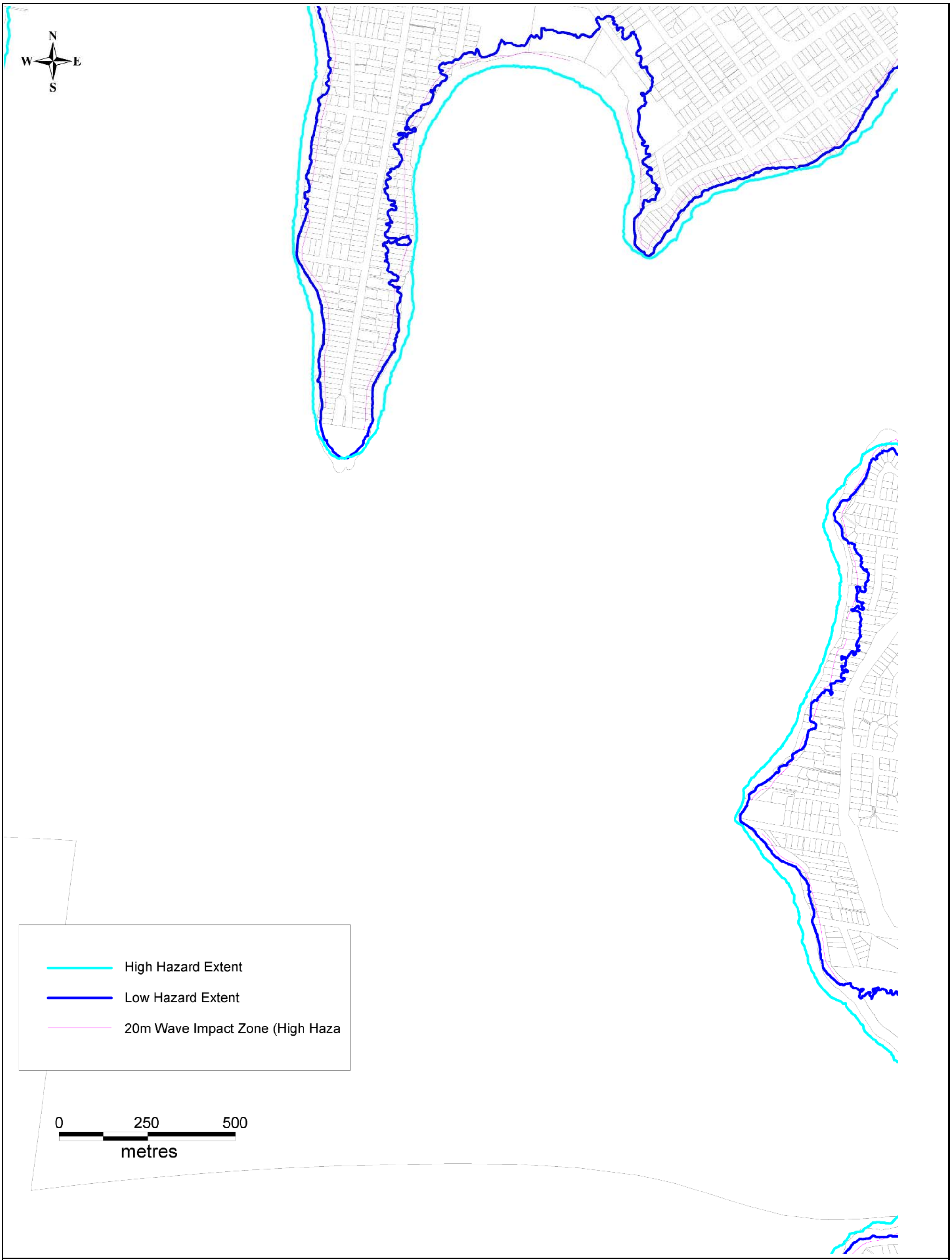
File: J:\CM\LJ2523\Figures\Hazard_Extents.wor

Brisbane Water Foreshore Flood Study

100yrARI PROVISIONAL FLOOD HAZARD EXTENTS

PLATE B

Figure 6.18B



Cardno Lawson Treloar

LJ2523/R2353v7 July 2013

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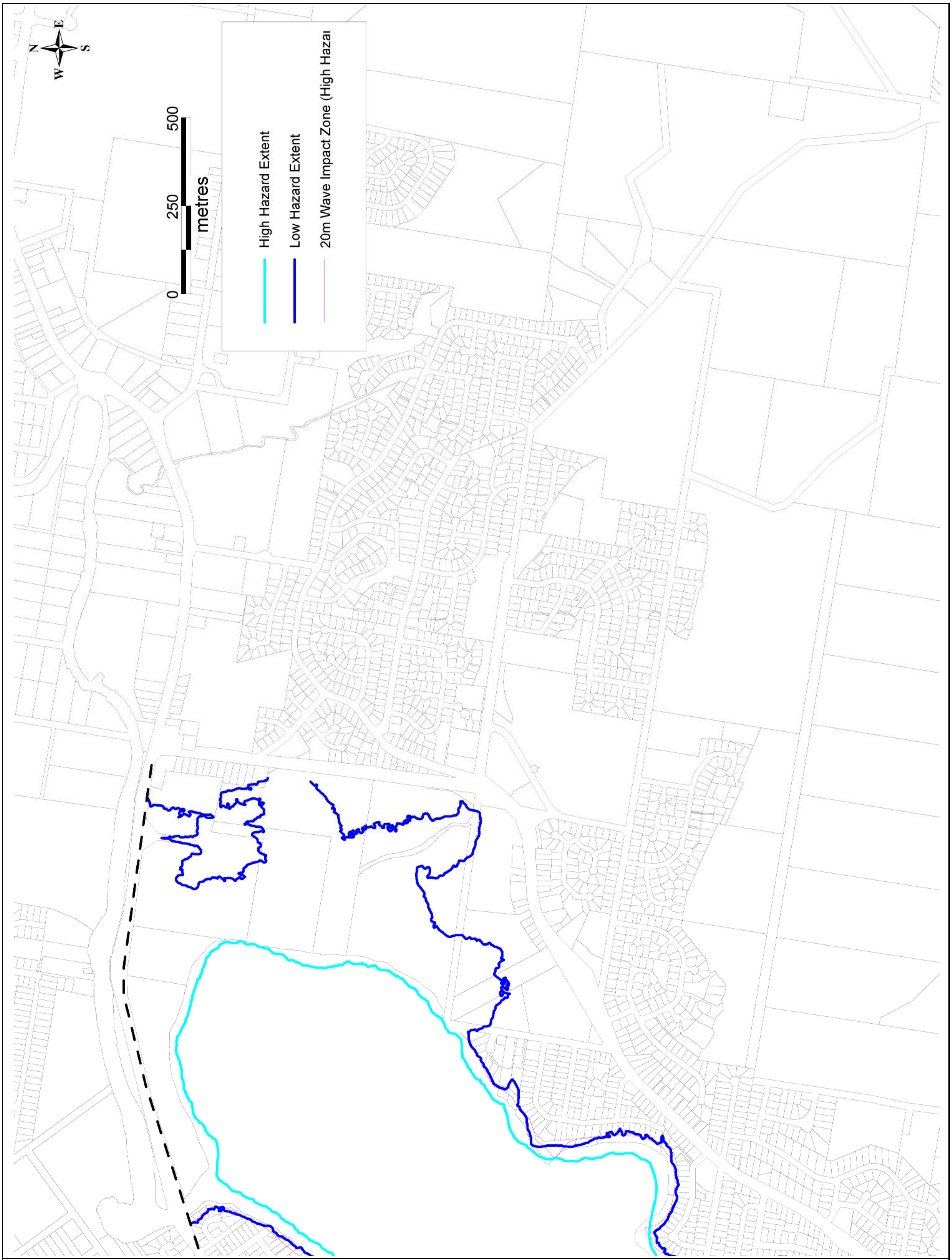
Brisbane Water Foreshore Flood Study

100yrARI PROVISIONAL FLOOD HAZARD EXTENTS

PLATE C

Figure 6.18C



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Lawson Treloar

LJ2523/R2353v7 July 2013

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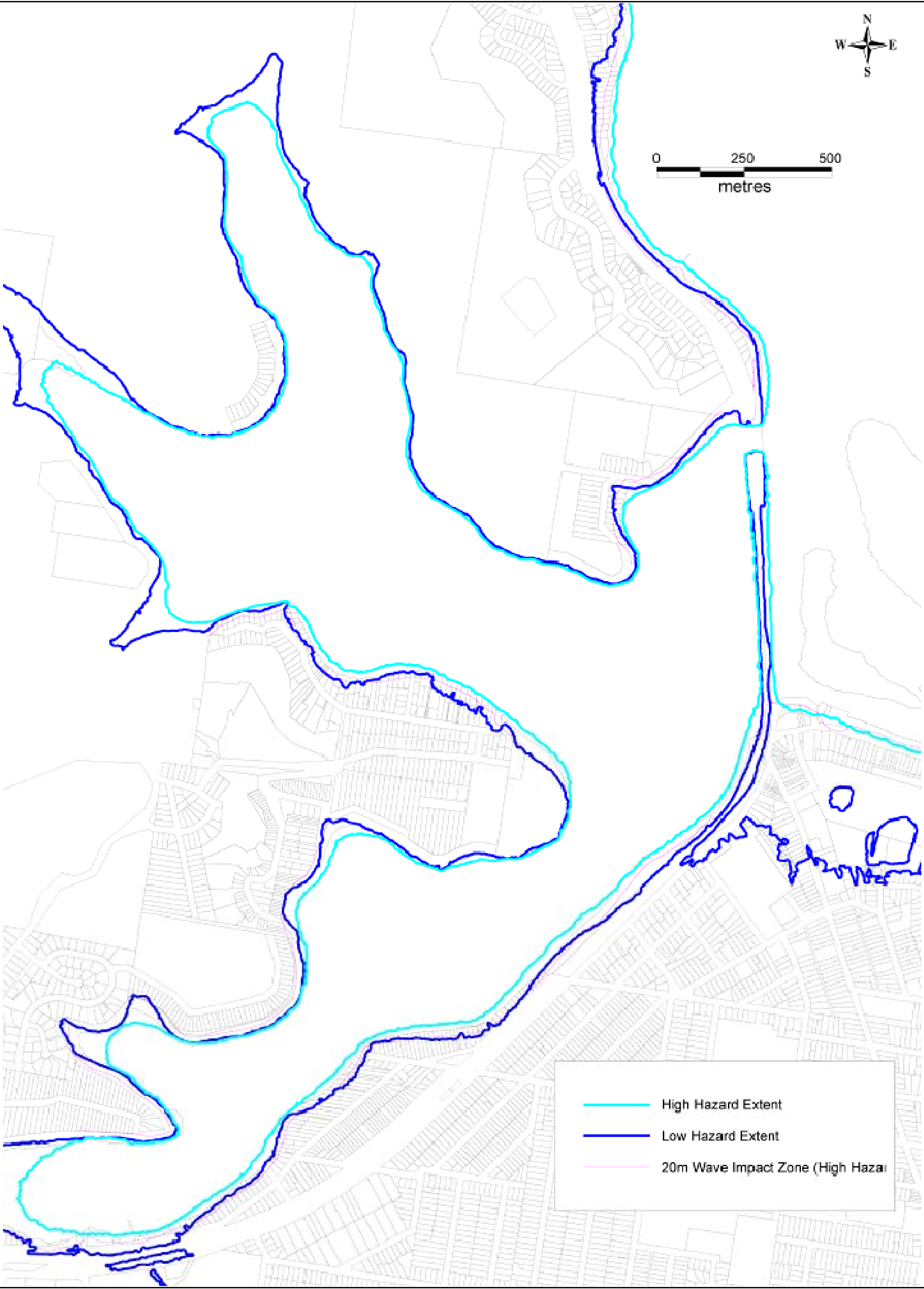
Brisbane Water Foreshore Flood Study

100yrARI PROVISIONAL FLOOD HAZARD EXTENTS
PLATE D
Figure 6.18D



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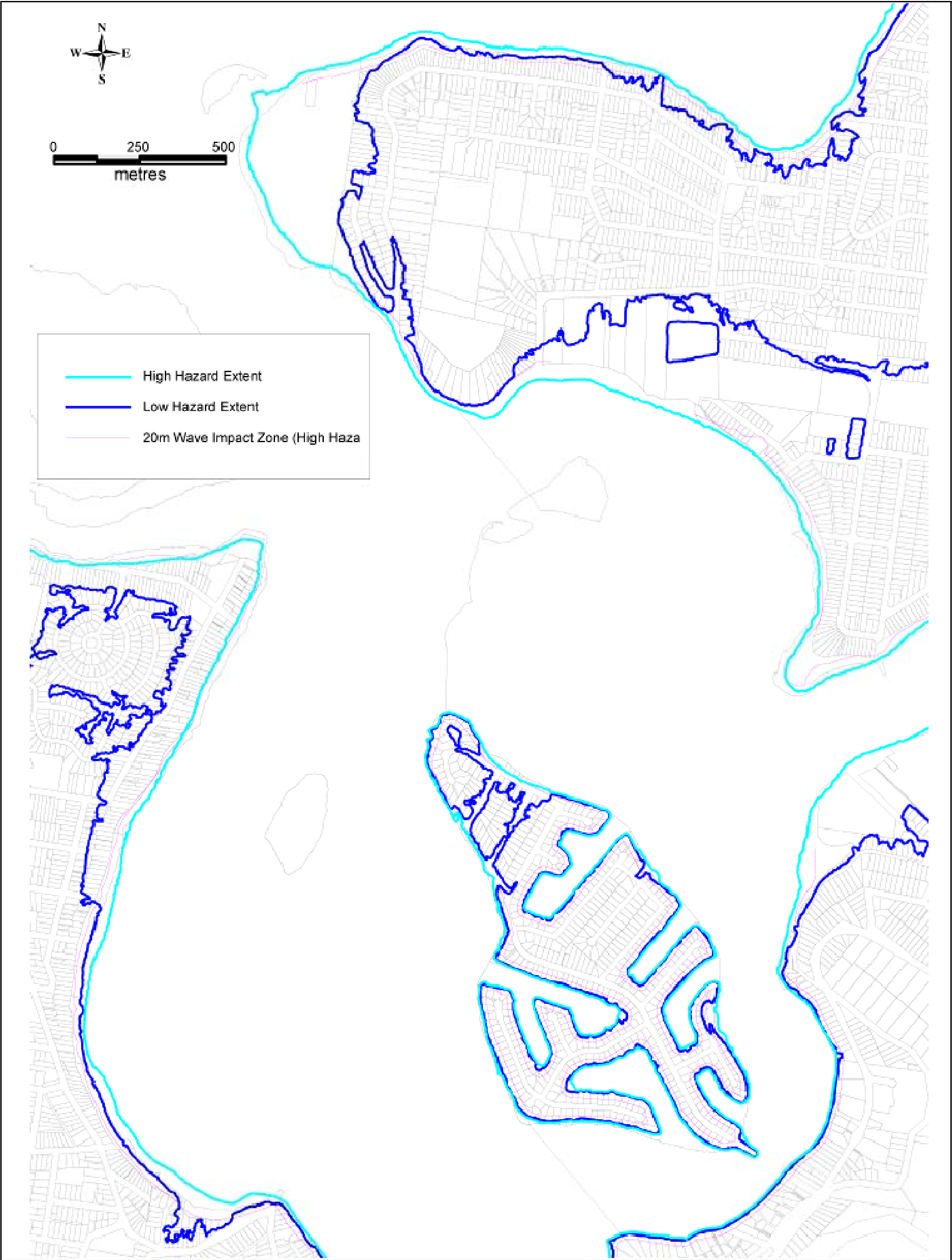
Lawson Treloar

LJ2523/R2353v7 July 2013

File: J:\CM\LJ2523\Figures\Hazard_Extents.wor

Brisbane Water Foreshore Flood Study

100yrARI PROVISIONAL FLOOD HAZARD EXTENTS
PLATE E
Figure 6.18E



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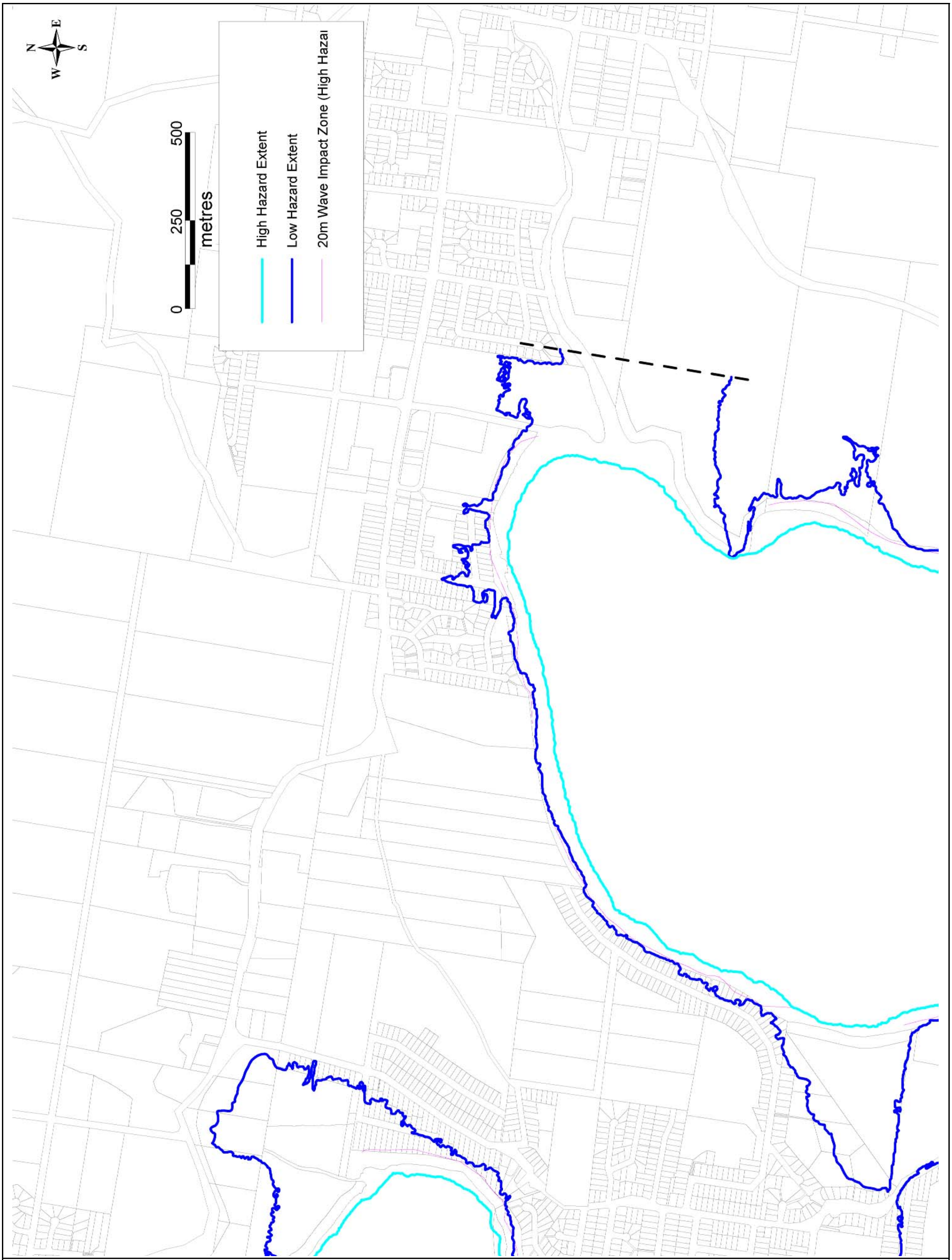
Brisbane Water Foreshore Flood Study

100yrARI PROVISIONAL FLOOD HAZARD EXTENTS

PLATE F

Figure 6.18F



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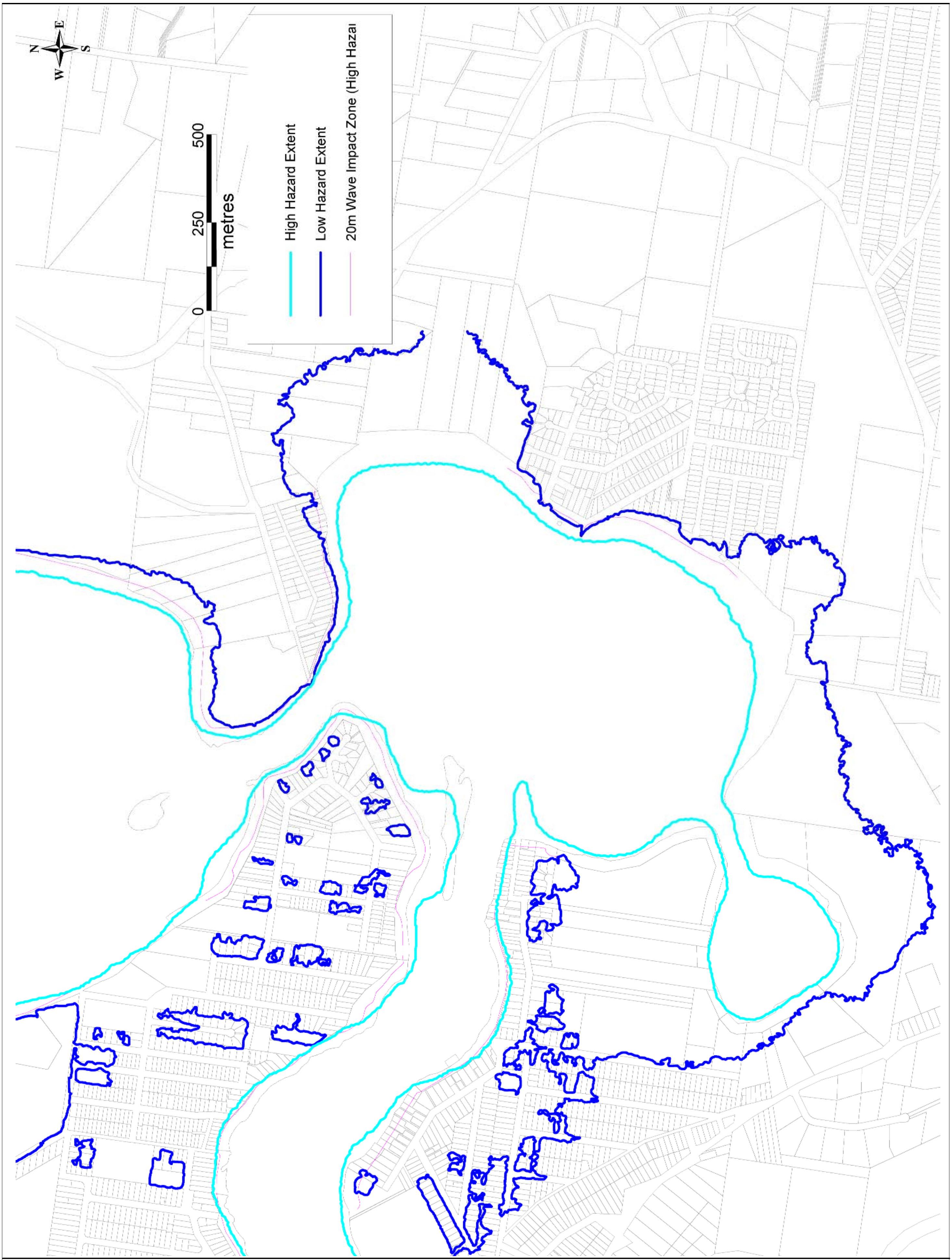
Brisbane Water Foreshore Flood Study

100yrARI PROVISIONAL FLOOD HAZARD EXTENTS
PLATE G

Figure 6.18G



Brisbane Water Foreshore Flood Study

100yrARI PROVISIONAL FLOOD HAZARD EXTENTS

PLATE H

Figure 6.18H

LJ2523/R2353v7 July 2013

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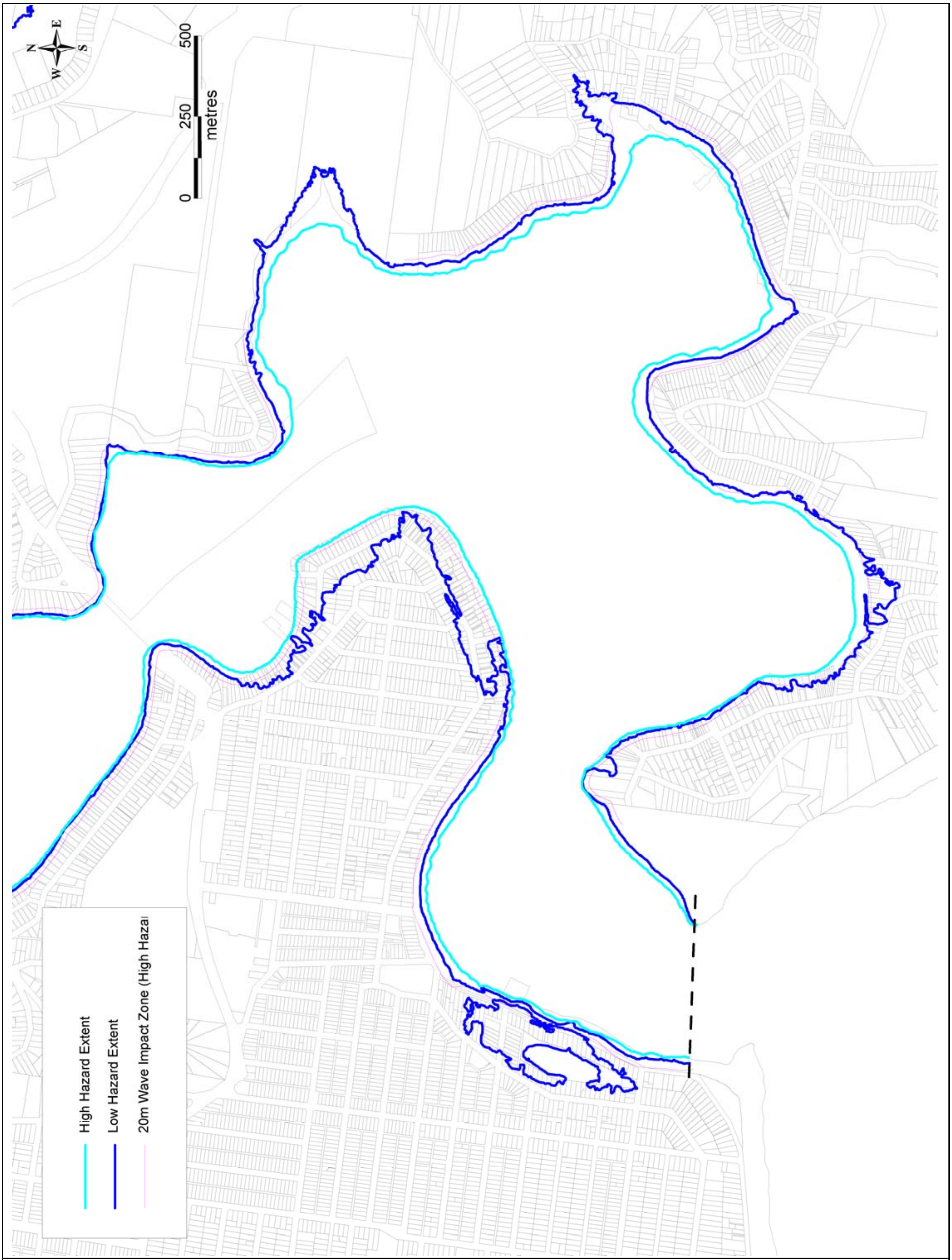

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LJ2523/R2353v7 July 2013

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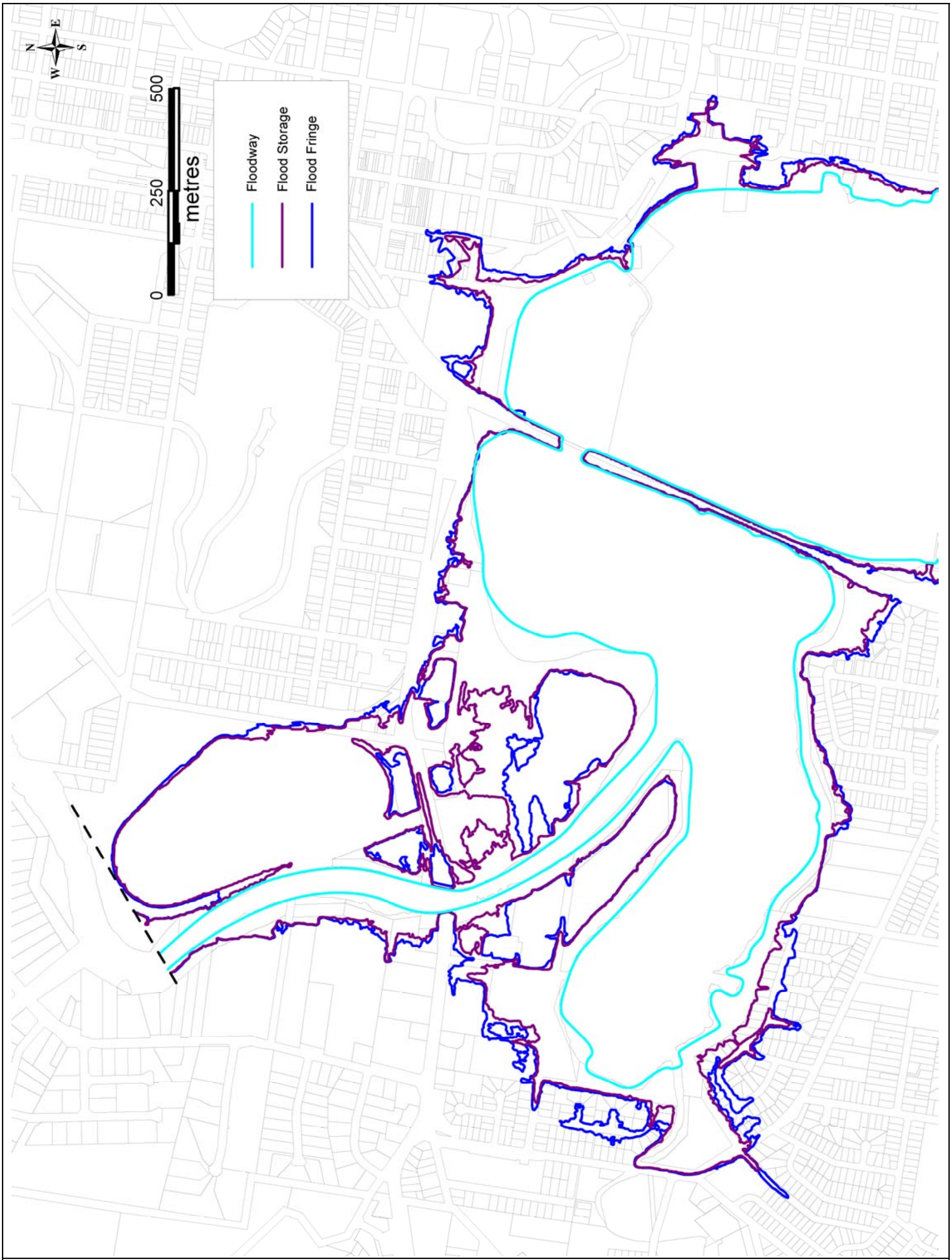
Brisbane Water Foreshore Flood Study

100yrARI PROVISIONAL FLOOD HAZARD EXTENTS

PLATE I

Figure 6.18I



Cardno Lawson Treloar

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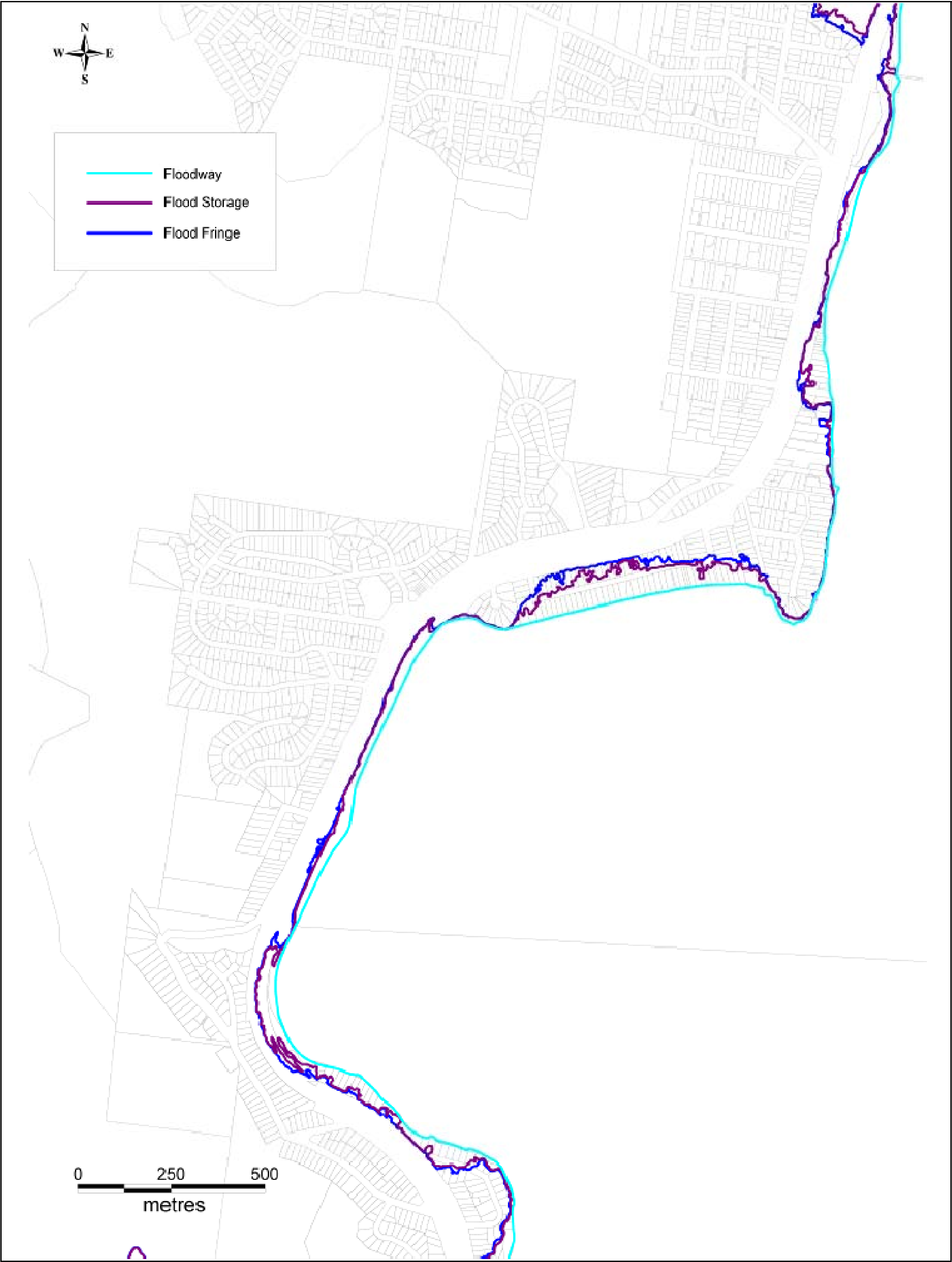
Brisbane Water Foreshore Flood Study

100yrARI HYDRAULIC CATEGORISATION
PLATE A
Figure 6.19A



Cardno Lawson Treloar

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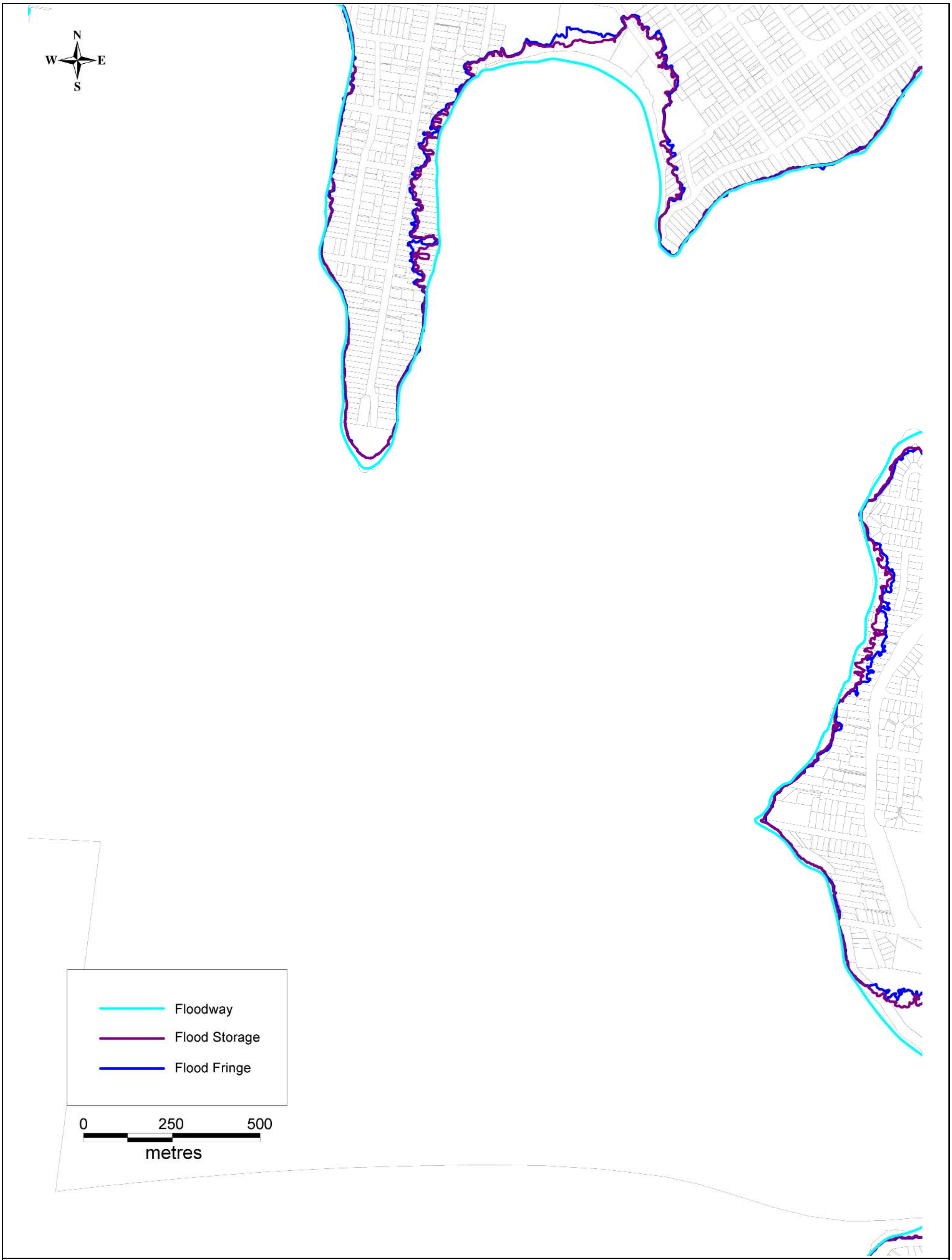
Brisbane Water Foreshore Flood Study

100yrARI HYDRAULIC CATEGORISATION

PLATE B

Figure 6.19B



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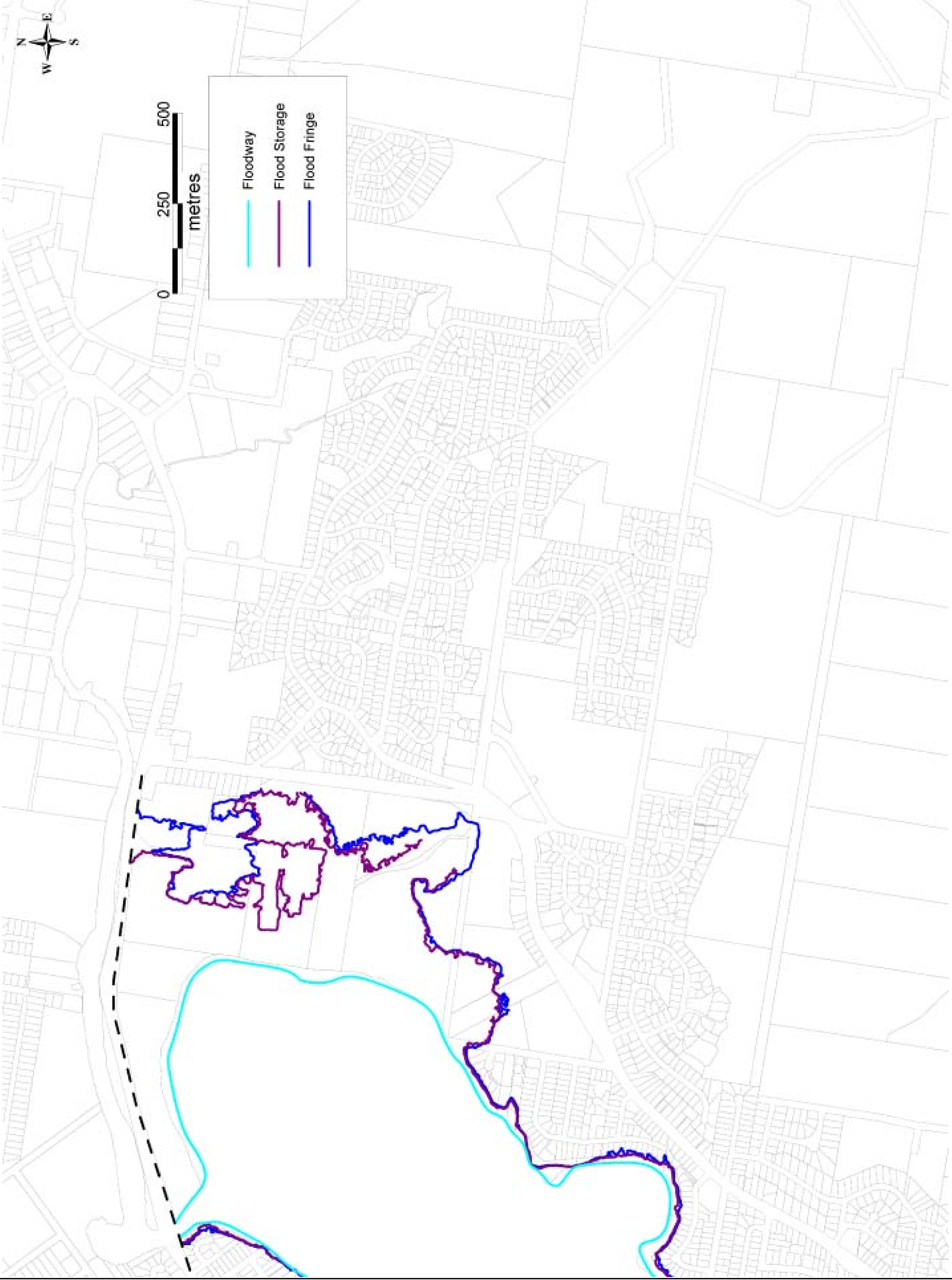
Brisbane Water Foreshore Flood Study

100yrARI HYDRAULIC CATEGORISATION

PLATE C

Figure 6.19C



Cardno Lawson Treloar

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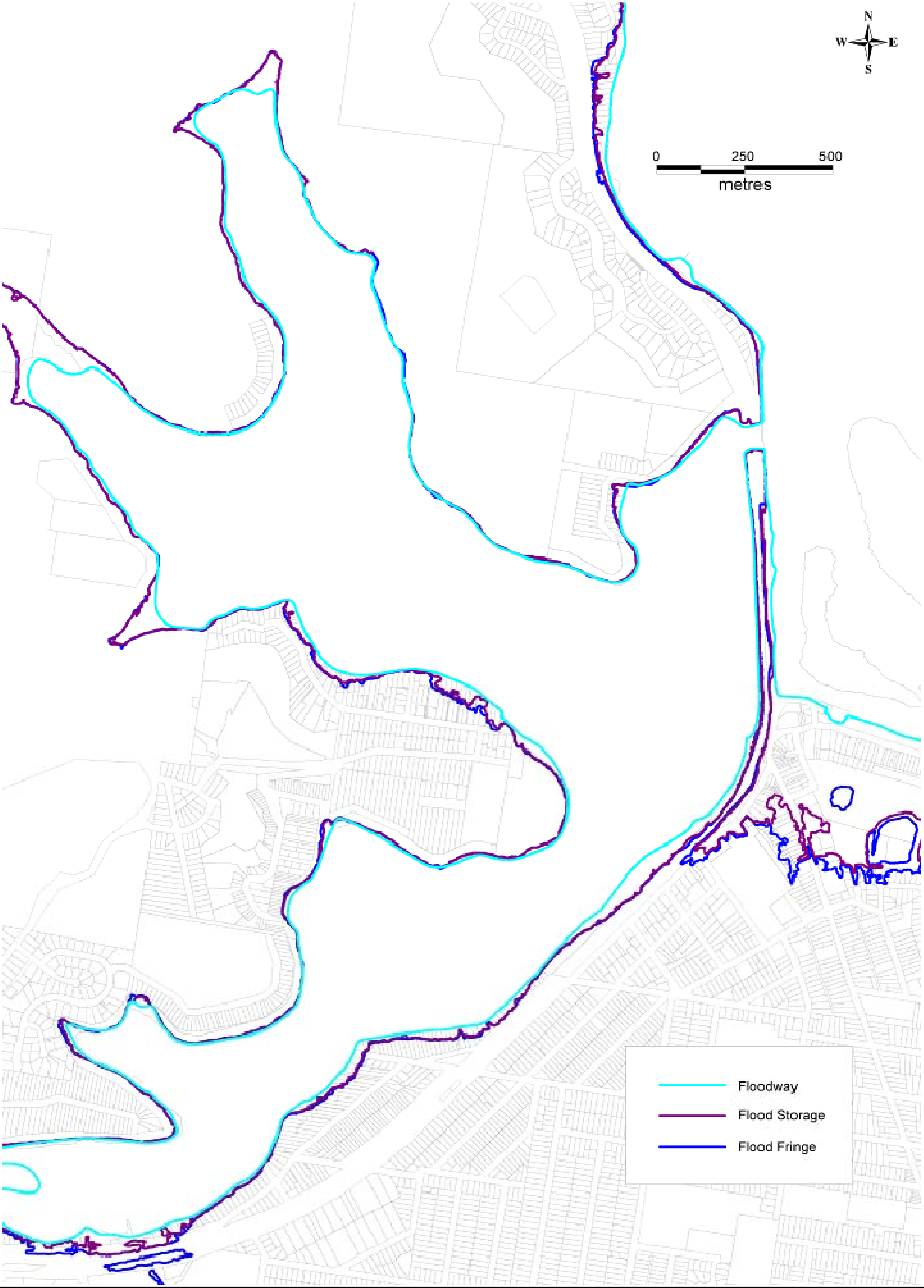
Brisbane Water Foreshore Flood Study

100yrARI HYDRAULIC CATEGORISATION
PLATE D
Figure 6.19D



Cardno Lawson Treloar

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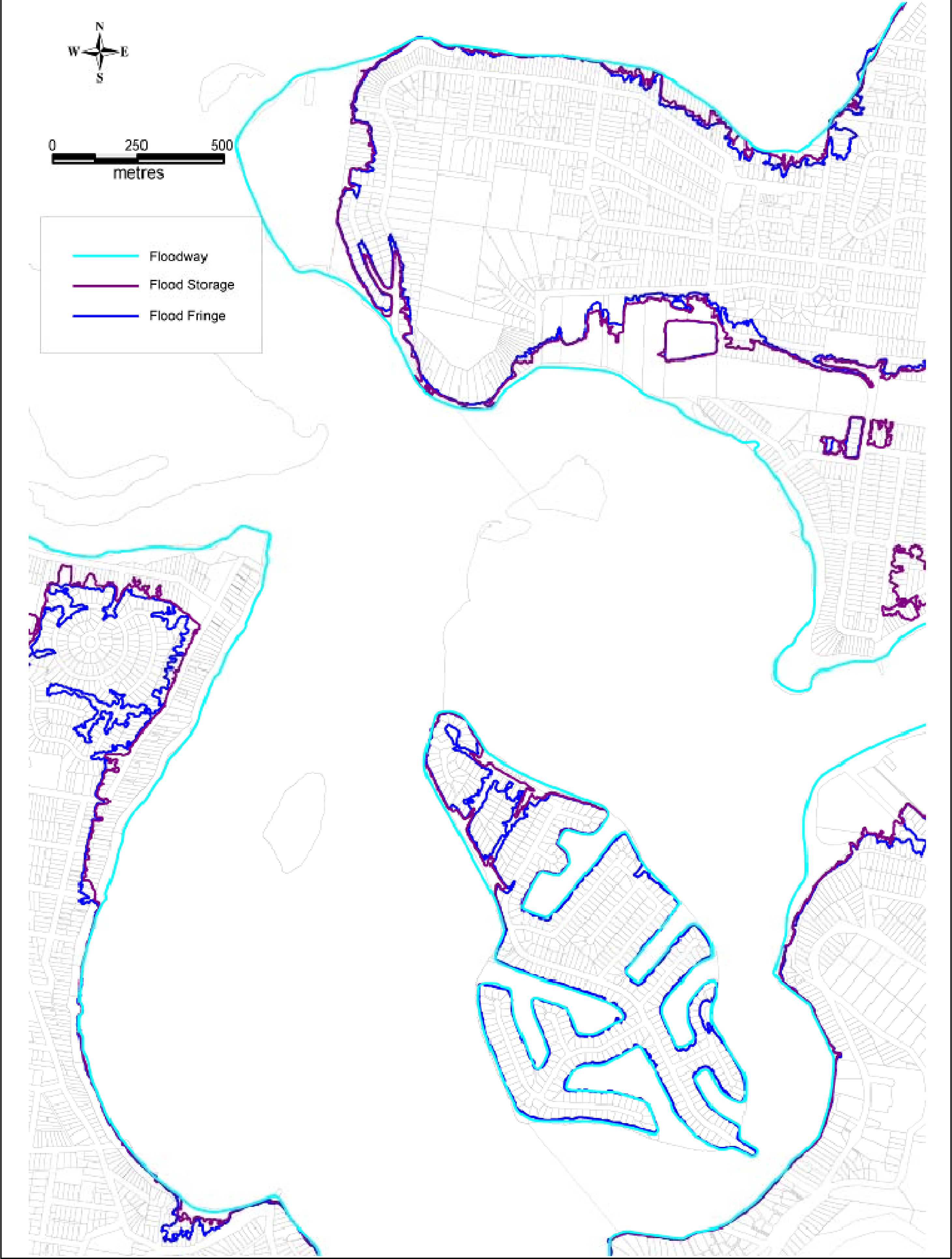
Brisbane Water Foreshore Flood Study

100yrARI HYDRAULIC CATEGORISATION
PLATE E
Figure 6.19E



Cardno Lawson Treloar

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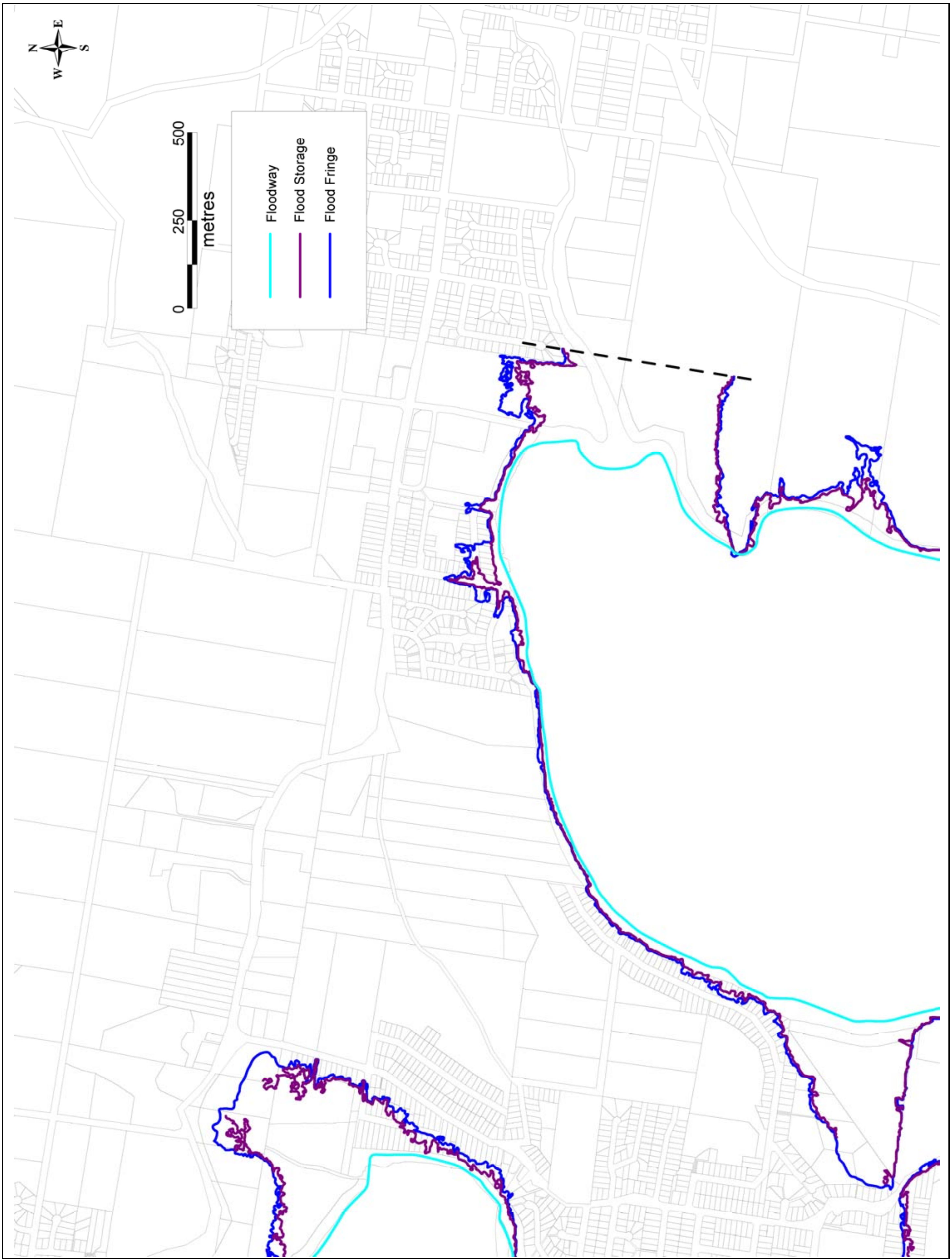
Brisbane Water Foreshore Flood Study

100yrARI HYDRAULIC CATEGORISATION

PLATE F

Figure 6.19F



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Lawson Treloar

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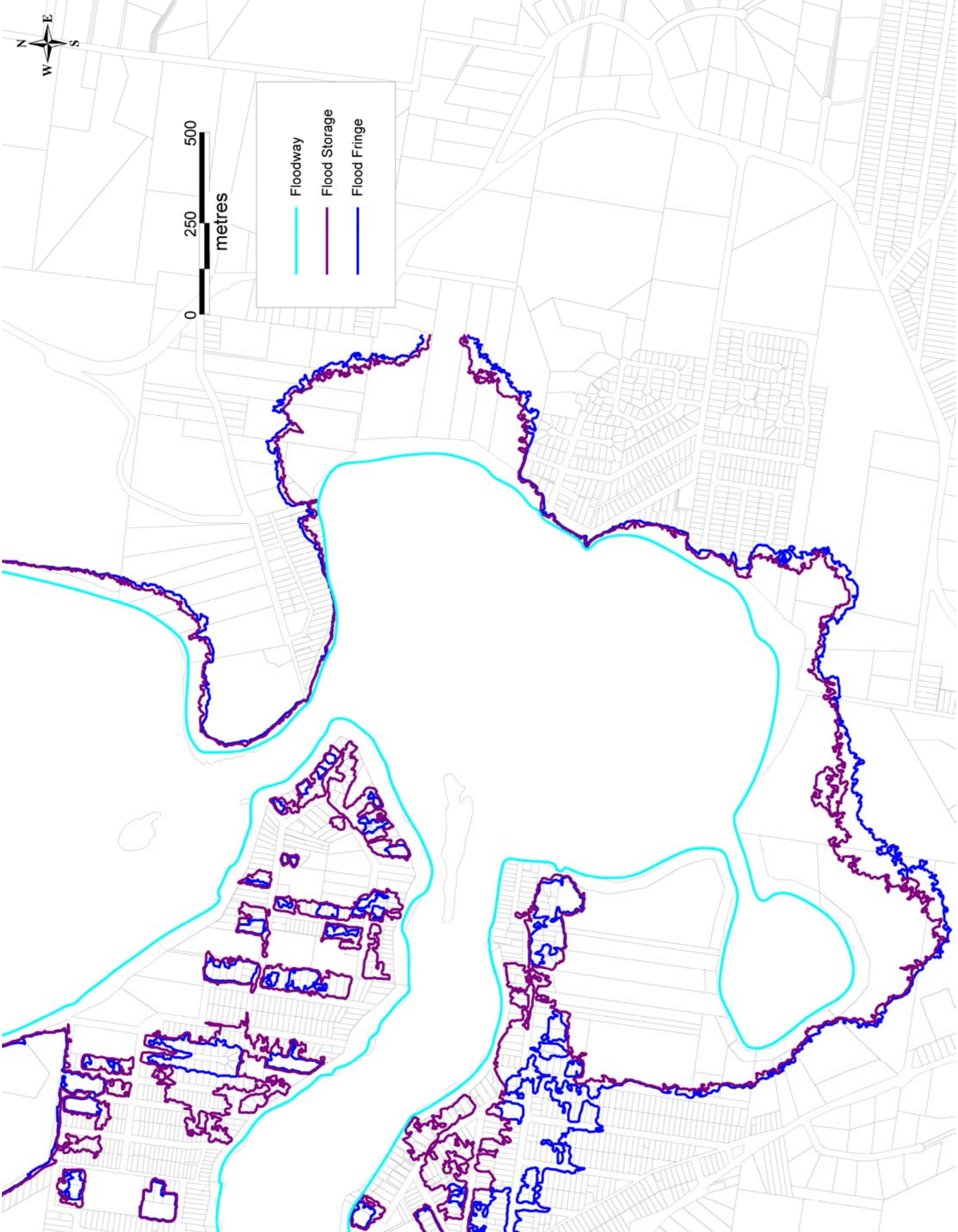
Brisbane Water Foreshore Flood Study

100yrARI HYDRAULIC CATEGORISATION
PLATE G
Figure 6.19G



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LJ2523/R2353v7 July 2013

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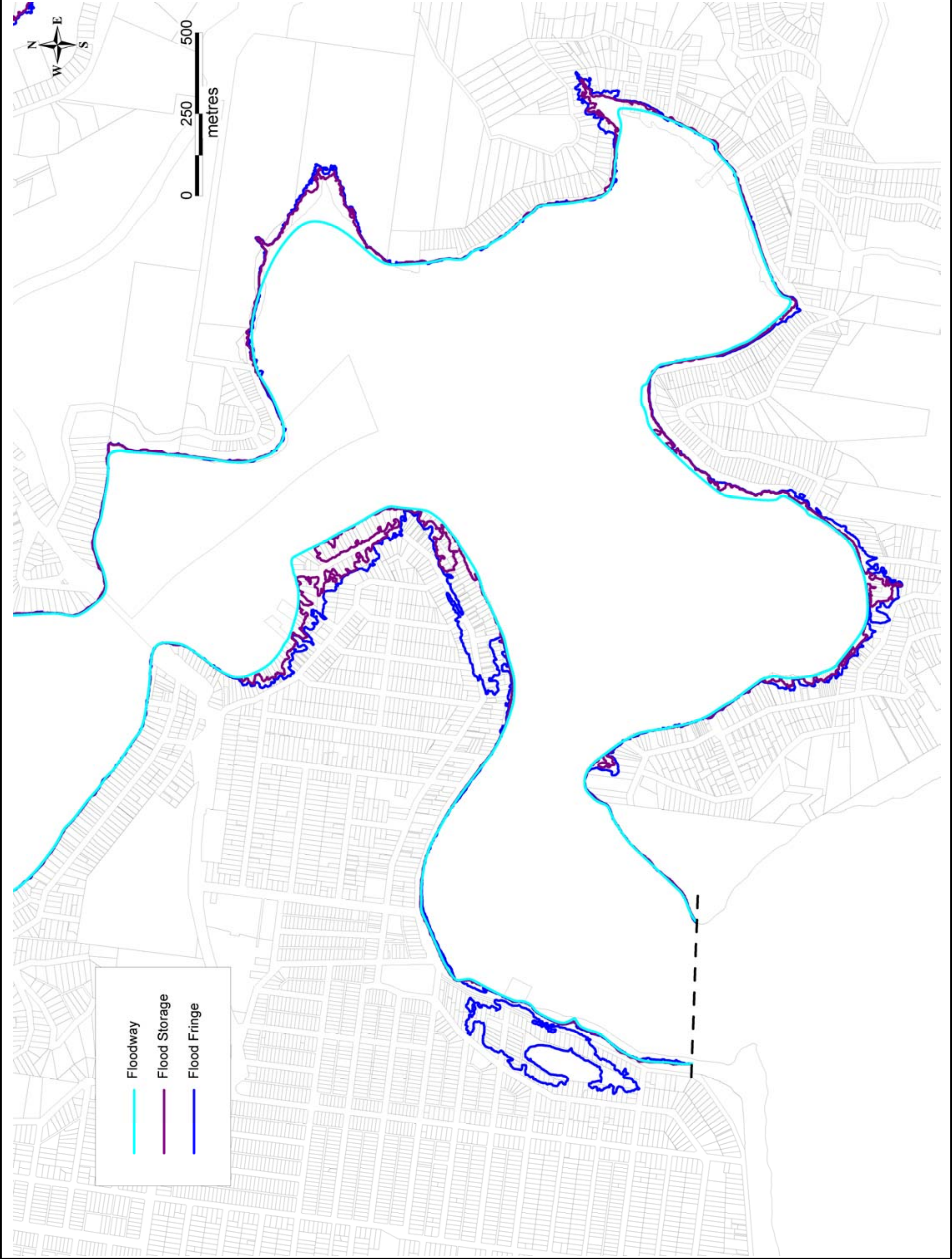
Brisbane Water Foreshore Flood Study

100yrARI HYDRAULIC CATEGORISATION
PLATE H
Figure 6.19H



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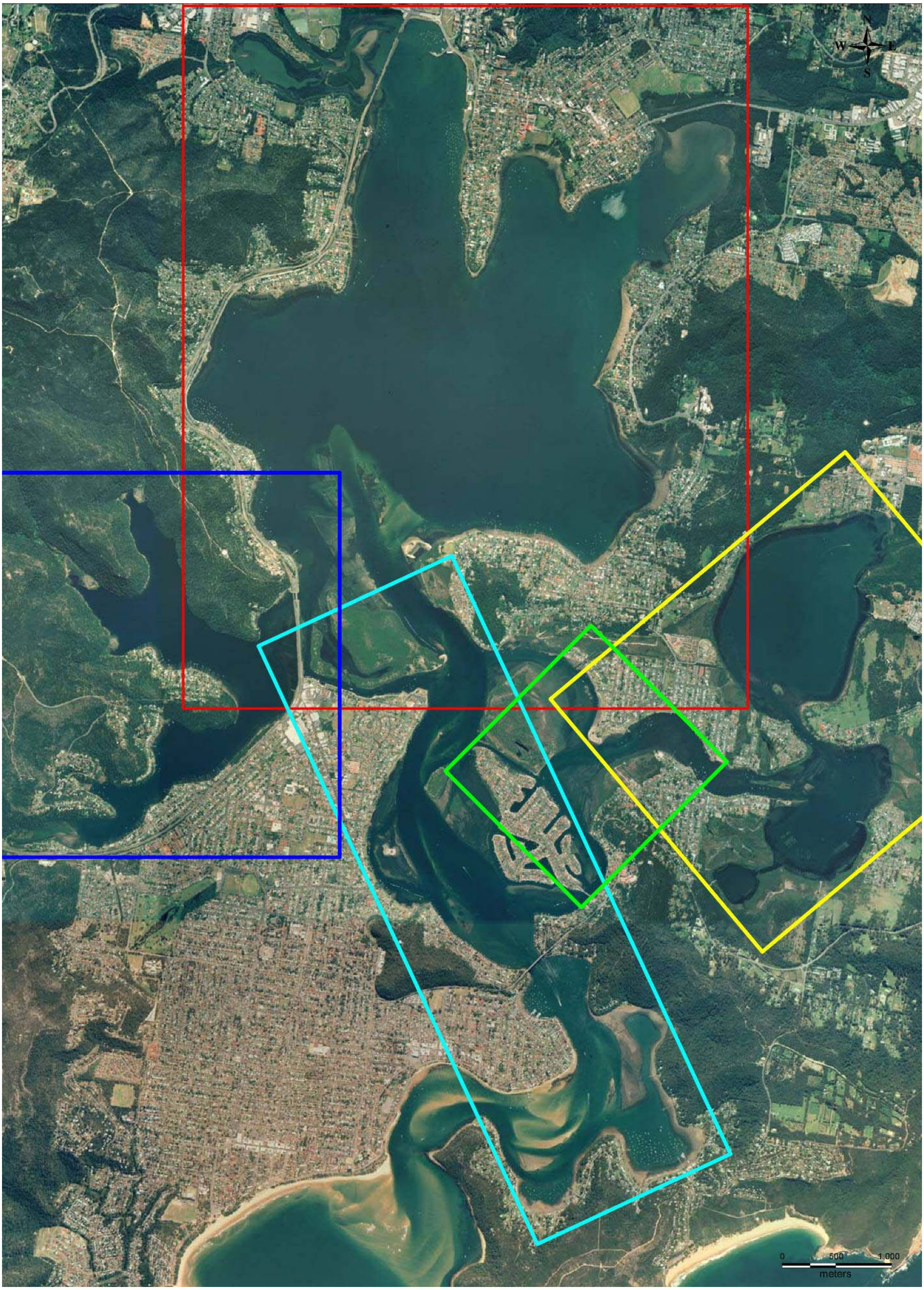
Brisbane Water Foreshore Flood Study

100yrARI HYDRAULIC CATEGORISATION
PLATE I
Figure 6.19I



Cardno Lawson Treloar

Brisbane Water Foreshore Flood Study

SUB-REGION SWAN MODELS

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File: J:\CM\LJ2523\Figures\SWAN_Grids.wor

Figure 7.1

Brisbane Water Foreshore Flood Study

EXAMPLES OF FORESHORE EDGE TREATMENTS

Figure 8.1

Brisbane Water Foreshore Flood Study

EXAMPLES OF FORESHORE EDGE TREATMENTS

Figure 8.2

Brisbane Water Foreshore Flood Study

WAVE OVERTOPPING OF GOSFORD SEAWALL – JUNE 2007
Image Captured by Gosford City Council
Figure 8.3

APPENDIX A

Joint Wind Speed and Direction Occurrence at Sydney Airport

Table A1: Joint Occurrence of Wind Speed and Direction at Mascot

Percentage Calms - 17.4

Dirn	Wind Speed (m/s)										
	0.0-2.5	2.5-5.0	5.0-7.5	7.5-10.0	10.0-12.5	12.5-15.0	15.0-17.5	17.5-20.0	20.0-22.5	22.5-25.0	**TOTAL**
N	0.48	1.73	0.98	0.33	0.07	0.01	0.00	0.00	0.00	0.00	3.60
NNE	0.25	1.36	1.39	0.88	0.37	0.08	0.01	0.00	0.00	0.00	4.34
NE	0.34	1.94	2.51	1.72	0.74	0.15	0.01	0.00	0.00	0.00	7.41
ENE	0.22	1.10	1.18	0.48	0.08	0.01	0.00	0.00	0.00	0.00	3.07
E	0.33	1.66	1.32	0.28	0.03	0.01	0.00	0.00	0.00	0.00	3.63
ESE	0.21	1.09	0.82	0.21	0.04	0.01	0.00	0.00	0.00	0.00	2.38
SE	0.31	1.82	1.95	0.79	0.19	0.05	0.02	0.00	0.00	0.00	5.13
SSE	0.19	1.61	2.28	1.31	0.56	0.18	0.05	0.01	0.00	0.00	6.19
S	0.31	1.84	3.13	2.86	1.62	0.67	0.18	0.03	0.01	0.00	10.66
SSW	0.16	0.84	1.05	1.01	0.54	0.23	0.06	0.02	0.00	0.00	3.92
SW	0.37	1.25	0.98	0.55	0.18	0.06	0.02	0.01	0.00	0.00	3.41
WSW	0.29	1.32	1.13	0.64	0.24	0.07	0.02	0.00	0.00	0.00	3.71
W	0.86	3.03	2.00	1.03	0.52	0.20	0.06	0.01	0.00	0.00	7.70
WNW	1.08	2.87	0.98	0.45	0.26	0.12	0.04	0.00	0.00	0.00	5.79
NW	1.78	4.34	1.19	0.44	0.22	0.07	0.02	0.00	0.00	0.00	8.07
NNW	0.59	1.90	0.69	0.26	0.10	0.02	0.01	0.00	0.00	0.00	3.56
TOTAL (%)	7.78	29.71	23.56	13.23	5.77	1.92	0.49	0.08	0.02	0.01	82.58
P of E (%)	82.58	74.79	45.08	21.52	8.29	2.52	0.60	0.11	0.03	0.01	

APPENDIX B

Tidal Plane and Range Data
(from Manly Hydraulics Laboratory Report MHL1319)

Table B1: Comparison of Tidal Planes – Woy Woy Inlet

Tidal Planes	Ocean	Brisbane Water				Woy Woy Inlet
	Site 0 (m AHD)	Site 2 (m AHD)	Site 4 (m AHD)	Site 6 (m AHD)	Site 9 (m AHD)	Site 16 (m AHD)
HHW(SS)	0.980	0.796	0.736	0.610	0.623	0.614
MHWS	0.646	0.519	0.471	0.369	0.384	0.376
MHW	0.518	0.435	0.400	0.318	0.331	0.322
MHWN	0.389	0.350	0.329	0.267	0.278	0.269
MTL	0.016	0.077	0.089	0.071	0.076	0.068
MLWN	-0.357	-0.196	-0.150	-0.124	-0.126	-0.133
MLW	-0.485	-0.280	-0.221	-0.175	-0.179	-0.186
MLWS	-0.614	-0.364	-0.292	-0.227	-0.232	-0.240
ISLW	-0.852	-0.562	-0.482	-0.398	-0.403	-0.410

Table B2: Comparison of Tidal Planes – Narara Creek

Tidal Planes	Ocean	Brisbane Water				Narara Creek	
	Site 0 (m AHD)	Site 2 (m AHD)	Site 4 (m AHD)	Site 6 (m AHD)	Site 9 (m AHD)	Site 20 (m AHD)	Site 22 (m AHD)
HHW(SS)	0.980	0.796	0.736	0.610	0.623	0.621	0.727
MHWS	0.646	0.519	0.471	0.369	0.384	0.385	0.362
MHW	0.518	0.435	0.400	0.318	0.331	0.333	0.325
MHWN	0.389	0.350	0.329	0.267	0.278	0.280	0.288
MTL	0.016	0.077	0.089	0.071	0.076	0.089	0.077
MLWN	-0.357	-0.196	-0.150	-0.124	-0.126	-0.102	-0.133
MLW	-0.485	-0.280	-0.221	-0.175	-0.179	-0.155	-0.171
MLWS	-0.614	-0.364	-0.292	-0.227	-0.232	-0.207	-0.208
ISLW	-0.852	-0.562	-0.482	-0.398	-0.403	-0.375	-0.469

Table B3: Comparison of Tidal Planes – Erina Creek

Tidal Planes	Ocean	Brisbane Water				Erina Creek	
	Site 0 (m AHD)	Site 2 (m AHD)	Site 4 (m AHD)	Site 6 (m AHD)	Site 9 (m AHD)	Site 10 (m AHD)	Site 18 (m AHD)
HHW(SS)	0.980	0.796	0.736	0.610	0.623	0.628	0.644
MHWS	0.646	0.519	0.471	0.369	0.384	0.391	0.398
MHW	0.518	0.435	0.400	0.318	0.331	0.338	0.343
MHWN	0.389	0.350	0.329	0.267	0.278	0.285	0.288
MTL	0.016	0.077	0.089	0.071	0.076	0.081	0.082
MLWN	-0.357	-0.196	-0.150	-0.124	-0.126	-0.123	-0.125
MLW	-0.485	-0.280	-0.221	-0.175	-0.179	-0.176	-0.180
MLWS	-0.614	-0.364	-0.292	-0.227	-0.232	-0.229	-0.235
ISLW	-0.852	-0.562	-0.482	-0.398	-0.403	-0.398	-0.410

Table B4: Comparison of Tidal Planes – Cockle Channel

Tidal Planes	Ocean Site 0 (m AHD)	Brisbane Water			Kincumber Broadwater	
		Site 2 (m AHD)	Site 4 (m AHD)	Site 6 (m AHD)	Site 11 (m AHD)	Site 14 (m AHD)
HHW(SS)	0.980	0.796	0.736	0.610	0.558	0.508
MHWS	0.646	0.519	0.471	0.369	0.334	0.293
MHW	0.518	0.435	0.400	0.318	0.293	0.257
MHWN	0.389	0.350	0.329	0.267	0.252	0.221
MTL	0.016	0.077	0.089	0.071	0.088	0.065
MLWN	-0.357	-0.196	-0.150	-0.124	-0.075	-0.092
MLW	-0.485	-0.280	-0.221	-0.175	-0.116	-0.128
MLWS	-0.614	-0.364	-0.292	-0.227	-0.157	-0.163
ISLW	-0.852	-0.562	-0.482	-0.398	-0.318	-0.317

* Note: Data from Site 14 was only available for a shorter period of time due to instrument malfunction

HHW (SS)	Higher Water (Spring Solstices)	MLWN	Mean Low Water Neaps
MHWS	Mean High Water Springs	MLW	Mean Low Water
MHW	Mean High Water	MLWS	Mean Low Water Springs
MHWN	Mean High Water Neaps	ISLW	Indian Spring Low Water
MTL	Mean Tide Level		

Note:- These tidal planes should not be used for mean high water boundary definition

Table B5: Comparison of Tidal Ranges – Woy Woy Inlet

Tidal Ranges	Ocean Site 0 (m AHD)	Brisbane Water				Woy Woy Inlet
		Site 2 (m)	Site 4 (m)	Site 6 (m)	Site 9 (m)	Site 16 (m)
HHW(SS)	1.832	1.358	1.218	1.008	1.026	1.023
Mean Spring	1.260	0.883	0.763	0.596	0.616	0.615
Mean	1.003	0.715	0.621	0.493	0.510	0.509
Mean Neap	0.746	0.546	0.479	0.390	0.404	0.402

Table B6: Comparison of Tidal Ranges – Narara Creek

Tidal Range	Ocean Site 0 (m AHD)	Brisbane Water				Narara Creek	
		Site 2 (m)	Site 4 (m)	Site 6 (m)	Site 9 (m)	Site 20 (m)	Site 22 (m)
HHW(SS)	1.832	1.358	1.218	1.008	1.026	0.996	1.196
Mean Spring	1.260	0.883	0.763	0.596	0.616	0.593	0.570
Mean	1.003	0.715	0.621	0.493	0.510	0.488	0.495
Mean Neap	0.746	0.546	0.479	0.390	0.404	0.382	0.421

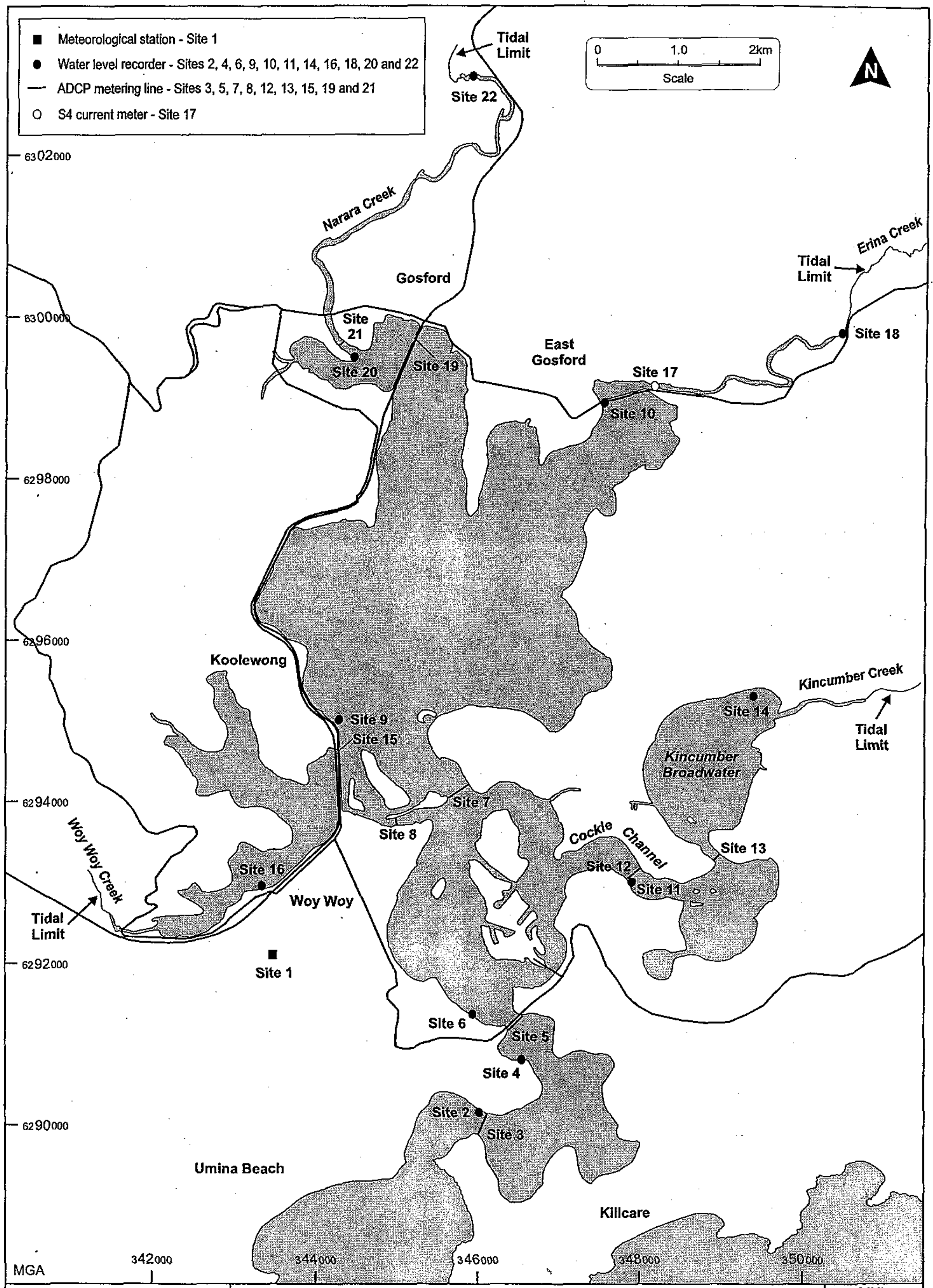
Table B7: Comparison of Tidal Ranges – Erina Creek

Tidal Range	Ocean Site 0 (m AHD)	Brisbane Water				Erina Creek	
		Site 2 (m)	Site 4 (m)	Site 6 (m)	Site 9 (m)	Site 10 (m)	Site 18 (m)
HHW(SS)	1.832	1.358	1.218	1.008	1.026	1.027	1.054
Mean Spring	1.260	0.883	0.763	0.596	0.616	0.620	0.634
Mean	1.003	0.715	0.621	0.493	0.510	0.514	0.523
Mean Neap	0.746	0.546	0.479	0.390	0.404	0.407	0.413

Table B8: Comparison of Tidal Ranges – Cockle Channel

Tidal Ranges	Ocean Site 0 (m AHD)	Brisbane Water			Kincumber Broadwater	
		Site 2 (m)	Site 4 (m)	Site 6 (m)	Site 11 (m)	Site 14 (m AHD)
HHW(SS)	1.832	1.358	1.218	1.008	0.875	0.826
Mean Spring	1.260	0.883	0.763	0.596	0.491	0.456
Mean	1.003	0.715	0.621	0.493	0.409	0.385
Mean Neap	0.746	0.546	0.479	0.390	0.327	0.313

* Note: Data from Site 14 was only available for a shorter period of time due to instrument malfunction.



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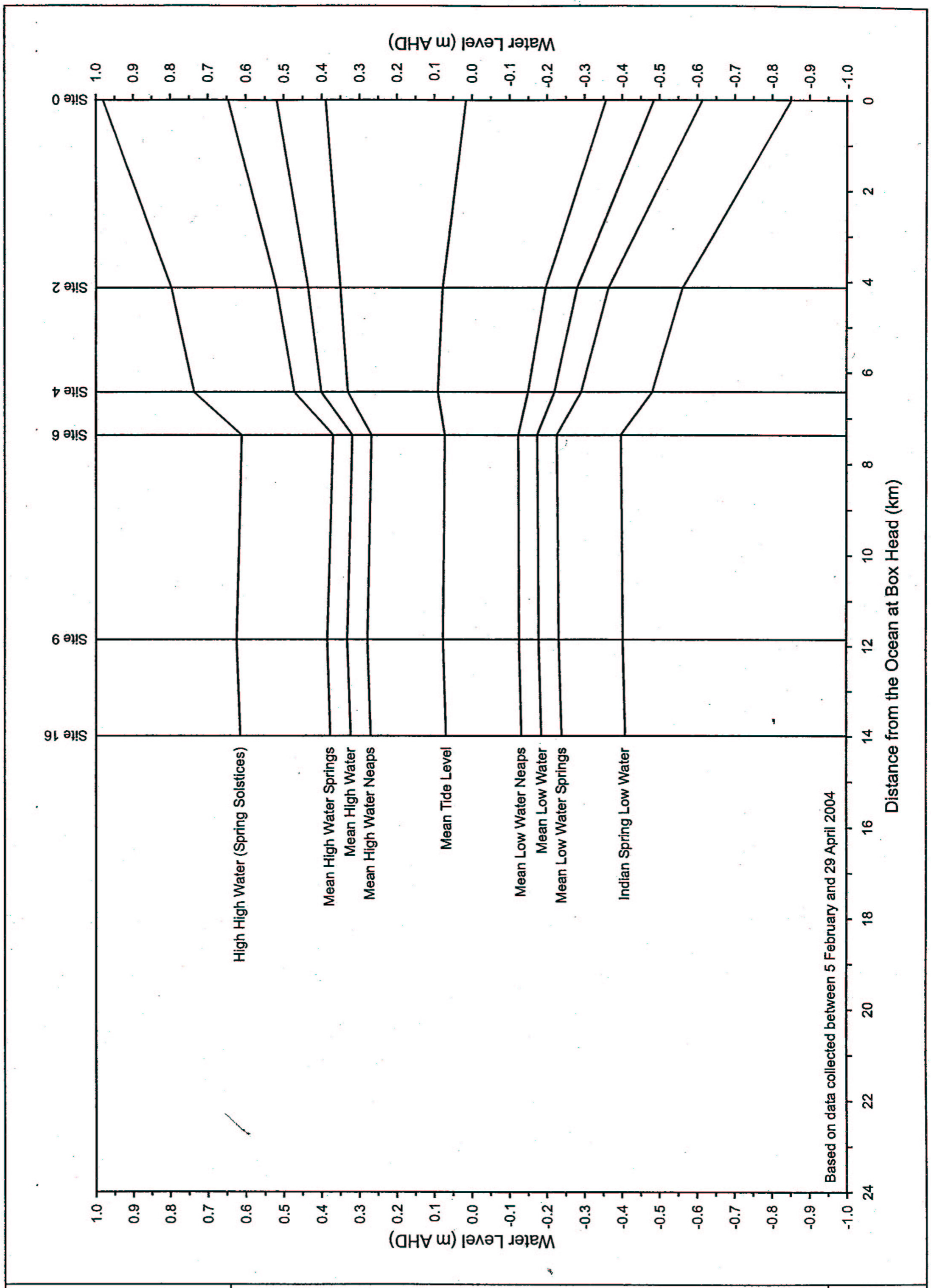
DETAILED LOCATION MAP OF STUDY AREA

MHL Report 1319
Figure 1.2
DRAWING 1319-1-02.CDR



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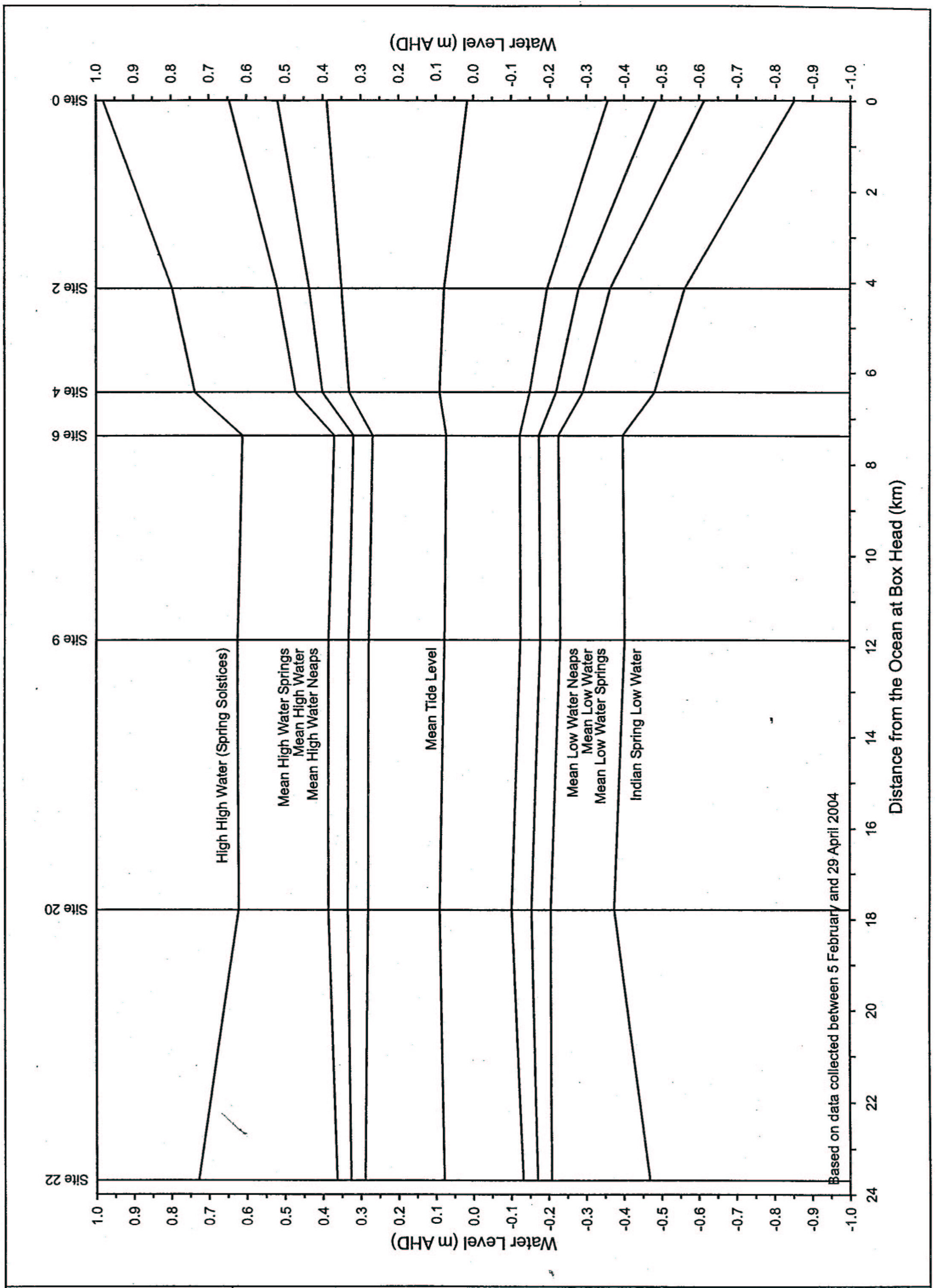
TIDAL PLANES - WOY WOY INLET
SITES 0, 2, 4, 6, 9 AND 16

MHL
Report 1319

Figure
3.2

DRAWING 1319-3-02.CDR



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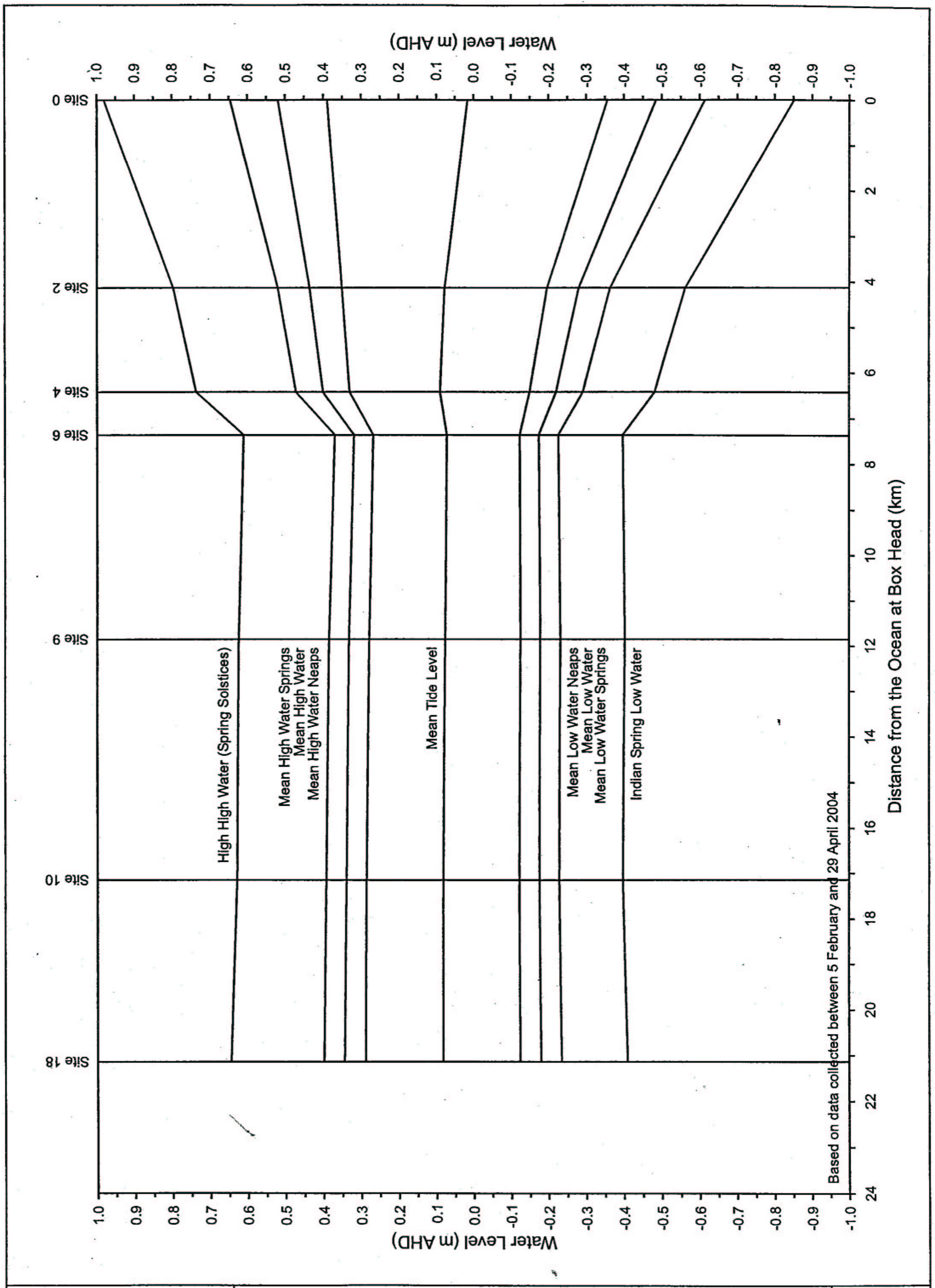
MANLY HYDRAULICS LABORATORY

TIDAL PLANES - NARARA CREEK
SITES 0, 2, 4, 6, 9, 20 AND 22

MHL
Report 1319

Figure
3.3

DRAWING 1319-3-03.CDR



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TIDAL PLANES - ERINA CREEK
SITES 0, 2, 4, 6, 9, 10 AND 18

MHL Report 1319
Figure 3.4
DRAWING 1319-3-04.CDR

APPENDIX C

COMMUNITY CONSULTATION

RESIDENT INFORMATION PACK AND QUESTIONAAIRE

Dear Property Owner,

RE: BRISBANE WATER FORESHORE FLOOD STUDY INFORMATION PACK

BACKGROUND

Gosford City Council (GCC) has engaged Cardno Lawson Treloar Pty Ltd, consulting engineers to undertake the "Brisbane Water Foreshore Flood Study".

Potentially flood-affected properties along the Brisbane Water Foreshore have received this information pack using the services of local walkers.

As a non-resident owner you have had the information pack posted to you.

COMMUNITY INFORMATION BROCHURE AND QUESTIONAIRE

An information package is attached, which provides further details of the floodplain risk management process of which this study is a part.

The accuracy of the study is mainly reliant on the collection of historical flood data obtained from residents who have lived in the area. As such, Council would appreciate your assistance with the collection of this data by completing the attached questionnaire and returning it in the reply-paid envelope.

STUDY INFORMATION CONTACTS

Your cooperation is vital to the success of this Foreshore Flood Study. Should you only wish to make a comment or seek clarification on any issue, please do not hesitate to contact Habib Rehman at Cardno Lawson Treloar.

Alternatively, you may also contact Moazzam Shah of Gosford City Council (Telephone: (02) 4325 8222, Email: moazzam.shah@gosford.nsw.gov.au).

Yours faithfully,

Habib Rehman
Telephone: (02) 9499 3000
Email: hrehman@cardno.com.au

Encl:
1. Community Information Brochure
2. Resident Questionnaire

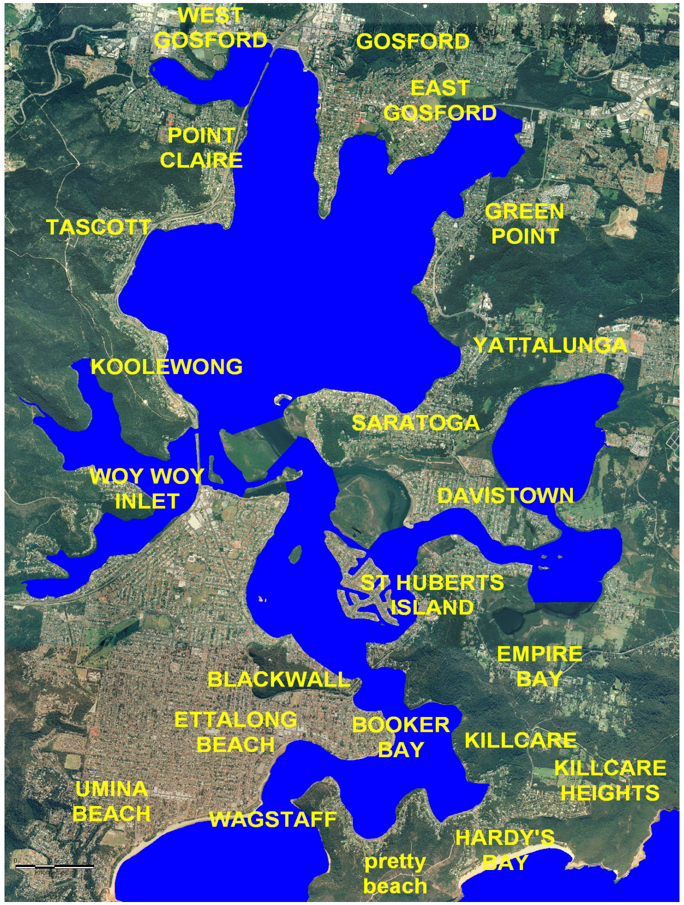
Cardno Lawson Treloar

NSW Government
DEPARTMENT OF NATURAL RESOURCES

GOSFORD CITY COUNCIL
CENTRAL COAST

BRISBANE WATER FORESHORE FLOOD STUDY

GOSFORD CITY COUNCIL



BACKGROUND

Residential and urban developments in and around Brisbane Water Estuary face numerous flooding and drainage issues as a result of rainfall induced flooding and elevated ocean levels.

Under the State Government's Flood Prone Land Policy, the management of flood prone land is the responsibility of Local Government. To manage flooding and tidal inundation risks in such areas Council has prepared numerous floodplain management plans for the tributaries of Brisbane Water in accordance with the NSW Government's Floodplain Risk Management Process.

To date the observed level of 1.95m AHD* in Brisbane Water during the 1974 storm event has been used as the basis for Flood Planning Levels in management areas. Council is now seeking to undertake an investigation to establish a more reliable estimate of the Flood Planning Level for the foreshore areas by establishing the 100-year ARI** flood level in Brisbane Water. This investigation would also provide a more reliable flood level data for use in future catchment flood studies.

BRISBANE WATER FORESHORE FLOOD STUDY

Gosford City Council has commissioned Cardno Lawson Treloar Consulting Engineers to undertake the Brisbane Water Foreshore Flood Study. The Study will investigate all possible natural mechanisms that can impact on water levels in Brisbane Water.

This study will consider catchment rainfall, ocean rise, tidal influences, and local wind waves that cause the level of Brisbane Water to rise at the shoreline.

Possible sea level rise and climate change due to the Greenhouse Effect will also be researched as part of the study process.

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* AHD Australian Height Datum, a common national surface level datum approximately corresponding to mean sea level.

** ARI Average Recurrence Interval, the long term average number of years between the occurrence of a flood as big as or larger than the selected event.

THE STUDY AREA

The study area includes the entire foreshore area around Brisbane Water Estuary including low lying areas in foreshore towns like Davistown, Empire Bay, Ettalong, Umina and Woy Woy.

STUDY OBJECTIVES

The main objective of this study is to determine water levels in Brisbane Water for the full range of flood events that can occur due to the various natural physical processes. Other outcomes from this study include public participation, and hydraulic and hazard categorisation to achieve affective and responsible floodplain risk management. The results of the study will provide valuable data for planning and future catchment flood studies in the area.

THE FLOODPLAIN MANAGEMENT PROCESS

The implementation of sound floodplain management practice is an important process which can be used to optimise development potential, and to obtain social and economic benefits from the reduction in flood damages.

Under the NSW Flood Prone Land Policy, the Floodplain Risk Management process aims to minimise the impact of flooding and flood liability on individual owners and occupiers of floodplains. The policy provides for technical and financial support by the State Government through the following sequential stages:

- **Formation of a Committee**
- **Gathering of Data**
- **Flood Study**
- **Floodplain Risk Management Study**
- **Floodplain Risk Management Plan**
- **Implementation of Plan**

After the formation of a committee, the second and third stage in the process is the collection of data and the preparation of a Flood Study. This study is undertaken to provide a comprehensive technical investigation of flood behaviour in the estuary. In the fourth stage, a Floodplain Risk Management Study (FRMS) is carried out to identify and compare various risk management options available in the estuary and surrounding catchments. Finally, a Floodplain Risk Management Plan (FRMP) is prepared to provide input into the strategic and statutory planning roles of the Council. The current study would complete the third stage of the process as discussed above.

WE NEED YOUR HELP

Community involvement is important at all stages of the Floodplain Management Process. As part of the initial phases of the project, Cardno Lawson Treloar is seeking to collect any available information regarding foreshore flooding in the study area.

The accuracy of the Study will be improved by the collection of historical flood data from residents who have lived in the area for a period of time. To achieve this objective, a questionnaire has been prepared to help identify flood levels and related information. This questionnaire along with reply-paid envelope is enclosed.

Please complete the questionnaire and return it in the reply-paid envelope within 2 weeks of receiving this information pack. Your comments will be considered in the preparation of the study. Please note that the return of the completed questionnaire is voluntary and any personal information included in the questionnaire will be treated according to the Privacy Laws of NSW.

There will also be a future exhibition of the draft study report seeking community submissions. You are welcome to comment on the study during the exhibition period.

As part of the study, ground survey of some foreshore areas may be required. This survey may extend into some of the properties fronting the foreshore. If so, prior information will be sent to the residents of such properties requesting their permission for surveyors to operate. Such surveys will be limited to outdoors.

WHO TO SPEAK TO?

Should you wish to seek clarification on any issue or obtain further information on the study, please do not hesitate to contact either **Habib Rehman** or **Doug Treloar** at Cardno Lawson Treloar. They can be contacted at:

Cardno Lawson Treloar Pty Ltd
Telephone: 02 9499 3000
Facsimile: 02 9499 3033
Email: hrehman@cardno.com.au
dtreloar@cardno.com.au

You may also wish to contact Moazzam Shah on 4325 8946 (email: moazzam.shah@gosford.nsw.gov.au) or Vic Tysoe on 4325 8397 (email: vic.tysoe@gosford.nsw.gov.au) at Gosford City Council to discuss any aspect of the project.

BRISBANE WATER FORESHORE FLOOD STUDY

QUESTIONNAIRE

Please answer the following ten questions as best as you can. When you have finished answering the questions, please return these pages in the enclosed "reply paid" envelope.

Please note that the return of the completed questionnaire is voluntary and any personal information included in the questionnaire will be subject to the Privacy and Personal Information Protection Act 1998. This information will only be used as an input into the Brisbane Water Foreshore Flood Study.

If you have any queries, please contact:

Moazzam Shah – GOSFORD CITY COUNCIL Ph:4325 8946
Email: Moazzam.shah@gosford.nsw.gov.au

Habib Rehman – CARDNO LAWSON TRELOAR Ph:9499 3000
Email: hrehman@cardno.com.au

House/Property No: ____________________

Street Name: ____________________

Suburb: ____________________

Question 1

How long have you lived at this property?

_______ Months
_______ Years

Question 2

What type of residence do you have?

WALL CONSTRUCTION		**FLOOR CONSTRUCTION**	
BRICK	_______	PIERED	_______
BRICK VENEER	_______	SLAB ON GROUND	_______
OTHER	_______	ONE STOREY	_______
		TWO STOREYS	_______
		THREE STOREYS	_______

Other (Please Specify): ____

Question 3a

Has your house/property ever been affected by estuary or river flooding during heavy rain or ocean storm events, high water level or wave action?

Estuary	Property:	YES	_______	NO	_______
(i.e. Brisbane Water)	House:	YES	_______	NO	_______
River Flooding	Property:	YES	_______	NO	_______
(i.e. overland catchment flooding)	House:	YES	_______	NO	_______

Question 3b

Can you remember if the flooding was a result of a high water level in the estuary?

ELEVATED WATER LEVEL YES _______ NO _______

Was there heavy rain?

HEAVY RAIN YES _______ NO _______

Was there a severe ocean storm?

OCEAN STORM YES _______ NO _______

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CENTRAL COAST

Question 4

With regard to your response to Question 3a what was the extent of flood inundation?

TOO LOW TO BE A CONCERN _______

SANDBAGS OR FLOOD INHIBITORS IN YARD _______

MOVING FURNITURE TO HIGHER LEVELS _______

EVACUATING PROPERTY _______

OTHER _______

Please Specify: ____

Question 5

If your house/property has never been affected by estuary or river flooding can you recall water reaching near your property?

YES _______ NO _______

(If yes please provide more details in Question 6).

Question 6

Can you remember when the flood inundation occurred? Please give us as much detail as possible.
To assist, events may have occurred on the following dates:

1. May 1998
2. February 1990
3. April 1988
4. March 1977
5. May 1974
6. ____________________
7. ____________________
8. ____________________

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DEPARTMENT OF NATURAL RESOURCES

GOSFORD CITY COUNCIL
CENTRAL COAST

Details of flood water entry and when it occurred (please add additional sheets if necessary):

Question 7a

If possible, could you draw a free hand sketch showing road names and the approximate location of the flooding on the attached blank sheet (Sheet 6 of 6)?

Question 7b

If you have experienced flooding from the estuary in this locality, do you have any record of the extents of the floods?

YES _______ NO _______

If you answered YES, please give as much detail as possible.

You may have an old photograph, or may have taken a video. Some people remember marks on walls and posts, and this information could prove quite important.

Alternatively, you may know someone who has lived in the locality for a long time who might have that type of information.

Details of information (please add additional sheets if necessary):

Question 8

Is there anything else you can tell us about the estuary behaviour or river flooding in this locality?

Question 9

Do you have any suggestions for works that could be done which might help alleviate the current problems if any (please add additional sheets if necessary)?

Examples might be:

- Development Controls (eg setting floor levels for new development)
- Other?

Question 10

We may need to contact you to request some additional details related to the information you provide. Can we contact you for further information?

YES _______ NO _______

Could you please provide us with the following details?

Name: ____________________
Day Time Phone Number: ____________________
Email Address: ____________________

Thank you for providing the above information. Please remember to put this questionnaire along with the map in the reply-paid envelope. It would be appreciated if these could be returned <u>within 2 weeks</u> of receiving this information pack.

Cardno Lawson Treloar

NSW Government
DEPARTMENT OF NATURAL RESOURCES

GOSFORD CITY COUNCIL
CENTRAL COAST

Table C1: Selected Responses to Resident Questionnaire

Adress	House Type	Resident Comment	Level Obtained by Surveyors
11 Pine Ave, Davistown	Other, unspecified	2mm water over garage floor slab. Drained away when street drain level dropped. May 1998 & February 1990.	Garage floor level
25 Elinya Lane, Davistown	Brick, brick veneer	Constant erosion at water edge due to silting up of Cockle Creek (Brisbane Water) 2005 - ? Sept 2006 marks on walls and posts.When heavy rain and high tides occur - Due to the siltation of Cockle Creek Water can not get away - Kyoga Ave - Parts of Elinya Lane are affected - No 23 Elinya Lane cannot access their property - as they have to drive through salt water in these conditions. High tides in this area on their own present the same problem.	marks on posts and walls
2 Magnolia Ave, Davistown	Brick veneer	May 1998, 1999. Water came onto property up to rear doorstep & surrounded house at high tide.	Rear Doorstep level
7 Restella Ave, Davistown	Fibro board	Sea water from tidal drain at rear of property flooded garage to depth of 150mm. Water came within 25mm of floor level in house.	Garage floor level and house floor level.
37 Blue Waters Pde, Tascott	Brick veneer	May 1998 & February 1990. Th e whole street was flooded 1998-1990 and we lived in 43 Blue Waters Pde. Flooding came in house at 37 Blue Waters Pde on both occasions but only came to brickwork at 43	Brickwork level on Estuary Side of House
129 Woy Woy Rd, Woy Woy	Fibro	September 2006 Heavy rain and king tide bought water into the yard to the laundry door for a distance of about 5m and was about 5 inches deep in places. Our property backs onto Correa Bay.	Mark at laundry door
9 Taylor St, Woy Woy Bay	Timber	High tides in the last 4 years.. Lapping edge of the sea wall.	Top of seawall level
5/84 Booker Bay Rd, Booker Bay	Brick veneer	May 1998 Water came into courtyard closest to waterfront.	Mark at waterfront edge of courtyard
176 North Burge Rd, Woy Woy	Brick, brick veneer	May 1998 One night I was up & about. I noticed an unusual phenomenon. The foreshore has disappeared underwater that reched the boundary brick wall but did not enter our property. I have not seen this phenomenon since. Unfortunately I did not make a note of the date.	Mark at bottom of boundary brick wall on estuary side.
89 Wagstaffe Ave, Wagstaffe	Weatherboard	May 1974 Storm surge caused by high winds coinciding with spring tide caused unusually high tide about 2ft above normal 2m tide in May 1974. Water came about 225mm over floor of boatshed & deck of jetty	Level of boatshed floor and jetty deck
12 Brisbane Water Dr, Koolewong	Timber, fibro	May 1974; At the waterfront the height of water over the property was 750mm and extended to under the house near the bearer a height of 220mm.	Floor level
41 Kurrawa Ave, Point Clare	Brick	Moving furniture to higher levels - I have marked the height of the flood on my garage wall.	Garage wall mark
90 Brisbane Water Dr, Koolewong	Brick veneer	March 1977; May 1974; - It was when Mother & Father lived here. Also, the year of cyclone Tracy boats were washed up the yard. The water rose to their back steps.	Level at bottom of back steps.

Table C1 cont.: Selected Responses to Resident Questionnaire

Adress	House Type	Resident Comment	Level Obtained by Surveyors
23A Steyne Rd, Saratoga	Brick veneer	I used to live at 23A Steyne Rd. In 1989 we had a combination of heavy rainfall & king tides. The backyard was about 3inches underwater but it did not enter the house. The garage flooded.	Garage Floor Level
40 North Burge Rd, Woy Woy	Brick veneer	September 2006 - Sandbags or flood inhibitors in yard, moving furniture to higher levels., Marks on wall downstairs (inside house) all items have been lifted on metal frames.	Levels of marks on dowstairs walls
7 Woy Woy Rd, Woy Woy	Other, unspecified	Too low to be a concern. My home is a renovated 100yr old boatshed. Hence my front room is over the mean water line. The flood boards are 1m off the sand, consequently I live with the tide movements & observe differences. My home is on the south side of Beauty Point, looking across to Horsefield Bay. Hence the waterway is mostly calm & the high tides usually are from 10pm over to 1am at night, hence no wave movement. This means the worst has been say 10cm from the floor boards, & has never caused any problems in the 19yrs I have lived here. We do have unrecorded king tides of 2.05m-this comes within the 10cm from floorboards. In the 19yrs I have never experienced storm swell with these king tides. Nor have I had storm swell with the normal recorded king tides of 2.01m. If I did get storm swell with these tides, adding at least 8-10cm, my floorboards would be wet. The water comes up over the sea walls, covers most jetties (not mine) & spreads 10-12m under my house. This is normal every 2.01 to 2.05 tide. Feb 2006-I came into this property in Dec 1987. Then came 3yrs of very heavy rain. Water level rose to within 20cm of top soil. Houses in Woy Woy Peninsula flooded but my property never suffered any changes as the rain water runs into the Bay. Except I remember the first time I experienced ocean storms causing tide swell, may have been during this period. The Hawkesbury River was in big trouble, the high tide coming in at 2pm was only to be 1.9m. My place was fine the 10cm increase meant just an extra high tide of 2m with no wave movement. March 1977 or May 1974-Only heard this from the family next door who owned this property. At this time, they did have say 20cm come up over the floorboards because of a 100yr hight tide, not predicted. It just gently subsided & carpets had to be taken out & dried. I was told the reidents did not know of this, until they woke up during the late night & put their feet into the water. It was reported by the 75yr old neighbour that this had never happened before & has not happened since. Aug 1997-It was a Friday night high seas high winds, Ettalong beach sand washed away. Watching up to 11pm that night at high tide but the wind from the westerly was causing breakers over my frotn wall, which does have fencing on it. But still the waves did not reach my floorboards. I am sure the boatshed/home next door got wet boards. The home was empty at the time. Aug 2006-The last lot of very heavy rain, did come about at high tide. Hence judged that the 1.8m predicted had become a 2.05m tide, up over the walls but still no floodboards wet.	Floor level
39 Gordon Rd, Empire Bay	Brick veneer	May 24th 1974 in Woy Woy, 3' of saltwater in boatshed. Huge southerly swell - wind 110mph. Drowned bays at the Haven.	Boatshed Floor level
6 Sorrento Rd, Empire Bay	Fibro cladding	Possibly April 1988 - We were getting ready to evacuate George? from house on corner Boongala & Sorrento - water came up to the joists. Too low to be a concern; killed trees and bushes; At high tide with easterly wind (gale) the water flowed on the lawn and footpath.	Floor level

Table C1 cont.: Selected Responses to Resident Questionnaire

Adress	House Type	Resident Comment	Level Obtained by Surveyors
19 Bluefish Cres, Tascott	Brick veneer	2001? Too low to be a concern; Did reach to low floor level 70cms - this was several years ago, there have been no flood problems in past 6 years.	Low floor level
180 North Burge Rd, Woy Woy	Hardiplank	Early 1994. Storm from south pushed waves across the reserve to a point about 1m from eastern boundary of property.	
85 Woy Woy Rd, South Woy Woy	Cladding	I lived with my parents in the waterfront property from 1958 till 1974 (May) when we had the flood which came 3m in the house so my pareents built further up the hill Nov 1974. We had to move furniture to higher level. Th eold house is used now for garden tools. The tide came up 21m on the property.	Floor level of old house/tool shed
117 Taylor St, Woy Woy Bay	Brick	May 1998 Two lower rooms were inundated to a depth of about 25-50mm. Moving furniture to higher levels Affected lower rooms-not an integral part of house. Furniture selected to suffer minimum damage in these circumstances.	Floor level of lower rooms,
306 Blackwall Rd, Woy Woy	Fibro	April 1988 & March 1977. Outside laundry & toilet which are at ground level approx. 75 to 100mm.	Floor level of outside laundry/toilet
34 Camellia Circle, Woy Woy	Brick veneer	May 1974 Other. Under the house to approx. 5cm to floor.	Floor level
10 Lalina Ave, Blackwall	Brick veneer	April 1988. Water reached to just above piers..	Level of top and bottom of piers. (ask resident if possible)
53 Victory Pde, Tascott	Brick veneer	Sandbags or flood inhibitors in yard; May 1974 Saturday night 6 inches of seawater through house - boat washed onto my lawn - same at high tide Sunday night. Several houses damaged by boats and people evacuated. Water 2ft in street - everyone lost carpets - when tide receded whole area covered sewage - 3 council trucks of plancks and rubbish on lawn.	Floor level
13 Havendale Cl, Koolewong	Brick veneer	April 1988; We had very heavy rain and with a king tide, water was unable to get away under the railway. Water then banked up and entered my home forcing us to lift everything off the floor (fridges and the like). The pipe at the end of Maruya Cl was increased but ours remains the same, and as the channel between the two is no longer there, I feel flooding could occur again. Moving furniture to higher levels	Floor level
15 Boongala Ave, Empire Bay	Brick	Too low it is a concern. Photos of water up to the first row of nails in the timber fence	Level of first row of nails in timber fence
3 Heron Place, St Huberts Island	Brick veneer	1977 flood was about 2 feet over the seawall	Top of Seawall level
9 Mundoora Ave, Yattalunga	Fibro	Moving furniture to higher levels; Whole house has been flooded. Outside laundry and toilet area too. May 74; Feb 90; May 98; In May 1974 whole house interior flooded. We had to rip up flooring and buy new flooring. In 1990 and 1998 we had flooding in yard, under house and through to the backyard, flooding laundry and toilet areas.	House floor level, Outside laundry/toilet floor level

Table C1 cont.: Selected Responses to Resident Questionnaire

Adress	House Type	Resident Comment	Level Obtained by Surveyors
35 Nautilus Cres, St Huberts Island	Brick veneer	May 1998; Higher than average tide. No damage.Our property extends to average high water mark & is fenced 6 metres at a higher ground level. Water rose to this fence with no damage.	Level at bottom of fence
10 Mercator Pde, St Huberts Island	Brick veneer	April 1988. Water was about 12cm above top of jetty.Too low to be a concern. Lost a lot of sand from back yard has continually eroded since.	Jetty level
15 Echuca Rd, Empire Bay	Hardiplank	February 1990. Water came to top of bottom step. Had two days of 6" each day. Too low to be a concern	Level at top of bottom step

APPENDIX D

RAFTS MODELLING – SUB-CATCHMENT DETAILS

Table D1: Brisbane Water Catchment Details

Total Catchment Area 16467 ha

Asumme the following catchment Roughness, Intial and Continuing Losses for corresponding land-use type

Land Use Type	Catchment Roughness	Initial Loss (mm)	Cont. Loss (mm/hr)
Forest	0.100	20	5
Rural	0.070	10	2.5
Residential	0.025	2	2.5
Comm/Indst	0.020	1	1
Road	0.015	1	0

Catchment ID	Residential Area (ha)	Comm / Indst Area (ha)	Forest Area (ha)	Rural Area (ha)	Road Area (ha)	Total Catchment Area (ha)	Catchment Slope (%)	Sub-Area 1 Type	Sub-Area 1 % Imp	Sub-Area2 Type	Sub-Area2 % Imp
Box_Head1	0.0	0.0	92.0	0.0	0.0	92.0	18.7	Forest	5.0	none	-
Brady1	0.0	35.0	0.0	11.7	0.0	46.6	0.7	Comm/Indst	80.0	Rural	10.0
Brady2	116.3	0.0	80.6	0.0	0.0	196.9	2.6	Residential	40.0	Forest	5.0
Caroline1	90.8	0.0	53.3	0.0	0.0	144.1	6.1	Residential	40.0	Forest	5.0
Chertsey1	67.3	0.0	205.3	0.0	0.0	272.6	3.6	Forest	5.0	Residential	40.0
Chetwynd1	11.3	0.0	0.0	157.4	0.0	168.7	2.8	Rural	10.0	Residential	40.0
Claire1	36.4	0.0	13.4	0.0	0.0	49.8	11.5	Residential	40.0	Forest	5.0
Clarence1	43.7	0.0	12.9	0.0	0.0	56.6	7.0	Residential	30.0	Forest	5.0
Clarence2	0.0	0.0	63.4	0.0	0.0	63.4	9.0	Forest	5.0	none	-
Cockle1	29.3	0.0	0.0	0.0	0.0	29.3	0.6	Residential	40.0	none	-
Egan1	0.0	0.0	348.3	53.9	0.0	402.2	2.8	Forest	5.0	Rural	10.0
Empire1	0.0	0.0	0.0	121.2	0.0	121.2	2.9	Rural	10.0	none	-
Empire1a	0.0	0.0	64.4	0.0	0.0	64.4	3.0	Forest	5.0	none	-
Empire2	53.4	0.0	0.0	65.8	0.0	119.2	4.2	Rural	10.0	Residential	40.0
Empire2a	0.0	0.0	76.8	0.0	0.0	76.8	3.0	Forest	5.0	none	-
Empire3	18.2	0.0	0.0	116.6	0.0	134.8	4.1	Rural	10.0	Residential	40.0

Table D1 cont.: Brisbane Water Catchment Details

Catchment ID	Residential Area (ha)	Comm / Indst Area (ha)	Forest Area (ha)	Rural Area (ha)	Road Area (ha)	Total Catchment Area (ha)	Catchment Slope (%)	Sub-Area 1 Type	Sub-Area 1 % Imp	Sub-Area2 Type	Sub-Area2 % Imp
Empire3a	0.0	0.0	147.4	0.0	0.0	147.4	5.0	Forest	5.0	none	-
Empire4	0.0	0.0	0.0	103.1	0.0	103.1	12.5	Rural	10.0	none	-
Empire4a	0.0	0.0	53.6	0.0	0.0	53.6	5.0	Forest	5.0	none	-
Empire5	79.9	0.0	39.2	0.0	0.0	119.1	5.4	Residential	40.0	Forest	5.0
Empire6	12.4	0.0	0.0	0.0	0.0	12.4	0.8	Residential	40.0	none	-
Erina_Ck1	0.0	0.0	0.0	91.7	0.0	91.7	4.5	Rural	10.0	none	-
Erina_Ck1a	0.0	0.0	119.0	1.2	0.0	120.2	6.0	Forest	5.0	Rural	10.0
Erina_Ck2	0.0	0.0	5.8	54.0	0.0	59.7	3.8	Rural	10.0	Forest	5.0
Erina_Ck2a	0.0	0.0	74.2	0.0	0.0	74.2	3.0	Forest	5.0	none	-
Erina_Ck3	0.0	0.0	23.0	133.7	0.0	156.7	1.9	Rural	10.0	Forest	5.0
Erina_Ck4	0.0	0.0	46.8	137.7	0.0	184.5	2.5	Rural	10.0	Forest	5.0
Erina_Ck5	0.0	0.0	142.0	81.3	0.0	223.3	2.5	Forest	5.0	Rural	10.0
Erina_Fair1	58.5	61.6	0.0	0.0	0.0	120.1	2.7	Comm/Indst	90.0	Residential	40.0
Fagans1	74.8	0.0	22.7	0.0	0.0	97.4	0.9	Residential	50.0	Forest	5.0
Fagans2	33.8	0.0	220.8	0.0	0.0	254.6	15.8	Forest	5.0	Residential	40.0
Fagans3	104.3	0.0	0.0	0.0	0.0	104.3	9.2	Residential	40.0	none	-
Fagans3a	0.0	0.0	102.2	0.0	0.0	102.2	6.0	Forest	5.0	none	-
Fagans4	0.0	122.6	39.8	0.0	0.0	162.4	9.2	Comm/Indst	80.0	Forest	5.0
Fires1	0.0	0.0	13.6	72.5	0.0	86.1	4.0	Rural	10.0	Forest	5.0
Fires2	0.0	0.0	104.1	0.0	0.0	104.1	5.0	Forest	5.0	none	-
Fires3	0.0	0.0	23.8	57.3	0.0	81.1	4.0	Rural	10.0	Forest	5.0
Fires4	0.0	0.0	60.6	0.0	0.0	60.6	5.0	Forest	5.0	none	-
Fires5	0.0	0.0	291.2	46.2	0.0	337.4	5.1	Forest	5.0	Rural	10.0
Fountain1	131.3	0.0	0.0	85.0	0.0	216.2	1.0	Residential	30.0	Rural	10.0
Fountain2	18.4	0.0	144.0	0.0	0.0	162.4	7.1	Forest	5.0	Residential	30.0
Fountain3	0.0	0.0	210.9	0.0	13.4	224.3	7.5	Forest	5.0	Road	90.0
Gosford1	45.5	0.0	0.0	0.0	0.0	45.5	6.1	Residential	40.0	none	-
Green1	12.5	0.0	61.9	0.0	0.0	74.4	3.1	Forest	5.0	Residential	45.0

Table D1 cont.: Brisbane Water Catchment Details

Catchment ID	Residential Area (ha)	Comm / Indst Area (ha)	Forest Area (ha)	Rural Area (ha)	Road Area (ha)	Total Catchment Area (ha)	Catchment Slope (%)	Sub-Area 1 Type	Sub-Area 1 % Imp	Sub-Area2 Type	Sub-Area2 % Imp
Green2	149.2	0.0	0.0	0.0	0.0	149.2	3.0	Residential	100.0	Residential	0.0
Green3	0.0	0.0	84.4	0.0	0.0	84.4	16.7	Forest	5.0	none	-
Green4	74.3	0.0	19.1	0.0	0.0	93.3	3.0	Residential	40.0	Forest	5.0
Hardy1	29.1	0.0	32.8	0.0	0.0	61.9	8.1	Forest	5.0	Residential	25.0
Hardy1a	0.0	0.0	71.2	31.0	0.0	102.2	8.0	Forest	5.0	Rural	10.0
Hardy2	29.6	0.0	32.1	0.0	0.0	61.7	14.5	Forest	5.0	Residential	25.0
Huberts1	65.6	0.0	0.0	0.0	0.0	65.6	0.9	Residential	40.0	none	-
Huberts2	32.0	0.0	16.7	0.0	0.0	48.7	21.5	Residential	40.0	Forest	5.0
Hylton_Pk1	116.4	0.0	73.7	0.0	0.0	190.1	9.0	Residential	40.0	Forest	5.0
Kincumber1	31.6	0.0	23.2	0.0	0.0	54.8	1.0	Residential	40.0	Forest	5.0
Kincumber1a	0.0	0.0	56.1	0.0	0.0	56.1	1.3	Forest	5.0	none	-
Kincumber1b	0.0	0.0	80.6	0.0	0.0	80.6	3.0	Forest	5.0	none	-
Kincumber2	70.2	0.0	54.2	0.0	0.0	124.4	9.6	Residential	40.0	Forest	5.0
Kincumber3	71.7	0.0	72.0	0.0	0.0	143.7	13.2	Forest	5.0	Residential	40.0
Kincumber4	36.5	0.0	18.8	0.0	0.0	55.3	0.5	Residential	40.0	Forest	5.0
Kincumber5	16.0	0.0	0.0	69.6	0.0	85.7	5.5	Rural	10.0	Residential	40.0
Kincumber5a	0.0	0.0	25.7	0.0	0.0	25.7	5.0	Forest	5.0	none	-
Kincumber6	125.0	0.0	43.1	0.0	0.0	168.1	3.1	Residential	40.0	Forest	5.0
Koolewong1	51.9	0.0	45.5	0.0	0.0	97.4	13.7	Residential	40.0	Forest	5.0
Koolewong2	0.0	0.0	46.9	0.0	0.0	46.9	13.0	Forest	5.0	none	-
Lintern1	53.7	0.0	44.8	0.0	0.0	98.5	3.0	Residential	40.0	Forest	5.0
Lisarow1	0.0	67.2	4.3	0.0	0.0	71.4	3.1	Comm/Indst	80.0	Forest	5.0
Lisarow1a	0.0	0.0	90.1	0.0	0.0	90.1	3.2	Forest	5.0	none	-
Lisarow2	175.6	0.0	29.8	0.0	0.0	205.5	6.8	Residential	40.0	Forest	5.0
Matcham1	0.0	0.0	63.4	104.1	0.0	167.5	3.1	Rural	10.0	Forest	5.0
Matcham2	0.0	0.0	134.4	44.1	0.0	178.5	3.1	Forest	5.0	Rural	10.0
Narara1	60.9	0.0	0.0	0.0	0.0	60.9	5.1	Residential	100.0	Residential	0.0
Narara1a	0.0	0.0	82.4	0.0	0.0	82.4	5.1	Forest	5.0	none	-

Table D1 cont.: Brisbane Water Catchment Details

Catchment ID	Residential Area (ha)	Comm / Indst Area (ha)	Forest Area (ha)	Rural Area (ha)	Road Area (ha)	Total Catchment Area (ha)	Catchment Slope (%)	Sub-Area 1 Type	Sub-Area 1 % Imp	Sub-Area2 Type	Sub-Area2 % Imp
Narara2	101.9	0.0	30.8	0.0	0.0	132.8	6.8	Residential	30.0	Forest	5.0
Narara3	25.9	0.0	0.0	59.8	0.0	85.8	6.0	Rural	10.0	Residential	40.0
Narara3a	0.0	0.0	227.0	0.0	0.0	227.0	8.7	Forest	5.0	none	-
Narara4	14.8	0.0	161.1	0.0	0.0	175.9	4.6	Forest	5.0	Residential	30.0
Narara5	0.0	0.0	348.6	0.0	0.0	348.6	8.1	Forest	5.0	none	-
Narara5a	0.0	0.0	0.0	156.8	37.5	194.3	3.0	Rural	10.0	Road	90.0
Narara6	0.0	0.0	322.8	0.0	0.0	322.8	7.0	Forest	5.0	none	-
Narara6a	0.0	0.0	0.0	227.3	24.6	251.9	6.2	Rural	10.0	Road	90.0
Nunn1	97.6	0.0	32.5	0.0	0.0	130.1	6.1	Forest	5.0	Residential	40.0
Nunn2	0.0	0.0	131.3	0.0	0.0	131.3	2.0	Forest	5.0	none	-
Paddy1	13.9	0.0	26.5	0.0	0.0	40.4	17.2	Forest	5.0	Residential	40.0
Pearl1	83.3	0.0	45.3	0.0	0.0	128.6	5.4	Residential	30.0	Forest	5.0
Pearl2	0.0	0.0	278.0	0.0	0.0	278.0	5.0	Forest	6.0	none	-
Pretty1	42.2	0.0	58.0	0.0	0.0	100.1	11.9	Forest	5.0	Residential	40.0
Riley_Bay1	0.0	0.0	126.2	0.0	0.0	126.2	18.0	Forest	5.0	none	-
Saratoga1	104.3	0.0	14.1	0.0	0.0	118.4	14.6	Residential	40.0	Forest	5.0
Tarragal_Glen1	46.1	0.0	0.0	39.9	0.0	86.0	2.9	Residential	40.0	Rural	10.0
Tarragal_Glen2	81.9	0.0	34.6	0.0	0.0	116.5	2.9	Residential	40.0	Forest	5.0
Tascott1	32.5	0.0	32.2	0.0	0.0	64.7	13.1	Residential	30.0	Forest	5.0
Tascott2	49.1	0.0	0.0	0.0	0.0	49.1	9.5	Residential	100.0	Residential	0.0
Tascott3	0.0	0.0	157.4	0.0	0.0	157.4	9.2	Forest	5.0	none	-
Umina1	152.8	0.0	0.0	0.0	0.0	152.8	2.5	Residential	100.0	Residential	0.0
Umina2	0.0	0.0	307.3	0.0	0.0	307.3	5.0	Forest	5.0	none	-
Umina3	84.7	0.0	2.5	0.0	0.0	87.2	5.0	Residential	40.0	Forest	5.0
Umina4	0.0	0.0	53.1	0.0	0.0	53.1	5.2	Forest	5.0	none	-
W_Gosford1	0.0	55.6	0.0	79.9	0.0	135.5	2.8	Rural	10.0	Comm/Indst	80.0
W_Gosford1a	32.9	0.0	0.0	76.4	0.0	109.3	8.9	Rural	10.0	Residential	40.0
W_Gosford2	0.0	103.6	0.0	0.0	0.0	103.6	7.0	Comm/Indst	80.0	none	-

Table D1 cont.: Brisbane Water Catchment Details

Catchment ID	Residential Area (ha)	Comm / Indst Area (ha)	Forest Area (ha)	Rural Area (ha)	Road Area (ha)	Total Catchment Area (ha)	Catchment Slope (%)	Sub-Area 1 Type	Sub-Area 1 % Imp	Sub-Area2 Type	Sub-Area2 % Imp
W_Gosford2a	0.0	0.0	97.3	0.0	0.0	97.3	4.0	Forest	5.0	none	-
W_Gosford3	0.0	60.4	46.9	0.0	0.0	107.3	10.7	Comm/Indst	90.0	Forest	5.0
W_Gosford4	0.0	0.0	203.4	0.0	0.0	203.4	13.7	Forest	10.0	none	-
W_Inlet1	38.8	0.0	76.2	0.0	0.0	115.0	17.8	Forest	5.0	Residential	25.0
W_Inlet2	0.0	0.0	558.3	0.0	0.0	558.3	5.7	Forest	5.0	none	-
Wingello1	94.0	0.0	34.7	3.1	0.0	131.7	4.1	Residential	40.0	Forest	5.0
Wingello2	26.7	0.0	183.0	0.0	0.0	209.7	7.3	Forest	5.0	Residential	40.0
Wingello3	43.6	0.0	0.0	0.0	0.0	43.6	5.5	Residential	100.0	Residential	0.0
Wingello4	0.0	0.0	141.1	0.0	0.0	141.1	7.0	Forest	5.0	none	-
Woy_P1	256.9	0.0	92.9	0.0	0.0	349.7	6.7	Residential	40.0	Forest	5.0
Woy_P2	87.6	0.0	0.0	0.0	0.0	87.6	0.3	Residential	100.0	Residential	0.0
Woy_P3	66.2	23.5	0.0	0.0	0.0	89.7	0.4	Residential	50.0	Comm/Indst	70.0
Woy_P4	93.8	0.0	0.0	0.0	0.0	93.8	0.6	Residential	100.0	Residential	0.0
Woy_P5	116.0	0.0	0.0	0.0	0.0	116.0	0.5	Residential	100.0	Residential	0.0
Woy_P6	0.0	0.0	44.3	0.0	0.0	44.3	28.6	Forest	5.0	none	-
Woy_P7	103.8	0.0	0.0	0.0	0.0	103.8	2.7	Residential	100.0	Residential	0.0
Woy_P8	179.9	0.0	0.0	0.0	0.0	179.9	0.6	Residential	100.0	Residential	0.0
Woy_P9	179.7	0.0	0.0	0.0	0.0	179.7	0.3	Residential	100.0	Residential	0.0
Woy1	0.0	0.0	309.3	0.0	0.0	309.3	7.3	Forest	5.0	none	-
Woy2	0.0	0.0	286.6	0.0	0.0	286.6	6.5	Forest	5.0	none	-
Woy3	24.3	0.0	117.1	0.0	0.0	141.5	9.8	Forest	5.0	Residential	25.0
Woy4	0.0	0.0	22.7	0.0	0.0	22.7	25.4	Forest	5.0	none	-
Wyoming1	95.3	13.7	0.0	0.0	0.0	109.0	6.8	Residential	40.0	Comm/Indst	90.0
Wyoming2	53.5	0.0	0.0	11.6	0.0	65.1	5.2	Residential	40.0	Rural	10.0
Wyoming3	31.7	0.0	0.0	0.0	0.0	31.7	5.1	Residential	100.0	Residential	0.0
Wyoming4	0.0	0.0	105.2	0.0	0.0	105.2	5.1	Forest	5.0	none	-

APPENDIX E

RAFTS MODELLING - PEAK DESIGN DISCHARGES

Table E1: Peak Design Discharges

Catchment ID	**100-Years ARI**				**50-Years ARI**				**20-Years ARI**				**10-Years ARI**				**5-Years ARI**			
	3 Hour	**6 Hour**	**9 Hour**	**12 Hour**	**3 Hour**	**6 Hour**	**9 Hour**	**12 Hour**	**3 Hour**	**6 Hour**	**9 Hour**	**12 Hour**	**3 Hour**	**6 Hour**	**9 Hour**	**12 Hour**	**3 Hour**	**6 Hour**	**9 Hour**	**12 Hour**
Box_Head1	16	17	15	15	14	14	13	13	11	12	11	12	9	10	9	10	8	8	8	8
Caroline1	35	27	24	25	31	23	21	22	27	20	19	20	23	16	16	16	20	14	13	14
Claire1	15	11	9	9	13	9	8	8	12	8	7	7	10	7	6	6	8	6	5	5
Cockle1	9	6	6	6	8	6	5	5	7	5	4	4	6	4	4	4	5	4	3	3
Dum_CCk1	86	86	80	86	74	74	70	75	64	62	61	65	52	50	51	54	44	41	43	45
Dum_ECk1	307	**317**	308	269	263	274	268	235	209	**227**	225	198	166	183	185	162	136	**151**	155	137
Dum_KCk1	75	**62**	61	55	66	54	54	48	58	**47**	47	41	49	39	39	34	42	**33**	33	29
Dum_NCk_1	457	**497**	480	436	392	426	419	380	314	**351**	356	322	250	281	294	264	204	**230**	247	221
Dum_WoyP7	39	30	26	27	33	27	23	24	28	24	20	21	22	20	17	18	19	17	15	15
Egan1	28	30	34	29	24	25	29	25	18	20	23	20	13	15	18	16	10	12	14	13
Empire1	23	24	24	22	20	21	20	19	16	17	17	16	13	13	14	13	10	11	12	10
Empire2	32	29	27	29	27	25	24	26	23	21	21	22	19	17	17	18	16	14	14	15
Empire3	39	40	39	39	33	34	34	33	27	29	29	28	21	23	24	23	17	19	20	19
Empire4	26	25	23	24	22	22	20	21	19	19	18	18	15	15	15	15	12	13	13	12
Empire5	30	22	20	21	27	19	18	18	24	17	16	16	20	14	13	14	17	12	11	12
Empire6	4	3	2	2	4	2	2	2	3	2	2	2	3	2	2	2	3	2	1	1
Fagans4	44	31	28	29	39	27	24	25	35	24	22	22	29	20	18	19	26	17	15	16
Gosford1	16	10	9	9	14	9	8	8	13	8	7	7	11	7	6	6	9	6	5	5
Green1	72	61	53	53	60	54	47	46	51	48	42	41	42	40	35	34	34	34	30	29
Green2	58	48	42	43	48	42	36	38	42	38	32	34	34	32	27	28	28	27	23	24
Hardy1	28	28	25	27	24	24	21	23	20	20	19	20	15	16	15	17	12	13	13	14
Hardy2	15	13	11	11	13	11	10	10	11	10	8	9	9	8	7	7	7	6	6	6
Huberts1	21	14	13	13	19	13	11	11	17	11	10	10	14	10	8	9	12	8	7	7
Huberts2	15	10	9	9	13	9	8	8	11	8	7	7	9	7	6	6	8	6	5	5
Kincumber1	14	15	16	17	12	13	14	14	11	10	12	12	9	8	10	10	7	6	8	8
Kincumber3	33	28	24	25	29	24	21	22	25	21	19	20	20	17	16	17	17	14	13	14

Table E1 cont.: Peak Design Discharges

Catchment ID	100-Years ARI				50-Years ARI				20-Years ARI				10-Years ARI				5-Years ARI			
	3 Hour	6 Hour	9 Hour	12 Hour	3 Hour	6 Hour	9 Hour	12 Hour	3 Hour	6 Hour	9 Hour	12 Hour	3 Hour	6 Hour	9 Hour	12 Hour	3 Hour	6 Hour	9 Hour	12 Hour
Kincumber4	13	10	9	10	11	9	8	8	10	8	7	8	8	6	6	6	7	5	5	5
Kincumber5	21	20	18	19	18	17	15	16	15	15	13	14	12	12	11	12	10	10	10	10
Koolewong1	31	28	24	25	26	24	21	22	22	21	19	20	17	16	15	16	14	13	13	14
Lintern1	21	15	15	16	18	13	13	14	16	12	11	12	14	10	9	10	12	8	8	8
Paddy1	10	8	7	7	8	7	6	6	7	6	6	6	5	5	5	5	4	4	4	4
Pearl1	43	48	50	51	37	40	43	44	31	33	37	37	25	25	30	30	21	20	25	24
Pretty1	21	19	17	17	18	16	14	15	16	14	13	14	13	11	11	11	11	9	9	10
Riley_Bay1	22	22	19	20	19	19	17	18	15	16	15	15	12	13	12	13	10	11	10	11
Saratoga1	39	26	23	23	34	23	20	20	31	21	18	18	26	17	15	15	23	15	13	13
Tascott1	16	13	11	12	14	12	10	10	12	10	9	9	10	8	7	8	8	7	6	7
Tascott2	30	31	29	31	25	27	25	27	20	22	22	23	16	18	18	19	13	14	15	16
Umina1	125	114	99	104	105	100	87	91	87	87	76	81	68	70	63	67	54	57	53	57
W_Inlet1	24	22	19	20	20	19	17	18	17	17	15	16	13	13	12	13	11	11	10	11
W_Inlet2	58	61	67	66	49	51	58	57	38	40	49	47	29	31	39	37	23	25	32	30
Woy_P1	94	67	60	62	83	59	53	55	74	51	47	49	63	43	40	41	55	37	34	35
Woy_P2	17	13	13	13	15	12	11	11	14	10	10	10	12	9	8	8	10	7	7	7
Woy_P3	28	19	17	17	25	17	15	15	22	15	13	14	18	13	11	12	16	11	10	10
Woy_P4	20	16	14	15	18	14	12	13	16	12	11	12	13	10	9	10	12	9	8	8
Woy_P5	24	19	17	18	21	16	15	16	19	14	13	14	16	12	11	12	14	10	10	10
Woy_P8	37	29	27	28	33	26	24	25	29	22	21	22	25	19	17	18	22	16	15	16
Woy_P9	35	26	26	26	31	23	22	23	28	20	20	20	24	17	16	17	21	14	14	14
Woy1	36	39	39	36	30	33	33	30	24	26	28	25	19	20	23	20	15	16	19	16
Woy2	32	35	35	32	27	29	30	27	22	24	25	23	17	18	21	18	13	14	17	14
Woy3	22	22	20	21	18	19	18	19	15	16	16	16	11	13	13	13	9	11	11	11
Woy4	6	5	4	4	5	4	4	4	4	4	3	3	3	3	3	3	2	3	2	2

Table E2: Peak Design Discharges

Catchment ID	200-Years ARI				PMF		Sensitivity Anaylsis (100-Year ARI 6hr)					
	3 Hour	6 Hour	9 Hour	12 Hour	3 Hour	6 Hour	CR +20%	CR -20%	Loss +20%	Loss -20%	%Imp +20%	%Imp -20%
Box_Head1	19	19	16	17	52	35	15	19	16	17	17	16
Caroline1	40	30	27	28	101	68	25	29	25	28	27	26
Claire1	17	12	10	11	36	24	10	11	10	11	11	11
Cockle1	11	7	6	6	26	18	6	6	6	6	6	6
Dum_CCk1	98	99	90	97	304	208	77	98	81	91	87	86
Dum_ECk1	352	361	348	305	1021	953	290	342	300	334	322	310
Dum_KCk1	85	70	69	62	208	151	59	67	59	64	62	62
Dum_NCk_1	526	570	544	495	1674	1414	444	557	466	527	498	490
Dum_WoyP7	44	34	30	30	99	69	29	32	30	31	28	30
Egan1	34	35	39	34	179	141	25	38	27	32	31	28
Empire1	27	28	27	25	98	74	20	29	23	26	26	23
Empire2	36	33	31	33	99	72	25	33	27	30	29	28
Empire3	45	46	44	44	133	101	35	45	38	42	40	40
Empire4	29	29	26	27	98	66	23	29	24	26	25	25
Empire5	34	25	23	24	97	67	21	24	22	23	23	22
Empire6	5	3	3	3	10	7	3	3	3	3	3	3
Fagans4	50	35	31	32	103	69	30	33	30	32	32	31
Gosford1	17	11	10	10	33	22	10	10	10	10	10	10
Green1	84	68	60	59	196	140	59	64	60	62	61	61
Green2	67	54	47	48	68	44	46	50	47	49	48	48
Hardy1	33	32	28	30	72	49	24	32	26	29	28	27
Hardy2	17	14	12	13	35	25	12	13	12	13	13	12
Huberts1	24	16	14	14	51	36	14	14	14	14	14	14
Huberts2	17	12	10	10	41	27	10	11	10	11	11	10
Kincumber1	17	18	18	19	50	45	12	19	14	16	15	15
Kincumber3	38	31	27	29	91	63	25	30	27	29	28	27

Table E2 cont.: Peak Design Discharges

Catchment ID	200-Years ARI				PMF		Sensitivity Anaylsis (100-Year ARI 6hr)					
	3 Hour	6 Hour	9 Hour	12 Hour	3 Hour	6 Hour	CR +20%	CR -20%	Loss +20%	Loss -20%	%Imp +20%	%Imp -20%
Kincumber4	15	12	10	11	40	28	10	12	10	11	11	10
Kincumber5	24	23	20	21	67	46	18	22	19	21	21	19
Koolewong1	36	32	27	29	91	62	25	30	27	29	28	28
Lintern1	23	18	17	18	86	61	14	17	15	16	16	15
Paddy1	12	9	8	8	30	22	8	9	8	8	8	8
Pearl1	50	56	57	58	168	122	40	58	44	52	48	48
Pretty1	25	21	19	20	56	38	17	21	18	20	19	18
Riley_Bay1	25	25	22	23	80	54	20	25	21	23	23	21
Saratoga1	43	29	25	25	99	66	26	26	25	26	26	26
Tascott1	18	15	13	13	46	31	12	14	13	13	13	13
Tascott2	35	35	33	35	111	77	28	36	29	32	31	31
Umina1	147	130	112	118	217	172	107	126	111	118	114	114
W_Inlet1	28	25	22	23	65	45	20	24	22	23	23	22
W_Inlet2	67	72	77	75	279	211	49	79	56	67	65	58
Woy_P1	106	75	67	70	214	147	64	71	65	69	68	66
Woy_P2	19	15	14	15	56	39	12	16	13	13	13	13
Woy_P3	31	22	19	19	59	41	19	20	19	20	20	19
Woy_P4	22	18	16	17	62	44	15	19	16	16	13	16
Woy_P5	27	21	19	20	75	53	17	22	18	19	19	19
Woy_P8	42	33	30	32	103	73	28	35	29	30	29	29
Woy_P9	39	29	29	29	101	70	25	31	25	26	17	26
Woy1	43	46	44	41	159	114	32	47	36	42	41	37
Woy2	38	41	40	37	145	105	29	43	32	38	37	33
Woy3	25	25	23	24	77	53	20	26	21	23	22	21
Woy4	7	5	5	5	15	10	4	5	5	5	5	5

APPENDIX F

HYDRAULIC MODELLING - CATCHMENT FLOOD RESULTS

Table F1: Delft3D Catchment Flood Results

Output Location	PMF	200yrARI		100yrARI		50yrARI		20yrARI		10yrARI		5yrARI	
	Peak WL (mAHD)	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration
1	1.03	1.03	9hrs	1.01	9hrs	0.99	9hrs	0.98	9hrs	0.98	9hrs	0.98	9hrs
2	1.05	1.05	9hrs	1.01	9hrs	0.99	9hrs	0.98	9hrs	0.97	9hrs	0.97	9hrs
3	1.07	1.06	9hrs	1.02	9hrs	0.99	9hrs	0.98	9hrs	0.97	9hrs	0.96	9hrs
4	1.07	1.07	9hrs	1.01	9hrs	0.97	9hrs	0.95	9hrs	0.94	9hrs	0.92	9hrs
5	1.08	1.07	9hrs	1.00	9hrs	0.96	9hrs	0.94	9hrs	0.92	9hrs	0.91	9hrs
6	1.10	1.09	9hrs	1.02	9hrs	0.97	9hrs	0.94	9hrs	0.91	9hrs	0.90	9hrs
7	1.11	1.11	9hrs	1.02	9hrs	0.97	9hrs	0.94	9hrs	0.92	9hrs	0.90	9hrs
8	1.11	1.11	9hrs	1.03	9hrs	0.97	9hrs	0.94	9hrs	0.92	9hrs	0.90	9hrs
9	1.11	1.11	9hrs	1.03	9hrs	0.97	9hrs	0.93	9hrs	0.90	9hrs	0.88	9hrs
10	1.19	1.12	9hrs	1.03	9hrs	0.98	9hrs	0.93	9hrs	0.90	9hrs	0.87	9hrs
11	1.20	1.13	9hrs	1.04	9hrs	0.98	9hrs	0.94	9hrs	0.91	9hrs	0.88	9hrs
12	1.22	1.14	9hrs	1.05	9hrs	0.99	9hrs	0.95	9hrs	0.91	9hrs	0.88	9hrs
13	1.22	1.14	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs	0.89	9hrs
14	1.23	1.14	9hrs	1.06	9hrs	1.01	9hrs	0.96	9hrs	0.93	9hrs	0.90	9hrs
15	1.28	1.17	9hrs	1.08	9hrs	1.02	9hrs	0.98	9hrs	0.94	9hrs	0.91	9hrs
16	1.29	1.18	9hrs	1.09	9hrs	1.03	9hrs	0.98	9hrs	0.94	9hrs	0.91	9hrs
17	1.32	1.19	9hrs	1.10	9hrs	1.04	9hrs	0.99	9hrs	0.95	9hrs	0.91	9hrs
18	1.33	1.19	9hrs	1.10	9hrs	1.04	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
19	1.33	1.19	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
20	1.33	1.20	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
21	1.33	1.19	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.96	9hrs	0.92	9hrs
22	1.33	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
23	1.34	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
24	1.43	1.23	9hrs	1.13	9hrs	1.07	9hrs	1.01	9hrs	0.96	9hrs	0.93	9hrs
25	1.36	1.19	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
26	1.33	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
27	1.33	1.19	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
28	1.33	1.19	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs

Table F1 cont.: Delft3D Catchment Flood Results

Output Location	PMF	200yrARI		100yrARI		50yrARI		20yrARI		10yrARI		5yrARI	
	Peak WL (mAHD)	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration
29	1.33	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
30	1.36	1.21	9hrs	1.12	9hrs	1.06	9hrs	1.01	9hrs	0.96	9hrs	0.93	9hrs
31	1.33	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
32	1.33	1.19	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
33	1.34	1.19	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
34	1.33	1.19	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
35	1.33	1.19	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
36	1.34	1.19	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
37	1.33	1.19	9hrs	1.10	9hrs	1.04	9hrs	0.99	9hrs	0.95	9hrs	0.92	9hrs
38	1.28	1.17	9hrs	1.08	9hrs	1.02	9hrs	0.98	9hrs	0.94	9hrs	0.91	9hrs
39	1.27	1.16	9hrs	1.07	9hrs	1.01	9hrs	0.97	9hrs	0.93	9hrs	0.90	9hrs
40	1.25	1.15	9hrs	1.06	9hrs	1.01	9hrs	0.96	9hrs	0.92	9hrs	0.89	9hrs
41	1.24	1.14	9hrs	1.05	9hrs	0.99	9hrs	0.95	9hrs	0.91	9hrs	0.88	9hrs
42	1.24	1.15	9hrs	1.06	9hrs	0.99	9hrs	0.94	9hrs	0.90	9hrs	0.87	9hrs
43	1.24	1.16	9hrs	1.07	9hrs	1.00	9hrs	0.95	9hrs	0.90	9hrs	0.86	9hrs
44	1.24	1.16	9hrs	1.07	9hrs	1.01	9hrs	0.95	9hrs	0.90	9hrs	0.87	9hrs
45	1.24	1.16	9hrs	1.07	9hrs	1.01	9hrs	0.95	9hrs	0.91	9hrs	0.87	9hrs
46	1.25	1.17	9hrs	1.07	9hrs	1.01	9hrs	0.96	9hrs	0.91	9hrs	0.88	9hrs
47	1.25	1.17	9hrs	1.08	9hrs	1.02	9hrs	0.96	9hrs	0.91	9hrs	0.88	9hrs
48	1.25	1.17	9hrs	1.08	9hrs	1.02	9hrs	0.96	9hrs	0.91	9hrs	0.88	9hrs
49	1.25	1.17	9hrs	1.08	9hrs	1.02	9hrs	0.96	9hrs	0.92	9hrs	0.88	9hrs
50	1.25	1.17	9hrs	1.08	9hrs	1.02	9hrs	0.96	9hrs	0.91	9hrs	0.88	9hrs
51	1.25	1.17	9hrs	1.08	9hrs	1.02	9hrs	0.96	9hrs	0.91	9hrs	0.88	9hrs
52	1.24	1.16	9hrs	1.07	9hrs	1.01	9hrs	0.95	9hrs	0.91	9hrs	0.87	9hrs
53	1.24	1.16	9hrs	1.07	9hrs	1.01	9hrs	0.95	9hrs	0.91	9hrs	0.87	9hrs
54	1.24	1.16	9hrs	1.07	9hrs	1.01	9hrs	0.95	9hrs	0.91	9hrs	0.87	9hrs
55	1.24	1.16	9hrs	1.07	9hrs	1.01	9hrs	0.95	9hrs	0.91	9hrs	0.87	9hrs
56	1.24	1.16	9hrs	1.07	9hrs	1.01	9hrs	0.95	9hrs	0.91	9hrs	0.87	9hrs

Table F1 cont.: Delft3D Catchment Flood Results

Output Location	PMF	200yrARI		100yrARI		50yrARI		20yrARI		10yrARI		5yrARI	
	Peak WL (mAHD)	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration
57	1.24	1.16	9hrs	1.07	9hrs	1.01	9hrs	0.95	9hrs	0.90	9hrs	0.87	9hrs
58	1.24	1.16	9hrs	1.06	9hrs	1.00	9hrs	0.94	9hrs	0.90	9hrs	0.86	9hrs
59	1.24	1.15	9hrs	1.06	9hrs	0.99	9hrs	0.94	9hrs	0.90	9hrs	0.86	9hrs
60	1.24	1.15	9hrs	1.05	9hrs	0.99	9hrs	0.95	9hrs	0.91	9hrs	0.88	9hrs
61	1.22	1.14	9hrs	1.05	9hrs	0.99	9hrs	0.94	9hrs	0.91	9hrs	0.88	9hrs
62	1.21	1.13	9hrs	1.04	9hrs	0.98	9hrs	0.94	9hrs	0.90	9hrs	0.87	9hrs
63	1.19	1.12	9hrs	1.04	9hrs	0.98	9hrs	0.93	9hrs	0.90	9hrs	0.87	9hrs
64	1.12	1.11	9hrs	1.03	9hrs	0.97	9hrs	0.93	9hrs	0.90	9hrs	0.87	9hrs
65	1.11	1.11	9hrs	1.03	9hrs	0.97	9hrs	0.94	9hrs	0.92	9hrs	0.90	9hrs
66	1.10	1.10	9hrs	1.02	9hrs	0.97	9hrs	0.94	9hrs	0.91	9hrs	0.90	9hrs
67	1.11	1.10	9hrs	1.02	9hrs	0.97	9hrs	0.95	9hrs	0.92	9hrs	0.91	9hrs
68	1.10	1.09	9hrs	1.02	9hrs	0.97	9hrs	0.95	9hrs	0.93	9hrs	0.91	9hrs
69	1.11	1.10	9hrs	1.03	9hrs	0.98	9hrs	0.95	9hrs	0.93	9hrs	0.92	9hrs
70	1.09	1.08	9hrs	1.01	9hrs	0.96	9hrs	0.94	9hrs	0.92	9hrs	0.90	9hrs
71	1.08	1.07	9hrs	1.01	9hrs	0.97	9hrs	0.95	9hrs	0.93	9hrs	0.92	9hrs
72	1.08	1.07	9hrs	1.01	9hrs	0.97	9hrs	0.95	9hrs	0.93	9hrs	0.92	9hrs
73	1.07	1.07	9hrs	1.01	9hrs	0.97	9hrs	0.95	9hrs	0.93	9hrs	0.92	9hrs
74	1.04	1.06	9hrs	1.00	9hrs	0.96	9hrs	0.95	9hrs	0.93	9hrs	0.92	9hrs
75	1.24	1.15	9hrs	1.06	9hrs	1.00	9hrs	0.96	9hrs	0.92	9hrs	0.89	9hrs
76	1.24	1.14	9hrs	1.05	9hrs	0.99	9hrs	0.95	9hrs	0.91	9hrs	0.88	9hrs
77	1.24	1.14	9hrs	1.05	9hrs	0.99	9hrs	0.95	9hrs	0.91	9hrs	0.88	9hrs
78	1.22	1.14	9hrs	1.05	9hrs	0.99	9hrs	0.95	9hrs	0.91	9hrs	0.88	9hrs
79	1.23	1.14	9hrs	1.05	9hrs	0.99	9hrs	0.95	9hrs	0.91	9hrs	0.88	9hrs
80	1.22	1.14	9hrs	1.05	9hrs	0.99	9hrs	0.95	9hrs	0.91	9hrs	0.88	9hrs
81	1.21	1.13	9hrs	1.04	9hrs	0.98	9hrs	0.94	9hrs	0.91	9hrs	0.87	9hrs
82	1.21	1.13	9hrs	1.04	9hrs	0.98	9hrs	0.94	9hrs	0.90	9hrs	0.87	9hrs
83	1.20	1.13	9hrs	1.04	9hrs	0.98	9hrs	0.94	9hrs	0.90	9hrs	0.87	9hrs
84	1.20	1.12	9hrs	1.04	9hrs	0.98	9hrs	0.94	9hrs	0.90	9hrs	0.87	9hrs

Table F1 cont.: Delft3D Catchment Flood Results

Output Location	PMF	200yrARI		100yrARI		50yrARI		20yrARI		10yrARI		5yrARI	
	Peak WL (mAHD)	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration
85	1.20	1.12	9hrs	1.04	9hrs	0.98	9hrs	0.94	9hrs	0.90	9hrs	0.87	9hrs
86	1.20	1.12	9hrs	1.04	9hrs	0.98	9hrs	0.94	9hrs	0.90	9hrs	0.87	9hrs
87	1.21	1.13	9hrs	1.05	9hrs	0.99	9hrs	0.95	9hrs	0.91	9hrs	0.88	9hrs
88	1.21	1.14	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs	0.89	9hrs
89	1.22	1.14	9hrs	1.05	9hrs	0.99	9hrs	0.95	9hrs	0.92	9hrs	0.89	9hrs
90	1.24	1.16	9hrs	1.07	9hrs	1.01	9hrs	0.95	9hrs	0.91	9hrs	0.87	9hrs
91	1.24	1.16	9hrs	1.07	9hrs	1.01	9hrs	0.95	9hrs	0.91	9hrs	0.87	9hrs
92	1.25	1.16	9hrs	1.07	9hrs	1.01	9hrs	0.95	9hrs	0.91	9hrs	0.87	9hrs
93	1.25	1.16	9hrs	1.07	9hrs	1.01	9hrs	0.95	9hrs	0.91	9hrs	0.87	9hrs
94	2.46	1.66	9hrs	1.46	9hrs	1.33	9hrs	1.19	9hrs	1.08	9hrs	1.01	9hrs
95	2.45	1.65	9hrs	1.44	9hrs	1.31	9hrs	1.17	9hrs	1.07	9hrs	0.99	9hrs
96	2.47	1.65	9hrs	1.44	9hrs	1.31	9hrs	1.17	9hrs	1.06	9hrs	0.99	9hrs
97	2.51	1.75	9hrs	1.54	9hrs	1.40	9hrs	1.26	9hrs	1.13	9hrs	1.05	9hrs
98	2.64	1.82	9hrs	1.64	9hrs	1.51	9hrs	1.37	9hrs	1.25	9hrs	1.14	9hrs
99	2.67	1.82	9hrs	1.64	9hrs	1.51	9hrs	1.37	9hrs	1.25	9hrs	1.14	9hrs
100	2.68	1.82	9hrs	1.64	9hrs	1.52	9hrs	1.37	9hrs	1.25	9hrs	1.14	9hrs
101	2.67	1.82	9hrs	1.64	9hrs	1.52	9hrs	1.37	9hrs	1.25	9hrs	1.14	9hrs
102	2.62	1.83	9hrs	1.64	9hrs	1.52	9hrs	1.38	9hrs	1.25	9hrs	1.15	9hrs
103	2.47	1.68	9hrs	1.48	9hrs	1.34	9hrs	1.21	9hrs	1.10	9hrs	1.02	9hrs
104	1.31	1.19	9hrs	1.10	9hrs	1.04	9hrs	0.99	9hrs	0.95	9hrs	0.92	9hrs
105	1.32	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
106	1.32	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
107	1.32	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
108	1.32	1.20	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
109	1.32	1.20	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
110	1.32	1.20	9hrs	1.11	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
111	1.32	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
112	1.32	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs

Table F1 cont.: Delft3D Catchment Flood Results

Output Location	PMF	200yrARI		100yrARI		50yrARI		20yrARI		10yrARI		5yrARI	
	Peak WL (mAHD)	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration	Peak WL (mAHD)	crit. duration
113	1.32	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.96	9hrs	0.92	9hrs
114	1.32	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.96	9hrs	0.92	9hrs
115	1.32	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.96	9hrs	0.92	9hrs
116	1.32	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.96	9hrs	0.92	9hrs
117	1.32	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.96	9hrs	0.92	9hrs
118	1.32	1.19	9hrs	1.10	9hrs	1.05	9hrs	1.00	9hrs	0.95	9hrs	0.92	9hrs
119	1.31	1.19	9hrs	1.10	9hrs	1.04	9hrs	0.99	9hrs	0.95	9hrs	0.92	9hrs

APPENDIX G

HYDRAULIC MODELLING – OCEAN STORM RESULTS

Table G1: Delft3D Ocean Storm Results

Output Location	Peak Water Level (mAHD)						
	PMF	200yrARI	100yrARI	50yrARI	20yrARI	10yrARI	5yrARI
1	2.07	1.83	1.76	1.71	1.64	1.59	1.54
2	2.08	1.85	1.78	1.7	1.63	1.56	1.51
3	2.07	1.85	1.79	1.73	1.68	1.64	1.55
4	1.91	1.7	1.65	1.57	1.52	1.46	1.4
5	1.85	1.65	1.59	1.53	1.47	1.41	1.36
6	1.85	1.64	1.56	1.5	1.44	1.39	1.34
7	1.87	1.65	1.58	1.52	1.45	1.4	1.35
8	1.89	1.67	1.59	1.53	1.46	1.4	1.36
9	1.83	1.59	1.54	1.48	1.4	1.34	1.29
10	1.82	1.59	1.53	1.46	1.39	1.32	1.26
11	1.85	1.6	1.54	1.48	1.4	1.33	1.27
12	1.89	1.63	1.57	1.5	1.42	1.35	1.28
13	1.92	1.65	1.58	1.51	1.43	1.36	1.29
14	1.94	1.66	1.59	1.52	1.43	1.37	1.3
15	1.97	1.68	1.61	1.53	1.45	1.38	1.32
16	2.02	1.71	1.63	1.55	1.47	1.4	1.33
17	2.06	1.73	1.66	1.58	1.48	1.41	1.34
18	2.11	1.77	1.68	1.6	1.51	1.43	1.35
19	2.16	1.82	1.71	1.62	1.53	1.45	1.37
20	2.16	1.8	1.71	1.62	1.53	1.44	1.37
21	2.18	1.8	1.72	1.63	1.53	1.45	1.37
22	2.14	1.78	1.7	1.61	1.51	1.44	1.36
23	2.18	1.8	1.72	1.63	1.53	1.45	1.37
24	2.23	1.83	1.75	1.65	1.55	1.47	1.39
25	2.16	1.79	1.71	1.62	1.52	1.44	1.37
26	2.1	1.76	1.68	1.59	1.5	1.43	1.35
27	2.14	1.78	1.7	1.61	1.52	1.44	1.36
28	2.09	1.76	1.68	1.59	1.5	1.43	1.35
29	2.1	1.76	1.68	1.6	1.5	1.43	1.35
30	2.08	1.75	1.67	1.59	1.5	1.42	1.35
31	2.06	1.74	1.66	1.58	1.49	1.42	1.34
32	2.06	1.74	1.66	1.58	1.49	1.41	1.34
33	2.04	1.72	1.65	1.57	1.48	1.41	1.34
34	2.01	1.71	1.63	1.56	1.47	1.4	1.33
35	1.99	1.7	1.62	1.54	1.46	1.39	1.33
36	2.02	1.71	1.64	1.56	1.47	1.4	1.33
37	2.04	1.72	1.65	1.57	1.48	1.41	1.33
38	1.99	1.7	1.62	1.54	1.46	1.39	1.32
39	1.94	1.67	1.59	1.52	1.44	1.37	1.3
40	1.88	1.63	1.56	1.49	1.41	1.35	1.28
41	1.81	1.58	1.52	1.45	1.38	1.32	1.26
42	1.75	1.55	1.49	1.43	1.36	1.3	1.24
43	1.64	1.49	1.44	1.38	1.31	1.26	1.21
44	1.57	1.45	1.4	1.35	1.3	1.25	1.2
45	1.56	1.45	1.4	1.35	1.29	1.25	1.2
46	1.61	1.47	1.42	1.37	1.31	1.26	1.21
47	1.7	1.52	1.47	1.41	1.35	1.29	1.24
48	1.74	1.54	1.49	1.43	1.36	1.3	1.24

Table G1 cont.: Delft3D Ocean Storm Results

Output Location	Peak Water Level (mAHD)						
	PMF	200yrARI	100yrARI	50yrARI	20yrARI	10yrARI	5yrARI
49	1.7	1.52	1.47	1.41	1.34	1.29	1.24
50	1.65	1.49	1.44	1.39	1.33	1.28	1.22
51	1.64	1.49	1.44	1.38	1.32	1.27	1.22
52	1.55	1.44	1.39	1.34	1.29	1.24	1.19
53	1.51	1.42	1.38	1.33	1.28	1.23	1.19
54	1.5	1.41	1.37	1.32	1.27	1.23	1.18
55	1.5	1.41	1.37	1.32	1.27	1.23	1.18
56	1.54	1.44	1.39	1.34	1.29	1.24	1.19
57	1.56	1.44	1.4	1.35	1.29	1.24	1.2
58	1.65	1.49	1.44	1.38	1.32	1.27	1.21
59	1.74	1.55	1.49	1.43	1.36	1.3	1.24
60	1.78	1.57	1.51	1.44	1.37	1.31	1.25
61	1.76	1.56	1.52	1.44	1.37	1.31	1.24
62	1.75	1.55	1.49	1.43	1.36	1.3	1.24
63	1.79	1.57	1.52	1.45	1.38	1.31	1.25
64	1.79	1.57	1.51	1.44	1.38	1.31	1.24
65	1.88	1.66	1.58	1.52	1.45	1.4	1.35
66	1.83	1.62	1.55	1.49	1.42	1.37	1.33
67	1.85	1.66	1.59	1.52	1.47	1.41	1.36
68	1.83	1.64	1.57	1.5	1.45	1.4	1.37
69	1.77	1.62	1.55	1.5	1.45	1.4	1.36
70	1.82	1.64	1.56	1.5	1.45	1.39	1.35
71	1.85	1.7	1.59	1.54	1.49	1.43	1.38
72	1.89	1.69	1.63	1.56	1.5	1.45	1.39
73	1.94	1.72	1.66	1.59	1.53	1.47	1.42
74	1.96	1.73	1.67	1.59	1.55	1.49	1.44
75	1.9	1.64	1.57	1.5	1.42	1.35	1.29
76	1.82	1.59	1.53	1.46	1.39	1.32	1.26
77	1.82	1.59	1.53	1.46	1.39	1.33	1.26
78	1.78	1.56	1.5	1.44	1.37	1.31	1.25
79	1.79	1.57	1.51	1.45	1.38	1.32	1.25
80	1.78	1.57	1.52	1.44	1.37	1.31	1.25
81	1.78	1.57	1.51	1.44	1.38	1.32	1.32
82	1.75	1.55	1.49	1.43	1.36	1.3	1.24
83	1.77	1.56	1.5	1.44	1.37	1.3	1.25
84	1.81	1.58	1.52	1.45	1.4	1.32	1.26
85	1.84	1.6	1.54	1.47	1.4	1.33	1.27
86	1.82	1.59	1.53	1.46	1.4	1.33	1.26
87	1.84	1.6	1.54	1.47	1.4	1.33	1.27
88	1.81	1.59	1.53	1.47	1.4	1.33	1.27
89	1.87	1.62	1.56	1.49	1.41	1.34	1.28
90	1.53	1.43	1.39	1.34	1.29	1.24	1.2
91	1.51	1.42	1.38	1.33	1.28	1.24	1.19
92	1.51	1.42	1.37	1.33	1.28	1.23	1.19
93	1.52	1.43	1.38	1.34	1.29	1.24	1.2
94	2.28	1.86	1.77	1.67	1.57	1.48	1.4
95	2.25	1.84	1.76	1.66	1.57	1.48	1.39
96	2.23	1.83	1.74	1.65	1.55	1.47	1.39

Table G1 cont.: Delft3D Ocean Storm Results

Output Location	Peak Water Level (mAHD)						
	PMF	200yrARI	100yrARI	50yrARI	20yrARI	10yrARI	5yrARI
97	2.21	1.82	1.73	1.64	1.54	1.46	1.38
98	2.26	1.85	1.76	1.67	1.56	1.48	1.4
99	2.3	1.87	1.79	1.69	1.58	1.5	1.41
100	2.36	1.91	1.82	1.72	1.6	1.52	1.43
101	2.32	1.88	1.79	1.7	1.59	1.5	1.41
102	2.28	1.86	1.77	1.67	1.57	1.48	1.4
103	2.27	1.85	1.77	1.67	1.56	1.48	1.4
104	2.08	1.75	1.66	1.58	1.49	1.42	1.35
105	2.05	1.72	1.65	1.57	1.48	1.41	1.33
106	2.04	1.72	1.64	1.56	1.47	1.41	1.33
107	2.03	1.72	1.64	1.56	1.48	1.41	1.33
108	2.05	1.73	1.65	1.57	1.48	1.41	1.34
109	2.06	1.73	1.66	1.58	1.48	1.42	1.34
110	2.07	1.74	1.66	1.58	1.49	1.42	1.34
111	2.07	1.72	1.65	1.57	1.48	1.41	1.34
112	2.07	1.74	1.66	1.58	1.49	1.42	1.35
113	2.08	1.75	1.67	1.58	1.49	1.42	1.35
114	2.15	1.79	1.7	1.61	1.52	1.44	1.36
115	2.12	1.76	1.68	1.6	1.5	1.43	1.35
116	2.15	1.79	1.7	1.62	1.52	1.44	1.36
117	2.09	1.75	1.67	1.59	1.49	1.42	1.35
118	2.06	1.73	1.65	1.57	1.48	1.41	1.34
119	2.08	1.75	1.67	1.58	1.49	1.43	1.34

APPENDIX H

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVES

Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE LOCATIONS

Figure H1

LJ2523/R2353v7 July 2013

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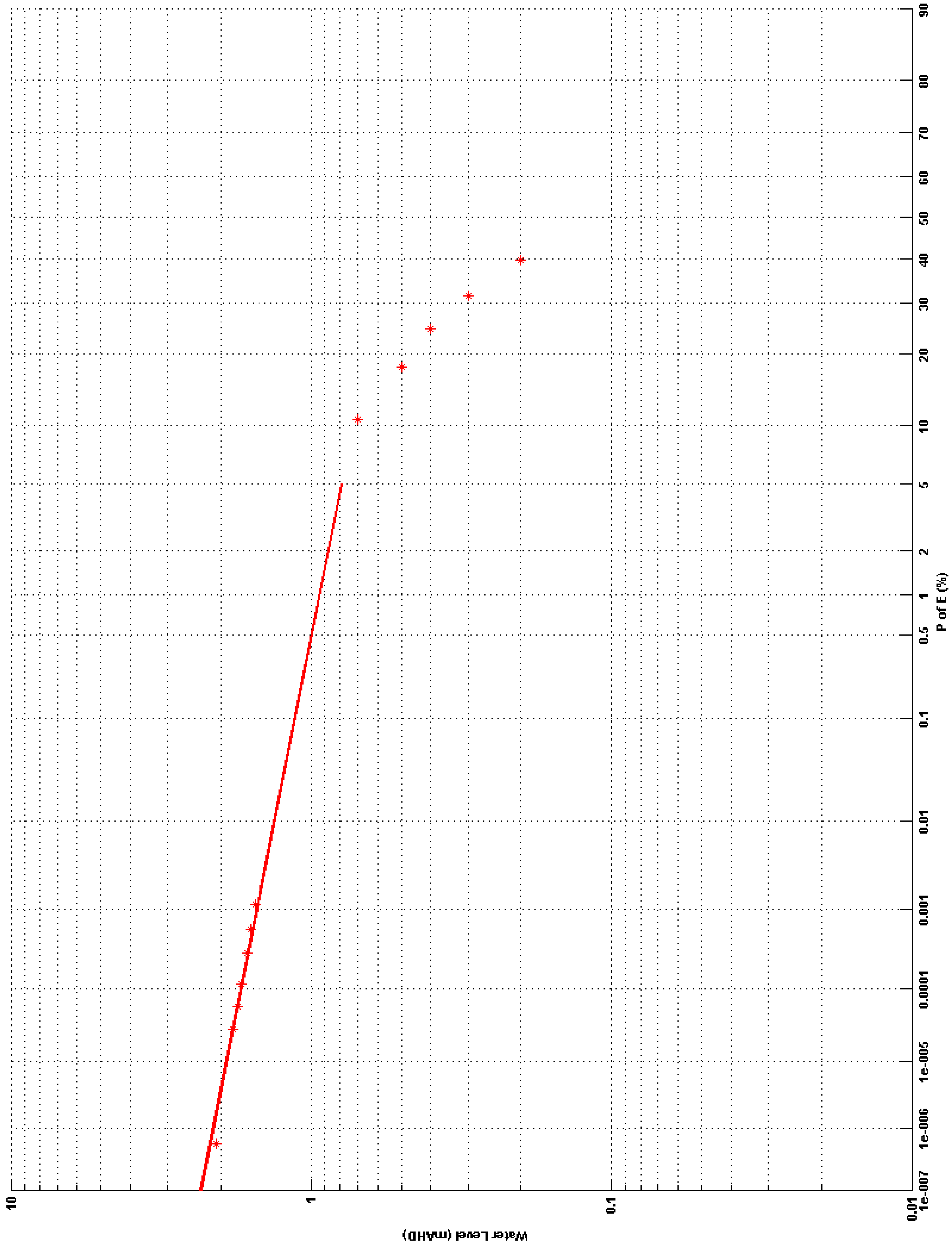

Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE
ETTALONG CREEK
Figure H2

LJ2523/R2353v7

July 2013

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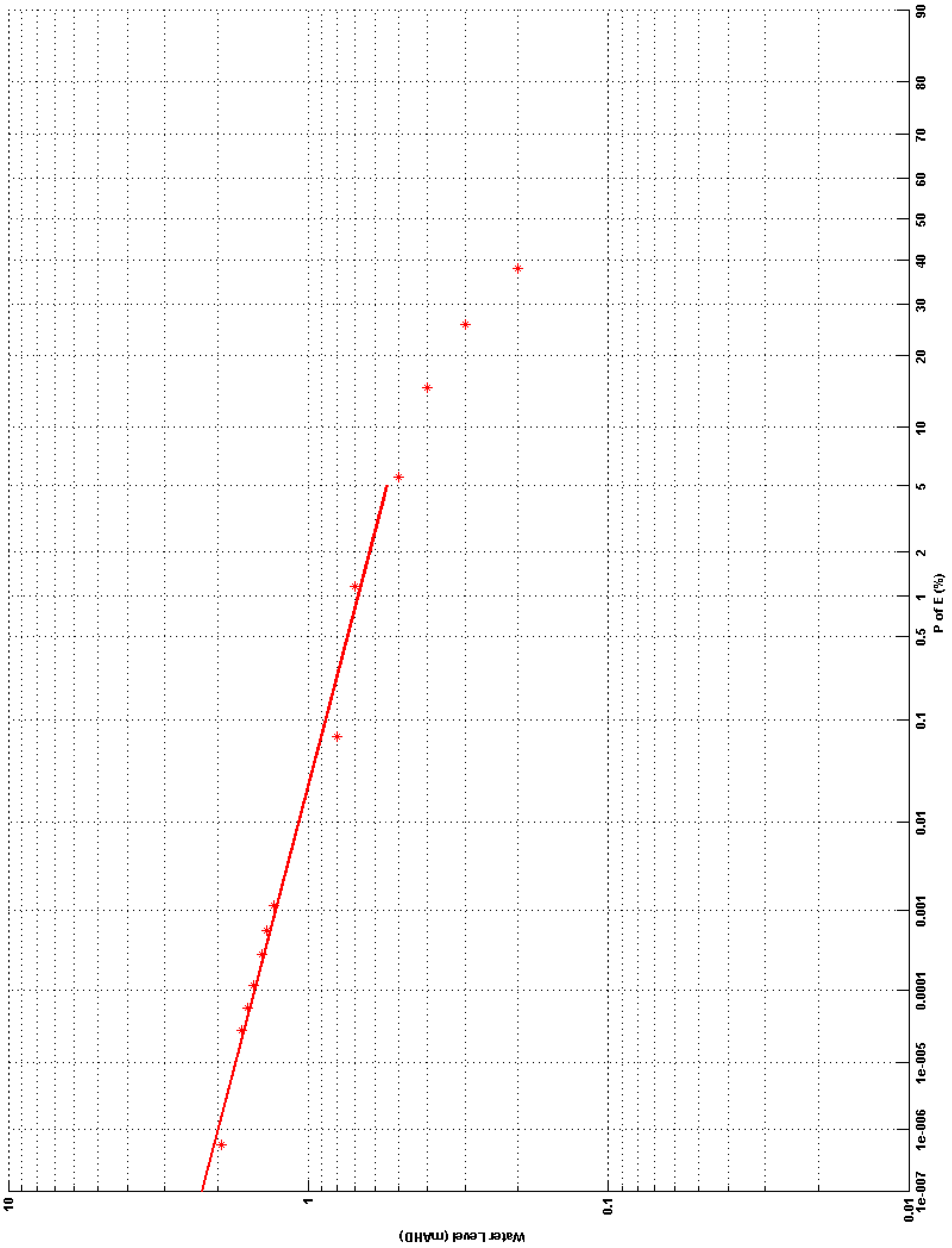

Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE
WOY WOY
Figure H3

LJ2523/R2353v7

July 2013

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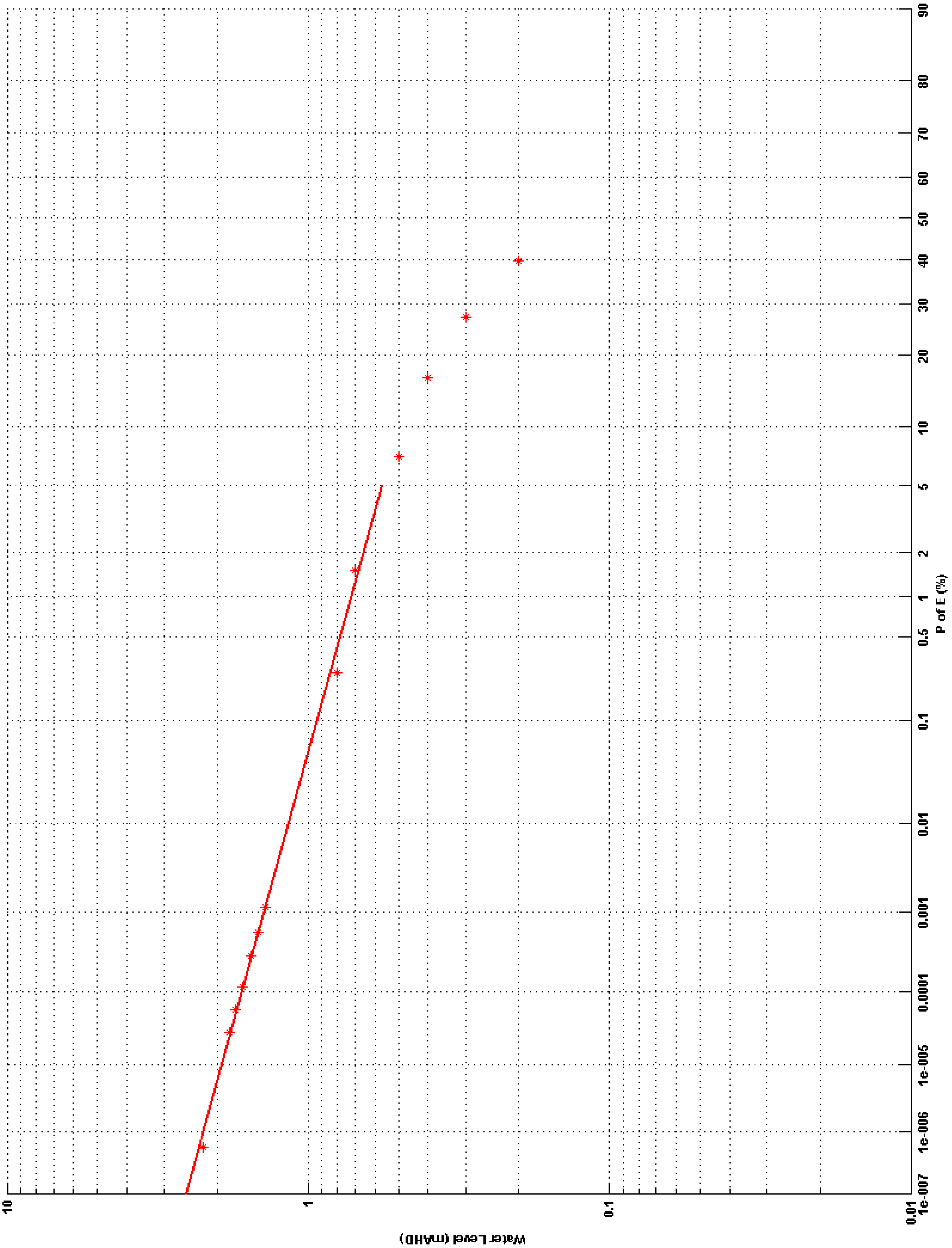

Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE
GOSFORD
Figure H4

LJ2523/R2353v7

July 2013

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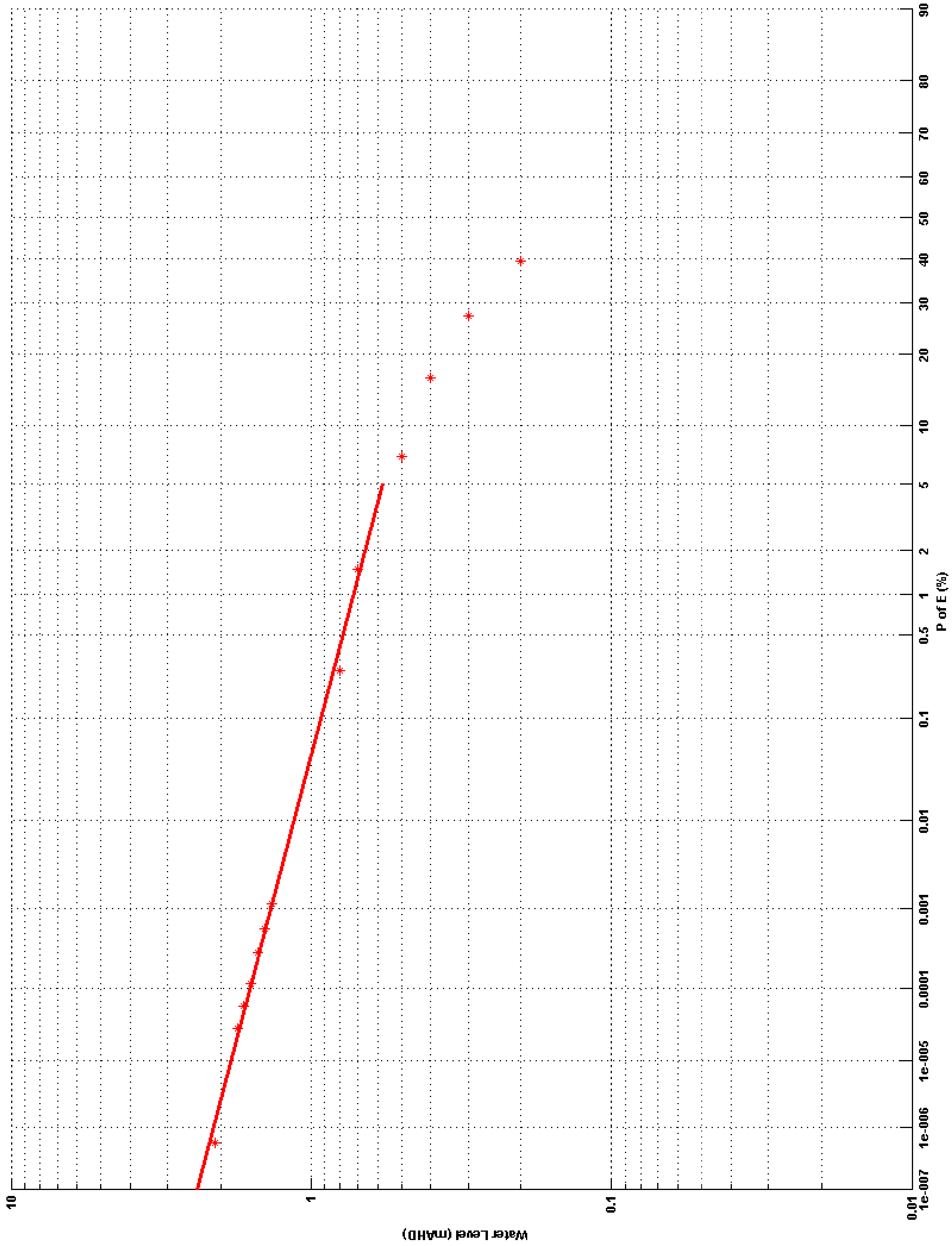

Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE
POINT FREDERICK

Figure H5

LJ2523/R2353v7

July 2013

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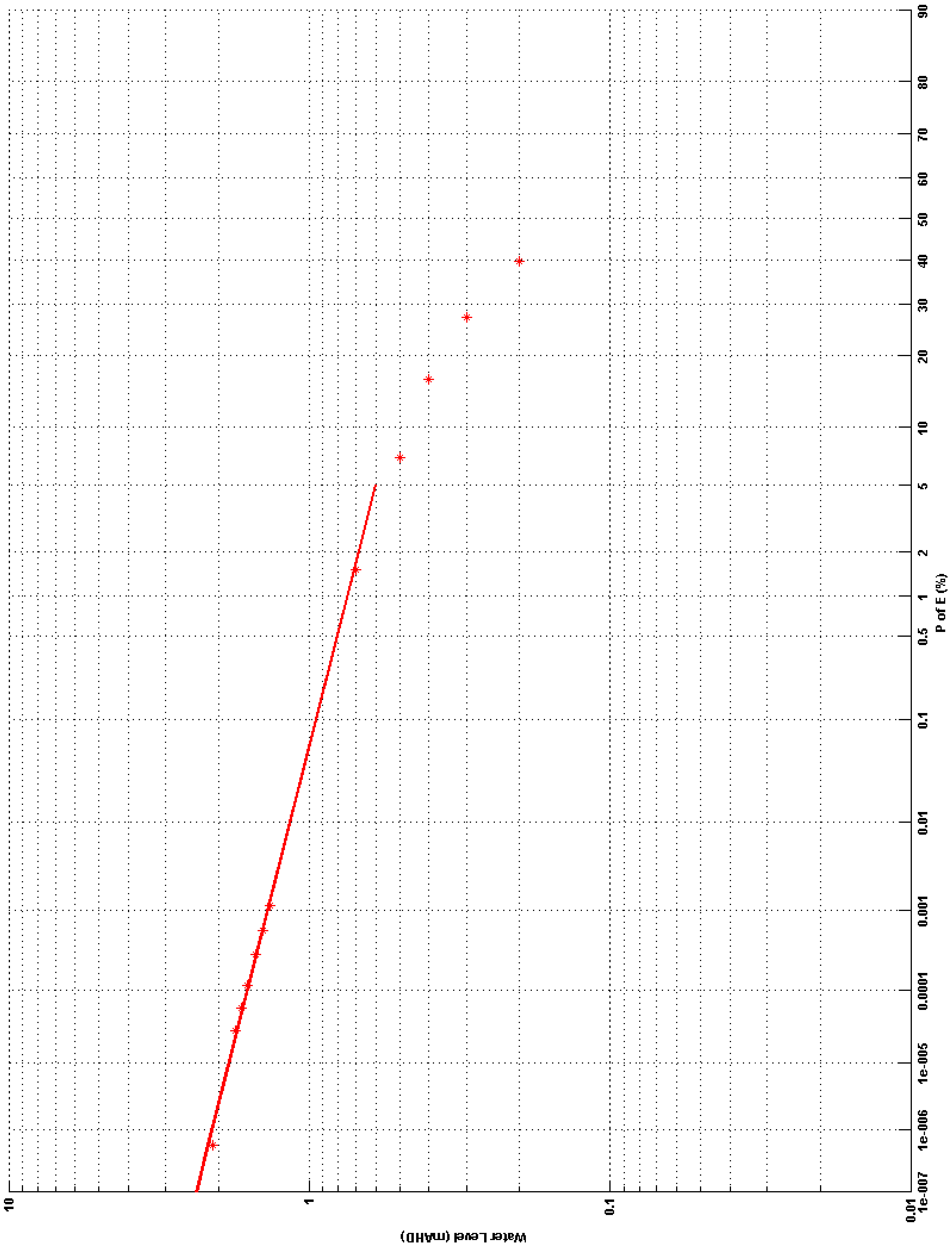

Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE
ERINA CREEK
Figure H6

LJ2523/R2353v7

July 2013

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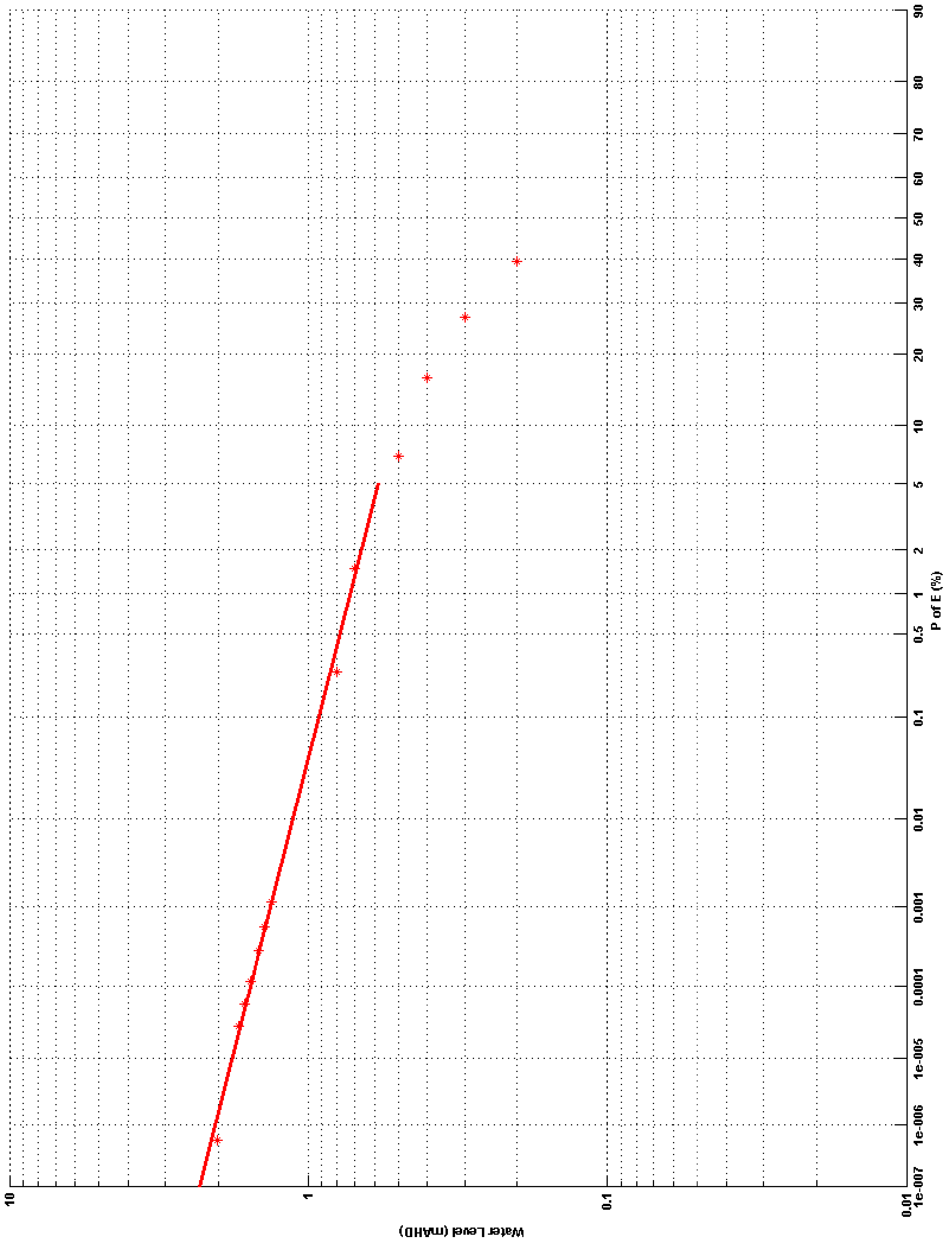

Cardno Lawson Treloar

Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE
SARATOGA

Figure H7

LJ2523/R2353v7

July 2013

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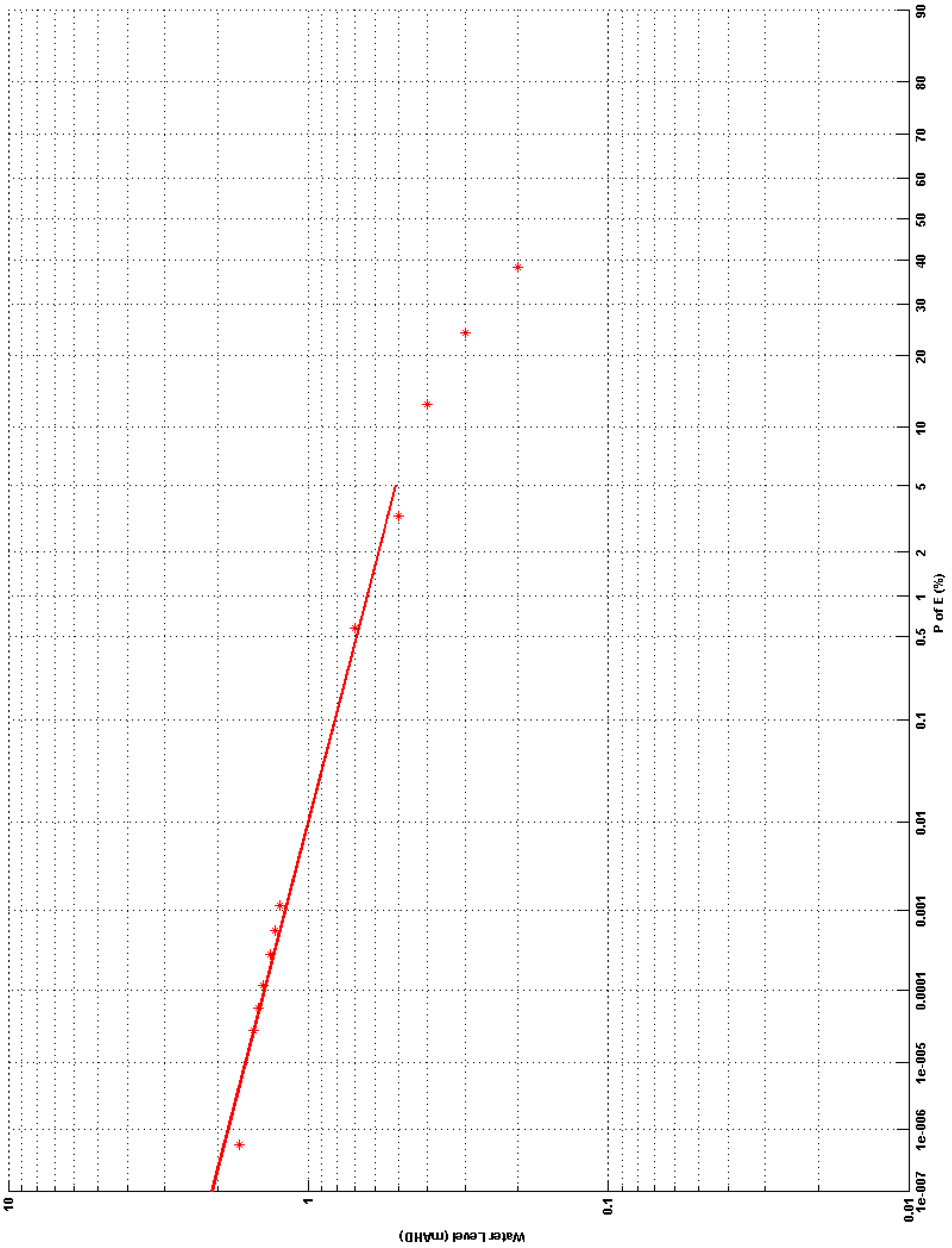

Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE
KINCUMBER CREEK
Figure H8

LJ2523/R2353v7

July 2013

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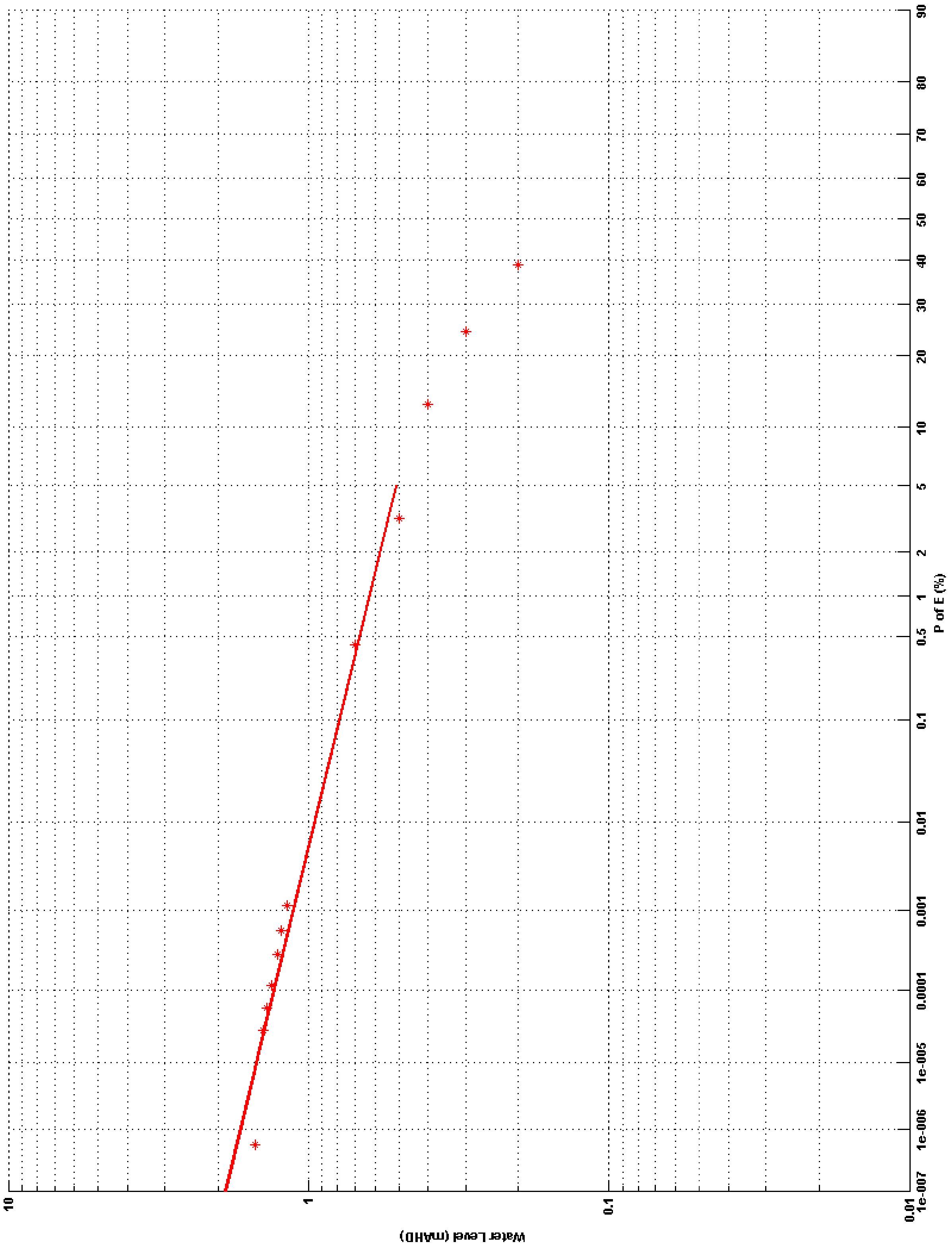

Cardno Lawson Treloar

Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE
BENSVILLE
Figure H9

LJ2523/R2353v7

July 2013

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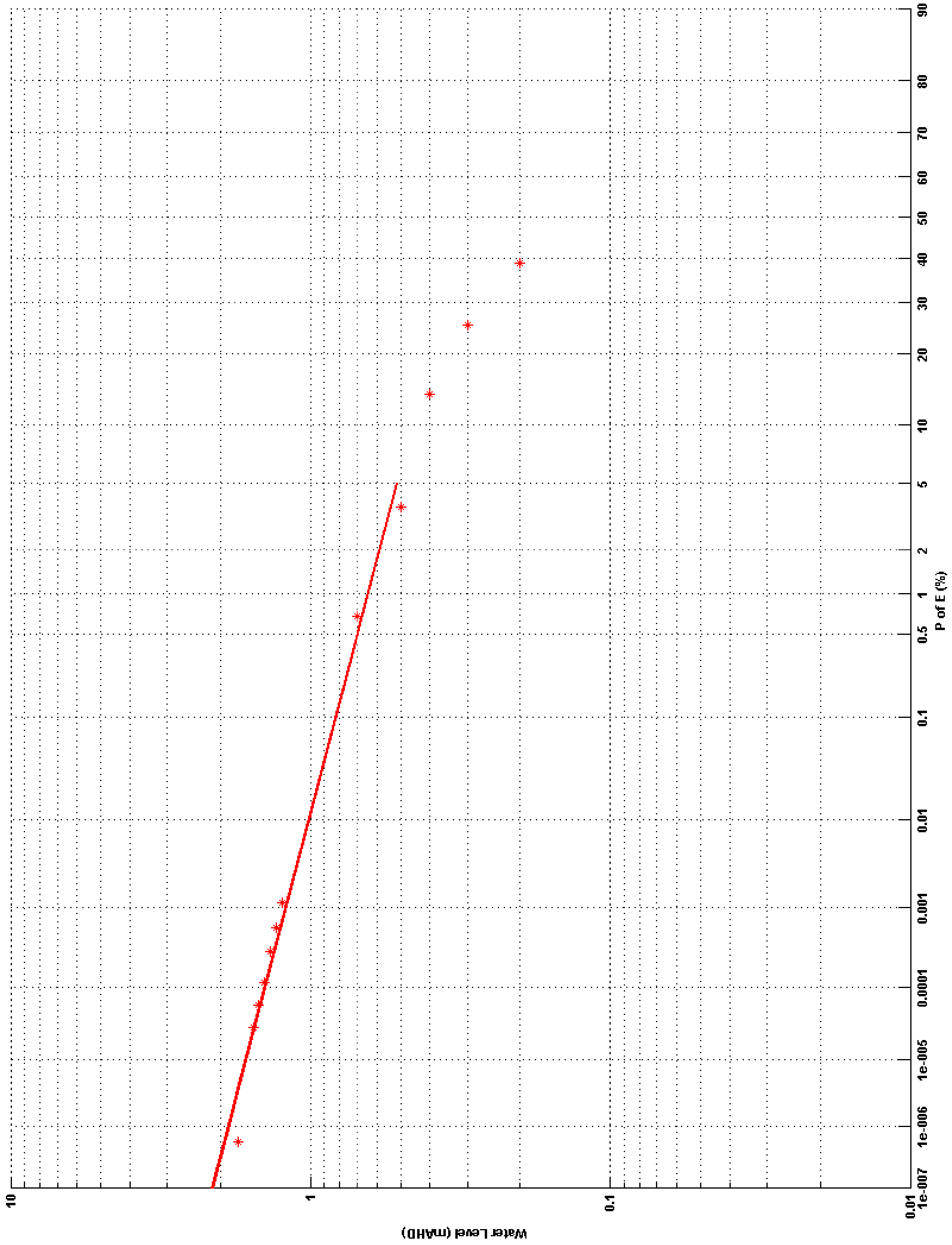

Cardno Lawson Treloar

LJ2523/R2353v7

July 2013

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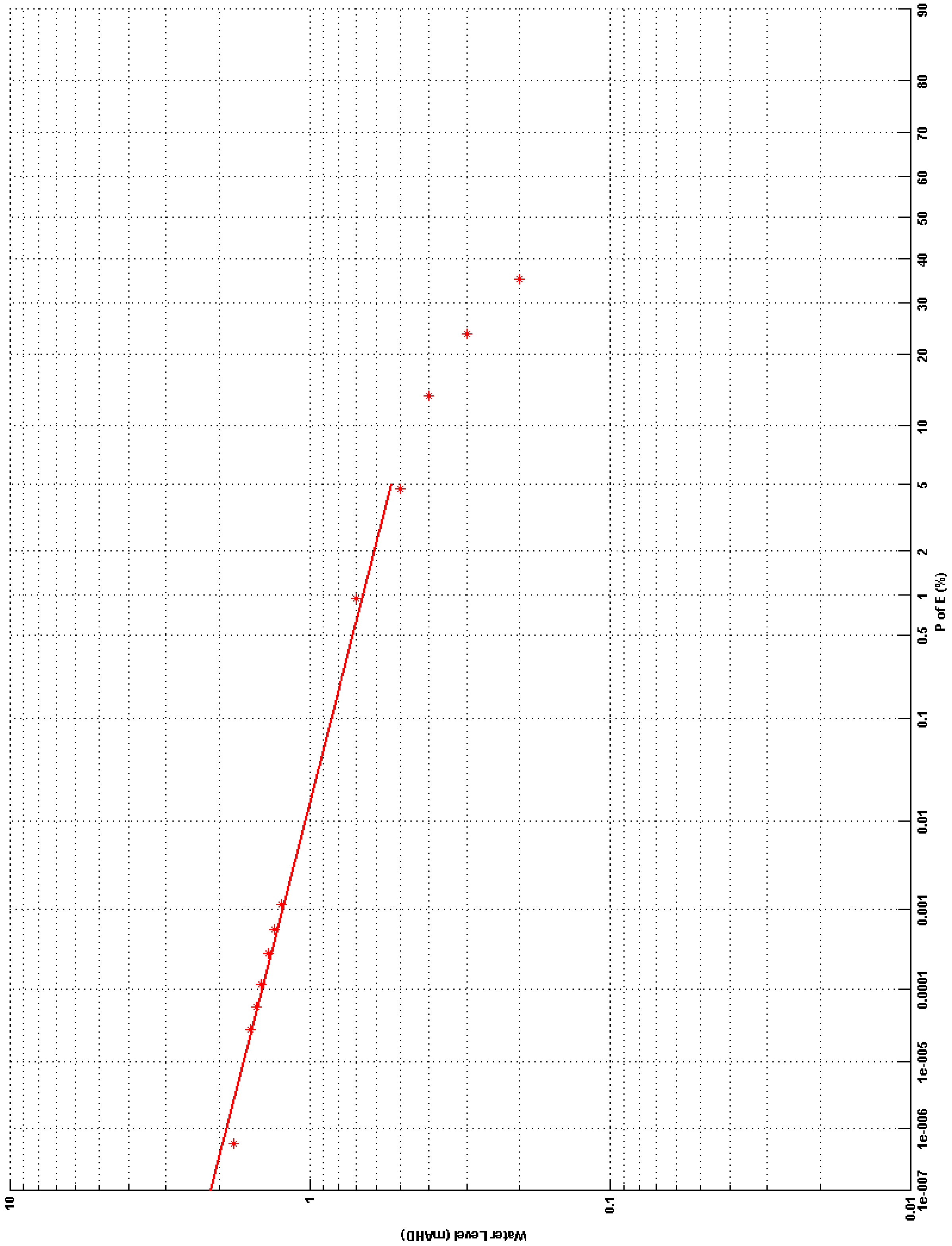
Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE
DAVISTOWN / EMPIRE BAY
Figure H10



Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE

RIP BRIDGE

Figure H11

LJ2523/R2353v7

July 2013

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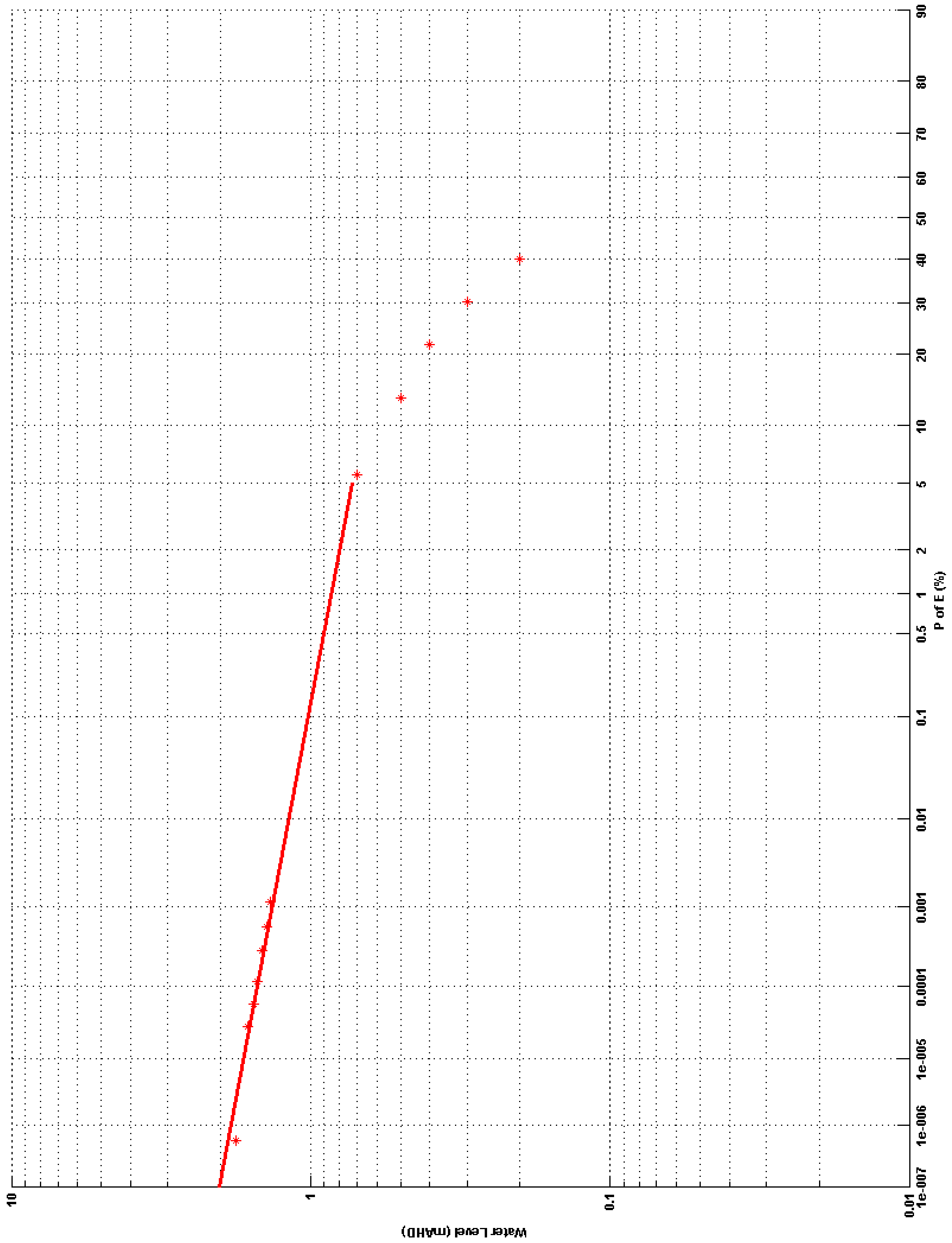

Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE
WAGSTAFFE
Figure H12

LJ2523/R2353v7

July 2013

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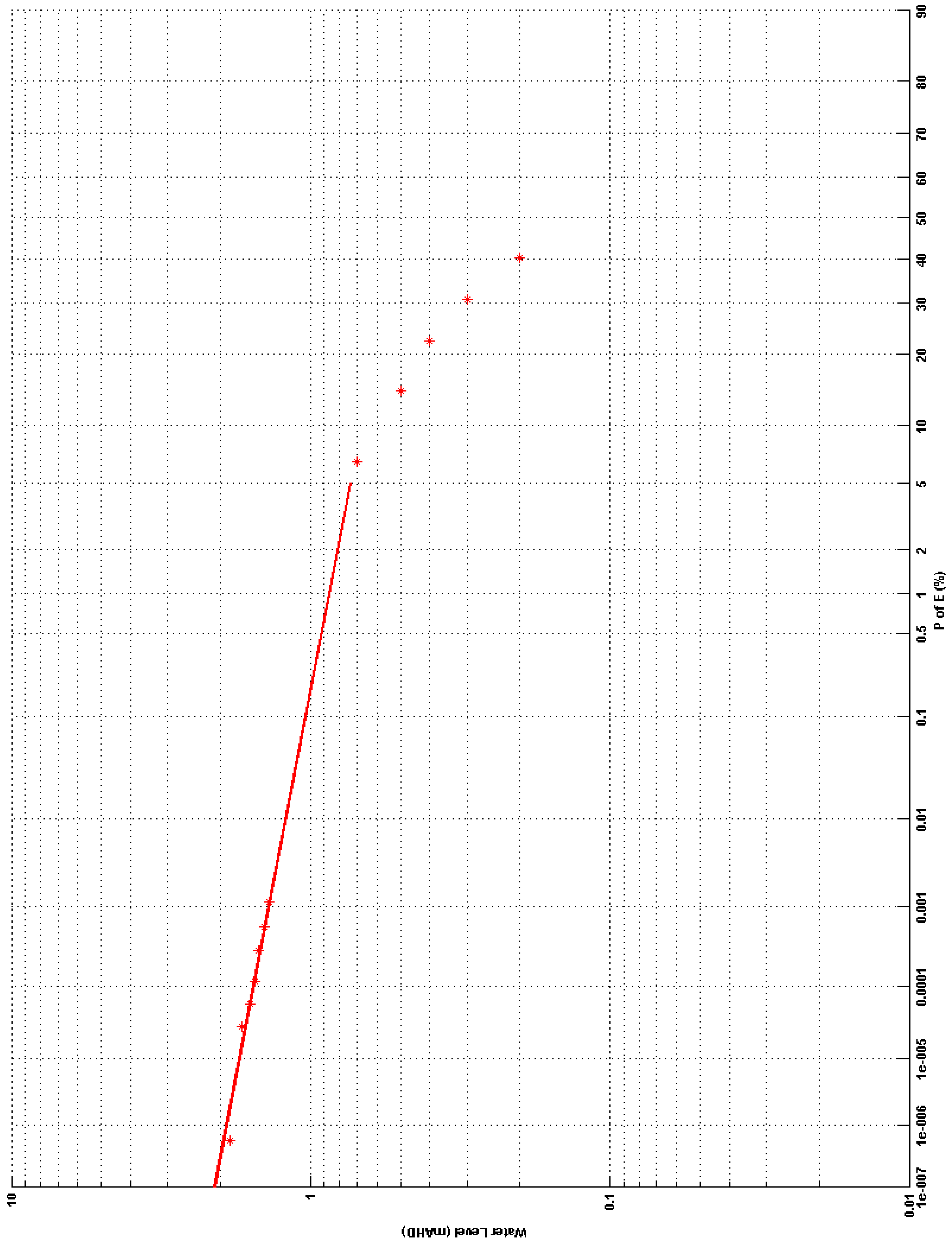

Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE
PRETTY BEACH

Figure H13

LJ2523/R2353v7

July 2013

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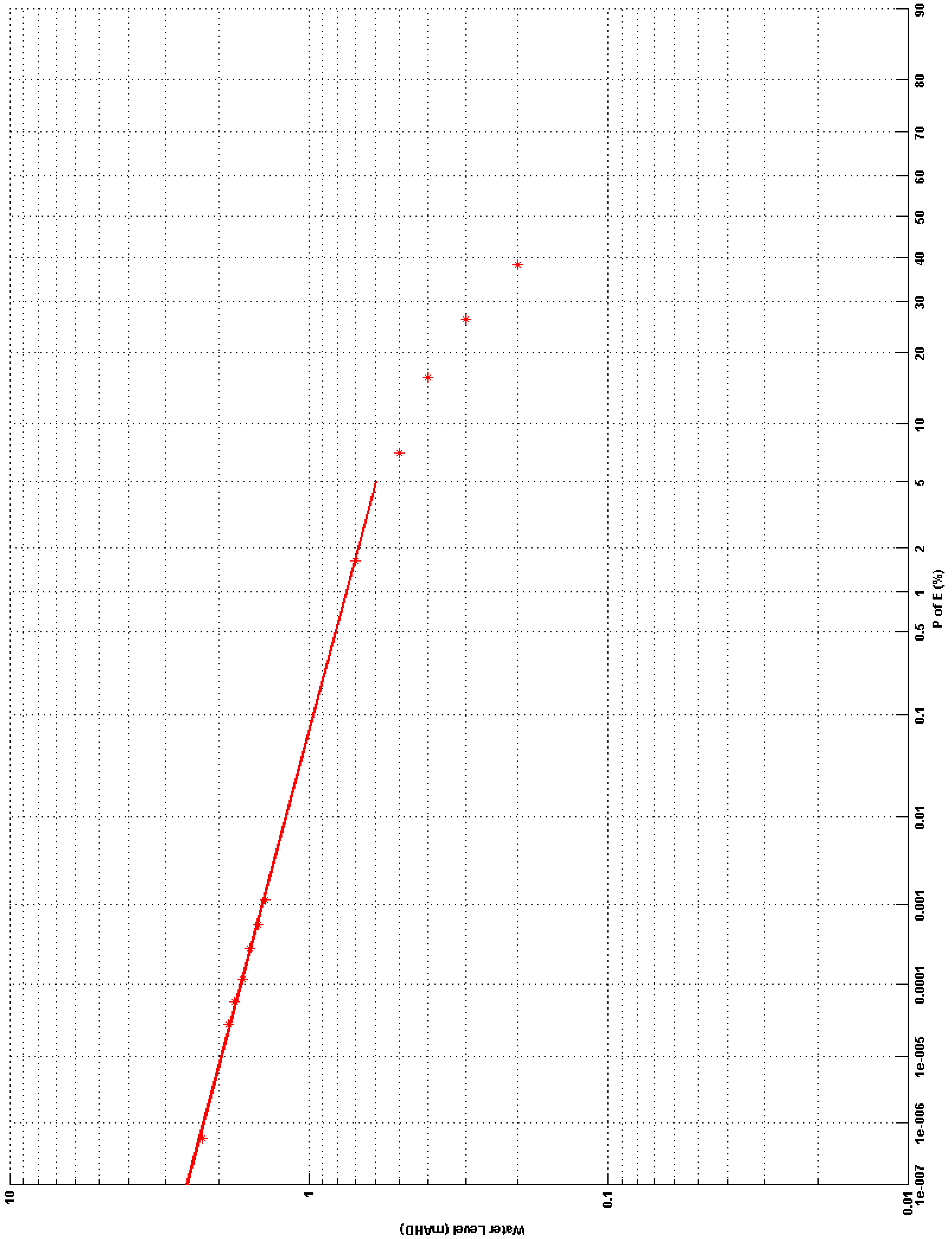

Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE
NARARA CREEK
Figure H14

LJ2523/R2353v7

July 2013

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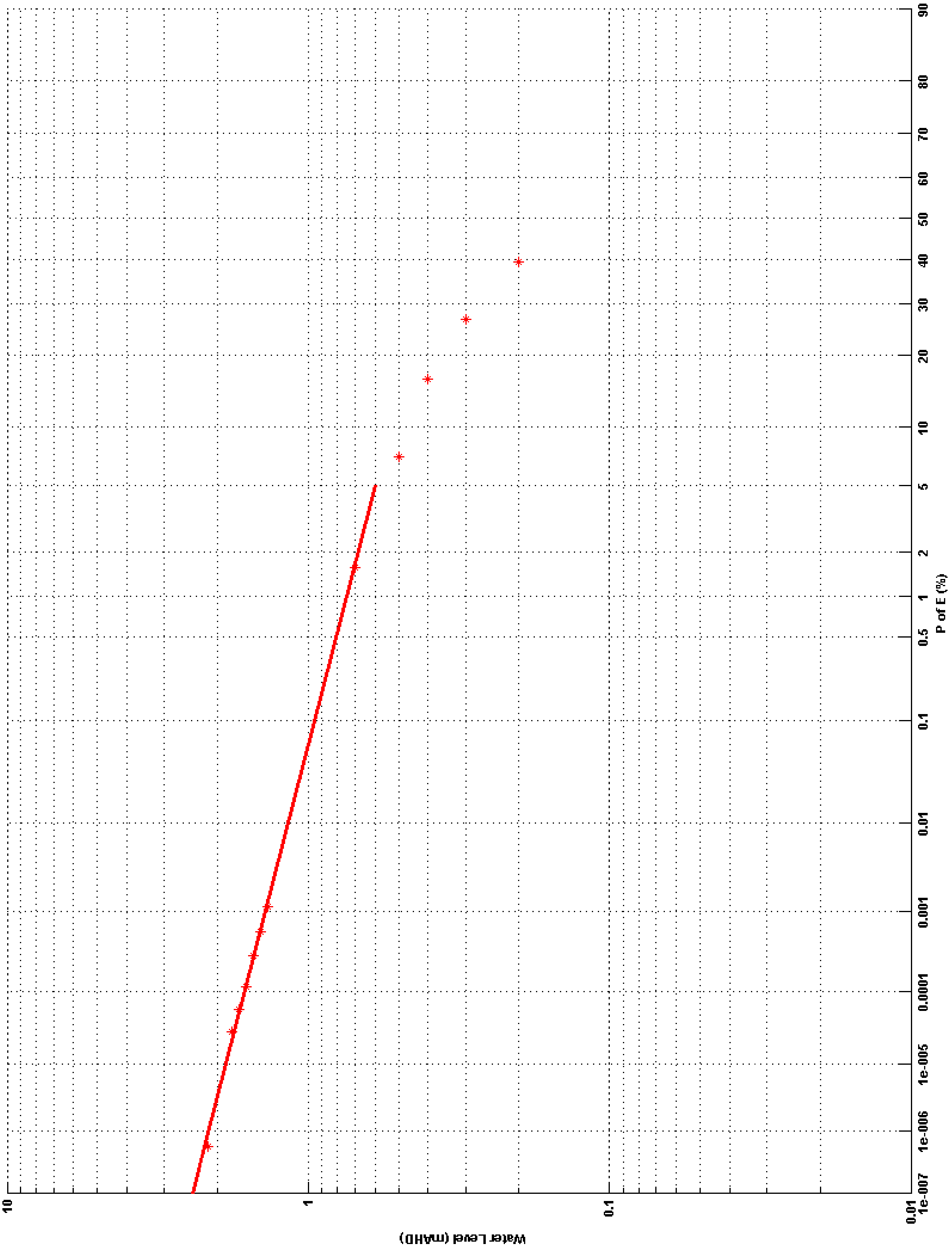


Brisbane Water Foreshore Flood Study

WATER LEVEL PROBABILITY OF EXCEEDANCE CURVE
WOY WOY BAY
Figure H15

LJ2523/R2353v7

July 2013

APPENDIX I

SWAN MODELLING – SEA AND SWELL WAVE RESULTS

Table I1: SWAN Model Results – Hs (m), Tz (sec)

Loc ID	5yrARI				10yrARI				20yrARI				50yrARI				100yrARI				200yrARI				PMF			
	Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell	
	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz
1	0.92	3.6	2.65	9.1	0.97	3.7	2.85	9.4	1.03	3.9	3.05	9.7	1.1	4.0	3.31	10.1	1.15	4.2	3.51	10.4	1.21	4.3	3.71	10.6	1.52	5.1	4.82	12.3
2	0.72	3.1	0.24	5.5	0.76	3.2	0.25	5.5	0.8	3.3	0.26	5.5	0.85	3.4	0.27	5.5	0.89	3.5	0.28	5.5	0.93	3.6	0.29	5.5	1.15	4.2	0.34	5.6
3	0.69	3.0	1.22	6.9	0.72	3.1	1.31	7.1	0.76	3.2	1.4	7.2	0.81	3.3	1.52	7.4	0.85	3.4	1.6	7.5	0.88	3.5	1.69	7.6	1.08	4.0	2.20	8.4
4	0.53	2.6	0.29	5.5	0.57	2.7	0.31	5.6	0.61	2.8	0.33	5.6	0.65	2.9	0.35	5.6	0.69	3.0	0.37	5.7	0.72	3.1	0.39	5.7	0.92	3.6	0.51	5.9
5	0.59	2.8	0.13	5.3	0.63	2.9	0.14	5.3	0.67	3.0	0.15	5.3	0.72	3.1	0.16	5.3	0.76	3.2	0.17	5.4	0.80	3.3	0.18	5.4	1.02	3.8	0.26	5.5
6	0.59	2.8	0.03	5.2	0.63	2.9	0.03	5.2	0.67	3.0	0.03	5.2	0.72	3.1	0.04	5.2	0.75	3.2	0.04	5.2	0.78	3.3	0.04	5.2	0.98	3.7	0.07	5.2
7	0.43	2.4	0	5.1	0.45	2.5	0	5.1	0.48	2.5	0	5.1	0.51	2.6	0.01	5.1	0.53	2.6	0.01	5.1	0.55	2.7	0.01	5.1	0.67	3.0	0.01	5.1
8	0.32	2.1	-	-	0.33	2.2	-	-	0.35	2.2	-	-	0.37	2.3	-	-	0.38	2.3	-	-	0.39	2.3	-	-	0.47	2.5	-	-
9	0.47	2.5	-	-	0.5	2.6	-	-	0.53	2.6	-	-	0.57	2.7	-	-	0.59	2.8	-	-	0.62	2.9	-	-	0.79	3.3	-	-
10	0.41	2.4	-	-	0.43	2.4	-	-	0.44	2.4	-	-	0.46	2.5	-	-	0.48	2.5	-	-	0.49	2.6	-	-	0.57	2.7	-	-
11	0.42	2.4	-	-	0.44	2.4	-	-	0.46	2.5	-	-	0.48	2.5	-	-	0.49	2.6	-	-	0.51	2.6	-	-	0.60	2.8	-	-
12	0.45	2.5	-	-	0.48	2.5	-	-	0.5	2.6	-	-	0.53	2.6	-	-	0.56	2.7	-	-	0.59	2.8	-	-	0.73	3.1	-	-
13	0.55	2.7	-	-	0.59	2.8	-	-	0.63	2.9	-	-	0.68	3.0	-	-	0.71	3.1	-	-	0.74	3.2	-	-	0.94	3.6	-	-
14	0.57	2.7	-	-	0.61	2.8	-	-	0.65	2.9	-	-	0.7	3.1	-	-	0.74	3.2	-	-	0.77	3.2	-	-	0.97	3.7	-	-
15	0.26	2.0	-	-	0.28	2.0	-	-	0.29	2.1	-	-	0.3	2.1	-	-	0.32	2.1	-	-	0.33	2.2	-	-	0.41	2.3	-	-
16	0.23	1.9	-	-	0.23	1.9	-	-	0.24	1.9	-	-	0.25	2.0	-	-	0.26	2.0	-	-	0.27	2.0	-	-	0.32	2.1	-	-
17	0.41	2.4	-	-	0.44	2.4	-	-	0.46	2.5	-	-	0.49	2.6	-	-	0.51	2.6	-	-	0.53	2.7	-	-	0.65	2.9	-	-
18	0.6	2.8	-	-	0.63	2.9	-	-	0.65	2.9	-	-	0.68	3.0	-	-	0.7	3.1	-	-	0.73	3.1	-	-	0.87	3.5	-	-
19	0.54	2.7	-	-	0.57	2.7	-	-	0.59	2.8	-	-	0.62	2.9	-	-	0.65	2.9	-	-	0.67	3.0	-	-	0.79	3.3	-	-
20	0.68	3.0	-	-	0.72	3.1	-	-	0.77	3.2	-	-	0.82	3.4	-	-	0.87	3.5	-	-	0.91	3.6	-	-	1.16	4.2	-	-
21	0.75	3.2	-	-	0.8	3.3	-	-	0.85	3.4	-	-	0.92	3.6	-	-	0.96	3.7	-	-	1.01	3.8	-	-	1.27	4.5	-	-
22	0.89	3.5	-	-	0.95	3.7	-	-	1.01	3.8	-	-	1.09	4.0	-	-	1.14	4.1	-	-	1.20	4.3	-	-	1.54	5.1	-	-
23	0.79	3.3	-	-	0.84	3.4	-	-	0.89	3.5	-	-	0.95	3.7	-	-	1	3.8	-	-	1.05	3.9	-	-	1.34	4.6	-	-
24	0.7	3.1	-	-	0.74	3.2	-	-	0.78	3.3	-	-	0.83	3.4	-	-	0.87	3.5	-	-	0.91	3.6	-	-	1.13	4.1	-	-
25	0.66	3.0	-	-	0.7	3.1	-	-	0.73	3.1	-	-	0.78	3.3	-	-	0.81	3.3	-	-	0.84	3.4	-	-	1.04	3.9	-	-
26	0.92	3.6	-	-	0.97	3.7	-	-	1.03	3.9	-	-	1.1	4.0	-	-	1.15	4.2	-	-	1.21	4.3	-	-	1.52	5.1	-	-
27	0.72	3.1	-	-	0.76	3.2	-	-	0.8	3.3	-	-	0.85	3.4	-	-	0.89	3.5	-	-	0.93	3.6	-	-	1.15	4.2	-	-
28	0.88	3.5	-	-	0.93	3.6	-	-	0.98	3.7	-	-	1.05	3.9	-	-	1.1	4.0	-	-	1.15	4.2	-	-	1.44	4.9	-	-
29	0.69	3.0	-	-	0.72	3.1	-	-	0.76	3.2	-	-	0.81	3.3	-	-	0.85	3.4	-	-	0.88	3.5	-	-	1.08	4.0	-	-
30	0.63	2.9	-	-	0.66	3.0	-	-	0.7	3.1	-	-	0.74	3.2	-	-	0.77	3.2	-	-	0.80	3.3	-	-	1.00	3.8	-	-

Table I1 cont.: SWAN Model Results – Hs (m), Tz (sec)

Loc ID	5yrARI				10yrARI				20yrARI				50yrARI				100yrARI				200yrARI				PMF			
	Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell	
	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz
31	0.64	2.9	-	-	0.68	3.0	-	-	0.72	3.1	-	-	0.77	3.2	-	-	0.81	3.3	-	-	0.84	3.4	-	-	1.04	3.9	-	-
32	0.74	3.2	-	-	0.79	3.3	-	-	0.83	3.4	-	-	0.89	3.5	-	-	0.93	3.6	-	-	0.97	3.7	-	-	1.22	4.3	-	-
33	0.83	3.4	-	-	0.87	3.5	-	-	0.92	3.6	-	-	0.98	3.7	-	-	1.02	3.8	-	-	1.06	4.0	-	-	1.31	4.5	-	-
34	0.74	3.2	-	-	0.78	3.3	-	-	0.83	3.4	-	-	0.88	3.5	-	-	0.92	3.6	-	-	0.96	3.7	-	-	1.18	4.2	-	-
35	0.71	3.1	-	-	0.75	3.2	-	-	0.78	3.3	-	-	0.83	3.4	-	-	0.86	3.5	-	-	0.89	3.5	-	-	1.06	3.9	-	-
36	0.62	2.9	-	-	0.65	2.9	-	-	0.67	3.0	-	-	0.7	3.1	-	-	0.73	3.1	-	-	0.75	3.2	-	-	0.87	3.5	-	-
37	0.62	2.9	-	-	0.64	2.9	-	-	0.66	3.0	-	-	0.69	3.0	-	-	0.71	3.1	-	-	0.73	3.1	-	-	0.85	3.4	-	-
38	0.52	2.6	-	-	0.54	2.7	-	-	0.57	2.7	-	-	0.6	2.8	-	-	0.63	2.9	-	-	0.65	2.9	-	-	0.77	3.2	-	-
39	0.64	2.9	-	-	0.68	3.0	-	-	0.72	3.1	-	-	0.76	3.2	-	-	0.8	3.3	-	-	0.83	3.4	-	-	1.03	3.9	-	-
40	0.41	2.4	-	-	0.44	2.4	-	-	0.46	2.5	-	-	0.49	2.6	-	-	0.51	2.6	-	-	0.54	2.7	-	-	0.68	3.0	-	-
41	0.41	2.4	-	-	0.43	2.4	-	-	0.45	2.5	-	-	0.48	2.5	-	-	0.51	2.6	-	-	0.53	2.7	-	-	0.65	2.9	-	-
42	0.46	2.5	-	-	0.49	2.6	-	-	0.52	2.6	-	-	0.56	2.7	-	-	0.59	2.8	-	-	0.62	2.9	-	-	0.76	3.2	-	-
43	0.39	2.3	-	-	0.42	2.4	-	-	0.45	2.5	-	-	0.48	2.5	-	-	0.51	2.6	-	-	0.54	2.7	-	-	0.68	3.0	-	-
44	0.29	2.1	-	-	0.3	2.1	-	-	0.32	2.1	-	-	0.34	2.2	-	-	0.36	2.2	-	-	0.37	2.3	-	-	0.45	2.4	-	-
45	0.55	2.7	-	-	0.59	2.8	-	-	0.63	2.9	-	-	0.68	3.0	-	-	0.71	3.1	-	-	0.75	3.2	-	-	0.97	3.7	-	-
46	0.39	2.3	-	-	0.41	2.4	-	-	0.42	2.4	-	-	0.44	2.4	-	-	0.45	2.5	-	-	0.47	2.5	-	-	0.56	2.7	-	-
47	0.48	2.5	-	-	0.51	2.6	-	-	0.54	2.7	-	-	0.58	2.8	-	-	0.61	2.8	-	-	0.64	2.9	-	-	0.81	3.3	-	-
48	0.63	2.9	-	-	0.68	3.0	-	-	0.72	3.1	-	-	0.77	3.2	-	-	0.82	3.4	-	-	0.86	3.5	-	-	1.08	4.0	-	-
49	0.58	2.8	-	-	0.61	2.8	-	-	0.64	2.9	-	-	0.68	3.0	-	-	0.71	3.1	-	-	0.74	3.2	-	-	0.91	3.6	-	-
50	0.56	2.7	-	-	0.6	2.8	-	-	0.63	2.9	-	-	0.67	3.0	-	-	0.7	3.1	-	-	0.73	3.1	-	-	0.93	3.6	-	-
51	0.44	2.4	-	-	0.46	2.5	-	-	0.48	2.5	-	-	0.5	2.6	-	-	0.52	2.6	-	-	0.54	2.7	-	-	0.63	2.9	-	-
52	0.56	2.7	-	-	0.6	2.8	-	-	0.63	2.9	-	-	0.68	3.0	-	-	0.71	3.1	-	-	0.74	3.2	-	-	0.94	3.6	-	-
53	0.51	2.6	-	-	0.54	2.7	-	-	0.57	2.7	-	-	0.61	2.8	-	-	0.64	2.9	-	-	0.67	3.0	-	-	0.84	3.4	-	-
54	0.48	2.5	-	-	0.51	2.6	-	-	0.54	2.7	-	-	0.57	2.7	-	-	0.6	2.8	-	-	0.63	2.9	-	-	0.77	3.2	-	-
55	0.36	2.2	-	-	0.37	2.3	-	-	0.38	2.3	-	-	0.39	2.3	-	-	0.4	2.3	-	-	0.41	2.4	-	-	0.46	2.5	-	-
56	0.44	2.4	-	-	0.47	2.5	-	-	0.5	2.6	-	-	0.54	2.7	-	-	0.57	2.7	-	-	0.60	2.8	-	-	0.77	3.2	-	-
57	0.33	2.2	-	-	0.34	2.2	-	-	0.36	2.2	-	-	0.38	2.3	-	-	0.4	2.3	-	-	0.42	2.4	-	-	0.51	2.6	-	-
58	0.28	2.0	-	-	0.3	2.1	-	-	0.31	2.1	-	-	0.33	2.2	-	-	0.35	2.2	-	-	0.37	2.3	-	-	0.46	2.5	-	-
59	0.37	2.3	-	-	0.39	2.3	-	-	0.41	2.4	-	-	0.43	2.4	-	-	0.45	2.5	-	-	0.47	2.5	-	-	0.59	2.8	-	-
60	0.24	1.9	-	-	0.26	2.0	-	-	0.27	2.0	-	-	0.29	2.1	-	-	0.3	2.1	-	-	0.31	2.1	-	-	0.39	2.3	-	-

Table I1 cont.: SWAN Model Results – Hs (m), Tz (sec)

Loc ID	5yrARI				10yrARI				20yrARI				50yrARI				100yrARI				200yrARI				PMF			
	Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell	
	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz
61	0.36	2.2	-	-	0.38	2.3	-	-	0.4	2.3	-	-	0.43	2.4	-	-	0.45	2.5	-	-	0.47	2.5	-	-	0.59	2.8	-	-
62	0.38	2.3	-	-	0.41	2.4	-	-	0.44	2.4	-	-	0.48	2.5	-	-	0.5	2.6	-	-	0.53	2.6	-	-	0.70	3.1	-	-
63	0.51	2.6	-	-	0.54	2.7	-	-	0.57	2.7	-	-	0.61	2.8	-	-	0.64	2.9	-	-	0.67	3.0	-	-	0.84	3.4	-	-
64	0.57	2.7	-	-	0.61	2.8	-	-	0.64	2.9	-	-	0.69	3.0	-	-	0.72	3.1	-	-	0.75	3.2	-	-	0.95	3.7	-	-
65	0.5	2.6	-	-	0.53	2.6	-	-	0.55	2.7	-	-	0.59	2.8	-	-	0.62	2.9	-	-	0.65	2.9	-	-	0.79	3.3	-	-
66	0.61	2.8	0.02	5.1	0.64	2.9	0.02	5.1	0.68	3.0	0.02	5.1	0.73	3.1	0.03	5.2	0.76	3.2	0.03	5.2	0.79	3.3	0.03	5.2	0.99	3.8	0.03	5.2
67	0.57	2.7	0.03	5.2	0.6	2.8	0.04	5.2	0.64	2.9	0.04	5.2	0.68	3.0	0.05	5.2	0.71	3.1	0.05	5.2	0.74	3.2	0.05	5.2	0.91	3.6	0.08	5.2
68	0.61	2.8	0.05	5.2	0.64	2.9	0.05	5.2	0.67	3.0	0.06	5.2	0.72	3.1	0.06	5.2	0.75	3.2	0.06	5.2	0.78	3.3	0.06	5.2	0.95	3.7	0.09	5.2
69	0.48	2.5	0.02	5.1	0.49	2.6	0.02	5.1	0.51	2.6	0.02	5.1	0.54	2.7	0.02	5.1	0.55	2.7	0.02	5.1	0.57	2.7	0.02	5.1	0.66	3.0	0.02	5.1
70	0.49	2.6	0.08	5.2	0.52	2.6	0.08	5.2	0.55	2.7	0.09	5.2	0.58	2.8	0.1	5.3	0.6	2.8	0.1	5.3	0.63	2.9	0.11	5.3	0.77	3.2	0.16	5.3
71	0.38	2.3	0.04	5.2	0.4	2.3	0.04	5.2	0.41	2.4	0.05	5.2	0.43	2.4	0.05	5.2	0.44	2.4	0.06	5.2	0.45	2.5	0.06	5.2	0.53	2.6	0.06	5.2
72	0.4	2.3	0.34	5.6	0.43	2.4	0.36	5.6	0.45	2.5	0.39	5.7	0.48	2.5	0.42	5.7	0.5	2.6	0.45	5.8	0.52	2.6	0.48	5.8	0.64	2.9	0.62	6.0
73	0.64	2.9	0.34	5.6	0.68	3.0	0.36	5.6	0.72	3.1	0.39	5.7	0.77	3.2	0.42	5.7	0.81	3.3	0.45	5.8	0.84	3.4	0.48	5.8	1.04	3.9	0.62	6.0
74	0.74	3.2	2	8.1	0.79	3.3	2.15	8.3	0.83	3.4	2.29	8.5	0.89	3.5	2.49	8.8	0.93	3.6	2.63	9.0	0.97	3.7	2.78	9.3	1.22	4.3	3.60	10.5
75	0.28	2.0	-	-	0.3	2.1	-	-	0.32	2.1	-	-	0.34	2.2	-	-	0.36	2.2	-	-	0.38	2.3	-	-	0.47	2.5	-	-
76	0.32	2.1	-	-	0.34	2.2	-	-	0.36	2.2	-	-	0.38	2.3	-	-	0.39	2.3	-	-	0.41	2.3	-	-	0.50	2.6	-	-
77	0.21	1.9	-	-	0.22	1.9	-	-	0.22	1.9	-	-	0.23	1.9	-	-	0.24	1.9	-	-	0.25	2.0	-	-	0.30	2.1	-	-
78	0.34	2.2	-	-	0.37	2.3	-	-	0.39	2.3	-	-	0.42	2.4	-	-	0.45	2.5	-	-	0.47	2.5	-	-	0.59	2.8	-	-
79	0.17	1.8	-	-	0.18	1.8	-	-	0.18	1.8	-	-	0.19	1.8	-	-	0.2	1.8	-	-	0.20	1.9	-	-	0.23	1.9	-	-
80	0.2	1.8	-	-	0.22	1.9	-	-	0.23	1.9	-	-	0.25	2.0	-	-	0.27	2.0	-	-	0.28	2.0	-	-	0.36	2.2	-	-
81	0.2	1.8	-	-	0.22	1.9	-	-	0.24	1.9	-	-	0.26	2.0	-	-	0.28	2.0	-	-	0.30	2.1	-	-	0.39	2.3	-	-
82	0.26	2.0	-	-	0.27	2.0	-	-	0.29	2.1	-	-	0.3	2.1	-	-	0.31	2.1	-	-	0.32	2.1	-	-	0.40	2.3	-	-
83	0.49	2.6	-	-	0.52	2.6	-	-	0.55	2.7	-	-	0.59	2.8	-	-	0.62	2.9	-	-	0.65	2.9	-	-	0.82	3.4	-	-
84	0.5	2.6	-	-	0.53	2.6	-	-	0.56	2.7	-	-	0.59	2.8	-	-	0.62	2.9	-	-	0.65	2.9	-	-	0.82	3.4	-	-
85	0.31	2.1	-	-	0.33	2.2	-	-	0.35	2.2	-	-	0.38	2.3	-	-	0.4	2.3	-	-	0.42	2.4	-	-	0.54	2.7	-	-
86	0.59	2.8	-	-	0.62	2.9	-	-	0.66	3.0	-	-	0.7	3.1	-	-	0.74	3.2	-	-	0.77	3.2	-	-	0.97	3.7	-	-
87	0.44	2.4	-	-	0.46	2.5	-	-	0.48	2.5	-	-	0.51	2.6	-	-	0.53	2.6	-	-	0.55	2.7	-	-	0.67	3.0	-	-
88	0.26	2.0	-	-	0.27	2.0	-	-	0.28	2.0	-	-	0.3	2.1	-	-	0.31	2.1	-	-	0.32	2.1	-	-	0.40	2.3	-	-
89	0.51	2.6	-	-	0.54	2.7	-	-	0.56	2.7	-	-	0.6	2.8	-	-	0.63	2.9	-	-	0.66	3.0	-	-	0.80	3.3	-	-
90	0.36	2.2	-	-	0.38	2.3	-	-	0.41	2.4	-	-	0.44	2.4	-	-	0.47	2.5	-	-	0.49	2.6	-	-	0.61	2.9	-	-

Table I1 cont.: SWAN Model Results – Hs (m), Tz (sec)

Loc ID	5yrARI				10yrARI				20yrARI				50yrARI				100yrARI				200yrARI				PMF			
	Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell		Sea		Swell	
	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz	Hs	Tz
91	0.33	2.2	-	-	0.36	2.2	-	-	0.38	2.3	-	-	0.4	2.3	-	-	0.42	2.4	-	-	0.44	2.4	-	-	0.56	2.7	-	-
92	0.25	2.0	-	-	0.27	2.0	-	-	0.28	2.0	-	-	0.29	2.1	-	-	0.31	2.1	-	-	0.32	2.1	-	-	0.37	2.3	-	-
93	0.26	2.0	-	-	0.28	2.0	-	-	0.29	2.1	-	-	0.31	2.1	-	-	0.33	2.2	-	-	0.35	2.2	-	-	0.44	2.4	-	-
94	0.42	2.4	-	-	0.45	2.5	-	-	0.48	2.5	-	-	0.52	2.6	-	-	0.55	2.7	-	-	0.58	2.8	-	-	0.75	3.2	-	-
95	0.47	2.5	-	-	0.5	2.6	-	-	0.52	2.6	-	-	0.56	2.7	-	-	0.58	2.8	-	-	0.61	2.8	-	-	0.75	3.2	-	-
96	0.33	2.2	-	-	0.35	2.2	-	-	0.37	2.3	-	-	0.39	2.3	-	-	0.41	2.4	-	-	0.43	2.4	-	-	0.52	2.6	-	-
97	0.28	2.0	-	-	0.29	2.1	-	-	0.3	2.1	-	-	0.32	2.1	-	-	0.33	2.2	-	-	0.34	2.2	-	-	0.42	2.4	-	-
98	0.33	2.2	-	-	0.34	2.2	-	-	0.36	2.2	-	-	0.38	2.3	-	-	0.4	2.3	-	-	0.42	2.4	-	-	0.51	2.6	-	-
99	0.28	2.0	-	-	0.29	2.1	-	-	0.3	2.1	-	-	0.31	2.1	-	-	0.32	2.1	-	-	0.33	2.2	-	-	0.41	2.3	-	-
100	0.36	2.2	-	-	0.38	2.3	-	-	0.41	2.4	-	-	0.44	2.4	-	-	0.47	2.5	-	-	0.50	2.6	-	-	0.64	2.9	-	-
101	0.39	2.3	-	-	0.42	2.4	-	-	0.44	2.4	-	-	0.48	2.5	-	-	0.5	2.6	-	-	0.52	2.6	-	-	0.64	2.9	-	-
102	0.35	2.2	-	-	0.37	2.3	-	-	0.39	2.3	-	-	0.42	2.4	-	-	0.44	2.4	-	-	0.46	2.5	-	-	0.58	2.8	-	-
103	0.35	2.2	-	-	0.37	2.3	-	-	0.39	2.3	-	-	0.42	2.4	-	-	0.45	2.5	-	-	0.47	2.5	-	-	0.59	2.8	-	-
104	0.49	2.6	-	-	0.51	2.6	-	-	0.54	2.7	-	-	0.58	2.8	-	-	0.61	2.8	-	-	0.64	2.9	-	-	0.78	3.3	-	-
105	0.5	2.6	-	-	0.53	2.6	-	-	0.56	2.7	-	-	0.59	2.8	-	-	0.62	2.9	-	-	0.65	2.9	-	-	0.82	3.4	-	-
106	0.52	2.6	-	-	0.55	2.7	-	-	0.58	2.8	-	-	0.61	2.8	-	-	0.64	2.9	-	-	0.67	3.0	-	-	0.84	3.4	-	-
107	0.42	2.4	-	-	0.45	2.5	-	-	0.48	2.5	-	-	0.51	2.6	-	-	0.53	2.6	-	-	0.56	2.7	-	-	0.70	3.1	-	-
108	0.39	2.3	-	-	0.41	2.4	-	-	0.43	2.4	-	-	0.46	2.5	-	-	0.48	2.5	-	-	0.50	2.6	-	-	0.62	2.9	-	-
109	0.38	2.3	-	-	0.4	2.3	-	-	0.42	2.4	-	-	0.45	2.5	-	-	0.47	2.5	-	-	0.49	2.6	-	-	0.61	2.9	-	-
110	0.44	2.4	-	-	0.47	2.5	-	-	0.51	2.6	-	-	0.55	2.7	-	-	0.58	2.8	-	-	0.61	2.8	-	-	0.78	3.3	-	-
111	0.38	2.3	-	-	0.4	2.3	-	-	0.42	2.4	-	-	0.45	2.5	-	-	0.47	2.5	-	-	0.49	2.5	-	-	0.58	2.8	-	-
112	0.39	2.3	-	-	0.41	2.4	-	-	0.42	2.4	-	-	0.44	2.4	-	-	0.46	2.5	-	-	0.47	2.5	-	-	0.55	2.7	-	-
113	0.38	2.3	-	-	0.4	2.3	-	-	0.41	2.4	-	-	0.43	2.4	-	-	0.45	2.5	-	-	0.46	2.5	-	-	0.54	2.7	-	-
114	0.38	2.3	-	-	0.41	2.4	-	-	0.43	2.4	-	-	0.46	2.5	-	-	0.49	2.6	-	-	0.51	2.6	-	-	0.63	2.9	-	-
115	0.55	2.7	-	-	0.59	2.8	-	-	0.63	2.9	-	-	0.68	3.0	-	-	0.72	3.1	-	-	0.75	3.2	-	-	0.95	3.7	-	-
116	0.48	2.5	-	-	0.51	2.6	-	-	0.54	2.7	-	-	0.59	2.8	-	-	0.62	2.9	-	-	0.65	2.9	-	-	0.82	3.4	-	-
117	0.56	2.7	-	-	0.59	2.8	-	-	0.63	2.9	-	-	0.67	3.0	-	-	0.7	3.1	-	-	0.73	3.1	-	-	0.93	3.6	-	-
118	0.53	2.6	-	-	0.57	2.7	-	-	0.6	2.8	-	-	0.65	2.9	-	-	0.68	3.0	-	-	0.71	3.1	-	-	0.91	3.6	-	-
119	0.38	2.3	-	-	0.41	2.4	-	-	0.44	2.4	-	-	0.47	2.5	-	-	0.5	2.6	-	-	0.53	2.6	-	-	0.67	3.0	-	-

APPENDIX J

WAVE RUN-UP AND FLOOD PLANNING LEVEL RESULTS

Table J1: 5yr ARI Wave Runup Results

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only
% Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to High Tide
^ Boat wave conditions adopted in run-up calculation
* Swell wave conditions adopted in run-up calculation

5-year ARI Offshore Storm Tide is **1.24mAHD**
**** Mean Sea Level Rise** of **0.3m included** within Table
Freeboard (0.3m) not included

Edge Treatment Types
1. 1 in 20 Natural Slope - 1.5mAHD crest
2. 1 in 20 Natural Slope - 2.5mAHD crest
3. 1 in 10 Beach Face - 1.5mAHD crest
4. 1 in 10 Beach Face - 2.5mAHD crest
5. 1 in 5 Embankment - 1.5mAHD crest
6. 1 in 5 Embankment - 2.5mAHD crest
7. 1 in 2 Seawall - 1.5mAHD crest
8. 1 in 2 Seawall - 2.5mAHD crest
9. Vertical Wall - 1.5mAHD crest
10. Vertical Wall - 2.5mAHD crest

Loc ID	5yrARI						Wave Setup (m)					Wave Runup Height (m)									
	Sea		Swell		Local Wind Setup% (m)	Design Water Level** (mAHD)	Edge Treatment Type ##					Edge Treatment Type ##									
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1&2	3&4	5&6	7&8	9&10	1	2	3	4	5	6	7	8	9	10
001	0.92	3.6	2.65	9.1	0.17	1.84	0.10	0.12	0.14	0.00	-0.06	1.33*	1.41*	1.33*	1.71*	1.33*	1.86*	1.33*	1.91*	1.33*	1.67*
002	0.72	3.1	0.24	5.5	0.18	1.81	0.08	0.09	0.11	0.00	-0.05	0.36	0.27*	0.36	0.54*	0.36	0.82	0.36	0.95	0.36	0.71
003	0.69	3.0	1.22	6.9	0.20	1.85	0.08	0.09	0.10	0.00	-0.05	0.61*	0.74*	0.61*	1.01*	0.61*	1.14*	0.61*	1.17*	0.61*	0.94*
004	0.53	2.6	0.29	5.5	0.17	1.70	0.06	0.07	0.08	0.00	-0.04	0.27	0.30*	0.27	0.59*	0.27	0.82*	0.27	0.94	0.27	0.53
005	0.59	2.8	0.13	5.3	0.18	1.66	0.06	0.08	0.09	0.00	-0.04	0.29	0.21	0.29	0.43	0.29	0.85	0.29	1.01	0.29	0.59
006	0.59	2.8	0.03	5.2	0.17	1.64	0.06	0.08	0.09	0.00	-0.04	0.29	0.35^	0.29	0.71^	0.29	0.96^	0.29	1.02	0.29	0.59
007	0.43	2.4	0.00	5.1	0.19	1.65	0.05	0.06	0.06	0.00	-0.03	0.22	0.16	0.22	0.31	0.22	0.63	0.22	0.93	0.22	0.43
008	0.32	2.1	-	-	0.18	1.66	0.04	0.04	0.05	0.00	-0.02	0.16	0.12	0.16	0.24	0.16	0.47	0.16	0.87	0.16	0.32
009	0.47	2.5	-	-	0.19	1.59	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.34	0.23	0.69	0.23	1.00	0.23	0.47
010	0.41	2.4	-	-	0.15	1.56	0.05	0.05	0.06	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	1.03^	0.25^	1.05^	0.25^	0.50^
011	0.42	2.4	-	-	0.16	1.57	0.05	0.05	0.06	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	1.02^	0.25^	1.04^	0.25^	0.50^
012	0.45	2.5	-	-	0.17	1.58	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	1.01^	0.25^	1.03^	0.25^	0.50^
013	0.55	2.7	-	-	0.20	1.59	0.06	0.07	0.08	0.00	-0.04	0.27	0.35^	0.27	0.71^	0.27	1.00^	0.27	1.05	0.27	0.55
014	0.57	2.7	-	-	0.24	1.60	0.06	0.07	0.09	0.00	-0.04	0.28	0.35^	0.28	0.71^	0.28	0.99^	0.28	1.05	0.28	0.57
015	0.26	2.0	-	-	0.23	1.62	0.03	0.03	0.04	0.00	-0.02	0.13	0.10	0.13	0.20	0.13	0.41	0.13	0.83	0.13	0.26
016	0.23	1.9	-	-	0.22	1.63	0.03	0.03	0.03	0.00	-0.02	0.11	0.09	0.11	0.18	0.11	0.36	0.11	0.74	0.11	0.23
017	0.41	2.4	-	-	0.56	1.64	0.05	0.05	0.06	0.00	-0.03	0.21	0.15	0.21	0.31	0.21	0.61	0.21	0.93	0.21	0.41
018	0.60	2.8	-	-	0.31	1.65	0.07	0.08	0.09	0.00	-0.04	0.30	0.35^	0.30	0.71^	0.30	0.95^	0.30	1.02	0.30	0.60
019	0.54	2.7	-	-	0.32	1.67	0.06	0.07	0.08	0.00	-0.04	0.27	0.35^	0.27	0.71^	0.27	0.94^	0.27	0.97	0.27	0.54
020	0.68	3.0	-	-	0.34	1.67	0.07	0.09	0.10	0.00	-0.05	0.34	0.35^	0.34	0.71^	0.34	0.94^	0.34	1.04	0.34	0.68
021	0.75	3.2	-	-	0.36	1.67	0.08	0.10	0.11	0.00	-0.05	0.38	0.35^	0.38	0.71^	0.38	0.94^	0.38	1.08	0.38	0.75
022	0.89	3.5	-	-	0.35	1.66	0.10	0.12	0.13	0.00	-0.06	0.44	0.35^	0.44	0.71^	0.44	1.00	0.44	1.16	0.44	0.87
023	0.79	3.3	-	-	0.39	1.67	0.09	0.10	0.12	0.00	-0.06	0.40	0.35^	0.40	0.71^	0.40	0.95	0.40	1.10	0.40	0.79
024	0.70	3.1	-	-	0.44	1.69	0.08	0.09	0.11	0.00	-0.05	0.35	0.35^	0.35	0.71^	0.35	0.92^	0.35	1.04	0.35	0.70
025	0.66	3.0	-	-	0.40	1.67	0.07	0.09	0.10	0.00	-0.05	0.33	0.24	0.33	0.49	0.33	0.88	0.33	1.03	0.33	0.66
026	0.92	3.6	-	-	0.37	1.65	0.10	0.12	0.14	0.00	-0.06	0.46	0.35^	0.46	0.71^	0.46	1.03	0.46	1.18	0.46	0.89
027	0.72	3.1	-	-	0.40	1.66	0.08	0.09	0.11	0.00	-0.05	0.36	0.35^	0.36	0.71^	0.36	0.94^	0.36	1.07	0.36	0.72
028	0.88	3.5	-	-	0.37	1.65	0.10	0.11	0.13	0.00	-0.06	0.44	0.35^	0.44	0.71^	0.44	1.01	0.44	1.16	0.44	0.87
029	0.69	3.0	-	-	0.39	1.65	0.08	0.09	0.10	0.00	-0.05	0.34	0.35^	0.34	0.71^	0.34	0.95^	0.34	1.07	0.34	0.69
030	0.63	2.9	-	-	0.42	1.65	0.07	0.08	0.09	0.00	-0.04	0.31	0.35^	0.31	0.71^	0.31	0.95^	0.31	1.04	0.31	0.63
031	0.64	2.9	-	-	0.37	1.64	0.07	0.08	0.10	0.00	-0.04	0.32	0.35^	0.32	0.71^	0.32	0.96^	0.32	1.05	0.32	0.64
032	0.74	3.2	-	-	0.35	1.64	0.08	0.10	0.11	0.00	-0.05	0.37	0.35^	0.37	0.71^	0.37	0.96^	0.37	1.10	0.37	0.74
033	0.83	3.4	-	-	0.33	1.64	0.09	0.11	0.12	0.00	-0.06	0.42	0.35^	0.42	0.71^	0.42	0.99	0.42	1.15	0.42	0.83
034	0.74	3.2	-	-	0.32	1.63	0.08	0.10	0.11	0.00	-0.05	0.37	0.35^	0.37	0.71^	0.37	0.97^	0.37	1.11	0.37	0.74
035	0.71	3.1	-	-	0.29	1.63	0.08	0.09	0.11	0.00	-0.05	0.35	0.35^	0.35	0.71^	0.35	0.97^	0.35	1.09	0.35	0.71
036	0.62	2.9	-	-	0.29	1.63	0.07	0.08	0.09	0.00	-0.04	0.31	0.35^	0.31	0.71^	0.31	0.97^	0.31	1.05	0.31	0.62
037	0.62	2.9	-	-	0.29	1.63	0.07	0.08	0.09	0.00	-0.04	0.31	0.35^	0.31	0.71^	0.31	0.97^	0.31	1.05	0.31	0.62

Table J1 cont.: 5yr ARI Wave Runup Results

Loc ID	5yrARI						Wave Setup (m)					Wave Runup Height (m)									
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type$^{\#\#}$					Edge Treatment Type$^{\#\#}$									
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1&2	3&4	5&6	7&8	9&10	1	2	3	4	5	6	7	8	9	10
038	0.52	2.6	-	-	0.26	1.62	0.06	0.07	0.08	0.00	-0.04	0.26	0.35^	0.26	0.71^	0.26	0.98^	0.26	1.00	0.26	0.52
039	0.64	2.9	-	-	0.24	1.60	0.07	0.08	0.10	0.00	-0.04	0.32	0.23	0.32	0.46	0.32	0.91	0.32	1.08	0.32	0.64
040	0.41	2.4	-	-	0.25	1.58	0.05	0.05	0.06	0.00	-0.03	0.21	0.15	0.21	0.31	0.21	0.61	0.21	0.98	0.21	0.41
041	0.41	2.4	-	-	0.21	1.56	0.05	0.05	0.06	0.00	-0.03	0.21	0.15	0.21	0.31	0.21	0.61	0.21	1.00	0.21	0.41
042	0.46	2.5	-	-	0.22	1.54	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.34	0.23	0.68	0.23	1.04	0.23	0.46
043	0.39	2.3	-	-	0.17	1.51	0.04	0.05	0.06	0.00	-0.03	0.20	0.14	0.20	0.29	0.20	0.57	0.20	1.03	0.20	0.39
044	0.29	2.1	-	-	0.16	1.50	0.03	0.04	0.04	0.00	-0.02	0.15	0.11	0.15	0.23	0.15	0.45	0.15	0.93	0.15	0.29
045	0.55	2.7	-	-	0.16	1.50	0.06	0.07	0.08	0.00	-0.04	0.27	0.20	0.27	0.40	0.27	0.80	0.27	1.12	0.27	0.55
046	0.39	2.3	-	-	0.15	1.51	0.04	0.05	0.06	0.00	-0.03	0.20	0.14	0.20	0.29	0.20	0.57	0.20	1.03	0.20	0.39
047	0.48	2.5	-	-	0.19	1.54	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	1.04^	0.25^	1.06^	0.25^	0.50^
048	0.63	2.9	-	-	0.24	1.54	0.07	0.08	0.09	0.00	-0.04	0.31	0.35^	0.31	0.71^	0.31	1.04^	0.31	1.13	0.31	0.63
049	0.58	2.8	-	-	0.25	1.54	0.06	0.08	0.09	0.00	-0.04	0.29	0.35^	0.29	0.71^	0.29	1.04^	0.29	1.10	0.29	0.58
050	0.56	2.7	-	-	0.20	1.52	0.06	0.07	0.08	0.00	-0.04	0.28	0.35^	0.28	0.71^	0.28	1.06^	0.28	1.11	0.28	0.56
051	0.44	2.4	-	-	0.17	1.52	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	1.06^	0.25^	1.08^	0.25^	0.50^
052	0.56	2.7	-	-	0.16	1.49	0.06	0.07	0.08	0.00	-0.04	0.28	0.35^	0.29	0.71^	0.29	1.08^	0.29	1.13	0.29	0.56
053	0.51	2.6	-	-	0.16	1.49	0.06	0.07	0.08	0.00	-0.04	0.26^	0.35^	0.26	0.71^	0.27	1.08^	0.27	1.11	0.26	0.51
054	0.48	2.5	-	-	0.13	1.48	0.05	0.06	0.07	0.00	-0.03	0.26^	0.35^	0.27^	0.71^	0.27^	1.09^	0.27^	1.11^	0.26^	0.50^
055	0.36	2.2	-	-	0.10	1.48	0.04	0.05	0.05	0.00	-0.03	0.18	0.13	0.19	0.26	0.20	0.53	0.20	1.04	0.19	0.36
056	0.44	2.4	-	-	0.14	1.49	0.05	0.06	0.07	0.00	-0.03	0.22	0.16	0.23	0.32	0.23	0.64	0.23	1.07	0.23	0.44
057	0.33	2.2	-	-	0.15	1.50	0.04	0.04	0.05	0.00	-0.02	0.17	0.13	0.17	0.25	0.17	0.51	0.17	1.01	0.17	0.33
058	0.28	2.0	-	-	0.16	1.51	0.03	0.04	0.04	0.00	-0.02	0.14	0.11	0.14	0.21	0.14	0.42	0.14	0.90	0.14	0.28
059	0.37	2.3	-	-	0.20	1.54	0.04	0.05	0.06	0.00	-0.03	0.19	0.14	0.19	0.28	0.19	0.56	0.19	1.00	0.19	0.37
060	0.24	1.9	-	-	0.19	1.55	0.03	0.03	0.04	0.00	-0.02	0.12	0.09	0.12	0.19	0.12	0.37	0.12	0.77	0.12	0.24
061	0.36	2.2	-	-	0.17	1.54	0.04	0.05	0.05	0.00	-0.03	0.18	0.13	0.18	0.26	0.18	0.53	0.18	0.99	0.18	0.36
062	0.38	2.3	-	-	0.15	1.54	0.04	0.05	0.06	0.00	-0.03	0.19	0.14	0.19	0.28	0.19	0.57	0.19	1.00	0.19	0.38
063	0.51	2.6	-	-	0.15	1.55	0.06	0.07	0.08	0.00	-0.04	0.25	0.19	0.25	0.37	0.25	0.74	0.25	1.06	0.25	0.51
064	0.57	2.7	-	-	0.18	1.54	0.06	0.07	0.09	0.00	-0.04	0.28	0.35^	0.28	0.71^	0.28	1.04^	0.28	1.10	0.28	0.57
065	0.50	2.6	-	-	0.19	1.65	0.05	0.06	0.08	0.00	-0.04	0.25^	0.35^	0.25^	0.71^	0.25^	0.95^	0.25^	0.97^	0.25^	0.50^
066	0.61	2.8	0.02	5.1	0.20	1.63	0.07	0.08	0.09	0.00	-0.04	0.30	0.35^	0.30	0.71^	0.30	0.97^	0.30	1.04	0.30	0.61
067	0.57	2.7	0.03	5.2	0.19	1.66	0.06	0.07	0.09	0.00	-0.04	0.28	0.20	0.28	0.41	0.28	0.81	0.28	1.00	0.28	0.57
068	0.61	2.8	0.05	5.2	0.16	1.67	0.07	0.08	0.09	0.00	-0.04	0.30	0.22	0.30	0.44	0.30	0.85	0.30	1.01	0.30	0.61
069	0.48	2.5	0.02	5.1	0.12	1.66	0.05	0.06	0.07	0.00	-0.03	0.24	0.17	0.24	0.35	0.24	0.69	0.24	0.95	0.24	0.48
070	0.49	2.6	0.08	5.2	0.15	1.65	0.05	0.06	0.07	0.00	-0.03	0.25	0.18	0.25	0.36	0.25	0.73	0.25	0.96	0.25	0.49
071	0.38	2.3	0.04	5.2	0.12	1.68	0.04	0.05	0.06	0.00	-0.03	0.19	0.14	0.19	0.28	0.19	0.57	0.19	0.88	0.19	0.38
072	0.40	2.3	0.34	5.6	0.17	1.69	0.04	0.05	0.06	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	0.92^	0.25^	0.94^	0.25^	0.50^
073	0.64	2.9	0.34	5.6	0.17	1.72	0.07	0.08	0.10	0.00	-0.04	0.32	0.35^	0.32	0.71^	0.32	0.89^	0.32	0.98	0.32	0.64
074	0.74	3.2	2.00	8.1	0.16	1.74	0.08	0.10	0.11	0.00	-0.05	1.00*	1.10*	1.00*	1.44*	1.00*	1.61*	1.00*	1.66*	1.00*	1.39*
075	0.28	2.0	-	-	0.21	1.59	0.03	0.04	0.04	0.00	-0.02	0.14	0.11	0.14	0.21	0.14	0.42	0.14	0.90	0.14	0.28
076	0.32	2.1	-	-	0.19	1.56	0.04	0.04	0.05	0.00	-0.02	0.16	0.12	0.16	0.24	0.16	0.47	0.16	0.95	0.16	0.32
077	0.21	1.9	-	-	0.17	1.56	0.02	0.03	0.03	0.00	-0.01	0.10	0.09	0.10	0.17	0.10	0.35	0.10	0.67	0.10	0.21
078	0.34	2.2	-	-	0.17	1.55	0.04	0.04	0.05	0.00	-0.02	0.17	0.13	0.17	0.26	0.17	0.51	0.17	0.97	0.17	0.34
079	0.17	1.8	-	-	0.16	1.55	0.02	0.02	0.03	0.00	-0.01	0.08	0.07	0.08	0.15	0.08	0.30	0.08	0.54	0.08	0.17
080	0.20	1.8	-	-	0.16	1.55	0.02	0.03	0.03	0.00	-0.01	0.10	0.08	0.10	0.16	0.10	0.32	0.10	0.64	0.10	0.20
081	0.20	1.8	-	-	0.16	1.62	0.02	0.03	0.03	0.00	-0.01	0.10	0.08	0.10	0.16	0.10	0.32	0.10	0.64	0.10	0.20
082	0.26	2.0	-	-	0.15	1.54	0.03	0.03	0.04	0.00	-0.02	0.13	0.10	0.13	0.20	0.13	0.41	0.13	0.83	0.13	0.26
083	0.49	2.6	-	-	0.16	1.55	0.05	0.06	0.07	0.00	-0.03	0.25	0.18	0.25	0.36	0.25	0.73	0.25	1.05	0.25	0.49

Table J1 cont.: 5yr ARI Wave Runup Results

Loc ID	5yrARI						Wave Setup (m)					Wave Runup Height (m)									
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type$^{\#\#}$					Edge Treatment Type$^{\#\#}$									
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1&2	3&4	5&6	7&8	9&10	1	2	3	4	5	6	7	8	9	10
084	0.50	2.6	-	-	0.16	1.56	0.05	0.06	0.08	0.00	-0.04	0.25	0.18	0.25	0.37	0.25	0.73	0.25	1.05	0.25	0.50
085	0.31	2.1	-	-	0.18	1.57	0.03	0.04	0.05	0.00	-0.02	0.16	0.12	0.16	0.23	0.16	0.47	0.16	0.94	0.16	0.31
086	0.59	2.8	-	-	0.16	1.56	0.06	0.08	0.09	0.00	-0.04	0.29	0.35^	0.29	0.71^	0.29	1.03^	0.29	1.09	0.29	0.59
087	0.44	2.4	-	-	0.18	1.57	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	1.02^	0.25^	1.04^	0.25^	0.50^
088	0.26	2.0	-	-	0.19	1.57	0.03	0.03	0.04	0.00	-0.02	0.25^	0.35^	0.25^	0.71^	0.25^	1.02^	0.25^	1.04^	0.25^	0.50^
089	0.51	2.6	-	-	0.20	1.58	0.06	0.07	0.08	0.00	-0.04	0.25	0.35^	0.25	0.71^	0.25	1.01^	0.25	1.03	0.25	0.51
090	0.36	2.2	-	-	0.09	1.50	0.04	0.05	0.05	0.00	-0.03	0.18	0.13	0.18	0.26	0.18	0.53	0.18	1.02	0.18	0.36
091	0.33	2.2	-	-	0.08	1.49	0.04	0.04	0.05	0.00	-0.02	0.16	0.13	0.17	0.25	0.17	0.51	0.18	1.02	0.17	0.33
092	0.25	2.0	-	-	0.19	1.49	0.03	0.03	0.04	0.00	-0.02	0.12	0.10	0.13	0.20	0.13	0.40	0.14	0.80	0.13	0.25
093	0.26	2.0	-	-	0.07	1.50	0.03	0.03	0.04	0.00	-0.02	0.13	0.10	0.13	0.20	0.13	0.41	0.13	0.83	0.13	0.26
094	0.42	2.4	-	-	0.46	1.70	0.05	0.05	0.06	0.00	-0.03	0.21	0.16	0.21	0.31	0.21	0.62	0.21	0.89	0.21	0.42
095	0.47	2.5	-	-	0.46	1.69	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.34	0.23	0.69	0.23	0.92	0.23	0.47
096	0.33	2.2	-	-	0.42	1.69	0.04	0.04	0.05	0.00	-0.02	0.17	0.13	0.17	0.25	0.17	0.51	0.17	0.85	0.17	0.33
097	0.28	2.0	-	-	0.37	1.68	0.03	0.04	0.04	0.00	-0.02	0.14	0.11	0.14	0.21	0.14	0.42	0.14	0.83	0.14	0.28
098	0.33	2.2	-	-	0.39	1.70	0.04	0.04	0.05	0.00	-0.02	0.17	0.13	0.17	0.25	0.17	0.51	0.17	0.84	0.17	0.33
099	0.28	2.0	-	-	0.40	1.71	0.03	0.04	0.04	0.00	-0.02	0.14	0.11	0.14	0.21	0.14	0.42	0.14	0.81	0.14	0.28
100	0.36	2.2	-	-	0.43	1.73	0.04	0.05	0.05	0.00	-0.03	0.18	0.13	0.18	0.26	0.18	0.53	0.18	0.83	0.18	0.36
101	0.39	2.3	-	-	0.42	1.71	0.04	0.05	0.06	0.00	-0.03	0.20	0.14	0.20	0.29	0.20	0.57	0.20	0.86	0.20	0.39
102	0.35	2.2	-	-	0.41	1.70	0.04	0.05	0.05	0.00	-0.02	0.18	0.13	0.18	0.26	0.18	0.52	0.18	0.85	0.18	0.35
103	0.35	2.2	-	-	0.43	1.70	0.04	0.05	0.05	0.00	-0.02	0.18	0.13	0.18	0.26	0.18	0.52	0.18	0.85	0.18	0.35
104	0.49	2.6	-	-	0.26	1.65	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	0.95^	0.25^	0.97^	0.25^	0.50^
105	0.50	2.6	-	-	0.23	1.63	0.05	0.06	0.08	0.00	-0.04	0.25^	0.35^	0.25^	0.71^	0.25^	0.97^	0.25^	0.99^	0.25^	0.50^
106	0.52	2.6	-	-	0.22	1.63	0.06	0.07	0.08	0.00	-0.04	0.26	0.35^	0.26	0.71^	0.26	0.97^	0.26	1.00	0.26	0.52
107	0.42	2.4	-	-	0.19	1.63	0.05	0.05	0.06	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	0.97^	0.25^	0.99^	0.25^	0.50^
108	0.39	2.3	-	-	0.18	1.64	0.04	0.05	0.06	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	0.96^	0.25^	0.98^	0.25^	0.50^
109	0.38	2.3	-	-	0.17	1.64	0.04	0.05	0.06	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	0.96^	0.25^	0.98^	0.25^	0.50^
110	0.44	2.4	-	-	0.20	1.64	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	0.96^	0.25^	0.98^	0.25^	0.50^
111	0.38	2.3	-	-	0.21	1.64	0.04	0.05	0.06	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	0.96^	0.25^	0.98^	0.25^	0.50^
112	0.39	2.3	-	-	0.22	1.65	0.04	0.05	0.06	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	0.95^	0.25^	0.97^	0.25^	0.50^
113	0.38	2.3	-	-	0.22	1.65	0.04	0.05	0.06	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	0.95^	0.25^	0.97^	0.25^	0.50^
114	0.38	2.3	-	-	0.24	1.66	0.04	0.05	0.06	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	0.94^	0.25^	0.96^	0.25^	0.50^
115	0.55	2.7	-	-	0.24	1.65	0.06	0.07	0.08	0.00	-0.04	0.27	0.35^	0.27	0.71^	0.27	0.95^	0.27	1.00	0.27	0.55
116	0.48	2.5	-	-	0.27	1.66	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	0.94^	0.25^	0.96^	0.25^	0.50^
117	0.56	2.7	-	-	0.23	1.65	0.06	0.07	0.08	0.00	-0.04	0.28	0.35^	0.28	0.71^	0.28	0.95^	0.28	1.00	0.28	0.56
118	0.53	2.6	-	-	0.23	1.64	0.06	0.07	0.08	0.00	-0.04	0.27	0.35^	0.27	0.71^	0.27	0.96^	0.27	0.99	0.27	0.53
119	0.38	2.3	-	-	0.24	1.64	0.04	0.05	0.06	0.00	-0.03	0.25^	0.35^	0.25^	0.71^	0.25^	0.96^	0.25^	0.98^	0.25^	0.50^

Table J2: 100yr ARI Wave Runup Results

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only
% Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to High Tide
^ Boat wave conditions adopted in run-up calculation
* Swell wave conditions adopted in run-up calculation

100-year ARI Offshore Storm Tide is **1.45mAHD**
**** Mean Sea Level Rise** of **0.3m included** within Table
Freeboard (0.3m) not included

Edge Treatment Types
1. 1 in 20 Natural Slope - 1.5mAHD crest
2. 1 in 20 Natural Slope - 2.5mAHD crest
3. 1 in 10 Beach Face - 1.5mAHD crest
4. 1 in 10 Beach Face - 2.5mAHD crest
5. 1 in 5 Embankment - 1.5mAHD crest
6. 1 in 5 Embankment - 2.5mAHD crest
7. 1 in 2 Seawall - 1.5mAHD crest
8. 1 in 2 Seawall - 2.5mAHD crest
9. Vertical Wall - 1.5mAHD crest
10. Vertical Wall - 2.5mAHD crest

Loc ID	100yrARI						Wave Setup (m)					Wave Runup Height (m)									
	Sea		Swell		Local Wind Setup% (m)	Design Water Level** (mAHD)	Edge Treatment Type ##					Edge Treatment Type ##									
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1&2	3&4	5&6	7&8	9&10	1	2	3	4	5	6	7	8	9	10
001	1.15	4.2	3.51	10.4	0.26	2.06	0.13	0.15	0.17	0.00	-0.08	1.75*	1.83*	1.75*	2.03*	1.75*	2.13*	1.75*	2.16*	1.75*	2.01*
002	0.89	3.5	0.28	5.5	0.28	2.08	0.10	0.12	0.13	0.00	-0.06	0.44	0.33	0.44	0.58	0.44	0.73	0.44	0.81	0.44	0.66
003	0.85	3.4	1.60	7.5	0.32	2.09	0.09	0.11	0.13	0.00	-0.06	0.80*	0.87*	0.80*	1.05*	0.80*	1.14*	0.80*	1.16*	0.80*	1.02*
004	0.69	3.0	0.37	5.7	0.27	1.95	0.08	0.09	0.10	0.00	-0.05	0.34	0.35*	0.34	0.59*	0.34	0.71	0.34	0.81	0.34	0.62
005	0.76	3.2	0.17	5.4	0.29	1.89	0.08	0.10	0.11	0.00	-0.05	0.38	0.28	0.38	0.56	0.38	0.79	0.38	0.90	0.38	0.69
006	0.75	3.2	0.04	5.2	0.27	1.86	0.08	0.10	0.11	0.00	-0.05	0.38	0.35^	0.38	0.66^	0.38	0.80	0.38	0.92	0.38	0.70
007	0.53	2.6	0.01	5.1	0.29	1.88	0.06	0.07	0.08	0.00	-0.04	0.27	0.19	0.27	0.38	0.27	0.67	0.27	0.79	0.27	0.53
008	0.38	2.3	-	-	0.29	1.89	0.04	0.05	0.06	0.00	-0.03	0.19	0.14	0.19	0.28	0.19	0.57	0.19	0.71	0.19	0.38
009	0.59	2.8	-	-	0.29	1.84	0.06	0.08	0.09	0.00	-0.04	0.29	0.21	0.29	0.43	0.29	0.73	0.29	0.86	0.29	0.59
010	0.48	2.5	-	-	0.24	1.83	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.68^	0.25^	0.80^	0.25^	0.82^	0.25^	0.50^
011	0.49	2.6	-	-	0.25	1.84	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.68^	0.25^	0.80^	0.25^	0.81^	0.25^	0.50^
012	0.56	2.7	-	-	0.28	1.87	0.06	0.07	0.08	0.00	-0.04	0.28	0.35^	0.28	0.66^	0.28	0.77^	0.28	0.82	0.28	0.56
013	0.71	3.1	-	-	0.33	1.88	0.08	0.09	0.11	0.00	-0.05	0.35	0.35^	0.35	0.65^	0.35	0.77	0.35	0.88	0.35	0.67
014	0.74	3.2	-	-	0.38	1.89	0.08	0.10	0.11	0.00	-0.05	0.37	0.35^	0.37	0.64^	0.37	0.78	0.37	0.89	0.37	0.68
015	0.32	2.1	-	-	0.37	1.91	0.04	0.04	0.05	0.00	-0.02	0.16	0.12	0.16	0.24	0.16	0.47	0.16	0.66	0.16	0.32
016	0.26	2.0	-	-	0.36	1.93	0.03	0.03	0.04	0.00	-0.02	0.13	0.10	0.13	0.20	0.13	0.41	0.13	0.61	0.13	0.26
017	0.51	2.6	-	-	0.65	1.96	0.06	0.07	0.08	0.00	-0.04	0.25	0.19	0.25	0.37	0.25	0.61	0.25	0.71	0.25	0.51
018	0.70	3.1	-	-	0.51	1.98	0.08	0.09	0.11	0.00	-0.05	0.35	0.35^	0.35	0.59^	0.35	0.70	0.35	0.79	0.35	0.61
019	0.65	2.9	-	-	0.53	2.01	0.07	0.08	0.10	0.00	-0.05	0.33	0.35^	0.33	0.57^	0.33	0.66^	0.33	0.74	0.33	0.57
020	0.87	3.5	-	-	0.55	2.01	0.10	0.11	0.13	0.00	-0.06	0.44	0.35^	0.44	0.60	0.44	0.77	0.44	0.86	0.44	0.68
021	0.96	3.7	-	-	0.58	2.02	0.11	0.12	0.14	0.00	-0.07	0.48	0.36	0.48	0.65	0.48	0.81	0.48	0.89	0.48	0.72
022	1.14	4.1	-	-	0.57	2.00	0.13	0.15	0.17	0.00	-0.08	0.57	0.44	0.57	0.75	0.57	0.92	0.57	1.00	0.57	0.83
023	1.00	3.8	-	-	0.63	2.02	0.11	0.13	0.15	0.00	-0.07	0.50	0.38	0.50	0.67	0.50	0.83	0.50	0.91	0.50	0.75
024	0.87	3.5	-	-	0.72	2.05	0.10	0.11	0.13	0.00	-0.06	0.44	0.35^	0.44	0.59	0.44	0.74	0.44	0.82	0.44	0.66
025	0.81	3.3	-	-	0.64	2.01	0.09	0.11	0.12	0.00	-0.06	0.41	0.30	0.41	0.56	0.41	0.73	0.41	0.83	0.41	0.65
026	1.15	4.2	-	-	0.59	1.98	0.13	0.15	0.17	0.00	-0.08	0.58	0.45	0.58	0.77	0.58	0.94	0.58	1.02	0.58	0.84
027	0.89	3.5	-	-	0.65	2.00	0.10	0.12	0.13	0.00	-0.06	0.44	0.35^	0.44	0.61	0.44	0.78	0.44	0.87	0.44	0.70
028	1.10	4.0	-	-	0.60	1.98	0.12	0.14	0.17	0.00	-0.08	0.55	0.42	0.55	0.73	0.55	0.91	0.55	1.00	0.55	0.82
029	0.85	3.4	-	-	0.64	1.98	0.09	0.11	0.13	0.00	-0.06	0.42	0.35^	0.42	0.59	0.42	0.77	0.42	0.87	0.42	0.69
030	0.77	3.2	-	-	0.68	1.97	0.08	0.10	0.12	0.00	-0.05	0.38	0.35^	0.38	0.59^	0.38	0.74	0.38	0.84	0.38	0.65
031	0.81	3.3	-	-	0.61	1.96	0.09	0.11	0.12	0.00	-0.06	0.41	0.35^	0.41	0.60^	0.41	0.77	0.41	0.87	0.41	0.68
032	0.93	3.6	-	-	0.57	1.96	0.10	0.12	0.14	0.00	-0.07	0.46	0.35^	0.46	0.65	0.46	0.83	0.46	0.93	0.46	0.74
033	1.02	3.8	-	-	0.53	1.95	0.11	0.13	0.15	0.00	-0.07	0.51	0.38	0.51	0.70	0.51	0.88	0.51	0.98	0.51	0.79
034	0.92	3.6	-	-	0.52	1.93	0.10	0.12	0.14	0.00	-0.06	0.46	0.35^	0.46	0.65	0.46	0.85	0.46	0.95	0.46	0.75
035	0.86	3.5	-	-	0.47	1.92	0.09	0.11	0.13	0.00	-0.06	0.43	0.35^	0.43	0.63	0.43	0.82	0.43	0.93	0.43	0.72
036	0.73	3.1	-	-	0.47	1.94	0.08	0.09	0.11	0.00	-0.05	0.37	0.35^	0.37	0.61^	0.37	0.74	0.37	0.84	0.37	0.65
037	0.71	3.1	-	-	0.47	1.95	0.08	0.09	0.11	0.00	-0.05	0.35	0.35^	0.35	0.61^	0.35	0.72	0.35	0.82	0.35	0.63

Table J2 cont.: 100yr ARI Wave Runup Results

Loc ID	100yrARI						Wave Setup (m)					Wave Runup Height (m)									
	Sea		Swell		Local Wind Setup% (m)	Design Water Level** (mAHD)	Edge Treatment Type ##					Edge Treatment Type ##									
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1&2	3&4	5&6	7&8	9&10	1	2	3	4	5	6	7	8	9	10
038	0.63	2.9	-	-	0.43	1.92	0.07	0.08	0.09	0.00	-0.04	0.31	0.35^	0.31	0.63^	0.31	0.73^	0.31	0.81	0.31	0.61
039	0.80	3.3	-	-	0.40	1.89	0.09	0.10	0.12	0.00	-0.06	0.40	0.29	0.40	0.59	0.40	0.81	0.40	0.92	0.40	0.71
040	0.51	2.6	-	-	0.41	1.86	0.06	0.07	0.08	0.00	-0.04	0.25	0.19	0.25	0.37	0.25	0.68	0.25	0.80	0.25	0.51
041	0.51	2.6	-	-	0.34	1.82	0.06	0.07	0.08	0.00	-0.04	0.25	0.19	0.25	0.37	0.25	0.70	0.25	0.83	0.25	0.51
042	0.59	2.8	-	-	0.35	1.79	0.06	0.08	0.09	0.00	-0.04	0.29	0.21	0.29	0.43	0.29	0.76	0.29	0.90	0.29	0.59
043	0.51	2.6	-	-	0.28	1.74	0.06	0.07	0.08	0.00	-0.04	0.25	0.19	0.25	0.37	0.25	0.74	0.25	0.90	0.25	0.51
044	0.36	2.2	-	-	0.25	1.70	0.04	0.05	0.05	0.00	-0.03	0.18	0.13	0.18	0.26	0.18	0.53	0.18	0.86	0.18	0.36
045	0.71	3.1	-	-	0.25	1.70	0.08	0.09	0.11	0.00	-0.05	0.35	0.26	0.35	0.52	0.35	0.88	0.35	1.03	0.35	0.71
046	0.45	2.5	-	-	0.22	1.72	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.34	0.23	0.67	0.23	0.89	0.23	0.45
047	0.61	2.8	-	-	0.30	1.77	0.07	0.08	0.09	0.00	-0.04	0.31	0.35^	0.31	0.71^	0.31	0.85^	0.31	0.92	0.31	0.61
048	0.82	3.4	-	-	0.38	1.79	0.09	0.11	0.12	0.00	-0.06	0.41	0.35^	0.41	0.71^	0.41	0.89	0.41	1.02	0.41	0.77
049	0.71	3.1	-	-	0.42	1.77	0.08	0.09	0.11	0.00	-0.05	0.35	0.35^	0.35	0.71^	0.35	0.85^	0.35	0.98	0.35	0.71
050	0.70	3.1	-	-	0.31	1.74	0.08	0.09	0.11	0.00	-0.05	0.35	0.35^	0.35	0.71^	0.35	0.88^	0.35	1.00	0.35	0.70
051	0.52	2.6	-	-	0.26	1.74	0.06	0.07	0.08	0.00	-0.04	0.26	0.35^	0.26	0.71^	0.26	0.88^	0.26	0.90	0.26	0.52
052	0.71	3.1	-	-	0.26	1.69	0.08	0.09	0.11	0.00	-0.05	0.35	0.35^	0.35	0.71^	0.35	0.92^	0.35	1.04	0.35	0.71
053	0.64	2.9	-	-	0.25	1.68	0.07	0.08	0.10	0.00	-0.04	0.32	0.35^	0.32	0.71^	0.32	0.93^	0.32	1.02	0.32	0.64
054	0.60	2.8	-	-	0.20	1.67	0.07	0.08	0.09	0.00	-0.04	0.30	0.35^	0.30	0.71^	0.30	0.94^	0.30	1.00	0.30	0.60
055	0.40	2.3	-	-	0.15	1.67	0.04	0.05	0.06	0.00	-0.03	0.20	0.15	0.20	0.29	0.20	0.58	0.20	0.90	0.20	0.40
056	0.57	2.7	-	-	0.21	1.69	0.06	0.07	0.09	0.00	-0.04	0.28	0.20	0.28	0.41	0.28	0.81	0.28	0.97	0.28	0.57
057	0.40	2.3	-	-	0.23	1.70	0.04	0.05	0.06	0.00	-0.03	0.20	0.15	0.20	0.29	0.20	0.58	0.20	0.88	0.20	0.40
058	0.35	2.2	-	-	0.26	1.74	0.04	0.05	0.05	0.00	-0.02	0.18	0.13	0.18	0.26	0.18	0.52	0.18	0.82	0.18	0.35
059	0.45	2.5	-	-	0.32	1.79	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.34	0.23	0.67	0.23	0.83	0.23	0.45
060	0.30	2.1	-	-	0.31	1.81	0.03	0.04	0.05	0.00	-0.02	0.15	0.11	0.15	0.23	0.15	0.46	0.15	0.73	0.15	0.30
061	0.45	2.5	-	-	0.27	1.82	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.34	0.23	0.67	0.23	0.80	0.23	0.45
062	0.50	2.6	-	-	0.24	1.79	0.05	0.06	0.08	0.00	-0.04	0.25	0.18	0.25	0.37	0.25	0.72	0.25	0.85	0.25	0.50
063	0.64	2.9	-	-	0.24	1.82	0.07	0.08	0.10	0.00	-0.04	0.32	0.23	0.32	0.46	0.32	0.77	0.32	0.90	0.32	0.64
064	0.72	3.1	-	-	0.28	1.81	0.08	0.09	0.11	0.00	-0.05	0.36	0.35^	0.36	0.70^	0.36	0.82^	0.36	0.95	0.36	0.71
065	0.62	2.9	-	-	0.30	1.88	0.07	0.08	0.09	0.00	-0.04	0.31	0.35^	0.31	0.65^	0.31	0.76^	0.31	0.84	0.31	0.62
066	0.76	3.2	0.03	5.2	0.31	1.85	0.08	0.10	0.11	0.00	-0.05	0.38	0.35^	0.38	0.67^	0.38	0.81	0.38	0.93	0.38	0.71
067	0.71	3.1	0.05	5.2	0.31	1.89	0.08	0.09	0.11	0.00	-0.05	0.35	0.26	0.35	0.52	0.35	0.76	0.35	0.87	0.35	0.66
068	0.75	3.2	0.06	5.2	0.25	1.87	0.08	0.10	0.11	0.00	-0.05	0.38	0.28	0.38	0.55	0.38	0.79	0.38	0.91	0.38	0.69
069	0.55	2.7	0.02	5.1	0.19	1.85	0.06	0.07	0.08	0.00	-0.04	0.27	0.20	0.27	0.40	0.27	0.70	0.27	0.83	0.27	0.55
070	0.60	2.8	0.10	5.3	0.23	1.86	0.07	0.08	0.09	0.00	-0.04	0.30	0.22	0.30	0.43	0.30	0.72	0.30	0.84	0.30	0.60
071	0.44	2.4	0.06	5.2	0.18	1.89	0.05	0.06	0.07	0.00	-0.03	0.22	0.16	0.22	0.32	0.22	0.62	0.22	0.74	0.22	0.44
072	0.50	2.6	0.45	5.8	0.27	1.93	0.05	0.06	0.08	0.00	-0.04	0.25^	0.39*	0.25^	0.63*	0.25^	0.72^	0.25^	0.73^	0.25^	0.50^
073	0.81	3.3	0.45	5.8	0.27	1.96	0.09	0.11	0.12	0.00	-0.06	0.41	0.39*	0.41	0.61*	0.41	0.77	0.41	0.87	0.41	0.68
074	0.93	3.6	2.63	9.0	0.26	1.97	0.10	0.12	0.14	0.00	-0.07	1.31*	1.38*	1.31*	1.63*	1.31*	1.75*	1.31*	1.79*	1.31*	1.60*
075	0.36	2.2	-	-	0.34	1.87	0.04	0.05	0.05	0.00	-0.03	0.18	0.13	0.18	0.26	0.18	0.53	0.18	0.71	0.18	0.36
076	0.39	2.3	-	-	0.30	1.83	0.04	0.05	0.06	0.00	-0.03	0.19	0.14	0.19	0.29	0.19	0.57	0.19	0.76	0.19	0.39
077	0.24	1.9	-	-	0.28	1.83	0.03	0.03	0.04	0.00	-0.02	0.12	0.09	0.12	0.19	0.12	0.37	0.12	0.69	0.12	0.24
078	0.45	2.5	-	-	0.28	1.80	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.34	0.23	0.67	0.23	0.82	0.23	0.45
079	0.20	1.8	-	-	0.26	1.81	0.02	0.03	0.03	0.00	-0.01	0.10	0.08	0.10	0.16	0.10	0.32	0.10	0.64	0.10	0.20
080	0.27	2.0	-	-	0.26	1.82	0.03	0.04	0.04	0.00	-0.02	0.14	0.10	0.14	0.21	0.14	0.42	0.14	0.71	0.14	0.27
081	0.28	2.0	-	-	0.26	1.81	0.03	0.04	0.04	0.00	-0.02	0.14	0.11	0.14	0.21	0.14	0.42	0.14	0.72	0.14	0.28
082	0.31	2.1	-	-	0.24	1.79	0.03	0.04	0.05	0.00	-0.02	0.16	0.12	0.16	0.23	0.16	0.47	0.16	0.75	0.16	0.31
083	0.62	2.9	-	-	0.25	1.80	0.07	0.08	0.09	0.00	-0.04	0.31	0.23	0.31	0.46	0.31	0.77	0.31	0.90	0.31	0.62

Table J2 cont.: 100yr ARI Wave Runup Results

Loc ID	100yrARI						Wave Setup (m)					Wave Runup Height (m)									
	Sea		Swell		Local Wind Setup% (m)	Design Water Level** (mAHD)	Edge Treatment Type ##					Edge Treatment Type ##									
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1&2	3&4	5&6	7&8	9&10	1	2	3	4	5	6	7	8	9	10
084	0.62	2.9	-	-	0.27	1.82	0.07	0.08	0.09	0.00	-0.04	0.31	0.23	0.31	0.46	0.31	0.76	0.31	0.89	0.31	0.62
085	0.40	2.3	-	-	0.30	1.84	0.04	0.05	0.06	0.00	-0.03	0.20	0.15	0.20	0.29	0.20	0.58	0.20	0.76	0.20	0.40
086	0.74	3.2	-	-	0.27	1.83	0.08	0.10	0.11	0.00	-0.05	0.37	0.35^	0.37	0.68^	0.37	0.82	0.37	0.94	0.37	0.71
087	0.53	2.6	-	-	0.30	1.84	0.06	0.07	0.08	0.00	-0.04	0.27	0.35^	0.27	0.68^	0.27	0.80^	0.27	0.83	0.27	0.53
088	0.31	2.1	-	-	0.30	1.83	0.03	0.04	0.05	0.00	-0.02	0.25^	0.35^	0.25^	0.68^	0.25^	0.80^	0.25^	0.82^	0.25^	0.50^
089	0.63	2.9	-	-	0.31	1.86	0.07	0.08	0.09	0.00	-0.04	0.31	0.35^	0.31	0.66^	0.31	0.78^	0.31	0.86	0.31	0.63
090	0.47	2.5	-	-	0.13	1.69	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.34	0.23	0.69	0.23	0.92	0.23	0.47
091	0.42	2.4	-	-	0.12	1.68	0.05	0.05	0.06	0.00	-0.03	0.21	0.16	0.21	0.31	0.21	0.62	0.21	0.90	0.21	0.42
092	0.31	2.1	-	-	0.20	1.67	0.03	0.04	0.05	0.00	-0.02	0.16	0.12	0.16	0.23	0.16	0.47	0.16	0.86	0.16	0.31
093	0.33	2.2	-	-	0.10	1.68	0.04	0.04	0.05	0.00	-0.02	0.17	0.13	0.17	0.25	0.17	0.51	0.17	0.86	0.17	0.33
094	0.55	2.7	-	-	0.73	2.07	0.06	0.07	0.08	0.00	-0.04	0.27	0.20	0.27	0.40	0.27	0.56	0.27	0.64	0.27	0.49
095	0.58	2.8	-	-	0.73	2.06	0.06	0.08	0.09	0.00	-0.04	0.29	0.21	0.29	0.43	0.29	0.58	0.29	0.67	0.29	0.51
096	0.41	2.4	-	-	0.68	2.04	0.05	0.05	0.06	0.00	-0.03	0.21	0.15	0.21	0.31	0.21	0.51	0.21	0.60	0.21	0.41
097	0.33	2.2	-	-	0.61	2.03	0.04	0.04	0.05	0.00	-0.02	0.17	0.13	0.17	0.25	0.17	0.48	0.17	0.56	0.17	0.33
098	0.40	2.3	-	-	0.63	2.06	0.04	0.05	0.06	0.00	-0.03	0.20	0.15	0.20	0.29	0.20	0.49	0.20	0.57	0.20	0.40
099	0.32	2.1	-	-	0.64	2.09	0.04	0.04	0.05	0.00	-0.02	0.16	0.12	0.16	0.24	0.16	0.43	0.16	0.51	0.16	0.32
100	0.47	2.5	-	-	0.69	2.12	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.34	0.23	0.49	0.23	0.56	0.23	0.43
101	0.50	2.6	-	-	0.67	2.09	0.05	0.06	0.08	0.00	-0.04	0.25	0.18	0.25	0.37	0.25	0.52	0.25	0.60	0.25	0.46
102	0.44	2.4	-	-	0.67	2.07	0.05	0.06	0.07	0.00	-0.03	0.22	0.16	0.22	0.32	0.22	0.50	0.22	0.59	0.22	0.44
103	0.45	2.5	-	-	0.70	2.07	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.34	0.23	0.51	0.23	0.59	0.23	0.44
104	0.61	2.8	-	-	0.42	1.96	0.07	0.08	0.09	0.00	-0.04	0.31	0.35^	0.31	0.60^	0.31	0.70^	0.31	0.77	0.31	0.58
105	0.62	2.9	-	-	0.37	1.95	0.07	0.08	0.09	0.00	-0.04	0.31	0.35^	0.31	0.61^	0.31	0.71^	0.31	0.78	0.31	0.59
106	0.64	2.9	-	-	0.34	1.94	0.07	0.08	0.10	0.00	-0.04	0.32	0.35^	0.32	0.61^	0.32	0.71^	0.32	0.80	0.32	0.60
107	0.53	2.6	-	-	0.30	1.94	0.06	0.07	0.08	0.00	-0.04	0.27	0.35^	0.27	0.61^	0.27	0.71^	0.27	0.74	0.27	0.53
108	0.48	2.5	-	-	0.29	1.95	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.61^	0.25^	0.71^	0.25^	0.72^	0.25^	0.50^
109	0.47	2.5	-	-	0.28	1.96	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.60^	0.25^	0.70^	0.25^	0.71^	0.25^	0.50^
110	0.58	2.8	-	-	0.31	1.96	0.06	0.08	0.09	0.00	-0.04	0.29	0.35^	0.29	0.60^	0.29	0.70^	0.29	0.75	0.29	0.56
111	0.47	2.5	-	-	0.33	1.95	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.61^	0.25^	0.71^	0.25^	0.72^	0.25^	0.50^
112	0.46	2.5	-	-	0.35	1.96	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.60^	0.25^	0.70^	0.25^	0.71^	0.25^	0.50^
113	0.45	2.5	-	-	0.36	1.97	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.59^	0.25^	0.69^	0.25^	0.70^	0.25^	0.50^
114	0.49	2.6	-	-	0.38	2.00	0.05	0.06	0.07	0.00	-0.03	0.25^	0.35^	0.25^	0.57^	0.25^	0.66^	0.25^	0.68^	0.25^	0.50^
115	0.72	3.1	-	-	0.38	1.98	0.08	0.09	0.11	0.00	-0.05	0.36	0.35^	0.36	0.59^	0.36	0.71	0.36	0.80	0.36	0.62
116	0.62	2.9	-	-	0.43	2.00	0.07	0.08	0.09	0.00	-0.04	0.31	0.35^	0.31	0.57^	0.31	0.66^	0.31	0.74	0.31	0.56
117	0.70	3.1	-	-	0.37	1.97	0.08	0.09	0.11	0.00	-0.05	0.35	0.35^	0.35	0.59^	0.35	0.70	0.35	0.80	0.35	0.62
118	0.68	3.0	-	-	0.36	1.95	0.07	0.09	0.10	0.00	-0.05	0.34	0.35^	0.34	0.61^	0.34	0.71^	0.34	0.81	0.34	0.62
119	0.50	2.6	-	-	0.39	1.97	0.05	0.06	0.08	0.00	-0.04	0.25^	0.35^	0.25^	0.59^	0.25^	0.69^	0.25^	0.70^	0.25^	0.50^

Table J3: PMF ARI Wave Runup Results

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only
$^{\%}$ Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to High Tide
^ Boat wave conditions adopted in run-up calculation
* Swell wave conditions adopted in run-up calculation

PMF Offshore Storm Tide is **1.76mAHD**
**** Mean Sea Level Rise** of **0.3m included** within Table
Freeboard (0.3m) not included

$^{\#\#}$ **Edge Treatment Types**
1. 1 in 20 Natural Slope - 1.5mAHD crest
2. 1 in 20 Natural Slope - 2.5mAHD crest
3. 1 in 10 Beach Face - 1.5mAHD crest
4. 1 in 10 Beach Face - 2.5mAHD crest
5. 1 in 5 Embankment - 1.5mAHD crest
6. 1 in 5 Embankment - 2.5mAHD crest
7. 1 in 2 Seawall - 1.5mAHD crest
8. 1 in 2 Seawall - 2.5mAHD crest
9. Vertical Wall - 1.5mAHD crest
10. Vertical Wall - 2.5mAHD crest

Loc ID	PMF						Wave Setup (m)					Wave Runup Height (m)									
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type $^{\#\#}$					Edge Treatment Type $^{\#\#}$									
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1&2	3&4	5&6	7&8	9&10	1	2	3	4	5	6	7	8	9	10
001	1.52	5.1	4.82	12.3	0.47	2.37	0.17	0.20	0.23	0.00	-0.11	2.41*	2.47*	2.41*	2.53*	2.41*	2.56*	2.41*	2.57*	2.41*	2.52*
002	1.15	4.2	0.34	5.6	0.50	2.38	0.13	0.15	0.17	0.00	-0.08	0.58	0.55	0.58	0.63	0.58	0.67	0.58	0.69	0.58	0.65
003	1.08	4.0	2.20	8.4	0.57	2.37	0.12	0.14	0.16	0.00	-0.08	1.10*	1.13*	1.10*	1.19*	1.10*	1.22*	1.10*	1.23*	1.10*	1.19*
004	0.92	3.6	0.51	5.9	0.48	2.21	0.10	0.12	0.14	0.00	-0.06	0.46	0.37*	0.46	0.56	0.46	0.66	0.46	0.71	0.46	0.61
005	1.02	3.8	0.26	5.5	0.52	2.15	0.11	0.13	0.15	0.00	-0.07	0.51	0.40	0.51	0.63	0.51	0.75	0.51	0.81	0.51	0.69
006	0.98	3.7	0.07	5.2	0.50	2.15	0.11	0.13	0.15	0.00	-0.07	0.49	0.37	0.49	0.61	0.49	0.73	0.49	0.79	0.49	0.67
007	0.67	3.0	0.01	5.1	0.53	2.17	0.07	0.09	0.10	0.00	-0.05	0.33	0.25	0.33	0.44	0.33	0.56	0.33	0.62	0.33	0.50
008	0.47	2.5	-	-	0.53	2.19	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.33	0.23	0.44	0.23	0.50	0.23	0.39
009	0.79	3.3	-	-	0.52	2.13	0.09	0.10	0.12	0.00	-0.06	0.40	0.29	0.40	0.52	0.40	0.65	0.40	0.71	0.40	0.58
010	0.57	2.7	-	-	0.43	2.12	0.06	0.07	0.09	0.00	-0.04	0.29	0.35^	0.29	0.50^	0.29	0.57^	0.29	0.61	0.29	0.48
011	0.60	2.8	-	-	0.45	2.15	0.07	0.08	0.09	0.00	-0.04	0.30	0.35^	0.30	0.48^	0.30	0.54^	0.30	0.60	0.30	0.48
012	0.73	3.1	-	-	0.50	2.19	0.08	0.09	0.11	0.00	-0.05	0.37	0.34^	0.37	0.46	0.37	0.57	0.37	0.63	0.37	0.52
013	0.94	3.6	-	-	0.58	2.22	0.10	0.12	0.14	0.00	-0.07	0.47	0.37	0.47	0.57	0.47	0.66	0.47	0.71	0.47	0.62
014	0.97	3.7	-	-	0.70	2.24	0.11	0.13	0.15	0.00	-0.07	0.48	0.40	0.48	0.58	0.48	0.67	0.48	0.71	0.48	0.62
015	0.41	2.3	-	-	0.66	2.27	0.05	0.05	0.06	0.00	-0.03	0.21	0.15	0.21	0.28	0.21	0.36	0.21	0.40	0.21	0.32
016	0.32	2.1	-	-	0.64	2.32	0.04	0.04	0.05	0.00	-0.02	0.16	0.12	0.16	0.22	0.16	0.28	0.16	0.31	0.16	0.25
017	0.65	2.9	-	-	0.85	2.36	0.07	0.08	0.10	0.00	-0.05	0.33	0.27	0.33	0.37	0.33	0.42	0.33	0.45	0.33	0.40
018	0.87	3.5	-	-	0.89	2.41	0.10	0.11	0.13	0.00	-0.06	0.44	0.41	0.44	0.47	0.44	0.50	0.44	0.52	0.44	0.49
019	0.79	3.3	-	-	0.93	2.46	0.09	0.10	0.12	0.00	-0.06	0.40	0.39	0.40	0.42	0.40	0.43	0.40	0.44	0.40	0.42
020	1.16	4.2	-	-	0.97	2.46	0.13	0.15	0.17	0.00	-0.08	0.58	0.58	0.58	0.61	0.58	0.62	0.58	0.63	0.58	0.61
021	1.27	4.5	-	-	1.03	2.48	0.14	0.17	0.19	0.00	-0.09	0.63	0.64	0.63	0.65	0.63	0.66	0.63	0.66	0.63	0.66
022	1.54	5.1	-	-	1.00	2.44	0.17	0.20	0.23	0.00	-0.11	0.77	0.77	0.77	0.81	0.77	0.83	0.77	0.84	0.77	0.81
023	1.34	4.6	-	-	1.11	2.48	0.15	0.17	0.20	0.00	-0.09	0.67	0.68	0.67	0.69	0.67	0.70	0.67	0.70	0.67	0.69
024	1.13	4.1	-	-	1.27	2.53	0.12	0.15	0.17	0.00	-0.08	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
025	1.04	3.9	-	-	1.14	2.46	0.11	0.14	0.16	0.00	-0.07	0.52	0.52	0.52	0.54	0.52	0.56	0.52	0.56	0.52	0.55
026	1.52	5.1	-	-	1.04	2.40	0.17	0.20	0.23	0.00	-0.11	0.76	0.75	0.76	0.81	0.76	0.84	0.76	0.86	0.76	0.82
027	1.15	4.2	-	-	1.15	2.44	0.13	0.15	0.17	0.00	-0.08	0.58	0.57	0.58	0.61	0.58	0.63	0.58	0.64	0.58	0.62
028	1.44	4.9	-	-	1.07	2.39	0.16	0.19	0.22	0.00	-0.10	0.72	0.71	0.72	0.78	0.72	0.81	0.72	0.83	0.72	0.79
029	1.08	4.0	-	-	1.12	2.40	0.12	0.14	0.16	0.00	-0.08	0.54	0.52	0.54	0.58	0.54	0.62	0.54	0.63	0.54	0.60
030	1.00	3.8	-	-	1.19	2.38	0.11	0.13	0.15	0.00	-0.07	0.50	0.47	0.50	0.55	0.50	0.59	0.50	0.61	0.50	0.57
031	1.04	3.9	-	-	1.07	2.36	0.11	0.14	0.16	0.00	-0.07	0.52	0.48	0.52	0.58	0.52	0.62	0.52	0.65	0.52	0.60
032	1.22	4.3	-	-	1.02	2.36	0.13	0.16	0.18	0.00	-0.09	0.61	0.58	0.61	0.67	0.61	0.72	0.61	0.74	0.61	0.69
033	1.31	4.5	-	-	0.93	2.34	0.14	0.17	0.20	0.00	-0.09	0.66	0.62	0.66	0.72	0.66	0.78	0.66	0.80	0.66	0.75
034	1.18	4.2	-	-	0.91	2.31	0.13	0.15	0.18	0.00	-0.08	0.59	0.54	0.59	0.67	0.59	0.73	0.59	0.76	0.59	0.69
035	1.06	3.9	-	-	0.84	2.29	0.12	0.14	0.16	0.00	-0.07	0.53	0.47	0.53	0.61	0.53	0.68	0.53	0.72	0.53	0.64
036	0.87	3.5	-	-	0.84	2.32	0.10	0.11	0.13	0.00	-0.06	0.44	0.38	0.44	0.50	0.44	0.56	0.44	0.60	0.44	0.53
037	0.85	3.4	-	-	0.84	2.34	0.09	0.11	0.13	0.00	-0.06	0.42	0.37	0.42	0.48	0.42	0.54	0.42	0.57	0.42	0.51

Table J3 cont.: PMF Wave Runup Results

Loc ID	PMF						Wave Setup (m)					Wave Runup Height (m)									
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type $^{\#\#}$					Edge Treatment Type $^{\#\#}$									
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1&2	3&4	5&6	7&8	9&10	1	2	3	4	5	6	7	8	9	10
038	0.77	3.2	-	-	0.78	2.29	0.08	0.10	0.12	0.00	-0.05	0.38	0.31^	0.38	0.46	0.38	0.53	0.38	0.57	0.38	0.50
039	1.03	3.9	-	-	0.72	2.24	0.11	0.13	0.15	0.00	-0.07	0.52	0.44	0.52	0.61	0.52	0.70	0.52	0.74	0.52	0.65
040	0.68	3.0	-	-	0.73	2.18	0.07	0.09	0.10	0.00	-0.05	0.34	0.25	0.34	0.44	0.34	0.55	0.34	0.62	0.34	0.50
041	0.65	2.9	-	-	0.60	2.11	0.07	0.08	0.10	0.00	-0.05	0.33	0.23	0.33	0.44	0.33	0.58	0.33	0.66	0.33	0.52
042	0.76	3.2	-	-	0.62	2.05	0.08	0.10	0.11	0.00	-0.05	0.38	0.28	0.38	0.52	0.38	0.68	0.38	0.77	0.38	0.61
043	0.68	3.0	-	-	0.49	1.94	0.07	0.09	0.10	0.00	-0.05	0.34	0.25	0.34	0.49	0.34	0.71	0.34	0.82	0.34	0.62
044	0.45	2.4	-	-	0.42	1.87	0.05	0.06	0.07	0.00	-0.03	0.23	0.16	0.23	0.32	0.23	0.63	0.23	0.76	0.23	0.45
045	0.97	3.7	-	-	0.42	1.86	0.11	0.13	0.15	0.00	-0.07	0.48	0.36	0.48	0.70	0.48	0.92	0.48	1.03	0.48	0.81
046	0.56	2.7	-	-	0.41	1.91	0.06	0.07	0.08	0.00	-0.04	0.28	0.20	0.28	0.40	0.28	0.67	0.28	0.78	0.28	0.56
047	0.81	3.3	-	-	0.53	2.00	0.09	0.11	0.12	0.00	-0.06	0.41	0.35^	0.41	0.57^	0.41	0.74	0.41	0.83	0.41	0.66
048	1.08	4.0	-	-	0.65	2.04	0.12	0.14	0.16	0.00	-0.08	0.54	0.42	0.54	0.71	0.54	0.86	0.54	0.94	0.54	0.78
049	0.91	3.6	-	-	0.70	2.00	0.10	0.12	0.14	0.00	-0.06	0.46	0.35^	0.46	0.63	0.46	0.80	0.46	0.88	0.46	0.71
050	0.93	3.6	-	-	0.54	1.95	0.10	0.12	0.14	0.00	-0.07	0.46	0.35^	0.46	0.65	0.46	0.84	0.46	0.94	0.46	0.74
051	0.63	2.9	-	-	0.44	1.94	0.07	0.08	0.09	0.00	-0.04	0.31	0.35^	0.31	0.61^	0.31	0.71^	0.31	0.79	0.31	0.60
052	0.94	3.6	-	-	0.44	1.85	0.10	0.12	0.14	0.00	-0.07	0.47	0.35^	0.47	0.68	0.47	0.91	0.47	1.03	0.47	0.80
053	0.84	3.4	-	-	0.42	1.81	0.09	0.11	0.13	0.00	-0.06	0.42	0.35^	0.42	0.70^	0.42	0.88	0.42	1.01	0.42	0.77
054	0.77	3.2	-	-	0.33	1.80	0.08	0.10	0.12	0.00	-0.05	0.38	0.35^	0.38	0.70^	0.38	0.85	0.38	0.98	0.38	0.74
055	0.46	2.5	-	-	0.26	1.80	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.34	0.23	0.68	0.23	0.82	0.23	0.46
056	0.77	3.2	-	-	0.36	1.84	0.08	0.10	0.12	0.00	-0.05	0.38	0.28	0.38	0.56	0.38	0.82	0.38	0.95	0.38	0.72
057	0.51	2.6	-	-	0.40	1.86	0.06	0.07	0.08	0.00	-0.04	0.25	0.19	0.25	0.37	0.25	0.68	0.25	0.80	0.25	0.51
058	0.46	2.5	-	-	0.46	1.95	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.34	0.23	0.59	0.23	0.70	0.23	0.46
059	0.59	2.8	-	-	0.58	2.04	0.06	0.08	0.09	0.00	-0.04	0.29	0.21	0.29	0.43	0.29	0.60	0.29	0.69	0.29	0.53
060	0.39	2.3	-	-	0.55	2.08	0.04	0.05	0.06	0.00	-0.03	0.19	0.14	0.19	0.29	0.19	0.47	0.19	0.55	0.19	0.39
061	0.59	2.8	-	-	0.48	2.06	0.06	0.08	0.09	0.00	-0.04	0.29	0.21	0.29	0.43	0.29	0.59	0.29	0.67	0.29	0.52
062	0.70	3.1	-	-	0.44	2.05	0.08	0.09	0.11	0.00	-0.05	0.35	0.26	0.35	0.50	0.35	0.65	0.35	0.74	0.35	0.58
063	0.84	3.4	-	-	0.43	2.09	0.09	0.11	0.13	0.00	-0.06	0.42	0.31	0.42	0.56	0.42	0.70	0.42	0.77	0.42	0.63
064	0.95	3.7	-	-	0.51	2.09	0.10	0.12	0.14	0.00	-0.07	0.48	0.36	0.48	0.62	0.48	0.76	0.48	0.83	0.48	0.69
065	0.79	3.3	-	-	0.56	2.18	0.09	0.10	0.12	0.00	-0.06	0.40	0.34^	0.40	0.50	0.40	0.61	0.40	0.67	0.40	0.56
066	0.99	3.8	0.03	5.2	0.54	2.13	0.11	0.13	0.15	0.00	-0.07	0.50	0.38	0.50	0.63	0.50	0.75	0.50	0.82	0.50	0.69
067	0.91	3.6	0.08	5.2	0.57	2.15	0.10	0.12	0.14	0.00	-0.06	0.46	0.34	0.46	0.58	0.46	0.70	0.46	0.76	0.46	0.64
068	0.95	3.7	0.09	5.2	0.47	2.13	0.10	0.12	0.14	0.00	-0.07	0.48	0.36	0.48	0.61	0.48	0.73	0.48	0.80	0.48	0.67
069	0.66	3.0	0.02	5.1	0.35	2.07	0.07	0.09	0.10	0.00	-0.05	0.33	0.24	0.33	0.47	0.33	0.62	0.33	0.70	0.33	0.55
070	0.77	3.2	0.16	5.3	0.42	2.12	0.08	0.10	0.12	0.00	-0.05	0.38	0.28	0.38	0.51	0.38	0.64	0.38	0.71	0.38	0.58
071	0.53	2.6	0.06	5.2	0.33	2.15	0.06	0.07	0.08	0.00	-0.04	0.27	0.19	0.27	0.37	0.27	0.50	0.27	0.56	0.27	0.44
072	0.64	2.9	0.62	6.0	0.47	2.19	0.07	0.08	0.10	0.00	-0.04	0.32	0.42*	0.32	0.52*	0.32	0.57*	0.32	0.59	0.32	0.48
073	1.04	3.9	0.62	6.0	0.47	2.24	0.11	0.14	0.16	0.00	-0.07	0.52	0.44	0.52	0.62	0.52	0.70	0.52	0.75	0.52	0.66
074	1.22	4.3	3.60	10.5	0.45	2.26	0.13	0.16	0.18	0.00	-0.09	1.80*	1.85*	1.80*	1.97*	1.80*	2.02*	1.80*	2.04*	1.80*	1.95*
075	0.47	2.5	-	-	0.63	2.20	0.05	0.06	0.07	0.00	-0.03	0.23	0.17	0.23	0.33	0.23	0.43	0.23	0.49	0.23	0.39
076	0.50	2.6	-	-	0.54	2.12	0.05	0.06	0.08	0.00	-0.04	0.25	0.18	0.25	0.37	0.25	0.50	0.25	0.57	0.25	0.44
077	0.30	2.1	-	-	0.50	2.12	0.03	0.04	0.05	0.00	-0.02	0.15	0.11	0.15	0.23	0.15	0.41	0.15	0.47	0.15	0.30
078	0.59	2.8	-	-	0.49	2.08	0.06	0.08	0.09	0.00	-0.04	0.29	0.21	0.29	0.43	0.29	0.57	0.29	0.65	0.29	0.51
079	0.23	1.9	-	-	0.47	2.09	0.03	0.03	0.03	0.00	-0.02	0.12	0.09	0.12	0.18	0.12	0.36	0.12	0.46	0.12	0.23
080	0.36	2.2	-	-	0.46	2.08	0.04	0.05	0.05	0.00	-0.03	0.18	0.13	0.18	0.26	0.18	0.46	0.18	0.54	0.18	0.36
081	0.39	2.3	-	-	0.46	2.08	0.04	0.05	0.06	0.00	-0.03	0.19	0.14	0.19	0.29	0.19	0.47	0.19	0.55	0.19	0.39
082	0.40	2.3	-	-	0.43	2.05	0.04	0.05	0.06	0.00	-0.03	0.20	0.15	0.20	0.29	0.20	0.50	0.20	0.58	0.20	0.40
083	0.82	3.4	-	-	0.45	2.07	0.09	0.11	0.12	0.00	-0.06	0.41	0.31	0.41	0.56	0.41	0.70	0.41	0.78	0.41	0.63

Table J3 cont.: PMF Wave Runup Results

Loc ID	PMF						Wave Setup (m)					Wave Runup Height (m)									
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type$^{\#\#}$					Edge Treatment Type$^{\#\#}$									
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1&2	3&4	5&6	7&8	9&10	1	2	3	4	5	6	7	8	9	10
084	0.82	3.4	-	-	0.48	2.11	0.09	0.11	0.12	0.00	-0.06	0.41	0.31	0.41	0.54	0.41	0.68	0.41	0.75	0.41	0.61
085	0.54	2.7	-	-	0.53	2.14	0.06	0.07	0.08	0.00	-0.04	0.27	0.20	0.27	0.39	0.27	0.51	0.27	0.58	0.27	0.45
086	0.97	3.7	-	-	0.47	2.12	0.11	0.13	0.15	0.00	-0.07	0.48	0.36	0.48	0.62	0.48	0.75	0.48	0.81	0.48	0.68
087	0.67	3.0	-	-	0.54	2.14	0.07	0.09	0.10	0.00	-0.05	0.33	0.35^	0.33	0.49^	0.33	0.58	0.33	0.64	0.33	0.52
088	0.40	2.3	-	-	0.51	2.11	0.04	0.05	0.06	0.00	-0.03	0.25^	0.35^	0.25^	0.50^	0.25^	0.57^	0.25^	0.58^	0.25^	0.45^
089	0.80	3.3	-	-	0.57	2.17	0.09	0.10	0.12	0.00	-0.06	0.40	0.35^	0.40	0.51	0.40	0.62	0.40	0.69	0.40	0.57
090	0.61	2.9	-	-	0.20	1.83	0.07	0.08	0.09	0.00	-0.04	0.31	0.23	0.31	0.45	0.31	0.75	0.31	0.87	0.31	0.61
091	0.56	2.7	-	-	0.18	1.81	0.06	0.07	0.08	0.00	-0.04	0.28	0.20	0.28	0.40	0.28	0.73	0.28	0.87	0.28	0.56
092	0.37	2.3	-	-	0.22	1.81	0.04	0.05	0.06	0.00	-0.03	0.19	0.14	0.19	0.28	0.19	0.56	0.19	0.77	0.19	0.37
093	0.44	2.4	-	-	0.16	1.82	0.05	0.06	0.07	0.00	-0.03	0.22	0.16	0.22	0.32	0.22	0.64	0.22	0.80	0.22	0.44
094	0.75	3.2	-	-	1.28	2.58	0.08	0.10	0.11	0.00	-0.05	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
095	0.75	3.2	-	-	1.28	2.55	0.08	0.10	0.11	0.00	-0.05	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
096	0.52	2.6	-	-	1.20	2.53	0.06	0.07	0.08	0.00	-0.04	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
097	0.42	2.4	-	-	1.10	2.51	0.05	0.05	0.06	0.00	-0.03	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
098	0.51	2.6	-	-	1.12	2.56	0.06	0.07	0.08	0.00	-0.04	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
099	0.41	2.3	-	-	1.13	2.60	0.05	0.05	0.06	0.00	-0.03	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
100	0.64	2.9	-	-	1.22	2.66	0.07	0.08	0.10	0.00	-0.04	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
101	0.64	2.9	-	-	1.19	2.62	0.07	0.08	0.10	0.00	-0.04	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
102	0.58	2.8	-	-	1.18	2.58	0.06	0.08	0.09	0.00	-0.04	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
103	0.59	2.8	-	-	1.23	2.57	0.06	0.08	0.09	0.00	-0.04	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
104	0.78	3.3	-	-	0.75	2.38	0.09	0.10	0.12	0.00	-0.05	0.39	0.35	0.39	0.44	0.39	0.48	0.39	0.50	0.39	0.46
105	0.82	3.4	-	-	0.64	2.35	0.09	0.11	0.12	0.00	-0.06	0.41	0.36	0.41	0.47	0.41	0.52	0.41	0.54	0.41	0.49
106	0.84	3.4	-	-	0.59	2.34	0.09	0.11	0.13	0.00	-0.06	0.42	0.37	0.42	0.48	0.42	0.53	0.42	0.56	0.42	0.51
107	0.70	3.1	-	-	0.53	2.33	0.08	0.09	0.11	0.00	-0.05	0.35	0.30^	0.35	0.41	0.35	0.47	0.35	0.50	0.35	0.44
108	0.62	2.9	-	-	0.50	2.35	0.07	0.08	0.09	0.00	-0.04	0.31	0.30^	0.31	0.36	0.31	0.41	0.31	0.44	0.31	0.39
109	0.61	2.9	-	-	0.47	2.36	0.07	0.08	0.09	0.00	-0.04	0.31	0.29^	0.31	0.35	0.31	0.40	0.31	0.43	0.31	0.38
110	0.78	3.3	-	-	0.54	2.37	0.09	0.10	0.12	0.00	-0.05	0.39	0.35	0.39	0.44	0.39	0.48	0.39	0.51	0.39	0.46
111	0.58	2.8	-	-	0.58	2.37	0.06	0.08	0.09	0.00	-0.04	0.29	0.29^	0.29	0.34^	0.29	0.38	0.29	0.41	0.29	0.36
112	0.55	2.7	-	-	0.61	2.37	0.06	0.07	0.08	0.00	-0.04	0.27	0.29^	0.27	0.34^	0.27	0.36	0.27	0.39	0.27	0.34
113	0.54	2.7	-	-	0.62	2.38	0.06	0.07	0.08	0.00	-0.04	0.27	0.29^	0.27	0.33^	0.27	0.35	0.27	0.38	0.27	0.33
114	0.63	2.9	-	-	0.67	2.45	0.07	0.08	0.09	0.00	-0.04	0.31	0.30	0.31	0.34	0.31	0.35	0.31	0.36	0.31	0.35
115	0.95	3.7	-	-	0.66	2.42	0.10	0.12	0.14	0.00	-0.07	0.48	0.46	0.48	0.51	0.48	0.54	0.48	0.55	0.48	0.52
116	0.82	3.4	-	-	0.75	2.45	0.09	0.11	0.12	0.00	-0.06	0.41	0.40	0.41	0.43	0.41	0.45	0.41	0.46	0.41	0.44
117	0.93	3.6	-	-	0.64	2.39	0.10	0.12	0.14	0.00	-0.07	0.46	0.43	0.46	0.51	0.46	0.55	0.46	0.57	0.46	0.53
118	0.91	3.6	-	-	0.63	2.36	0.10	0.12	0.14	0.00	-0.06	0.46	0.41	0.46	0.51	0.46	0.56	0.46	0.58	0.46	0.53
119	0.67	3.0	-	-	0.69	2.38	0.07	0.09	0.10	0.00	-0.05	0.33	0.29	0.33	0.38	0.33	0.42	0.33	0.44	0.33	0.40

Table J4: 100yr ARI Wave Runup Levels and FPL

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only
% Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to High Tide
^ Boat wave conditions adopted in run-up calculation
* Swell wave conditions adopted in run-up calculation

100-year ARI Offshore Storm Tide is **1.45mAHD**
Mean Sea Level Rise not included
Freeboard (0.3m) not included

Edge Treatment Types
1. 1 in 20 Natural Slope - 1.5mAHD crest
2. 1 in 20 Natural Slope - 2.5mAHD crest
3. 1 in 10 Beach Face - 1.5mAHD crest
4. 1 in 10 Beach Face - 2.5mAHD crest
5. 1 in 5 Embankment - 1.5mAHD crest
6. 1 in 5 Embankment - 2.5mAHD crest
7. 1 in 2 Seawall - 1.5mAHD crest
8. 1 in 2 Seawall - 2.5mAHD crest
9. Vertical Wall - 1.5mAHD crest
10. Vertical Wall - 2.5mAHD crest

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup% (m)	Design Water Level (mAHD)	Edge Treatment Type ##										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
001	1.15	4.2	3.51	10.4	0.26	1.76	3.51*	3.61*	3.51*	3.95*	3.51*	4.12*	3.51*	4.17*	3.51*	3.91*	4.17
002	0.89	3.5	0.28	5.5	0.28	1.78	2.22	2.11	2.22	2.44	2.22	2.71	2.22	2.84	2.22	2.59	2.84
003	0.85	3.4	1.60	7.5	0.32	1.79	2.59*	2.70*	2.59*	3.01*	2.59*	3.16*	2.59*	3.20*	2.59*	2.95*	3.20
004	0.69	3.0	0.37	5.7	0.27	1.65	1.99	2.00*	1.99	2.34*	1.99	2.55*	1.99	2.72	1.99	2.34	2.72
005	0.76	3.2	0.17	5.4	0.29	1.59	1.97	1.87	1.97	2.15	1.97	2.57	1.97	2.74	1.97	2.35	2.74
006	0.75	3.2	0.04	5.2	0.27	1.56	1.93	1.91^	1.93	2.27^	1.93	2.59^	1.93	2.73	1.93	2.31	2.73
007	0.53	2.6	0.01	5.1	0.29	1.58	1.85	1.77	1.85	1.96	1.85	2.34	1.85	2.62	1.85	2.11	2.62
008	0.38	2.3	-	-	0.29	1.59	1.78	1.73	1.78	1.87	1.78	2.16	1.78	2.55	1.78	1.97	2.55
009	0.59	2.8	-	-	0.29	1.54	1.83	1.75	1.83	1.97	1.83	2.40	1.83	2.65	1.83	2.13	2.65
010	0.48	2.5	-	-	0.24	1.53	1.78^	1.88^	1.78^	2.24^	1.78^	2.58^	1.78^	2.60^	1.78^	2.03^	2.60
011	0.49	2.6	-	-	0.25	1.54	1.79^	1.89^	1.79^	2.25^	1.79^	2.58^	1.79^	2.60^	1.79^	2.04^	2.60
012	0.56	2.7	-	-	0.28	1.57	1.85	1.92^	1.85	2.28^	1.85	2.59^	1.85	2.64	1.85	2.13	2.64
013	0.71	3.1	-	-	0.33	1.58	1.94	1.93^	1.94	2.29^	1.94	2.59^	1.94	2.72	1.94	2.29	2.72
014	0.74	3.2	-	-	0.38	1.59	1.96	1.94^	1.96	2.30^	1.96	2.59^	1.96	2.73	1.96	2.33	2.73
015	0.32	2.1	-	-	0.37	1.61	1.77	1.73	1.77	1.85	1.77	2.08	1.77	2.52	1.77	1.93	2.52
016	0.26	2.0	-	-	0.36	1.63	1.76	1.73	1.76	1.83	1.76	2.04	1.76	2.46	1.76	1.89	2.46
017	0.51	2.6	-	-	0.65	1.66	1.91	1.85	1.91	2.03	1.91	2.40	1.91	2.63	1.91	2.17	2.63
018	0.70	3.1	-	-	0.51	1.68	2.03	2.03^	2.03	2.39^	2.03	2.61^	2.03	2.73	2.03	2.38	2.73
019	0.65	2.9	-	-	0.53	1.71	2.04	2.06^	2.04	2.42^	2.04	2.61^	2.04	2.71	2.04	2.36	2.71
020	0.87	3.5	-	-	0.55	1.71	2.15	2.06^	2.15	2.42^	2.15	2.68	2.15	2.82	2.15	2.54	2.82
021	0.96	3.7	-	-	0.58	1.72	2.20	2.08	2.20	2.44	2.20	2.73	2.20	2.87	2.20	2.59	2.87
022	1.14	4.1	-	-	0.57	1.70	2.27	2.14	2.27	2.55	2.27	2.82	2.27	2.95	2.27	2.67	2.95
023	1.00	3.8	-	-	0.63	1.72	2.22	2.10	2.22	2.48	2.22	2.75	2.22	2.89	2.22	2.61	2.89
024	0.87	3.5	-	-	0.72	1.75	2.19	2.10^	2.19	2.46^	2.19	2.69	2.19	2.82	2.19	2.56	2.82
025	0.81	3.3	-	-	0.64	1.71	2.12	2.01	2.12	2.30	2.12	2.64	2.12	2.79	2.12	2.51	2.79
026	1.15	4.2	-	-	0.59	1.68	2.25	2.13	2.25	2.55	2.25	2.82	2.25	2.96	2.25	2.67	2.96
027	0.89	3.5	-	-	0.65	1.70	2.15	2.05^	2.15	2.41^	2.15	2.68	2.15	2.83	2.15	2.55	2.83
028	1.10	4.0	-	-	0.60	1.68	2.23	2.10	2.23	2.51	2.23	2.79	2.23	2.93	2.23	2.64	2.93
029	0.85	3.4	-	-	0.64	1.68	2.10	2.03^	2.10	2.39^	2.10	2.65	2.10	2.80	2.10	2.52	2.80
030	0.77	3.2	-	-	0.68	1.67	2.05	2.02^	2.05	2.38^	2.05	2.61^	2.05	2.76	2.05	2.44	2.76
031	0.81	3.3	-	-	0.61	1.66	2.06	2.01^	2.06	2.37^	2.06	2.62	2.06	2.78	2.06	2.47	2.78
032	0.93	3.6	-	-	0.57	1.66	2.12	2.01^	2.12	2.37^	2.12	2.69	2.12	2.84	2.12	2.55	2.84
033	1.02	3.8	-	-	0.53	1.65	2.16	2.03	2.16	2.42	2.16	2.73	2.16	2.88	2.16	2.59	2.88
034	0.92	3.6	-	-	0.52	1.63	2.09	1.98^	2.09	2.34^	2.09	2.67	2.09	2.83	2.09	2.53	2.83
035	0.86	3.5	-	-	0.47	1.62	2.05	1.97^	2.05	2.33^	2.05	2.64	2.05	2.80	2.05	2.48	2.80
036	0.73	3.1	-	-	0.47	1.64	2.00	1.99^	2.00	2.35^	2.00	2.60^	2.00	2.74	2.00	2.37	2.74
037	0.71	3.1	-	-	0.47	1.65	2.00	2.00^	2.00	2.36^	2.00	2.60^	2.00	2.73	2.00	2.36	2.73
038	0.63	2.9	-	-	0.43	1.62	1.94	1.97^	1.94	2.33^	1.94	2.60^	1.94	2.68	1.94	2.25	2.68

Table J4 cont.: 100yr ARI Wave Runup Levels and FPL

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level (mAHD)	Edge Treatment Type$^{\#\#}$										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
039	0.80	3.3	-	-	0.40	1.59	1.99	1.88	1.99	2.18	1.99	2.59	1.99	2.76	1.99	2.39	2.76
040	0.51	2.6	-	-	0.41	1.56	1.81	1.75	1.81	1.93	1.81	2.30	1.81	2.61	1.81	2.07	2.61
041	0.51	2.6	-	-	0.34	1.52	1.77	1.71	1.77	1.89	1.77	2.26	1.77	2.60	1.77	2.03	2.60
042	0.59	2.8	-	-	0.35	1.49	1.79	1.70	1.79	1.92	1.80	2.35	1.80	2.64	1.80	2.08	2.64
043	0.51	2.6	-	-	0.28	1.44	1.68	1.63	1.72	1.81	1.74	2.18	1.75	2.59	1.73	1.95	2.59
044	0.36	2.2	-	-	0.25	1.40	1.54	1.53	1.61	1.66	1.65	1.93	1.67	2.51	1.63	1.76	2.51
045	0.71	3.1	-	-	0.25	1.40	1.72	1.66	1.79	1.92	1.83	2.44	1.85	2.69	1.81	2.11	2.69
046	0.45	2.5	-	-	0.22	1.42	1.62	1.59	1.67	1.76	1.70	2.09	1.72	2.56	1.69	1.87	2.56
047	0.61	2.8	-	-	0.30	1.47	1.77	1.82^	1.79	2.18^	1.80	2.57^	1.81	2.65	1.80	2.08	2.65
048	0.82	3.4	-	-	0.38	1.49	1.90	1.84^	1.91	2.20^	1.91	2.57	1.92	2.76	1.91	2.31	2.76
049	0.71	3.1	-	-	0.42	1.47	1.82	1.82^	1.84	2.18^	1.85	2.57^	1.86	2.70	1.85	2.18	2.70
050	0.70	3.1	-	-	0.31	1.44	1.77	1.79^	1.82	2.15^	1.84	2.56^	1.85	2.69	1.83	2.14	2.69
051	0.52	2.6	-	-	0.26	1.44	1.71^	1.79^	1.73^	2.15^	1.74^	2.56^	1.76	2.60	1.73	1.96	2.60
052	0.71	3.1	-	-	0.26	1.39	1.71	1.74^	1.79	2.10^	1.82	2.55^	1.84	2.69	1.81	2.10	2.69
053	0.64	2.9	-	-	0.25	1.38	1.67^	1.73^	1.74	2.09^	1.78	2.55^	1.81	2.65	1.77	2.02	2.65
054	0.60	2.8	-	-	0.20	1.37	1.66^	1.72^	1.71	2.08^	1.76	2.55^	1.79	2.63	1.74	1.97	2.63
055	0.40	2.3	-	-	0.15	1.37	1.52	1.52	1.61	1.66	1.66	1.95	1.68	2.52	1.64	1.77	2.52
056	0.57	2.7	-	-	0.21	1.39	1.63	1.59	1.71	1.80	1.75	2.20	1.77	2.61	1.73	1.96	2.61
057	0.40	2.3	-	-	0.23	1.40	1.56	1.55	1.63	1.69	1.67	1.98	1.69	2.53	1.65	1.80	2.53
058	0.35	2.2	-	-	0.26	1.44	1.60	1.57	1.64	1.70	1.66	1.96	1.67	2.51	1.65	1.79	2.51
059	0.45	2.5	-	-	0.32	1.49	1.72	1.66	1.72	1.83	1.73	2.16	1.73	2.57	1.72	1.94	2.57
060	0.30	2.1	-	-	0.31	1.51	1.66	1.62	1.66	1.74	1.66	1.97	1.66	2.47	1.66	1.81	2.47
061	0.45	2.5	-	-	0.27	1.52	1.74	1.69	1.74	1.86	1.74	2.19	1.74	2.57	1.74	1.97	2.57
062	0.50	2.6	-	-	0.24	1.49	1.74	1.67	1.75	1.86	1.75	2.22	1.75	2.59	1.75	1.99	2.59
063	0.64	2.9	-	-	0.24	1.52	1.84	1.75	1.84	1.98	1.84	2.45	1.84	2.67	1.84	2.16	2.67
064	0.72	3.1	-	-	0.28	1.51	1.87	1.86^	1.87	2.22^	1.87	2.58^	1.87	2.71	1.87	2.23	2.71
065	0.62	2.9	-	-	0.30	1.58	1.89	1.93^	1.89	2.29^	1.89	2.59^	1.89	2.67	1.89	2.20	2.67
066	0.76	3.2	0.03	5.2	0.31	1.55	1.93	1.90^	1.93	2.26^	1.93	2.58^	1.93	2.74	1.93	2.31	2.74
067	0.71	3.1	0.05	5.2	0.31	1.59	1.95	1.85	1.95	2.11	1.95	2.55	1.95	2.72	1.95	2.30	2.72
068	0.75	3.2	0.06	5.2	0.25	1.57	1.95	1.85	1.95	2.12	1.95	2.56	1.95	2.73	1.95	2.32	2.73
069	0.55	2.7	0.02	5.1	0.19	1.55	1.82	1.75	1.82	1.95	1.82	2.35	1.82	2.63	1.82	2.10	2.63
070	0.60	2.8	0.10	5.3	0.23	1.56	1.86	1.78	1.86	1.99	1.86	2.43	1.86	2.66	1.86	2.16	2.66
071	0.44	2.4	0.06	5.2	0.18	1.59	1.81	1.75	1.81	1.91	1.81	2.23	1.81	2.58	1.81	2.03	2.58
072	0.50	2.6	0.45	5.8	0.27	1.63	1.88^	2.02*	1.88^	2.41*	1.88^	2.60^	1.88^	2.62^	1.88^	2.13^	2.62
073	0.81	3.3	0.45	5.8	0.27	1.66	2.06	2.05*	2.06	2.44*	2.06	2.62	2.06	2.78	2.06	2.47	2.78
074	0.93	3.6	2.63	9.0	0.26	1.67	2.98*	3.08*	2.98*	3.46*	2.98*	3.65*	2.98*	3.71*	2.98*	3.42*	3.71
075	0.36	2.2	-	-	0.34	1.57	1.75	1.70	1.75	1.83	1.75	2.10	1.75	2.54	1.75	1.93	2.54
076	0.39	2.3	-	-	0.30	1.53	1.72	1.67	1.72	1.82	1.72	2.10	1.72	2.54	1.72	1.92	2.54
077	0.24	1.9	-	-	0.28	1.53	1.65	1.62	1.65	1.72	1.65	1.90	1.65	2.30	1.65	1.77	2.30
078	0.45	2.5	-	-	0.28	1.50	1.73	1.67	1.73	1.84	1.73	2.17	1.73	2.57	1.73	1.95	2.57
079	0.20	1.8	-	-	0.26	1.51	1.61	1.59	1.61	1.67	1.61	1.83	1.61	2.15	1.61	1.71	2.15
080	0.27	2.0	-	-	0.26	1.52	1.65	1.62	1.65	1.73	1.65	1.94	1.65	2.38	1.65	1.79	2.38
081	0.28	2.0	-	-	0.26	1.51	1.65	1.62	1.65	1.72	1.65	1.93	1.65	2.41	1.65	1.79	2.41
082	0.31	2.1	-	-	0.24	1.49	1.64	1.61	1.65	1.72	1.65	1.96	1.66	2.48	1.65	1.80	2.48
083	0.62	2.9	-	-	0.25	1.50	1.81	1.73	1.81	1.96	1.81	2.41	1.81	2.66	1.81	2.12	2.66

Table J4 cont.: 100yr ARI Wave Runup Levels and FPL

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level (mAHD)	Edge Treatment Type$^{\#\#}$										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
084	0.62	2.9	-	-	0.27	1.52	1.83	1.75	1.83	1.98	1.83	2.43	1.83	2.66	1.83	2.14	2.66
085	0.40	2.3	-	-	0.30	1.54	1.74	1.69	1.74	1.83	1.74	2.12	1.74	2.55	1.74	1.94	2.55
086	0.74	3.2	-	-	0.27	1.53	1.90	1.88^	1.90	2.24^	1.90	2.58^	1.90	2.72	1.90	2.27	2.72
087	0.53	2.6	-	-	0.30	1.54	1.80	1.89^	1.80	2.25^	1.80	2.58^	1.80	2.62	1.80	2.07	2.62
088	0.31	2.1	-	-	0.30	1.53	1.78^	1.88^	1.78^	2.24^	1.78^	2.58^	1.78^	2.60^	1.78^	2.03^	2.60
089	0.63	2.9	-	-	0.31	1.56	1.87	1.91^	1.87	2.27^	1.87	2.59^	1.87	2.67	1.87	2.19	2.67
090	0.47	2.5	-	-	0.13	1.39	1.59	1.56	1.66	1.73	1.70	2.08	1.72	2.56	1.68	1.86	2.56
091	0.42	2.4	-	-	0.12	1.38	1.55	1.54	1.63	1.69	1.67	2.00	1.70	2.54	1.65	1.80	2.54
092	0.31	2.1	-	-	0.20	1.37	1.49	1.49	1.57	1.60	1.61	1.84	1.64	2.36	1.59	1.68	2.36
093	0.33	2.2	-	-	0.10	1.38	1.51	1.51	1.59	1.63	1.63	1.89	1.65	2.44	1.61	1.71	2.44
094	0.55	2.7	-	-	0.73	1.77	2.04	1.97	2.04	2.17	2.04	2.52	2.04	2.66	2.04	2.32	2.66
095	0.58	2.8	-	-	0.73	1.76	2.05	1.97	2.05	2.19	2.05	2.54	2.05	2.68	2.05	2.34	2.68
096	0.41	2.4	-	-	0.68	1.74	1.95	1.89	1.95	2.05	1.95	2.35	1.95	2.59	1.95	2.15	2.59
097	0.33	2.2	-	-	0.61	1.73	1.90	1.86	1.90	1.98	1.90	2.24	1.90	2.55	1.90	2.06	2.55
098	0.40	2.3	-	-	0.63	1.76	1.96	1.91	1.96	2.05	1.96	2.34	1.96	2.59	1.96	2.16	2.59
099	0.32	2.1	-	-	0.64	1.79	1.95	1.91	1.95	2.03	1.95	2.26	1.95	2.55	1.95	2.11	2.55
100	0.47	2.5	-	-	0.69	1.82	2.06	1.99	2.06	2.16	2.06	2.50	2.06	2.63	2.06	2.29	2.63
101	0.50	2.6	-	-	0.67	1.79	2.04	1.97	2.04	2.16	2.04	2.51	2.04	2.64	2.04	2.29	2.64
102	0.44	2.4	-	-	0.67	1.77	1.99	1.93	1.99	2.09	1.99	2.41	1.99	2.61	1.99	2.21	2.61
103	0.45	2.5	-	-	0.70	1.77	1.99	1.94	1.99	2.11	1.99	2.44	1.99	2.61	1.99	2.22	2.61
104	0.61	2.8	-	-	0.42	1.66	1.96	2.01^	1.96	2.37^	1.96	2.60^	1.96	2.68	1.96	2.27	2.68
105	0.62	2.9	-	-	0.37	1.65	1.96	2.00^	1.96	2.36^	1.96	2.60^	1.96	2.68	1.96	2.27	2.68
106	0.64	2.9	-	-	0.34	1.64	1.96	1.99^	1.96	2.35^	1.96	2.60^	1.96	2.69	1.96	2.28	2.69
107	0.53	2.6	-	-	0.30	1.64	1.90	1.99^	1.90	2.35^	1.90	2.60^	1.90	2.63	1.90	2.17	2.63
108	0.48	2.5	-	-	0.29	1.65	1.90^	2.00^	1.90^	2.36^	1.90^	2.60^	1.90^	2.62^	1.90^	2.15^	2.62
109	0.47	2.5	-	-	0.28	1.66	1.91^	2.01^	1.91^	2.37^	1.91^	2.60^	1.91^	2.62^	1.91^	2.16^	2.62
110	0.58	2.8	-	-	0.31	1.66	1.95	2.01^	1.95	2.37^	1.95	2.60^	1.95	2.66	1.95	2.24	2.66
111	0.47	2.5	-	-	0.33	1.65	1.90^	2.00^	1.90^	2.36^	1.90^	2.60^	1.90^	2.62^	1.90^	2.15^	2.62
112	0.46	2.5	-	-	0.35	1.66	1.91^	2.01^	1.91^	2.37^	1.91^	2.60^	1.91^	2.62^	1.91^	2.16^	2.62
113	0.45	2.5	-	-	0.36	1.67	1.92^	2.02^	1.92^	2.38^	1.92^	2.61^	1.92^	2.62^	1.92^	2.17^	2.62
114	0.49	2.6	-	-	0.38	1.70	1.95^	2.05^	1.95^	2.41^	1.95^	2.61^	1.95^	2.63^	1.95^	2.20^	2.63
115	0.72	3.1	-	-	0.38	1.68	2.04	2.03^	2.04	2.39^	2.04	2.61^	2.04	2.74	2.04	2.40	2.74
116	0.62	2.9	-	-	0.43	1.70	2.01	2.05^	2.01	2.41^	2.01	2.61^	2.01	2.69	2.01	2.32	2.69
117	0.70	3.1	-	-	0.37	1.67	2.02	2.02^	2.02	2.38^	2.02	2.61^	2.02	2.72	2.02	2.37	2.72
118	0.68	3.0	-	-	0.36	1.65	1.99	2.00^	1.99	2.36^	1.99	2.60^	1.99	2.71	1.99	2.33	2.71
119	0.50	2.6	-	-	0.39	1.67	1.92^	2.02^	1.92^	2.38^	1.92^	2.61^	1.92^	2.62^	1.92^	2.17^	2.62

Table J5: 100yr ARI Wave Runup Levels and FPL with 0.3m MSLR

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only
$^{\%}$ Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to High Tide
^ Boat wave conditions adopted in run-up calculation
* Swell wave conditions adopted in run-up calculation

100-year ARI Offshore Storm Tide is **1.45mAHD**
**** Mean Sea Level Rise** of **0.3m included** within the Design Water Level
Freeboard (0.3m) not included

$^{\#\#}$ **Edge Treatment Types**

1. 1 in 20 Natural Slope - 1.5mAHD crest
2. 1 in 20 Natural Slope - 2.5mAHD crest
3. 1 in 10 Beach Face - 1.5mAHD crest
4. 1 in 10 Beach Face - 2.5mAHD crest
5. 1 in 5 Embankment - 1.5mAHD crest
6. 1 in 5 Embankment - 2.5mAHD crest
7. 1 in 2 Seawall - 1.5mAHD crest
8. 1 in 2 Seawall - 2.5mAHD crest
9. Vertical Wall - 1.5mAHD crest
10. Vertical Wall - 2.5mAHD crest

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type $^{\#\#}$										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
001	1.15	4.2	3.51	10.4	0.26	2.06	3.81*	3.89*	3.81*	4.09*	3.81*	4.19*	3.81*	4.22*	3.81*	4.07*	4.22
002	0.89	3.5	0.28	5.5	0.28	2.08	2.52	2.41	2.52	2.66	2.52	2.81	2.52	2.89	2.52	2.74	2.89
003	0.85	3.4	1.60	7.5	0.32	2.09	2.89*	2.96*	2.89*	3.14*	2.89*	3.23*	2.89*	3.25*	2.89*	3.11*	3.25
004	0.69	3.0	0.37	5.7	0.27	1.95	2.30	2.30*	2.30	2.54*	2.30	2.66	2.30	2.76	2.30	2.57	2.76
005	0.76	3.2	0.17	5.4	0.29	1.89	2.27	2.17	2.27	2.45	2.27	2.68	2.27	2.79	2.27	2.58	2.79
006	0.75	3.2	0.04	5.2	0.27	1.86	2.24	2.21^	2.24	2.52^	2.24	2.66	2.24	2.78	2.24	2.56	2.78
007	0.53	2.6	0.01	5.1	0.29	1.88	2.14	2.07	2.14	2.26	2.14	2.55	2.14	2.67	2.14	2.41	2.67
008	0.38	2.3	-	-	0.29	1.89	2.08	2.03	2.08	2.17	2.08	2.46	2.08	2.60	2.08	2.27	2.60
009	0.59	2.8	-	-	0.29	1.84	2.14	2.05	2.14	2.27	2.14	2.57	2.14	2.70	2.14	2.43	2.70
010	0.48	2.5	-	-	0.24	1.83	2.08^	2.18^	2.08^	2.51^	2.08^	2.63^	2.08^	2.65^	2.08^	2.33^	2.65
011	0.49	2.6	-	-	0.25	1.84	2.09^	2.19^	2.09^	2.52^	2.09^	2.64^	2.09^	2.65^	2.09^	2.34^	2.65
012	0.56	2.7	-	-	0.28	1.87	2.15	2.22^	2.15	2.53^	2.15	2.64^	2.15	2.69	2.15	2.43	2.69
013	0.71	3.1	-	-	0.33	1.88	2.23	2.23^	2.23	2.53^	2.23	2.65	2.23	2.76	2.23	2.55	2.76
014	0.74	3.2	-	-	0.38	1.89	2.26	2.24^	2.26	2.53^	2.26	2.67	2.26	2.78	2.26	2.57	2.78
015	0.32	2.1	-	-	0.37	1.91	2.07	2.03	2.07	2.15	2.07	2.38	2.07	2.57	2.07	2.23	2.57
016	0.26	2.0	-	-	0.36	1.93	2.06	2.03	2.06	2.13	2.06	2.34	2.06	2.54	2.06	2.19	2.54
017	0.51	2.6	-	-	0.65	1.96	2.22	2.15	2.22	2.33	2.22	2.57	2.22	2.67	2.22	2.47	2.67
018	0.70	3.1	-	-	0.51	1.98	2.33	2.33^	2.33	2.57^	2.33	2.68	2.33	2.77	2.33	2.59	2.77
019	0.65	2.9	-	-	0.53	2.01	2.33	2.36^	2.33	2.58^	2.33	2.67^	2.33	2.75	2.33	2.58	2.75
020	0.87	3.5	-	-	0.55	2.01	2.44	2.36^	2.44	2.61	2.44	2.78	2.44	2.87	2.44	2.69	2.87
021	0.96	3.7	-	-	0.58	2.02	2.50	2.38	2.50	2.67	2.50	2.83	2.50	2.91	2.50	2.74	2.91
022	1.14	4.1	-	-	0.57	2.00	2.57	2.44	2.57	2.75	2.57	2.92	2.57	3.00	2.57	2.83	3.00
023	1.00	3.8	-	-	0.63	2.02	2.52	2.40	2.52	2.69	2.52	2.85	2.52	2.93	2.52	2.77	2.93
024	0.87	3.5	-	-	0.72	2.05	2.48	2.40^	2.48	2.64	2.48	2.79	2.48	2.87	2.48	2.71	2.87
025	0.81	3.3	-	-	0.64	2.01	2.41	2.31	2.41	2.57	2.41	2.74	2.41	2.84	2.41	2.66	2.84
026	1.15	4.2	-	-	0.59	1.98	2.56	2.43	2.56	2.75	2.56	2.92	2.56	3.00	2.56	2.82	3.00
027	0.89	3.5	-	-	0.65	2.00	2.44	2.35^	2.44	2.61	2.44	2.78	2.44	2.87	2.44	2.70	2.87
028	1.10	4.0	-	-	0.60	1.98	2.53	2.40	2.53	2.71	2.53	2.89	2.53	2.98	2.53	2.80	2.98
029	0.85	3.4	-	-	0.64	1.98	2.41	2.33^	2.41	2.57	2.41	2.75	2.41	2.85	2.41	2.67	2.85
030	0.77	3.2	-	-	0.68	1.97	2.36	2.32^	2.36	2.56^	2.36	2.71	2.36	2.81	2.36	2.62	2.81
031	0.81	3.3	-	-	0.61	1.96	2.37	2.31^	2.37	2.56^	2.37	2.73	2.37	2.83	2.37	2.64	2.83
032	0.93	3.6	-	-	0.57	1.96	2.43	2.31^	2.43	2.61	2.43	2.79	2.43	2.89	2.43	2.70	2.89
033	1.02	3.8	-	-	0.53	1.95	2.46	2.33	2.46	2.65	2.46	2.83	2.46	2.93	2.46	2.74	2.93
034	0.92	3.6	-	-	0.52	1.93	2.39	2.28^	2.39	2.58	2.39	2.78	2.39	2.88	2.39	2.68	2.88
035	0.86	3.5	-	-	0.47	1.92	2.35	2.27^	2.35	2.55	2.35	2.74	2.35	2.85	2.35	2.64	2.85
036	0.73	3.1	-	-	0.47	1.94	2.31	2.29^	2.31	2.55^	2.31	2.68	2.31	2.78	2.31	2.59	2.78
037	0.71	3.1	-	-	0.47	1.95	2.31	2.30^	2.31	2.56^	2.31	2.67	2.31	2.77	2.31	2.58	2.77
038	0.63	2.9	-	-	0.43	1.92	2.23	2.27^	2.23	2.55^	2.23	2.65^	2.23	2.73	2.23	2.53	2.73

Table J5 cont.: 100yr ARI Wave Runup Levels and FPL with 0.3m MSLR

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type$^{\#\#}$										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
039	0.80	3.3	-	-	0.40	1.89	2.29	2.18	2.29	2.48	2.29	2.70	2.29	2.81	2.29	2.60	2.81
040	0.51	2.6	-	-	0.41	1.86	2.12	2.05	2.12	2.23	2.12	2.54	2.12	2.66	2.12	2.37	2.66
041	0.51	2.6	-	-	0.34	1.82	2.08	2.01	2.08	2.19	2.08	2.52	2.08	2.65	2.08	2.33	2.65
042	0.59	2.8	-	-	0.35	1.79	2.08	2.00	2.08	2.22	2.08	2.55	2.08	2.69	2.08	2.38	2.69
043	0.51	2.6	-	-	0.28	1.74	2.00	1.93	2.00	2.11	2.00	2.48	2.00	2.64	2.00	2.25	2.64
044	0.36	2.2	-	-	0.25	1.70	1.88	1.83	1.88	1.96	1.88	2.23	1.88	2.56	1.88	2.06	2.56
045	0.71	3.1	-	-	0.25	1.70	2.06	1.96	2.06	2.22	2.06	2.58	2.06	2.73	2.06	2.41	2.73
046	0.45	2.5	-	-	0.22	1.72	1.95	1.89	1.95	2.06	1.95	2.39	1.95	2.61	1.95	2.17	2.61
047	0.61	2.8	-	-	0.30	1.77	2.07	2.12^	2.07	2.48^	2.07	2.62^	2.07	2.69	2.07	2.38	2.69
048	0.82	3.4	-	-	0.38	1.79	2.20	2.14^	2.20	2.50^	2.20	2.68	2.20	2.81	2.20	2.56	2.81
049	0.71	3.1	-	-	0.42	1.77	2.12	2.12^	2.12	2.48^	2.12	2.62^	2.12	2.75	2.12	2.48	2.75
050	0.70	3.1	-	-	0.31	1.74	2.09	2.09^	2.09	2.45^	2.09	2.62^	2.09	2.74	2.09	2.44	2.74
051	0.52	2.6	-	-	0.26	1.74	2.00	2.09^	2.00	2.45^	2.00	2.62^	2.00	2.64	2.00	2.26	2.64
052	0.71	3.1	-	-	0.26	1.69	2.05	2.04^	2.05	2.40^	2.05	2.61^	2.05	2.73	2.05	2.40	2.73
053	0.64	2.9	-	-	0.25	1.68	2.00	2.03^	2.00	2.39^	2.00	2.61^	2.00	2.70	2.00	2.32	2.70
054	0.60	2.8	-	-	0.20	1.67	1.97	2.02^	1.97	2.38^	1.97	2.61^	1.97	2.67	1.97	2.27	2.67
055	0.40	2.3	-	-	0.15	1.67	1.87	1.82	1.87	1.96	1.87	2.25	1.87	2.57	1.87	2.07	2.57
056	0.57	2.7	-	-	0.21	1.69	1.98	1.89	1.98	2.10	1.98	2.50	1.98	2.66	1.98	2.26	2.66
057	0.40	2.3	-	-	0.23	1.70	1.90	1.85	1.90	1.99	1.90	2.28	1.90	2.58	1.90	2.10	2.58
058	0.35	2.2	-	-	0.26	1.74	1.92	1.87	1.92	2.00	1.92	2.26	1.92	2.56	1.92	2.09	2.56
059	0.45	2.5	-	-	0.32	1.79	2.01	1.96	2.01	2.13	2.01	2.46	2.01	2.62	2.01	2.24	2.62
060	0.30	2.1	-	-	0.31	1.81	1.96	1.92	1.96	2.04	1.96	2.27	1.96	2.54	1.96	2.11	2.54
061	0.45	2.5	-	-	0.27	1.82	2.05	1.99	2.05	2.16	2.05	2.49	2.05	2.62	2.05	2.27	2.62
062	0.50	2.6	-	-	0.24	1.79	2.04	1.97	2.04	2.16	2.04	2.51	2.04	2.64	2.04	2.29	2.64
063	0.64	2.9	-	-	0.24	1.82	2.14	2.05	2.14	2.28	2.14	2.59	2.14	2.72	2.14	2.46	2.72
064	0.72	3.1	-	-	0.28	1.81	2.17	2.16^	2.17	2.51^	2.17	2.63^	2.17	2.76	2.17	2.52	2.76
065	0.62	2.9	-	-	0.30	1.88	2.19	2.23^	2.19	2.53^	2.19	2.64^	2.19	2.72	2.19	2.50	2.72
066	0.76	3.2	0.03	5.2	0.31	1.85	2.23	2.20^	2.23	2.52^	2.23	2.66	2.23	2.78	2.23	2.56	2.78
067	0.71	3.1	0.05	5.2	0.31	1.89	2.24	2.15	2.24	2.41	2.24	2.65	2.24	2.76	2.24	2.55	2.76
068	0.75	3.2	0.06	5.2	0.25	1.87	2.25	2.15	2.25	2.42	2.25	2.66	2.25	2.78	2.25	2.56	2.78
069	0.55	2.7	0.02	5.1	0.19	1.85	2.13	2.05	2.13	2.25	2.13	2.55	2.13	2.68	2.13	2.40	2.68
070	0.60	2.8	0.10	5.3	0.23	1.86	2.16	2.08	2.16	2.29	2.16	2.58	2.16	2.70	2.16	2.46	2.70
071	0.44	2.4	0.06	5.2	0.18	1.89	2.11	2.05	2.11	2.21	2.11	2.51	2.11	2.63	2.11	2.33	2.63
072	0.50	2.6	0.45	5.8	0.27	1.93	2.18^	2.32*	2.18^	2.56*	2.18^	2.65^	2.18^	2.66^	2.18^	2.43^	2.66
073	0.81	3.3	0.45	5.8	0.27	1.96	2.37	2.35*	2.37	2.57*	2.37	2.73	2.37	2.83	2.37	2.64	2.83
074	0.93	3.6	2.63	9.0	0.26	1.97	3.29*	3.35*	3.29*	3.60*	3.29*	3.72*	3.29*	3.76*	3.29*	3.57*	3.76
075	0.36	2.2	-	-	0.34	1.87	2.05	2.00	2.05	2.13	2.05	2.40	2.05	2.58	2.05	2.23	2.58
076	0.39	2.3	-	-	0.30	1.83	2.03	1.97	2.03	2.12	2.03	2.40	2.03	2.59	2.03	2.22	2.59
077	0.24	1.9	-	-	0.28	1.83	1.95	1.92	1.95	2.02	1.95	2.20	1.95	2.52	1.95	2.07	2.52
078	0.45	2.5	-	-	0.28	1.80	2.02	1.97	2.02	2.14	2.02	2.47	2.02	2.62	2.02	2.25	2.62
079	0.20	1.8	-	-	0.26	1.81	1.91	1.89	1.91	1.97	1.91	2.13	1.91	2.45	1.91	2.01	2.45
080	0.27	2.0	-	-	0.26	1.82	1.96	1.92	1.96	2.03	1.96	2.24	1.96	2.53	1.96	2.09	2.53
081	0.28	2.0	-	-	0.26	1.81	1.95	1.92	1.95	2.02	1.95	2.23	1.95	2.53	1.95	2.09	2.53
082	0.31	2.1	-	-	0.24	1.79	1.94	1.91	1.94	2.02	1.94	2.26	1.94	2.54	1.94	2.10	2.54
083	0.62	2.9	-	-	0.25	1.80	2.11	2.03	2.11	2.26	2.11	2.57	2.11	2.70	2.11	2.42	2.70

Table J5 cont.: 100yr ARI Wave Runup Levels and FPL with 0.3m MSLR

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type$^{\#\#}$										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
084	0.62	2.9	-	-	0.27	1.82	2.13	2.05	2.13	2.28	2.13	2.58	2.13	2.71	2.13	2.44	2.71
085	0.40	2.3	-	-	0.30	1.84	2.04	1.99	2.04	2.13	2.04	2.42	2.04	2.60	2.04	2.24	2.60
086	0.74	3.2	-	-	0.27	1.83	2.20	2.18^	2.20	2.51^	2.20	2.65	2.20	2.77	2.20	2.54	2.77
087	0.53	2.6	-	-	0.30	1.84	2.11	2.19^	2.11	2.52^	2.11	2.64^	2.11	2.67	2.11	2.37	2.67
088	0.31	2.1	-	-	0.30	1.83	2.08^	2.18^	2.08^	2.51^	2.08^	2.63^	2.08^	2.65^	2.08^	2.33^	2.65
089	0.63	2.9	-	-	0.31	1.86	2.18	2.21^	2.18	2.52^	2.18	2.64^	2.18	2.72	2.18	2.49	2.72
090	0.47	2.5	-	-	0.13	1.69	1.93	1.86	1.93	2.03	1.93	2.38	1.93	2.61	1.93	2.16	2.61
091	0.42	2.4	-	-	0.12	1.68	1.89	1.84	1.89	1.99	1.89	2.30	1.89	2.58	1.89	2.10	2.58
092	0.31	2.1	-	-	0.20	1.67	1.82	1.79	1.82	1.90	1.82	2.14	1.82	2.53	1.82	1.98	2.53
093	0.33	2.2	-	-	0.10	1.68	1.85	1.81	1.85	1.93	1.85	2.19	1.85	2.54	1.85	2.01	2.54
094	0.55	2.7	-	-	0.73	2.07	2.34	2.27	2.34	2.47	2.34	2.63	2.34	2.71	2.34	2.56	2.71
095	0.58	2.8	-	-	0.73	2.06	2.35	2.27	2.35	2.49	2.35	2.64	2.35	2.73	2.35	2.57	2.73
096	0.41	2.4	-	-	0.68	2.04	2.24	2.19	2.24	2.35	2.24	2.55	2.24	2.64	2.24	2.45	2.64
097	0.33	2.2	-	-	0.61	2.03	2.19	2.16	2.19	2.28	2.19	2.51	2.19	2.59	2.19	2.36	2.59
098	0.40	2.3	-	-	0.63	2.06	2.26	2.21	2.26	2.35	2.26	2.55	2.26	2.63	2.26	2.46	2.63
099	0.32	2.1	-	-	0.64	2.09	2.25	2.21	2.25	2.33	2.25	2.52	2.25	2.60	2.25	2.41	2.60
100	0.47	2.5	-	-	0.69	2.12	2.36	2.29	2.36	2.46	2.36	2.61	2.36	2.68	2.36	2.55	2.68
101	0.50	2.6	-	-	0.67	2.09	2.34	2.27	2.34	2.46	2.34	2.61	2.34	2.69	2.34	2.55	2.69
102	0.44	2.4	-	-	0.67	2.07	2.29	2.23	2.29	2.39	2.29	2.57	2.29	2.66	2.29	2.51	2.66
103	0.45	2.5	-	-	0.70	2.07	2.29	2.24	2.29	2.41	2.29	2.58	2.29	2.66	2.29	2.51	2.66
104	0.61	2.8	-	-	0.42	1.96	2.27	2.31^	2.27	2.56^	2.27	2.66^	2.27	2.73	2.27	2.54	2.73
105	0.62	2.9	-	-	0.37	1.95	2.26	2.30^	2.26	2.56^	2.26	2.66^	2.26	2.73	2.26	2.54	2.73
106	0.64	2.9	-	-	0.34	1.94	2.26	2.29^	2.26	2.55^	2.26	2.65^	2.26	2.74	2.26	2.54	2.74
107	0.53	2.6	-	-	0.30	1.94	2.21	2.29^	2.21	2.55^	2.21	2.65^	2.21	2.68	2.21	2.47	2.68
108	0.48	2.5	-	-	0.29	1.95	2.20^	2.30^	2.20^	2.56^	2.20^	2.66^	2.20^	2.67^	2.20^	2.45^	2.67
109	0.47	2.5	-	-	0.28	1.96	2.21^	2.31^	2.21^	2.56^	2.21^	2.66^	2.21^	2.67^	2.21^	2.46^	2.67
110	0.58	2.8	-	-	0.31	1.96	2.25	2.31^	2.25	2.56^	2.25	2.66^	2.25	2.71	2.25	2.52	2.71
111	0.47	2.5	-	-	0.33	1.95	2.20^	2.30^	2.20^	2.56^	2.20^	2.66^	2.20^	2.67^	2.20^	2.45^	2.67
112	0.46	2.5	-	-	0.35	1.96	2.21^	2.31^	2.21^	2.56^	2.21^	2.66^	2.21^	2.67^	2.21^	2.46^	2.67
113	0.45	2.5	-	-	0.36	1.97	2.22^	2.32^	2.22^	2.56^	2.22^	2.66^	2.22^	2.67^	2.22^	2.47^	2.67
114	0.49	2.6	-	-	0.38	2.00	2.25^	2.35^	2.25^	2.57^	2.25^	2.66^	2.25^	2.68^	2.25^	2.50^	2.68
115	0.72	3.1	-	-	0.38	1.98	2.34	2.33^	2.34	2.57^	2.34	2.69	2.34	2.78	2.34	2.60	2.78
116	0.62	2.9	-	-	0.43	2.00	2.31	2.35^	2.31	2.57^	2.31	2.66^	2.31	2.74	2.31	2.56	2.74
117	0.70	3.1	-	-	0.37	1.97	2.32	2.32^	2.32	2.56^	2.32	2.67	2.32	2.77	2.32	2.59	2.77
118	0.68	3.0	-	-	0.36	1.95	2.29	2.30^	2.29	2.56^	2.29	2.66^	2.29	2.76	2.29	2.57	2.76
119	0.50	2.6	-	-	0.39	1.97	2.22^	2.32^	2.22^	2.56^	2.22^	2.66^	2.22^	2.67^	2.22^	2.47^	2.67

Table J6: 100yr ARI Wave Runup Levels and FPL with 0.18m MSLR

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only
% Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to High Tide
^ Boat wave conditions adopted in run-up calculation
* Swell wave conditions adopted in run-up calculation

100-year ARI Offshore Storm Tide is **1.45mAHD**
**** Mean Sea Level Rise** of **0.18m included** within the Design Water Level
Freeboard (0.3m) not included

Edge Treatment Types

1. 1 in 20 Natural Slope - 1.5mAHD crest
2. 1 in 20 Natural Slope - 2.5mAHD crest
3. 1 in 10 Beach Face - 1.5mAHD crest
4. 1 in 10 Beach Face - 2.5mAHD crest
5. 1 in 5 Embankment - 1.5mAHD crest
6. 1 in 5 Embankment - 2.5mAHD crest
7. 1 in 2 Seawall - 1.5mAHD crest
8. 1 in 2 Seawall - 2.5mAHD crest
9. Vertical Wall - 1.5mAHD crest
10. Vertical Wall - 2.5mAHD crest

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup% (m)	Design Water Level** (mAHD)	Edge Treatment Type ##										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
001	1.15	4.2	3.51	10.4	0.26	1.94	3.70*	3.78*	3.70*	4.03*	3.70*	4.16*	3.70*	4.20*	3.70*	4.00*	4.20
002	0.89	3.5	0.28	5.5	0.28	1.96	2.41	2.29	2.41	2.58	2.41	2.77	2.41	2.87	2.41	2.68	2.87
003	0.85	3.4	1.60	7.5	0.32	1.97	2.77*	2.86*	2.77*	3.09*	2.77*	3.20*	2.77*	3.23*	2.77*	3.05*	3.23
004	0.69	3.0	0.37	5.7	0.27	1.83	2.18	2.18*	2.18	2.51*	2.18	2.62	2.18	2.75	2.18	2.51	2.75
005	0.76	3.2	0.17	5.4	0.29	1.77	2.15	2.05	2.15	2.33	2.15	2.63	2.15	2.77	2.15	2.52	2.77
006	0.75	3.2	0.04	5.2	0.27	1.74	2.12	2.09^	2.12	2.45^	2.12	2.62	2.12	2.76	2.12	2.49	2.76
007	0.53	2.6	0.01	5.1	0.29	1.76	2.02	1.95	2.02	2.14	2.02	2.51	2.02	2.65	2.02	2.29	2.65
008	0.38	2.3	-	-	0.29	1.77	1.96	1.91	1.96	2.05	1.96	2.34	1.96	2.58	1.96	2.15	2.58
009	0.59	2.8	-	-	0.29	1.72	2.02	1.93	2.02	2.15	2.02	2.53	2.02	2.68	2.02	2.31	2.68
010	0.48	2.5	-	-	0.24	1.71	1.96^	2.06^	1.96^	2.42^	1.96^	2.61^	1.96^	2.63^	1.96^	2.21^	2.63
011	0.49	2.6	-	-	0.25	1.72	1.97^	2.07^	1.97^	2.43^	1.97^	2.61^	1.97^	2.63^	1.97^	2.22^	2.63
012	0.56	2.7	-	-	0.28	1.75	2.03	2.10^	2.03	2.46^	2.03	2.62^	2.03	2.67	2.03	2.31	2.67
013	0.71	3.1	-	-	0.33	1.76	2.11	2.11^	2.11	2.47^	2.11	2.62^	2.11	2.74	2.11	2.47	2.74
014	0.74	3.2	-	-	0.38	1.77	2.14	2.12^	2.14	2.48^	2.14	2.63	2.14	2.76	2.14	2.51	2.76
015	0.32	2.1	-	-	0.37	1.79	1.95	1.91	1.95	2.03	1.95	2.26	1.95	2.55	1.95	2.11	2.55
016	0.26	2.0	-	-	0.36	1.81	1.94	1.91	1.94	2.01	1.94	2.22	1.94	2.52	1.94	2.07	2.52
017	0.51	2.6	-	-	0.65	1.84	2.10	2.03	2.10	2.21	2.10	2.53	2.10	2.65	2.10	2.35	2.65
018	0.70	3.1	-	-	0.51	1.86	2.21	2.21^	2.21	2.52^	2.21	2.64^	2.21	2.76	2.21	2.53	2.76
019	0.65	2.9	-	-	0.53	1.89	2.21	2.24^	2.21	2.53^	2.21	2.64^	2.21	2.73	2.21	2.52	2.73
020	0.87	3.5	-	-	0.55	1.89	2.32	2.24^	2.32	2.53^	2.32	2.74	2.32	2.85	2.32	2.63	2.85
021	0.96	3.7	-	-	0.58	1.90	2.38	2.26	2.38	2.58	2.38	2.79	2.38	2.89	2.38	2.68	2.89
022	1.14	4.1	-	-	0.57	1.88	2.45	2.32	2.45	2.67	2.45	2.88	2.45	2.98	2.45	2.77	2.98
023	1.00	3.8	-	-	0.63	1.90	2.40	2.28	2.40	2.61	2.40	2.81	2.40	2.91	2.40	2.70	2.91
024	0.87	3.5	-	-	0.72	1.93	2.37	2.28^	2.37	2.56	2.37	2.75	2.37	2.85	2.37	2.65	2.85
025	0.81	3.3	-	-	0.64	1.89	2.29	2.19	2.29	2.48	2.29	2.70	2.29	2.82	2.29	2.60	2.82
026	1.15	4.2	-	-	0.59	1.86	2.44	2.31	2.44	2.67	2.44	2.88	2.44	2.98	2.44	2.76	2.98
027	0.89	3.5	-	-	0.65	1.88	2.32	2.23^	2.32	2.53^	2.32	2.74	2.32	2.86	2.32	2.64	2.86
028	1.10	4.0	-	-	0.60	1.86	2.41	2.28	2.41	2.63	2.41	2.85	2.41	2.96	2.41	2.73	2.96
029	0.85	3.4	-	-	0.64	1.86	2.29	2.21^	2.29	2.52^	2.29	2.71	2.29	2.83	2.29	2.61	2.83
030	0.77	3.2	-	-	0.68	1.85	2.24	2.20^	2.24	2.52^	2.24	2.67	2.24	2.79	2.24	2.56	2.79
031	0.81	3.3	-	-	0.61	1.84	2.25	2.19^	2.25	2.52^	2.25	2.68	2.25	2.81	2.25	2.58	2.81
032	0.93	3.6	-	-	0.57	1.84	2.31	2.19^	2.31	2.52	2.31	2.75	2.31	2.87	2.31	2.64	2.87
033	1.02	3.8	-	-	0.53	1.83	2.34	2.21	2.34	2.57	2.34	2.79	2.34	2.91	2.34	2.68	2.91
034	0.92	3.6	-	-	0.52	1.81	2.27	2.16^	2.27	2.51^	2.27	2.73	2.27	2.86	2.27	2.62	2.86
035	0.86	3.5	-	-	0.47	1.80	2.23	2.15^	2.23	2.50^	2.23	2.70	2.23	2.83	2.23	2.58	2.83
036	0.73	3.1	-	-	0.47	1.82	2.19	2.17^	2.19	2.51^	2.19	2.63	2.19	2.76	2.19	2.53	2.76
037	0.71	3.1	-	-	0.47	1.83	2.19	2.18^	2.19	2.51^	2.19	2.63^	2.19	2.76	2.19	2.52	2.76
038	0.63	2.9	-	-	0.43	1.80	2.11	2.15^	2.11	2.50^	2.11	2.63^	2.11	2.71	2.11	2.43	2.71

Table J6 cont.: 100yr ARI Wave Runup Levels and FPL with 0.18m MSLR

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup% (m)	Design Water Level** (mAHD)	Edge Treatment Type ##										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
039	0.80	3.3	-	-	0.40	1.77	2.17	2.06	2.17	2.36	2.17	2.66	2.17	2.79	2.17	2.54	2.79
040	0.51	2.6	-	-	0.41	1.74	2.00	1.93	2.00	2.11	2.00	2.48	2.00	2.64	2.00	2.25	2.64
041	0.51	2.6	-	-	0.34	1.70	1.96	1.89	1.96	2.07	1.96	2.44	1.96	2.63	1.96	2.21	2.63
042	0.59	2.8	-	-	0.35	1.67	1.96	1.88	1.96	2.10	1.96	2.51	1.96	2.67	1.96	2.26	2.67
043	0.51	2.6	-	-	0.28	1.62	1.88	1.81	1.88	1.99	1.88	2.36	1.88	2.62	1.88	2.13	2.62
044	0.36	2.2	-	-	0.25	1.58	1.76	1.71	1.76	1.84	1.76	2.11	1.76	2.54	1.76	1.94	2.54
045	0.71	3.1	-	-	0.25	1.58	1.94	1.84	1.94	2.10	1.94	2.54	1.94	2.72	1.94	2.29	2.72
046	0.45	2.5	-	-	0.22	1.60	1.83	1.77	1.83	1.94	1.83	2.27	1.83	2.59	1.83	2.05	2.59
047	0.61	2.8	-	-	0.30	1.65	1.95	2.00^	1.95	2.36^	1.95	2.60^	1.95	2.68	1.95	2.26	2.68
048	0.82	3.4	-	-	0.38	1.67	2.08	2.02^	2.08	2.38^	2.08	2.64	2.08	2.79	2.08	2.49	2.79
049	0.71	3.1	-	-	0.42	1.65	2.00	2.00^	2.00	2.36^	2.00	2.60^	2.00	2.73	2.00	2.36	2.73
050	0.70	3.1	-	-	0.31	1.62	1.97	1.97^	1.97	2.33^	1.97	2.60^	1.97	2.72	1.97	2.32	2.72
051	0.52	2.6	-	-	0.26	1.62	1.88	1.97^	1.88	2.33^	1.88	2.60^	1.88	2.62	1.88	2.14	2.62
052	0.71	3.1	-	-	0.26	1.57	1.93	1.92^	1.93	2.28^	1.93	2.59^	1.93	2.71	1.93	2.28	2.71
053	0.64	2.9	-	-	0.25	1.56	1.88	1.91^	1.88	2.27^	1.88	2.59^	1.88	2.68	1.88	2.20	2.68
054	0.60	2.8	-	-	0.20	1.55	1.85	1.90^	1.85	2.26^	1.85	2.58^	1.85	2.65	1.85	2.15	2.65
055	0.40	2.3	-	-	0.15	1.55	1.75	1.70	1.75	1.84	1.75	2.13	1.75	2.55	1.75	1.95	2.55
056	0.57	2.7	-	-	0.21	1.57	1.86	1.77	1.86	1.98	1.86	2.38	1.86	2.64	1.86	2.14	2.64
057	0.40	2.3	-	-	0.23	1.58	1.78	1.73	1.78	1.87	1.78	2.16	1.78	2.56	1.78	1.98	2.56
058	0.35	2.2	-	-	0.26	1.62	1.80	1.75	1.80	1.88	1.80	2.14	1.80	2.54	1.80	1.97	2.54
059	0.45	2.5	-	-	0.32	1.67	1.89	1.84	1.89	2.01	1.89	2.34	1.89	2.60	1.89	2.12	2.60
060	0.30	2.1	-	-	0.31	1.69	1.84	1.80	1.84	1.92	1.84	2.15	1.84	2.52	1.84	1.99	2.52
061	0.45	2.5	-	-	0.27	1.70	1.93	1.87	1.93	2.04	1.93	2.37	1.93	2.60	1.93	2.15	2.60
062	0.50	2.6	-	-	0.24	1.67	1.92	1.85	1.92	2.04	1.92	2.40	1.92	2.62	1.92	2.17	2.62
063	0.64	2.9	-	-	0.24	1.70	2.02	1.93	2.02	2.16	2.02	2.54	2.02	2.70	2.02	2.34	2.70
064	0.72	3.1	-	-	0.28	1.69	2.05	2.04^	2.05	2.40^	2.05	2.61^	2.05	2.74	2.05	2.41	2.74
065	0.62	2.9	-	-	0.30	1.76	2.07	2.11^	2.07	2.47^	2.07	2.62^	2.07	2.70	2.07	2.38	2.70
066	0.76	3.2	0.03	5.2	0.31	1.73	2.11	2.08^	2.11	2.44^	2.11	2.62	2.11	2.76	2.11	2.49	2.76
067	0.71	3.1	0.05	5.2	0.31	1.77	2.12	2.03	2.12	2.29	2.12	2.61	2.12	2.75	2.12	2.48	2.75
068	0.75	3.2	0.06	5.2	0.25	1.75	2.13	2.03	2.13	2.30	2.13	2.62	2.13	2.76	2.13	2.50	2.76
069	0.55	2.7	0.02	5.1	0.19	1.73	2.01	1.93	2.01	2.13	2.01	2.51	2.01	2.66	2.01	2.28	2.66
070	0.60	2.8	0.10	5.3	0.23	1.74	2.04	1.96	2.04	2.17	2.04	2.54	2.04	2.68	2.04	2.34	2.68
071	0.44	2.4	0.06	5.2	0.18	1.77	1.99	1.93	1.99	2.09	1.99	2.41	1.99	2.61	1.99	2.21	2.61
072	0.50	2.6	0.45	5.8	0.27	1.81	2.06^	2.20*	2.06^	2.53*	2.06^	2.63^	2.06^	2.65^	2.06^	2.31^	2.65
073	0.81	3.3	0.45	5.8	0.27	1.84	2.25	2.23*	2.25	2.53*	2.25	2.68	2.25	2.81	2.25	2.58	2.81
074	0.93	3.6	2.63	9.0	0.26	1.85	3.17*	3.24*	3.17*	3.54*	3.17*	3.69*	3.17*	3.74*	3.17*	3.51*	3.74
075	0.36	2.2	-	-	0.34	1.75	1.93	1.88	1.93	2.01	1.93	2.28	1.93	2.56	1.93	2.11	2.56
076	0.39	2.3	-	-	0.30	1.71	1.91	1.85	1.91	2.00	1.91	2.28	1.91	2.57	1.91	2.10	2.57
077	0.24	1.9	-	-	0.28	1.71	1.83	1.80	1.83	1.90	1.83	2.08	1.83	2.48	1.83	1.95	2.48
078	0.45	2.5	-	-	0.28	1.68	1.91	1.85	1.91	2.02	1.91	2.35	1.91	2.60	1.91	2.13	2.60
079	0.20	1.8	-	-	0.26	1.69	1.79	1.77	1.79	1.85	1.79	2.01	1.79	2.33	1.79	1.89	2.33
080	0.27	2.0	-	-	0.26	1.70	1.84	1.80	1.84	1.91	1.84	2.12	1.84	2.51	1.84	1.97	2.51
081	0.28	2.0	-	-	0.26	1.69	1.83	1.80	1.83	1.90	1.83	2.11	1.83	2.51	1.83	1.97	2.51
082	0.31	2.1	-	-	0.24	1.67	1.82	1.79	1.82	1.90	1.82	2.14	1.82	2.53	1.82	1.98	2.53
083	0.62	2.9	-	-	0.25	1.68	1.99	1.91	1.99	2.14	1.99	2.53	1.99	2.69	1.99	2.30	2.69

Table J6 cont.: 100yr ARI Wave Runup Levels and FPL with 0.18m MSLR

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type$^{\#\#}$										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
084	0.62	2.9	-	-	0.27	1.70	2.01	1.93	2.01	2.16	2.01	2.54	2.01	2.69	2.01	2.32	2.69
085	0.40	2.3	-	-	0.30	1.72	1.92	1.87	1.92	2.01	1.92	2.30	1.92	2.58	1.92	2.12	2.58
086	0.74	3.2	-	-	0.27	1.71	2.08	2.06^	2.08	2.42^	2.08	2.61^	2.08	2.75	2.08	2.45	2.75
087	0.53	2.6	-	-	0.30	1.72	1.99	2.07^	1.99	2.43^	1.99	2.61^	1.99	2.65	1.99	2.25	2.65
088	0.31	2.1	-	-	0.30	1.71	1.96^	2.06^	1.96^	2.42^	1.96^	2.61^	1.96^	2.63^	1.96^	2.21^	2.63
089	0.63	2.9	-	-	0.31	1.74	2.06	2.09^	2.06	2.45^	2.06	2.62^	2.06	2.70	2.06	2.37	2.70
090	0.47	2.5	-	-	0.13	1.57	1.81	1.74	1.81	1.91	1.81	2.26	1.81	2.59	1.81	2.04	2.59
091	0.42	2.4	-	-	0.12	1.56	1.77	1.72	1.77	1.87	1.77	2.18	1.77	2.56	1.77	1.98	2.56
092	0.31	2.1	-	-	0.20	1.55	1.70	1.67	1.70	1.78	1.70	2.02	1.70	2.51	1.70	1.86	2.51
093	0.33	2.2	-	-	0.10	1.56	1.73	1.69	1.73	1.81	1.73	2.07	1.73	2.52	1.73	1.89	2.52
094	0.55	2.7	-	-	0.73	1.95	2.23	2.15	2.23	2.35	2.23	2.59	2.23	2.69	2.23	2.50	2.69
095	0.58	2.8	-	-	0.73	1.94	2.23	2.15	2.23	2.37	2.23	2.60	2.23	2.71	2.23	2.51	2.71
096	0.41	2.4	-	-	0.68	1.92	2.12	2.07	2.12	2.23	2.12	2.51	2.12	2.62	2.12	2.33	2.62
097	0.33	2.2	-	-	0.61	1.91	2.07	2.04	2.07	2.16	2.07	2.42	2.07	2.57	2.07	2.24	2.57
098	0.40	2.3	-	-	0.63	1.94	2.14	2.09	2.14	2.23	2.14	2.51	2.14	2.61	2.14	2.34	2.61
099	0.32	2.1	-	-	0.64	1.97	2.13	2.09	2.13	2.21	2.13	2.44	2.13	2.58	2.13	2.29	2.58
100	0.47	2.5	-	-	0.69	2.00	2.23	2.17	2.23	2.34	2.23	2.56	2.23	2.66	2.23	2.47	2.66
101	0.50	2.6	-	-	0.67	1.97	2.22	2.15	2.22	2.34	2.22	2.57	2.22	2.67	2.22	2.47	2.67
102	0.44	2.4	-	-	0.67	1.95	2.17	2.11	2.17	2.27	2.17	2.53	2.17	2.64	2.17	2.39	2.64
103	0.45	2.5	-	-	0.70	1.95	2.18	2.12	2.18	2.29	2.18	2.54	2.18	2.64	2.18	2.40	2.64
104	0.61	2.8	-	-	0.42	1.84	2.15	2.19^	2.15	2.52^	2.15	2.64^	2.15	2.71	2.15	2.45	2.71
105	0.62	2.9	-	-	0.37	1.83	2.14	2.18^	2.14	2.51^	2.14	2.63^	2.14	2.71	2.14	2.45	2.71
106	0.64	2.9	-	-	0.34	1.82	2.14	2.17^	2.14	2.51^	2.14	2.63^	2.14	2.72	2.14	2.46	2.72
107	0.53	2.6	-	-	0.30	1.82	2.09	2.17^	2.09	2.51^	2.09	2.63^	2.09	2.66	2.09	2.35	2.66
108	0.48	2.5	-	-	0.29	1.83	2.08^	2.18^	2.08^	2.51^	2.08^	2.63^	2.08^	2.65^	2.08^	2.33^	2.65
109	0.47	2.5	-	-	0.28	1.84	2.09^	2.19^	2.09^	2.52^	2.09^	2.64^	2.09^	2.65^	2.09^	2.34^	2.65
110	0.58	2.8	-	-	0.31	1.84	2.13	2.19^	2.13	2.52^	2.13	2.64^	2.13	2.69	2.13	2.42	2.69
111	0.47	2.5	-	-	0.33	1.83	2.08^	2.18^	2.08^	2.51^	2.08^	2.63^	2.08^	2.65^	2.08^	2.33^	2.65
112	0.46	2.5	-	-	0.35	1.84	2.09^	2.19^	2.09^	2.52^	2.09^	2.64^	2.09^	2.65^	2.09^	2.34^	2.65
113	0.45	2.5	-	-	0.36	1.85	2.10^	2.20^	2.10^	2.52^	2.10^	2.64^	2.10^	2.65^	2.10^	2.35^	2.65
114	0.49	2.6	-	-	0.38	1.88	2.13^	2.23^	2.13^	2.53^	2.13^	2.64^	2.13^	2.66^	2.13^	2.38^	2.66
115	0.72	3.1	-	-	0.38	1.86	2.22	2.21^	2.22	2.52^	2.22	2.64	2.22	2.77	2.22	2.54	2.77
116	0.62	2.9	-	-	0.43	1.88	2.19	2.23^	2.19	2.53^	2.19	2.64^	2.19	2.72	2.19	2.50	2.72
117	0.70	3.1	-	-	0.37	1.85	2.20	2.20^	2.20	2.52^	2.20	2.64^	2.20	2.75	2.20	2.53	2.75
118	0.68	3.0	-	-	0.36	1.83	2.17	2.18^	2.17	2.51^	2.17	2.63^	2.17	2.74	2.17	2.51	2.74
119	0.50	2.6	-	-	0.39	1.85	2.10^	2.20^	2.10^	2.52^	2.10^	2.64^	2.10^	2.65^	2.10^	2.35^	2.65

Table J7: 100yr ARI Wave Runup Levels and FPL with 0.55m MSLR

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only
% Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to High Tide
^ Boat wave conditions adopted in run-up calculation
* Swell wave conditions adopted in run-up calculation

100-year ARI Offshore Storm Tide is **1.45mAHD**
**** Mean Sea Level Rise** of **0.55m included** within the Design Water Level
Freeboard (0.3m) not included

Edge Treatment Types
1. 1 in 20 Natural Slope - 1.5mAHD crest
2. 1 in 20 Natural Slope - 2.5mAHD crest
3. 1 in 10 Beach Face - 1.5mAHD crest
4. 1 in 10 Beach Face - 2.5mAHD crest
5. 1 in 5 Embankment - 1.5mAHD crest
6. 1 in 5 Embankment - 2.5mAHD crest
7. 1 in 2 Seawall - 1.5mAHD crest
8. 1 in 2 Seawall - 2.5mAHD crest
9. Vertical Wall - 1.5mAHD crest
10. Vertical Wall - 2.5mAHD crest

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type ##										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
001	1.15	4.2	3.51	10.4	0.26	2.31	4.06*	4.12*	4.06*	4.20*	4.06*	4.25*	4.06*	4.26*	4.06*	4.19*	4.26
002	0.89	3.5	0.28	5.5	0.28	2.33	2.77	2.72	2.77	2.84	2.77	2.90	2.77	2.93	2.77	2.87	2.93
003	0.85	3.4	1.60	7.5	0.32	2.34	3.14*	3.18*	3.14*	3.25*	3.14*	3.28*	3.14*	3.29*	3.14*	3.23*	3.29
004	0.69	3.0	0.37	5.7	0.27	2.20	2.55	2.53*	2.55	2.64	2.55	2.75	2.55	2.80	2.55	2.70	2.80
005	0.76	3.2	0.17	5.4	0.29	2.14	2.52	2.42	2.52	2.64	2.52	2.76	2.52	2.83	2.52	2.70	2.83
006	0.75	3.2	0.04	5.2	0.27	2.11	2.48	2.46^	2.48	2.61^	2.48	2.75	2.48	2.82	2.48	2.68	2.82
007	0.53	2.6	0.01	5.1	0.29	2.13	2.40	2.32	2.40	2.51	2.40	2.64	2.40	2.71	2.40	2.58	2.71
008	0.38	2.3	-	-	0.29	2.14	2.33	2.28	2.33	2.42	2.33	2.57	2.33	2.64	2.33	2.51	2.64
009	0.59	2.8	-	-	0.29	2.09	2.38	2.30	2.38	2.51	2.38	2.66	2.38	2.74	2.38	2.59	2.74
010	0.48	2.5	-	-	0.24	2.08	2.33^	2.43^	2.33^	2.60^	2.33^	2.68^	2.33^	2.69^	2.33^	2.54^	2.69
011	0.49	2.6	-	-	0.25	2.09	2.34^	2.44^	2.34^	2.61^	2.34^	2.68^	2.34^	2.69^	2.34^	2.55^	2.69
012	0.56	2.7	-	-	0.28	2.12	2.40	2.47^	2.40	2.62^	2.40	2.69^	2.40	2.73	2.40	2.59	2.73
013	0.71	3.1	-	-	0.33	2.13	2.49	2.48^	2.49	2.62^	2.49	2.73	2.49	2.80	2.49	2.67	2.80
014	0.74	3.2	-	-	0.38	2.14	2.51	2.49^	2.51	2.63	2.51	2.75	2.51	2.82	2.51	2.69	2.82
015	0.32	2.1	-	-	0.37	2.16	2.32	2.28	2.32	2.40	2.32	2.55	2.32	2.61	2.32	2.48	2.61
016	0.26	2.0	-	-	0.36	2.18	2.31	2.28	2.31	2.38	2.31	2.53	2.31	2.58	2.31	2.44	2.58
017	0.51	2.6	-	-	0.65	2.21	2.47	2.40	2.47	2.56	2.47	2.66	2.47	2.71	2.47	2.61	2.71
018	0.70	3.1	-	-	0.51	2.23	2.58	2.56^	2.58	2.67	2.58	2.76	2.58	2.81	2.58	2.72	2.81
019	0.65	2.9	-	-	0.53	2.26	2.58	2.58^	2.58	2.67^	2.58	2.75	2.58	2.79	2.58	2.71	2.79
020	0.87	3.5	-	-	0.55	2.26	2.69	2.62	2.69	2.78	2.69	2.86	2.69	2.91	2.69	2.82	2.91
021	0.96	3.7	-	-	0.58	2.27	2.75	2.68	2.75	2.83	2.75	2.91	2.75	2.95	2.75	2.87	2.95
022	1.14	4.1	-	-	0.57	2.25	2.82	2.75	2.82	2.92	2.82	3.00	2.82	3.04	2.82	2.95	3.04
023	1.00	3.8	-	-	0.63	2.27	2.77	2.70	2.77	2.86	2.77	2.93	2.77	2.97	2.77	2.89	2.97
024	0.87	3.5	-	-	0.72	2.30	2.73	2.67	2.73	2.81	2.73	2.88	2.73	2.91	2.73	2.84	2.91
025	0.81	3.3	-	-	0.64	2.26	2.66	2.58	2.66	2.75	2.66	2.83	2.66	2.87	2.66	2.79	2.87
026	1.15	4.2	-	-	0.59	2.23	2.81	2.73	2.81	2.91	2.81	3.00	2.81	3.04	2.81	2.95	3.04
027	0.89	3.5	-	-	0.65	2.25	2.69	2.61	2.69	2.78	2.69	2.87	2.69	2.91	2.69	2.83	2.91
028	1.10	4.0	-	-	0.60	2.23	2.78	2.70	2.78	2.88	2.78	2.97	2.78	3.02	2.78	2.92	3.02
029	0.85	3.4	-	-	0.64	2.23	2.66	2.56^	2.66	2.75	2.66	2.84	2.66	2.89	2.66	2.80	2.89
030	0.77	3.2	-	-	0.68	2.22	2.61	2.55^	2.61	2.70	2.61	2.79	2.61	2.85	2.61	2.75	2.85
031	0.81	3.3	-	-	0.61	2.21	2.62	2.55^	2.62	2.71	2.62	2.81	2.62	2.87	2.62	2.77	2.87
032	0.93	3.6	-	-	0.57	2.21	2.68	2.58	2.68	2.78	2.68	2.88	2.68	2.93	2.68	2.83	2.93
033	1.02	3.8	-	-	0.53	2.20	2.71	2.61	2.71	2.82	2.71	2.92	2.71	2.97	2.71	2.87	2.97
034	0.92	3.6	-	-	0.52	2.18	2.64	2.53	2.64	2.75	2.64	2.86	2.64	2.92	2.64	2.81	2.92
035	0.86	3.5	-	-	0.47	2.17	2.60	2.52^	2.60	2.72	2.60	2.83	2.60	2.89	2.60	2.77	2.89
036	0.73	3.1	-	-	0.47	2.19	2.56	2.53^	2.56	2.65	2.56	2.76	2.56	2.82	2.56	2.71	2.82
037	0.71	3.1	-	-	0.47	2.20	2.56	2.54^	2.56	2.65	2.56	2.76	2.56	2.81	2.56	2.71	2.81
038	0.63	2.9	-	-	0.43	2.17	2.49	2.52^	2.49	2.64^	2.49	2.71	2.49	2.77	2.49	2.65	2.77

Table J7 cont.: 100yr ARI Wave Runup Levels and FPL with 0.55m MSLR

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type$^{\#\#}$										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
039	0.80	3.3	-	-	0.40	2.14	2.54	2.43	2.54	2.66	2.54	2.78	2.54	2.85	2.54	2.72	2.85
040	0.51	2.6	-	-	0.41	2.11	2.36	2.30	2.36	2.48	2.36	2.62	2.36	2.70	2.36	2.56	2.70
041	0.51	2.6	-	-	0.34	2.07	2.32	2.26	2.32	2.44	2.32	2.61	2.32	2.69	2.32	2.54	2.69
042	0.59	2.8	-	-	0.35	2.04	2.33	2.25	2.33	2.47	2.33	2.64	2.33	2.73	2.33	2.57	2.73
043	0.51	2.6	-	-	0.28	1.99	2.25	2.18	2.25	2.36	2.25	2.58	2.25	2.68	2.25	2.50	2.68
044	0.36	2.2	-	-	0.25	1.95	2.13	2.08	2.13	2.21	2.13	2.48	2.13	2.60	2.13	2.31	2.60
045	0.71	3.1	-	-	0.25	1.95	2.31	2.21	2.31	2.47	2.31	2.67	2.31	2.77	2.31	2.58	2.77
046	0.45	2.5	-	-	0.22	1.97	2.20	2.14	2.20	2.31	2.20	2.55	2.20	2.65	2.20	2.42	2.65
047	0.61	2.8	-	-	0.30	2.02	2.32	2.37^	2.32	2.58^	2.32	2.67^	2.32	2.73	2.32	2.57	2.73
048	0.82	3.4	-	-	0.38	2.04	2.45	2.39^	2.45	2.61	2.45	2.76	2.45	2.84	2.45	2.68	2.84
049	0.71	3.1	-	-	0.42	2.02	2.37	2.37^	2.37	2.58^	2.37	2.70	2.37	2.79	2.37	2.62	2.79
050	0.70	3.1	-	-	0.31	1.99	2.34	2.34^	2.34	2.57^	2.34	2.68	2.34	2.78	2.34	2.60	2.78
051	0.52	2.6	-	-	0.26	1.99	2.25	2.34^	2.25	2.57^	2.25	2.66^	2.25	2.68	2.25	2.51	2.68
052	0.71	3.1	-	-	0.26	1.94	2.30	2.29^	2.30	2.55^	2.30	2.67	2.30	2.77	2.30	2.58	2.77
053	0.64	2.9	-	-	0.25	1.93	2.25	2.28^	2.25	2.55^	2.25	2.65^	2.25	2.74	2.25	2.54	2.74
054	0.60	2.8	-	-	0.20	1.92	2.22	2.27^	2.22	2.55^	2.22	2.65^	2.22	2.71	2.22	2.51	2.71
055	0.40	2.3	-	-	0.15	1.92	2.12	2.07	2.12	2.21	2.12	2.50	2.12	2.61	2.12	2.32	2.61
056	0.57	2.7	-	-	0.21	1.94	2.23	2.14	2.23	2.35	2.23	2.59	2.23	2.70	2.23	2.51	2.70
057	0.40	2.3	-	-	0.23	1.95	2.15	2.10	2.15	2.24	2.15	2.51	2.15	2.62	2.15	2.35	2.62
058	0.35	2.2	-	-	0.26	1.99	2.17	2.12	2.17	2.25	2.17	2.50	2.17	2.60	2.17	2.34	2.60
059	0.45	2.5	-	-	0.32	2.04	2.26	2.21	2.26	2.38	2.26	2.57	2.26	2.66	2.26	2.49	2.66
060	0.30	2.1	-	-	0.31	2.06	2.21	2.17	2.21	2.29	2.21	2.51	2.21	2.58	2.21	2.36	2.58
061	0.45	2.5	-	-	0.27	2.07	2.29	2.24	2.29	2.41	2.29	2.58	2.29	2.66	2.29	2.51	2.66
062	0.50	2.6	-	-	0.24	2.04	2.29	2.22	2.29	2.41	2.29	2.60	2.29	2.68	2.29	2.52	2.68
063	0.64	2.9	-	-	0.24	2.07	2.39	2.30	2.39	2.52	2.39	2.68	2.39	2.76	2.39	2.61	2.76
064	0.72	3.1	-	-	0.28	2.06	2.42	2.41^	2.42	2.60^	2.42	2.71	2.42	2.80	2.42	2.64	2.80
065	0.62	2.9	-	-	0.30	2.13	2.44	2.48^	2.44	2.62^	2.44	2.69^	2.44	2.76	2.44	2.63	2.76
066	0.76	3.2	0.03	5.2	0.31	2.10	2.48	2.45^	2.48	2.61^	2.48	2.75	2.48	2.82	2.48	2.68	2.82
067	0.71	3.1	0.05	5.2	0.31	2.14	2.50	2.40	2.50	2.61	2.50	2.74	2.50	2.80	2.50	2.68	2.80
068	0.75	3.2	0.06	5.2	0.25	2.12	2.50	2.40	2.50	2.62	2.50	2.75	2.50	2.82	2.50	2.69	2.82
069	0.55	2.7	0.02	5.1	0.19	2.10	2.37	2.30	2.37	2.50	2.37	2.64	2.37	2.72	2.37	2.58	2.72
070	0.60	2.8	0.10	5.3	0.23	2.11	2.41	2.33	2.41	2.53	2.41	2.67	2.41	2.74	2.41	2.61	2.74
071	0.44	2.4	0.06	5.2	0.18	2.14	2.36	2.30	2.36	2.46	2.36	2.60	2.36	2.67	2.36	2.54	2.67
072	0.50	2.6	0.45	5.8	0.27	2.18	2.43^	2.54*	2.43^	2.64^	2.43^	2.70^	2.43^	2.70^	2.43^	2.59^	2.70
073	0.81	3.3	0.45	5.8	0.27	2.21	2.62	2.56*	2.62	2.71	2.62	2.81	2.62	2.87	2.62	2.77	2.87
074	0.93	3.6	2.63	9.0	0.26	2.22	3.54*	3.58*	3.54*	3.71*	3.54*	3.78*	3.54*	3.80*	3.54*	3.70*	3.80
075	0.36	2.2	-	-	0.34	2.12	2.30	2.25	2.30	2.38	2.30	2.55	2.30	2.62	2.30	2.48	2.62
076	0.39	2.3	-	-	0.30	2.08	2.27	2.22	2.27	2.37	2.27	2.55	2.27	2.63	2.27	2.47	2.63
077	0.24	1.9	-	-	0.28	2.08	2.20	2.17	2.20	2.27	2.20	2.45	2.20	2.56	2.20	2.32	2.56
078	0.45	2.5	-	-	0.28	2.05	2.27	2.22	2.27	2.39	2.27	2.58	2.27	2.66	2.27	2.50	2.66
079	0.20	1.8	-	-	0.26	2.06	2.16	2.14	2.16	2.22	2.16	2.38	2.16	2.53	2.16	2.26	2.53
080	0.27	2.0	-	-	0.26	2.07	2.20	2.17	2.20	2.28	2.20	2.49	2.20	2.57	2.20	2.34	2.57
081	0.28	2.0	-	-	0.26	2.06	2.20	2.17	2.20	2.27	2.20	2.48	2.20	2.57	2.20	2.34	2.57
082	0.31	2.1	-	-	0.24	2.04	2.19	2.16	2.19	2.27	2.19	2.50	2.19	2.58	2.19	2.35	2.58
083	0.62	2.9	-	-	0.25	2.05	2.36	2.28	2.36	2.50	2.36	2.66	2.36	2.74	2.36	2.59	2.74

Table J7 cont.: 100yr ARI Wave Runup Levels and FPL with 0.55m MSLR

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type$^{\#\#}$										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
084	0.62	2.9	-	-	0.27	2.07	2.38	2.30	2.38	2.52	2.38	2.67	2.38	2.75	2.38	2.60	2.75
085	0.40	2.3	-	-	0.30	2.09	2.29	2.24	2.29	2.38	2.29	2.56	2.29	2.64	2.29	2.49	2.64
086	0.74	3.2	-	-	0.27	2.08	2.45	2.43^	2.45	2.60^	2.45	2.73	2.45	2.81	2.45	2.66	2.81
087	0.53	2.6	-	-	0.30	2.09	2.35	2.44^	2.35	2.61^	2.35	2.68^	2.35	2.70	2.35	2.56	2.70
088	0.31	2.1	-	-	0.30	2.08	2.33^	2.43^	2.33^	2.60^	2.33^	2.68^	2.33^	2.69^	2.33^	2.54^	2.69
089	0.63	2.9	-	-	0.31	2.11	2.42	2.46^	2.42	2.61^	2.42	2.69	2.42	2.76	2.42	2.62	2.76
090	0.47	2.5	-	-	0.13	1.94	2.18	2.11	2.18	2.28	2.18	2.54	2.18	2.65	2.18	2.41	2.65
091	0.42	2.4	-	-	0.12	1.93	2.14	2.09	2.14	2.24	2.14	2.52	2.14	2.62	2.14	2.35	2.62
092	0.31	2.1	-	-	0.20	1.92	2.07	2.04	2.07	2.15	2.07	2.39	2.07	2.57	2.07	2.23	2.57
093	0.33	2.2	-	-	0.10	1.93	2.10	2.06	2.10	2.18	2.10	2.44	2.10	2.58	2.10	2.26	2.58
094	0.55	2.7	-	-	0.73	2.32	2.59	2.53	2.59	2.65	2.59	2.72	2.59	2.75	2.59	2.69	2.75
095	0.58	2.8	-	-	0.73	2.31	2.60	2.53	2.60	2.66	2.60	2.73	2.60	2.77	2.60	2.70	2.77
096	0.41	2.4	-	-	0.68	2.29	2.49	2.44	2.49	2.57	2.49	2.64	2.49	2.68	2.49	2.60	2.68
097	0.33	2.2	-	-	0.61	2.28	2.44	2.41	2.44	2.52	2.44	2.59	2.44	2.63	2.44	2.56	2.63
098	0.40	2.3	-	-	0.63	2.31	2.51	2.46	2.51	2.57	2.51	2.64	2.51	2.67	2.51	2.61	2.67
099	0.32	2.1	-	-	0.64	2.34	2.50	2.46	2.50	2.55	2.50	2.61	2.50	2.64	2.50	2.58	2.64
100	0.47	2.5	-	-	0.69	2.37	2.61	2.56	2.61	2.65	2.61	2.69	2.61	2.72	2.61	2.67	2.72
101	0.50	2.6	-	-	0.67	2.34	2.59	2.53	2.59	2.64	2.59	2.70	2.59	2.73	2.59	2.67	2.73
102	0.44	2.4	-	-	0.67	2.32	2.54	2.48	2.54	2.60	2.54	2.66	2.54	2.70	2.54	2.63	2.70
103	0.45	2.5	-	-	0.70	2.32	2.54	2.49	2.54	2.61	2.54	2.67	2.54	2.70	2.54	2.64	2.70
104	0.61	2.8	-	-	0.42	2.21	2.52	2.55^	2.52	2.65^	2.52	2.71	2.52	2.76	2.52	2.66	2.76
105	0.62	2.9	-	-	0.37	2.20	2.51	2.54^	2.51	2.65^	2.51	2.71	2.51	2.77	2.51	2.66	2.77
106	0.64	2.9	-	-	0.34	2.19	2.51	2.53^	2.51	2.64^	2.51	2.72	2.51	2.78	2.51	2.67	2.78
107	0.53	2.6	-	-	0.30	2.19	2.46	2.53^	2.46	2.64^	2.46	2.70^	2.46	2.72	2.46	2.61	2.72
108	0.48	2.5	-	-	0.29	2.20	2.45^	2.54^	2.45^	2.65^	2.45^	2.70^	2.45^	2.71^	2.45^	2.60^	2.71
109	0.47	2.5	-	-	0.28	2.21	2.46^	2.55^	2.46^	2.65^	2.46^	2.70^	2.46^	2.71^	2.46^	2.61^	2.71
110	0.58	2.8	-	-	0.31	2.21	2.50	2.55^	2.50	2.65^	2.50	2.70^	2.50	2.75	2.50	2.65	2.75
111	0.47	2.5	-	-	0.33	2.20	2.45^	2.54^	2.45^	2.65^	2.45^	2.70^	2.45^	2.71^	2.45^	2.60^	2.71
112	0.46	2.5	-	-	0.35	2.21	2.46^	2.55^	2.46^	2.65^	2.46^	2.70^	2.46^	2.71^	2.46^	2.61^	2.71
113	0.45	2.5	-	-	0.36	2.22	2.47^	2.55^	2.47^	2.65^	2.47^	2.70^	2.47^	2.71^	2.47^	2.61^	2.71
114	0.49	2.6	-	-	0.38	2.25	2.50^	2.57^	2.50^	2.66^	2.50^	2.71^	2.50^	2.72^	2.50^	2.63^	2.72
115	0.72	3.1	-	-	0.38	2.23	2.59	2.56^	2.59	2.68	2.59	2.77	2.59	2.82	2.59	2.73	2.82
116	0.62	2.9	-	-	0.43	2.25	2.56	2.57^	2.56	2.66^	2.56	2.73	2.56	2.78	2.56	2.69	2.78
117	0.70	3.1	-	-	0.37	2.22	2.57	2.55^	2.57	2.66	2.57	2.76	2.57	2.81	2.57	2.71	2.81
118	0.68	3.0	-	-	0.36	2.20	2.54	2.54^	2.54	2.65^	2.54	2.74	2.54	2.80	2.54	2.69	2.80
119	0.50	2.6	-	-	0.39	2.22	2.47^	2.55^	2.47^	2.65^	2.47^	2.70^	2.47^	2.71^	2.47^	2.61^	2.71

Table J8: 100yr ARI Wave Runup Levels and FPL with 0.91m MSLR

Wave Parameters based on Sydney Wind Data (1939-1997) from ENE-Sth only
% Local Wind Setup value taken as maximum setup from Nth-Sth and is relative to High Tide
^ Boat wave conditions adopted in run-up calculation
* Swell wave conditions adopted in run-up calculation

100-year ARI Offshore Storm Tide is **1.45mAHD**
**** Mean Sea Level Rise** of **0.91m included** within the Design Water Level
Freeboard (0.3m) not included

Edge Treatment Types
1. 1 in 20 Natural Slope - 1.5mAHD crest
2. 1 in 20 Natural Slope - 2.5mAHD crest
3. 1 in 10 Beach Face - 1.5mAHD crest
4. 1 in 10 Beach Face - 2.5mAHD crest
5. 1 in 5 Embankment - 1.5mAHD crest
6. 1 in 5 Embankment - 2.5mAHD crest
7. 1 in 2 Seawall - 1.5mAHD crest
8. 1 in 2 Seawall - 2.5mAHD crest
9. Vertical Wall - 1.5mAHD crest
10. Vertical Wall - 2.5mAHD crest

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup% (m)	Design Water Level** (mAHD)	Edge Treatment Type ##										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
001	1.15	4.2	3.51	10.4	0.26	2.67	4.43*	4.43*	4.43*	4.43*	4.43*	4.43*	4.43*	4.43*	4.43*	4.43*	4.43
002	0.89	3.5	0.28	5.5	0.28	2.69	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
003	0.85	3.4	1.60	7.5	0.32	2.70	3.50*	3.50*	3.50*	3.50*	3.50*	3.50*	3.50*	3.50*	3.50*	3.50*	3.50
004	0.69	3.0	0.37	5.7	0.27	2.56	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
005	0.76	3.2	0.17	5.4	0.29	2.50	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88
006	0.75	3.2	0.04	5.2	0.27	2.47	2.85	2.84	2.85	2.86	2.85	2.87	2.85	2.88	2.85	2.87	2.88
007	0.53	2.6	0.01	5.1	0.29	2.49	2.76	2.76	2.76	2.76	2.76	2.77	2.76	2.77	2.76	2.77	2.77
008	0.38	2.3	-	-	0.29	2.50	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69
009	0.59	2.8	-	-	0.29	2.45	2.75	2.73	2.75	2.77	2.75	2.78	2.75	2.79	2.75	2.78	2.79
010	0.48	2.5	-	-	0.24	2.44	2.69^	2.71^	2.69^	2.73^	2.69^	2.74^	2.69^	2.75^	2.69^	2.72^	2.75
011	0.49	2.6	-	-	0.25	2.45	2.70^	2.72^	2.70^	2.74^	2.70^	2.75^	2.70^	2.75^	2.70^	2.73^	2.75
012	0.56	2.7	-	-	0.28	2.48	2.76	2.76	2.76	2.77	2.76	2.78	2.76	2.78	2.76	2.78	2.78
013	0.71	3.1	-	-	0.33	2.49	2.85	2.85	2.85	2.86	2.85	2.86	2.85	2.86	2.85	2.86	2.86
014	0.74	3.2	-	-	0.38	2.50	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87
015	0.32	2.1	-	-	0.37	2.52	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68
016	0.26	2.0	-	-	0.36	2.54	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67
017	0.51	2.6	-	-	0.65	2.57	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
018	0.70	3.1	-	-	0.51	2.59	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94
019	0.65	2.9	-	-	0.53	2.62	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95
020	0.87	3.5	-	-	0.55	2.62	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06
021	0.96	3.7	-	-	0.58	2.63	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11
022	1.14	4.1	-	-	0.57	2.61	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
023	1.00	3.8	-	-	0.63	2.63	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13
024	0.87	3.5	-	-	0.72	2.66	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10
025	0.81	3.3	-	-	0.64	2.62	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03
026	1.15	4.2	-	-	0.59	2.59	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16
027	0.89	3.5	-	-	0.65	2.61	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06
028	1.10	4.0	-	-	0.60	2.59	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
029	0.85	3.4	-	-	0.64	2.59	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01
030	0.77	3.2	-	-	0.68	2.58	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96
031	0.81	3.3	-	-	0.61	2.57	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97
032	0.93	3.6	-	-	0.57	2.57	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03
033	1.02	3.8	-	-	0.53	2.56	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
034	0.92	3.6	-	-	0.52	2.54	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
035	0.86	3.5	-	-	0.47	2.53	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96
036	0.73	3.1	-	-	0.47	2.55	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91
037	0.71	3.1	-	-	0.47	2.56	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91
038	0.63	2.9	-	-	0.43	2.53	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84

Table J8 cont.: 100yr ARI Wave Runup Levels and FPL with 0.91m MSLR

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type$^{\#\#}$										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
039	0.80	3.3	-	-	0.40	2.50	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
040	0.51	2.6	-	-	0.41	2.47	2.73	2.72	2.73	2.74	2.73	2.75	2.73	2.76	2.73	2.74	2.76
041	0.51	2.6	-	-	0.34	2.43	2.69	2.66	2.69	2.71	2.69	2.74	2.69	2.75	2.69	2.72	2.75
042	0.59	2.8	-	-	0.35	2.40	2.70	2.66	2.70	2.73	2.70	2.77	2.70	2.78	2.70	2.75	2.78
043	0.51	2.6	-	-	0.28	2.35	2.61	2.55	2.61	2.65	2.61	2.71	2.61	2.74	2.61	2.68	2.74
044	0.36	2.2	-	-	0.25	2.31	2.49	2.44	2.49	2.55	2.49	2.62	2.49	2.65	2.49	2.59	2.65
045	0.71	3.1	-	-	0.25	2.31	2.66	2.60	2.66	2.73	2.66	2.80	2.66	2.83	2.66	2.77	2.83
046	0.45	2.5	-	-	0.22	2.33	2.55	2.50	2.55	2.61	2.55	2.67	2.55	2.70	2.55	2.64	2.70
047	0.61	2.8	-	-	0.30	2.38	2.69	2.67^	2.69	2.73	2.69	2.77	2.69	2.79	2.69	2.75	2.79
048	0.82	3.4	-	-	0.38	2.40	2.81	2.78	2.81	2.85	2.81	2.88	2.81	2.90	2.81	2.87	2.90
049	0.71	3.1	-	-	0.42	2.38	2.74	2.70	2.74	2.78	2.74	2.82	2.74	2.84	2.74	2.80	2.84
050	0.70	3.1	-	-	0.31	2.35	2.70	2.65	2.70	2.75	2.70	2.81	2.70	2.83	2.70	2.78	2.83
051	0.52	2.6	-	-	0.26	2.35	2.61	2.65^	2.61	2.70^	2.61	2.73^	2.61	2.74	2.61	2.69	2.74
052	0.71	3.1	-	-	0.26	2.30	2.65	2.61^	2.65	2.72	2.65	2.79	2.65	2.83	2.65	2.76	2.83
053	0.64	2.9	-	-	0.25	2.29	2.61	2.60^	2.61	2.68^	2.61	2.75	2.61	2.79	2.61	2.72	2.79
054	0.60	2.8	-	-	0.20	2.28	2.58	2.60^	2.58	2.68^	2.58	2.73	2.58	2.77	2.58	2.69	2.77
055	0.40	2.3	-	-	0.15	2.28	2.48	2.43	2.48	2.55	2.48	2.63	2.48	2.67	2.48	2.59	2.67
056	0.57	2.7	-	-	0.21	2.30	2.58	2.51	2.58	2.65	2.58	2.72	2.58	2.76	2.58	2.69	2.76
057	0.40	2.3	-	-	0.23	2.31	2.51	2.46	2.51	2.57	2.51	2.64	2.51	2.67	2.51	2.61	2.67
058	0.35	2.2	-	-	0.26	2.35	2.53	2.48	2.53	2.58	2.53	2.63	2.53	2.65	2.53	2.60	2.65
059	0.45	2.5	-	-	0.32	2.40	2.63	2.59	2.63	2.66	2.63	2.70	2.63	2.71	2.63	2.68	2.71
060	0.30	2.1	-	-	0.31	2.42	2.57	2.55	2.57	2.60	2.57	2.63	2.57	2.64	2.57	2.61	2.64
061	0.45	2.5	-	-	0.27	2.43	2.66	2.63	2.66	2.68	2.66	2.71	2.66	2.72	2.66	2.69	2.72
062	0.50	2.6	-	-	0.24	2.40	2.65	2.62	2.65	2.69	2.65	2.72	2.65	2.74	2.65	2.70	2.74
063	0.64	2.9	-	-	0.24	2.43	2.75	2.73	2.75	2.78	2.75	2.80	2.75	2.82	2.75	2.79	2.82
064	0.72	3.1	-	-	0.28	2.42	2.78	2.76	2.78	2.81	2.78	2.84	2.78	2.85	2.78	2.83	2.85
065	0.62	2.9	-	-	0.30	2.49	2.80	2.80	2.80	2.81	2.80	2.81	2.80	2.81	2.80	2.81	2.81
066	0.76	3.2	0.03	5.2	0.31	2.46	2.84	2.83	2.84	2.86	2.84	2.87	2.84	2.88	2.84	2.87	2.88
067	0.71	3.1	0.05	5.2	0.31	2.50	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85
068	0.75	3.2	0.06	5.2	0.25	2.48	2.86	2.85	2.86	2.87	2.86	2.88	2.86	2.88	2.86	2.87	2.88
069	0.55	2.7	0.02	5.1	0.19	2.46	2.74	2.72	2.74	2.75	2.74	2.77	2.74	2.77	2.74	2.76	2.77
070	0.60	2.8	0.10	5.3	0.23	2.47	2.77	2.76	2.77	2.78	2.77	2.80	2.77	2.80	2.77	2.79	2.80
071	0.44	2.4	0.06	5.2	0.18	2.50	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
072	0.50	2.6	0.45	5.8	0.27	2.54	2.79^	2.79^	2.79^	2.79^	2.79^	2.79^	2.79^	2.79^	2.79^	2.79^	2.79
073	0.81	3.3	0.45	5.8	0.27	2.57	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97
074	0.93	3.6	2.63	9.0	0.26	2.58	3.89*	3.89*	3.89*	3.89*	3.89*	3.89*	3.89*	3.89*	3.89*	3.89*	3.89
075	0.36	2.2	-	-	0.34	2.48	2.66	2.66	2.66	2.67	2.66	2.68	2.66	2.68	2.66	2.67	2.68
076	0.39	2.3	-	-	0.30	2.44	2.64	2.62	2.64	2.66	2.64	2.68	2.64	2.69	2.64	2.67	2.69
077	0.24	1.9	-	-	0.28	2.44	2.56	2.54	2.56	2.58	2.56	2.60	2.56	2.61	2.56	2.59	2.61
078	0.45	2.5	-	-	0.28	2.41	2.64	2.61	2.64	2.67	2.64	2.70	2.64	2.72	2.64	2.68	2.72
079	0.20	1.8	-	-	0.26	2.42	2.52	2.50	2.52	2.55	2.52	2.58	2.52	2.59	2.52	2.56	2.59
080	0.27	2.0	-	-	0.26	2.43	2.57	2.54	2.57	2.59	2.57	2.61	2.57	2.63	2.57	2.60	2.63
081	0.28	2.0	-	-	0.26	2.42	2.56	2.53	2.56	2.59	2.56	2.62	2.56	2.63	2.56	2.60	2.63
082	0.31	2.1	-	-	0.24	2.40	2.56	2.52	2.56	2.59	2.56	2.62	2.56	2.64	2.56	2.61	2.64
083	0.62	2.9	-	-	0.25	2.41	2.72	2.69	2.72	2.75	2.72	2.79	2.72	2.80	2.72	2.77	2.80

Table J8 cont.: 100yr ARI Wave Runup Levels and FPL with 0.91m MSLR

Loc ID	100yrARI						Wave Runup Level (mAHD)										FPL (mAHD)
	Sea		Swell		Local Wind Setup$^{\%}$ (m)	Design Water Level** (mAHD)	Edge Treatment Type$^{\#\#}$										
	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)			1	2	3	4	5	6	7	8	9	10	
084	0.62	2.9	-	-	0.27	2.43	2.74	2.72	2.74	2.77	2.74	2.79	2.74	2.81	2.74	2.78	2.81
085	0.40	2.3	-	-	0.30	2.45	2.65	2.63	2.65	2.67	2.65	2.69	2.65	2.70	2.65	2.68	2.70
086	0.74	3.2	-	-	0.27	2.44	2.81	2.80	2.81	2.84	2.81	2.86	2.81	2.87	2.81	2.85	2.87
087	0.53	2.6	-	-	0.30	2.45	2.72	2.72^	2.72	2.74^	2.72	2.75	2.72	2.76	2.72	2.74	2.76
088	0.31	2.1	-	-	0.30	2.44	2.69^	2.71^	2.69^	2.73^	2.69^	2.74^	2.69^	2.75^	2.69^	2.72^	2.75
089	0.63	2.9	-	-	0.31	2.47	2.79	2.78	2.79	2.80	2.79	2.81	2.79	2.82	2.79	2.81	2.82
090	0.47	2.5	-	-	0.13	2.30	2.53	2.47	2.53	2.60	2.53	2.67	2.53	2.71	2.53	2.64	2.71
091	0.42	2.4	-	-	0.12	2.29	2.50	2.45	2.50	2.57	2.50	2.64	2.50	2.68	2.50	2.61	2.68
092	0.31	2.1	-	-	0.20	2.28	2.43	2.40	2.43	2.51	2.43	2.58	2.43	2.62	2.43	2.55	2.62
093	0.33	2.2	-	-	0.10	2.29	2.45	2.42	2.45	2.53	2.45	2.60	2.45	2.63	2.45	2.56	2.63
094	0.55	2.7	-	-	0.73	2.68	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96
095	0.58	2.8	-	-	0.73	2.67	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96	2.96
096	0.41	2.4	-	-	0.68	2.65	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86
097	0.33	2.2	-	-	0.61	2.64	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81
098	0.40	2.3	-	-	0.63	2.67	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87
099	0.32	2.1	-	-	0.64	2.70	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86
100	0.47	2.5	-	-	0.69	2.73	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97
101	0.50	2.6	-	-	0.67	2.70	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95
102	0.44	2.4	-	-	0.67	2.68	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
103	0.45	2.5	-	-	0.70	2.68	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91
104	0.61	2.8	-	-	0.42	2.57	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87
105	0.62	2.9	-	-	0.37	2.56	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87
106	0.64	2.9	-	-	0.34	2.55	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87	2.87
107	0.53	2.6	-	-	0.30	2.55	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81
108	0.48	2.5	-	-	0.29	2.56	2.81^	2.81^	2.81^	2.81^	2.81^	2.81^	2.81^	2.81^	2.81^	2.81^	2.81
109	0.47	2.5	-	-	0.28	2.57	2.82^	2.82^	2.82^	2.82^	2.82^	2.82^	2.82^	2.82^	2.82^	2.82^	2.82
110	0.58	2.8	-	-	0.31	2.57	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86
111	0.47	2.5	-	-	0.33	2.56	2.81^	2.81^	2.81^	2.81^	2.81^	2.81^	2.81^	2.81^	2.81^	2.81^	2.81
112	0.46	2.5	-	-	0.35	2.57	2.82^	2.82^	2.82^	2.82^	2.82^	2.82^	2.82^	2.82^	2.82^	2.82^	2.82
113	0.45	2.5	-	-	0.36	2.58	2.83^	2.83^	2.83^	2.83^	2.83^	2.83^	2.83^	2.83^	2.83^	2.83^	2.83
114	0.49	2.6	-	-	0.38	2.61	2.86^	2.86^	2.86^	2.86^	2.86^	2.86^	2.86^	2.86^	2.86^	2.86^	2.86
115	0.72	3.1	-	-	0.38	2.59	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95
116	0.62	2.9	-	-	0.43	2.61	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92
117	0.70	3.1	-	-	0.37	2.58	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93
118	0.68	3.0	-	-	0.36	2.56	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
119	0.50	2.6	-	-	0.39	2.58	2.83^	2.83^	2.83^	2.83^	2.83^	2.83^	2.83^	2.83^	2.83^	2.83^	2.83

APPENDIX K

WAVE RUN-UP EQUATIONS

Paramters:

H_s - significant wave height

T - wave period

H_o - deepwater wave height

L_o - deepwater wave length $\left(= gT^2/2\pi\right)$

s_{op} - deepwater wave steepness $\left(= H_o/L_o\right)$

α - slope angle

ξ_{op} - surf similarity parameter $\left(= \tan\alpha/\sqrt{s_{op}}\right)$

$R_{u2\%}$ - Run-up height exceeded by 2% of waves

R_c - freeboard

K_{TO} - Transmitted overtopping wave coefficient

H_{TO} - Transmitted overtopping wave height

SWL - Still water level

Wave run-up without overtopping

De Waal and van der Meer (1992)

$$\frac{R_{u2\%}}{H_s} = \begin{cases} 1.6\xi_{op} & for \quad 0.5 < \xi_{op} \leq 2 \\ 3.2 & for \quad 2 < \xi_{op} \leq 3-4 \end{cases}$$

$$Level = SWL + R_{u2\%}$$

Wave run-up with overtopping

Van der Meer and Janssen (1995)

$$K_{TO} = C\left(1.0 - R_c/R_{u2\%}\right)$$

where $C = 0.51$ for transmitted wave at the crest

$$H_{TO} = K_{TO} \times H_s$$

$$Level = SWL + H_{TO}$$

Wave overtopping when still water is above the crest

Public Works Department (1990)

$$Level = SWL + \frac{H_s}{2}$$

Wave overtopping of a vertical wall

$$Level = SWL + H_s$$

APPENDIX L

Submissions from the Draft Report Public Exhibition

K.1 Public Submission 1

Received: Friday, 31 January 2008

DETAILS WITHHELD
YATTALUNGA NSW 2251

31 January 2008

Mr Sean Garber
Cardno-Lawson Treloar Pty Limited
Level 2 Pacific Highway
GORDON NSW 2072

Submission on Draft Brisbane Water Foreshore Flood Study

As I see it, the main problems affecting the foreshore and properties fronting many areas of the Brisbane Water are as follows:-

a) **Flooding** - due to the three scenarios: heavy rain, high tides and strong winds.

b) **Erosion** - the continual erosion of the foreshore due to wave action created by strong winds, especially when tides are high.

c) **Drainage** - runoff from open drains and adjoining properties creating mud flats and pollution.

d) **Pollution on the waterfront** - especially from lawn clippings, plastic and various stages of decaying timber. After strong westerly winds and tide movement, there is always a mixture of lawn clippings mixed with seaweed, together with an assortment of rubbish. This breaks down into a slimy rotting state, giving off a pungent odour if not removed.

This area has been neglected for many years as far as drainage and water runoff collection are concerned, especially during heavy rain. Drainage from Davistown Road flows unchecked through open drains with no collection or filtration traps for rubbish, soil etc, and I am constantly cleaning up the rubbish and seaweed so as to eliminate the vermin problem.

The increase of building developments upstream from Egans Creek has added to the build up of the mud flat problem in the Yattalunga bay.

My recommendation to resolve these problems is the construction of a seawall similar to the one at Davistown.

Attached hereto is a copy of my previous submission of 11 October 2006.

Yours sincerely

Name Withheld

K.1.1 Response to Submission

This study was commissioned to define the extent of foreshore flooding from estuarine waters, including processes such as high tides, storm surges and wind wave action. Issues of rainfall and drainage flooding are to be addressed in local flood studies. Issues of erosion and possible actions to lessen the impact of flooding on the foreshore areas will be addressed in the subsequent management study and plan.

Attached to the submission was a series of photographs from historical foreshore flooding events as a result of elevated estuary water levels and wave action. They are an excellent illustration of some of the processes that were defined in the study.

K.1.2 Amendments to the Report

Figures have been included in Section 6.4.1 making use of the photographs attached to the submission, in order to further clarify the potential nature and extent of foreshore flooding along the Brisbane Water foreshore.

K.2 Public Submission 2

Received: Friday, 13 February 2008

Re: Submissions on Draft Brisbane Water Foreshore Flood Study

I have examined the study with great interest as I was instrumental in preparing the existing flood planning system as a result of the 1974 storm and flood. I was employed by Gosford City Council for nearly 30 years and witnessed the aftermath of the 1974 event and was involved in collecting much of the flood level information from that time. I also directed the preparation of Council's Coastal management plan.

My initial examination showed a thorough and extensive study. The results clearly show the dominance of the ocean event around the foreshores and the calibrations appear satisfactory, so there should be confidence in the results of the still water levels. It is also interesting to note that the ocean level driven PMF is not at alarmingly high levels.

I further examined your investigations to determine the EPL and it appears that there could be some inconsistencies in this work. In such a large volume of processed data it is easy to be confused by the quantity of results. For simplicity I examined seven locations that I have some reasonable knowledge of to see how a planning level compared to a PMF. I have tabled my lists using your site nos and a local name.

24	Gosford	EPL 2.82	PMF 2.23	Diff 0.59
22	Pt Clare	2.95	2.14	0.81
32	Green Pt	2.84	2.06	0.78
108	WoyWoy bay	2.62	2.05	0.57
13	Brickwharf Rd	2.72	1.92	0.80
52	Humphreys Rd	2.69	1.55	1.14
86	St Huberts Is	2.72	1.82	0.90

I understand your EPL calculation is done using different foreshore treatments but this seems to produce different end results in similar areas. Sites 108 and 52 both have similar shelter ie. not long fetches but the planning level at site 52 has a much larger difference above the flood level.

The site 24 has the largest fetch of all sites but has a margin above the PMF that is less than other exposed sites.Site 13 has only moderate fetch and the margin above the PMF is greater than the Gosford site 24.

Whilst the report points out that different foreshore treatments change the runup and the setup, I feel that the EPL proposed may be taken as 'Gospel' which may result in buildings at inappropriately high or low levels. In most of the extensive areas with low land levels like Woy Woy and Davistown there are submerged walls with very similar wave exposures over a large number of houses and should probably be dealt with on an area basis rather than as individual sites, as the proposed EPL seems to indicate.

I have also noted that the report does not do any study of the possible effects of a Tsunami. I have read in the local media that SES have in the past done exercises on how to handle a Tsunami disaster, but I understand that no-one has yet applied the possibility one to any hydraulic models for Gosford. My understanding is that high level Tsunamis are only expected to be caused by meteor collisions and the earthquake generated type are not expected to be large on the NSW coast. Maybe some discussion of this should be included in the report, and maybe a moderate tsunami of say 4.0 m height should be modelled. My expectation would be that the shape of the waterway would, when associated with the wave frequency, attenuate the tsunami significantly and the effect upstream of the Rip may be quite low. This exercise could show which are the likely areas of affection which may be a very useful planning tool.

I hope I have explained my concerns clearly, but if further explanation is needed please phone me on XXXX XXXX. If in future you need any input about things that happened in the past, I would not mind trying to assist, as an individual or even possibly on the committee.

Yours faithfully *Name Withheld*

K.2.1 Response to Submission

1. Derivation of the EPL

The apparent discrepancies outlined in the submission above are a result of the nature of wave run-up and overtopping of the foreshore edge treatments. Results of the study are considered realistic and account for foreshore flooding from wave activity in addition to a design still water level.

Firstly it should be noted that the Estuarine Planning Level (EPL) is a preliminary level based on the edge treatment option that produces the highest run-up level. For almost all locations this is for a 1 in 2 seawall with a 2.5mAHD crest level. This is certainly not representative of the vast majority of shorelines around Brisbane Water; however, it provides a worst case initial level. It is intended that in practice the EPL can be applied on a site by site edge treatment basis using the tabulated data in the Appendix I.

The physical processes of wave run-up and overtopping result in inundation levels with variable differences from the design still water line. This point is best illustrated by consideration of the same locations identified within the submission above.

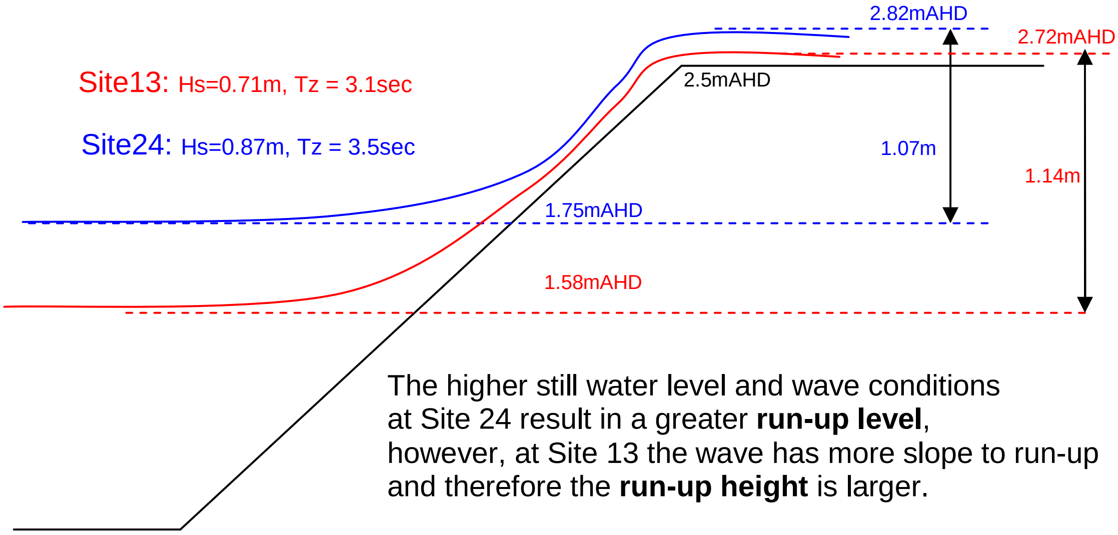
Looking at sites 52 and 108, the wave conditions and design still water levels are presented below. Site 52 has a greater wave height due to the alignment of its fetch to the south which is subjected to higher and more frequent storm wind conditions. A run-up height is also included based on the wave run-up equation (without overtopping) in Appendix J. These run-up heights are based on a continuous and hypothetically endless slope of 1 in 2 resulting in the run-up reaching a level of 3.7 and 3.15 mAHD respectively.

Site	Hs (m)	Tz (sec)	WL (mAHD)	Run-up Amount (m)	Runup Level (mAHD)	Hto (m)	EPL (mAHD)
52	0.71	3.1	1.39	2.3	3.7	0.19	2.69
108	0.48	2.5	1.65	1.5	3.15	0.12	2.62

However, run-up on the structure can only occur up to the crest level (2.5mAHD) at which point overtopping of the crest occurs. This results in a pulse, or wave, of water that travels over the foreshore area. The values presented above show that at both locations wave run-up would exceed the 2.5mAHD crest and wave overtopping will occur.

The height of this overtopping wave is determined using the equation for a transmitted wave in Appendix J. Differences between the transmitted wave heights at the two locations is much reduced when compared to the differences in potential run-up levels. This is because past the crest the slope of the edge treatment is no longer present to propel the surge of water higher. The foreshore level is now calculated by adding the overtopping wave height to the foreshore land level.

We can consider two other sites; 13 and 24. Site 24 has a higher storm tide level and larger wave conditions. Despite this the run-up height at site 13 is larger as it has more foreshore slope (above the water line) for the wave to run-up. While this results in a larger run-up height, the level (or depth) of inundation is greater under the more severe conditions at sites 24. This is shown in the diagram below.



The higher still water level and wave conditions at Site 24 result in a greater **run-up level**, however, at Site 13 the wave has more slope to run-up and therefore the **run-up height** is larger.

If a foreshore edge treatment crest of 1.5mAHD were considered, then the EPL would be significantly lower than the numbers presented above, as wave overtopping would occur at 1.5mAHD and not 2.5mAHD. However, more critically, the depth of overtopping would be greater and the EPL above the foreshore ground level would be greater.

The definition of an EPL within this study has attempted to take account for the physical processes of wave run-up and overtopping over the range of potential foreshore edge treatments present within Brisbane Water. It is perhaps counter-intuitive to suggest that if the freeboard to the foreshore crest is greater, the foreshore flood level is higher, however, this accounts for the fact that a higher edge allows the wave to run-up to a higher level, thereby increasing the EPL..

2. Consideration of Tsunami Events

Tsunami events are very complicated to include in such a study aimed towards the setting of EPL, due mainly to the uncertainty in their return periods. Historically, tsunamis generated from distant sub-sea earthquakes or locally by landslides on the continental shelf have affected the mid-NSW coast. For this study site, such events are likely to be very rare with return periods well in excess of 100-years ARI. Geoscience Australia is currently undertaking a study to quantify the tsunami risk for the whole Australian coastline, and consideration of tsunami events specifically by Council would best wait until the findings of the GA study are defined. As yet, there are no coastal planning design guidelines for tsunamis on the NSW coast. The highest recorded (Fort Denison) tsunami (0.8m trough to peak) in this region occurred in 1960 and was caused by an earthquake in Chile. A tsunami of this magnitude is unlikely to have a significant impact along the majority of the Brisbane Water foreshore, especially north of ‘the Rip’, due to the complex shape and attenuating properties of the estuary.

While the investigation of tsunami events was not included in this study, their occurrence and potential impact is something that may be considered in any management plan.

K.2.2 Amendments to the Report

See new Section 6.5 discussing tsunami events. The above discussion regarding the tsunami events has been included in the text of the report.

K.3 Public Submission 3

Received: Friday, 15 February 2008

Brisbane Water Foreshore Flood Study Submission: Flood study should address climate change

The Brisbane Water Foreshore Flood Study is a good historical assessment of flooding in the area. Its method for establishing flood level requirements for the next 100 years is flawed, however, because it is based almost entirely on this historical assessment.

By doing this, it fails to recognise or take into account the effects that climate change will have on flooding. The consultants should be asked to redraft the report responding to the issues raised in the Intergovernmental Panel on Climate Change Fourth Assessment Report and other current scientific material, and having consulted Australian meteorologists and ocean scientists about the expected effects of climate change.

Despite attributing one figure (300mm) for sea-level rise to the IPCC, the draft foreshore strategy does not appear to have taken any of the other IPCC statements about sea level rise and storm frequency and intensity into account.

For example, the IPCC report specifically excludes melting of polar ice from its estimates of mean sea level rise. (It should be noted that the estimates without ice also range up to 590mm sea level rise in some scenarios.)

In relation to polar ice, the IPCC estimated a sea level rise of seven metres (7000mm) with the melting of the Greenland ice sheet alone. There are very few parts of the Woy Woy Peninsula that are much above this elevation. The IPCC predicts that this will occur if global warming reaches and stays above 1.9 degrees warmer than pre-Industrial levels.

Even the countries most actively addressing climate change are having trouble taking action that would see global warming limited to less than two degrees in the longer term.

At the very least, a substantial sea level rise can be expected due to polar ice melt. What is not clear is the timeframe. It may take more than a millenium, but the report does not rule out this possibility within the next 100 years. And the seven metre estimate does not include the melting and movement of other polar ice masses.

Of more immediate importance are the statements made by the IPCC about the "increased risk of extreme weather events" in "low-lying coastal systems".

Specifically referring to Australia, it predicts "sea level rise and increases in the severity and frequency of storms and coastal flooding". It talks of the likely increase in the intensity of tropical cyclones, the occurrence of extreme high tides and events of heavy rainfall. It says heavy precipitation events are very likely to become more common and will increase flood risk.

By contrast, the draft strategy makes no reference to this. Nor is there reference, apart from one picture, to the best recent local example - the Newcastle storm of June last year which brought wild weather to Gosford and resulted in major flooding, with consequent threats to water, sewerage and electricity infrastructure.

As it was, this storm caused widespread electricity blackouts, cut land-based and radio communications, as well as causing widespread local flooding. Water and sewerage systems broke down as power was cut to pumping stations, either because powerlines had been brought down or flood levels had been under-estimated in the siting of the pumping stations.

Had this storm been centred on Gosford rather than Newcastle, the damage and other local consequences could be expected to have been of at least the same disastrous proportions as suffered in Newcastle and surrounding areas.
It is intense storms of this nature that the IPCC is predicting will become both more frequent and more intense. The New Orleans floods in the wake of Hurricane Katrina should serve as a warning of the costs and human consequences that can flow from these sorts of storms.

The Woy Woy Peninsula is in a similarly vulnerable position, being a low-lying coastal sandplain accommodating as much as one quarter of Gosford's population with limited evacuation potential.

The draft strategy pays some attention to the Woy Woy Peninsula and its history of flooding. However, while it acknowledges the importance of ocean storms to flood levels, it dismisses the 1974 flood as being an event expected to occur once in 10,000 years.

This conclusion could be justified if we were facing a future where the climate was expected to be much the same as it has been in the past. However, given the IPCC report shows that this is not the case, council should take such information into account and use a cautious approach when preparing its strategies.

A Queensland study of "East Coast lows", which form along the coast of eastern Australia causing storms like last June's, has shown that they have doubled in frequency in the last 20 years.

With a corresponding increase in intensity, this means that storms that historically were regarded as occurring once in every 100 years could in future be occurring once every five or six years. The IPCC report says that, at best, these storms can be expected to continue to increase in frequency and intensity until the causes of climate change are eliminated and climate change itself is reversed – which will extend over the period of at least the next 100 years or so.

Given the council strategy's 100-year outlook and its own finding of the importance of ocean storms on flood levels, it is surprising that it has not investigated the likely increase of frequency and intensity of these storms.

A reading of the IPCC and other scientific reports would suggest that, even if rainfall has not been a major factor affecting flooding around Brisbane Water in the past, it can be expected to be a much greater factor in the future.

It should be remembered that the IPCC Report is a conservative document and one that has suffered amelioration at the hands of the political interests of both the United States and China.

A discussion paper prepared by Griffith University 'Climate Response - Issues, Costs and Liabilities in Adapting to Climate Change in Australia' (editor R. Buckley 2007) highlights the potential liabilities for local and state government in not applying a precautionary approach and undertaking adaptive management actions in response to predicted risks.

Also this report states that the IPCC report "urges government to limit development in low lying estuarine areas", which is relevant in the light of proposed future growth planned for the Peninsula. If there is one lesson that should be learnt from the Central Coast water crisis, it is the importance of long-term planning based on available information.

K.3.1 Response to Submission

The study in its existing form is considered adequate in terms of addressing the uncertainties of climate change based on current understanding and scientific consensus. This submission can be summarised to three main points to be addressed below:-

1. The study does not include sufficient allowance for sea level rise.

2. The study does not consider the predictions that storms will increase in both intensity and frequency.

3. The above two points underestimate the vulnerability of the Woy Woy Peninsula and Davistown regions to which comparison is made with New Orleans.

1. The study does not include sufficient allowance for sea level rise.

Predictions of global sea level rise due to the Greenhouse effect vary considerably. It is impossible to state conclusively by how much the sea may rise, and no policy yet exists regarding the appropriate provision that should be made in the design of new coastal developments.

In 2001 the Intergovernmental Panel on Climate Change (IPCC) released estimates of sea level rise based on a range of climate models and scenarios. These estimates ranged from 0.09m to 0.88m by the year 2100. The 4th IPCC report on climate change, published in mid-2007, predicts slightly lower estimates of sea-level rise of between 0.18m and 0.59m by 2100. These estimates exclude the potential sea level rise increase that might be caused by a continuation of ice sheet melting in polar regions. The additional sea-level rise, if this were to occur, is estimated to be between 0.1 and 0.2m by 2100. For the NSW coast the most recent guidelines from the Department of Environment and Climate Change suggest sea-level scenarios of between 0.18m and 0.91m by 2100 (DECC, 2007).

Within the study, investigations adopting a mean sea level rise of 0.3m were undertaken, which is considered a mid-range value of all available reliable predictions to 2100. The outcomes of this suggest that there is no attenuation of this rise through the estuary; that is, a mean sea level rise of 0.3m would result in an increase of 0.3m along all foreshore areas up to Gosford. This can be assumed true for other sea level rise cases, assuming minimal change in effective conveyance and storage within the estuary physiography.

In defining foreshore planning levels, the method described in the report allows for the adoption of any amount of sea level rise. Section 8.7 defines the estuarine planning level as:-

$PL = DWL + WRH$

where:
PL - Planning Level
DWL - Design Water Level
WRH - Wave Run-up Height

The DWL is adopted as the design storm tide level plus local wind set-up, based on historical records, plus mean sea level rise. While a mean sea level rise of 0.3m is presented in this report, there exists sufficient flexibility for this to be revised in subsequent stages of the Estuary Management Process, where the risk of adopting a certain estimate can be better assessed.

2. The study does not consider the predictions that storms will increase in both intensity and frequency

Changes in the frequency and intensity of storms are also considered likely with continuing climate change, although the nature of this change is far from certain.

Heavy precipitation events are earmarked by the IPCC to increase in intensity. Although not explicitly addressed in the report, consideration of rainfall events up to and including the Probable Maximum Flood were included. That analysis found that the PMF catchment event does not cause significant elevation of the estuary level and is insignificant, in terms of planning levels, when compared to ocean storm contributions. Should foreshore planning levels be based on the 100-years ARI level, as has been done in this study, the PMF catchment event is considered to account for any potential increase in the 100-years ARI rainfall intensity associated with climate change for a 100-years planning period.

The design coastal storm condition for the Central Coast region for ARI's greater than 10-years are East Coast Low (ECL) events. These complex weather systems often originate from a tropical low pressure region and generally move southwards down the NSW coast; but have been known to move northward. They can be particularly damaging to the central-NSW coast because they can form relatively close to the coastline and often generate powerful offshore waves from the east to south-east sector. As a result these waves experience less refraction compared to more southerly weather systems and larger waves can interact with the coastline. They also generate a range of offshore wave directions as they move along the coastline. ECL events can also generate a storm surge, which can further increase the impact on shoreline areas. It has been observed that ECL's can occur frequently when conditions are favourable; that is, they tend to be episodic. This was observed in 1974 when two ECL storms damaged the mid-NSW coast a few weeks apart. That event, which resulted in the highest recorded water level at the Fort Denison tide gauge, is generally considered to be between a 100-years and 200-years ARI event (not 10,000-years ARI as cited in the submission), a finding that is consistent with the outcomes of this study as described in Section 6.4.1.1 and Figure 6.11.

More recently the June 2007 period featured several intense ECL events, including the storm that caused extensive damage in the Newcastle region. Despite its severe nature no widespread inundation of low lying areas from high estuary water levels was reported. Local flooding was indeed a major concern, predominantly as a result of high rainfall and catchment flooding events. However, catchment flooding events are not within the scope of this report and will be the subject of subsequent catchment flood studies. In terms of levels within the Brisbane Water Estuary, peak levels were not extreme, with the peak of the storm occurring at a low tide. To this end, only brief treatment of this event was provided.

There is no current consensus on the impact of climate change on coastal storms in the Central Coast region. Recent studies, for example CSIRO (2007) and McInnes *et al* (2007), present climate change predictions which indicate both increased and decreased wind speeds along the NSW coast, depending on the model and/or climate change scenario applied. Of more importance for the NSW central coast is the potential change in ECL event frequency or intensity due to climate change. Current understanding on ECL events is limited, although it is widely believed that the ENSO cycle has a significant influence on the frequency of ECL events. A study of "East Coast Lows" along the Queensland coast, (AGSO, 2000), identified that east coast lows have doubled in frequency over the last 30 years, most notably due to the 1970-1980 period of high frequency events, and while it identifies that this as significant it also makes the point that this "*appears linked to broader climatic variations*" such as the Southern Oscillation Index and not specifically to climate change. It should be noted that prior to approximately 1960, ECL's events were generally identified based on their impact on the populated coast. ECL's which form far offshore in the Tasman Sea may not generate significant coast impacts in terms of storm surge or even nearshore wave heights. With the advent of radar and satellite technology around 1960, ECL's which form far offshore can be more easily identified. Considering the historical record of ECL events since 1960 suggests that the ENSO cycle is perhaps the dominant influence on the frequency and intensity of these storm events. The period between 1970 and 1980 contained the most frequent and powerful ECL events which have been observed along the NSW coast to date.

Climate change models to date have not been able to investigate changes to wind conditions generated by small scale systems such as ECL events. CSIRO (2007) concludes that for ECL events "*model studies do not as yet indicate how the occurrence of east coast low pressure systems may change*".

Due to the lack of consensus related to climate change impacts on the frequency and/or intensity of these events it is appropriate to adopt coastal storm conditions based on the current climatology and historical records.

3. The above two points underestimate the vulnerability of the Woy Woy Peninsula to which comparison is made with New Orleans

The comparison of Woy Woy to New Orleans is not appropriate. Much of New Orleans is below sea level. It is surrounded by lakes on three sides and bisected by America's largest river. The main threat to flooding in New Orleans, as a result of extensive fluvial flood mitigation works, is that of storm surge which can regularly reach 4 to 5m during intense hurricanes. Brisbane Water is not located in an active tropical cyclone region and even studies which predict the largest increase in the southern extent of the east Australia cyclone region due to climate change processes do not predict cyclones off the Central Coast of NSW within the next 50 to 100 years (CSIRO, 2007).

On the other hand storm activity and associated storm surge along the NSW is a result of ECLs which produce storm surges of around 1 to 1.5m (including wave setup). Furthermore , the complex shape of the estuary and significant hydraulic control at ‘the Rip’ play a significant role in attenuating storm surges in the upper half of the estuary, thereby protecting low lying areas of Woy Woy, Davistown and Empire Bay.

The nature and severity of the resulting inundation at Woy Woy can not be reasonably compared to that of New Orleans. Flooding in New Orleans was greatly affected by the failure of levies, whereas no such structures exist in Brisbane Water. However, extensive areas of Woy Woy will be at increased risk of inundation should significant sea level rise occur and such considerations will need to be considered in the future estuary management study and subsequent plan.

K.3.2 References

AGSO, (2000): Natural hazards and the risks they pose to South-East Queensland. Australian Geological Survey Organisation, Canberra, Australia.

CSIRO (2007). “Climate Change in Australia – Technical Report”. Published by CSIRO and Bureau of Meteorology. October 2007.

DECC (2007). “Floodplain Risk Management Guideline – Practical Consideration of Climate Change. Published by the Department of Environment and Climate Change, NSW. October 2007.

McInnes K,L., Macadam I., Abbs A.J., O’Farrel S.P., Ogrady J. and Ranasinghe R (2007). “Projected Changes in Climatological Forcing conditions for Coastal Erosion in NSW. Proceedings of Coasts and Ports 2007. Melbourne July 2007.

K.3.3 Amendments to the Report

See new Section 6.4.1.2 for a summary and discussion of the June 2007 Storm. Being the most recent East Coast Low event discussion of its severity is included to place a context to calculated design levels.

See revised Section 6.7 discussing climate change. The above discussions regarding the consideration of climate change within this study have been included in terms of both sea level rise and storm intensity and frequency.

Public Comment 1

Central Coast Express Advocate – 29th February 2008

Flood study attacked for ignoring rise in sea levels

JOHN SIMPSON

A LEADING environmental group has attacked Gosford Council's Brisbane Water flood study saying it fails to take a predicted rise in sea levels into account.

The Australian Conservation Foundation's Central Coast branch has fears for low-lying suburbs around the waterway.

Branch president Mark Snell said there was scope for the Peninsula to undergo a New Orleans-like flooding event if climate change predictions came true.

Mr Snell said the study was "a good historical assessment" but was flawed.

"The study has seriously underestimated potential sea level rise and has totally ignored predictions of more frequent and intense coastal storms," he said.

"Given that the study identifies ocean storms as the single most important factor affecting flood levels, it is surprising that it has failed to take predicted changes to their frequency and intensity into account."

Mr Snell said the study did not consider a wild storm last June which brought major flooding to Gosford and surrounding areas.

"Water and sewerage systems broke down as power was cut to pumping stations, either because powerlines had been brought down or flood levels had been underestimated in the siting of the pumping stations," he said.

"It is intense storms of this nature that are predicted to become both more frequent and more intense."

He said the council could be legally liable if it failed to take a "precautionary approach" to climate change predictions.

He called for the study to be revised, taking into consideration international reports on climate change and independent scientific advice.

Mark Snell has fears about the Brisbane Water flood study.

Picture: MARK SCOTT Buy this picture SCP67975: phone 1300 301 705

Consultants look at submissions

CONSULTING engineers Cardno Lawson Treloar prepared the Brisbane Water foreshore Flood study.

The draft strategy was on public exhibition between January 18 and February 15 and submissions were received.

Submissions will now be considered.

It is the first stage of the council's floodplain risk management process.

The article printed in the Central Coast Express Advocate on the 29th February 2008 is in parts misleading. The reader is directed to the response given to Public Submission 3 that addresses the inaccuracies of the points raised in the article.

APPENDIX M

Glossary of Terms

GLOSSARY*

Amenity	Those features of an estuary/beach that foster its use for various purposes, eg. Clear water and sandy beaches make beach-side recreation attractive.
Annual Exceedence Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1%AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large.
ARI	Average Recurrence Interval
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Bed Load	That portion of the total sediment load that flowing water moves along the bed by the rolling or saltating of sediment particles.
Cadastre, Cadastral Base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Calibration	The process by which the results of a computer model are brought to agreement with observed data.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
CD	Chart Datum, common datum for navigation charts - 0.92m below AHD in the Sydney coastal region. Typically Lowest Astronomical Tide. It varies within estuaries.
Design Flood	A significant event to be considered in the design process; various works within the floodplain may adopt different design events. e.g. some roads may be designed to be overtopped in the 1 in 1 year or 100%AEP flood event, others adopt lower risk levels.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.

Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Diurnal	A daily variation, as in day and night.
Ebb Tide	The outgoing tidal movement of water within an estuary.
Eddies	Large, approximately circular, swirling movements of water, often metres or tens of metres across. Eddies are caused by shear between the flow and a boundary or by flow separation from a boundary.
Estuarine Processes	Those processes that affect the physical, chemical and biological behaviour of an estuary, eg. predation, water movement, sediment movement, water quality, etc.
Estuary	An enclosed or semi-enclosed body of water having an open or intermittently open connection to coastal waters and in which water levels vary in a periodic fashion in response to ocean tides.
Flash Flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flocculate	The coalescence, through physical and chemical processes, of individual suspended particles into larger particles ('flocs').
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood Fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood Hazard	Potential risk to life and limb caused by flooding.
Flood Planning Area	The area of land below the flood planning level and thus subject to flood related development controls.

Flood Planning Levels	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the “Standard flood event” of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood Storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Flood Tide	The incoming tidal movement of water within an estuary.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain Management Measures	The full range of techniques available to floodplain managers.
Floodplain Management Options	The measures which might be feasible for the management of a particular area.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodway Areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Fluvial	Relating to non-tidal flows.
Fluvial Processes	The erosive and transport processes that deliver terrestrial sediment to creeks, rivers, estuaries and coastal waters.

Fluvial Sediments	Land-based sediments carried to estuarine waters by rivers.
Foreshore	The area of shore between low and high tide marks and land adjacent thereto.
Fortnightly Tides	The variation in tide levels caused by the monthly variation of Spring and Neap Tides.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Geomorphology	The study of the origin, characteristics and development of land forms.
High Hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
H_s (Significant Wave Height)	H_s may be defined as the average of the highest 1/3 of wave heights in a wave record ($H_{1/3}$), or from the zeroth spectral moment (H_{mo}), though there is a difference of about 5 to 8%.
Hydraulic Regime	The variation of estuarine discharges in response to seasonal freshwater inflows and tides.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Intertidal	Pertaining to those areas of land covered by water at high tide, but exposed at low tide, eg. intertidal habitat.
Isohaline	A line connecting those parts of a water mass having the same salinity, ie, a contour of equal salinity levels.
Littoral Drift Processes	Wave, current and wind processes that facilitate the transport of water and sediments along a shoreline.
Littoral Zone	An area of the coastline in which sediment movement by wave, current and wind action is prevalent.

Low Hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream Flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management Plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mangroves	An intertidal plant community dominated by trees.
Marine Sediments	Sediments in sea and estuarine areas that have a marine origin.
Mathematical/Computer Models	The mathematical representation of the physical processes involved in runoff, stream flow and estuarine/sea flows. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, wave and current processes.
MHL	Manly Hydraulics Laboratory
MSL	Mean Sea Level
Neap Tides	Tides with the smallest range in a monthly cycle. Neap tides occur when the sun and moon lie at right angles relative to the earth (the gravitational effects of the moon and sun act in opposition on the ocean).
NPER	National Professional Engineers Register. Maintained by the Institution of Engineers, Australia.
NSW	New South Wales
NTU	Nephelometric Turbidity Units
Numerical Model	A mathematical representation of a physical, chemical or biological process of interest. Computers are often required to solve the underlying equations; see Mathematical.

Peak Discharge	The maximum discharge occurring during a flood event.
Phase Lag	Difference in time of the occurrence between high (or low water) and maximum flood (or ebb) velocity at some point in an estuary or sea area.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedence Probability.
Probable Maximum Flood	The flood calculated to be the maximum that is likely to occur.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Salinity	The total mass of dissolved salts per unit mass of water. Seawater has a salinity of about 35g/kg or 35 parts per thousand.
Saltation	The movement of sediment particles along the bed of a water body in a series of 'hops' or 'jumps'. Turbulent fluctuations near the bed lift sediment particles off the bed and into the flow where they are carried a short distance before falling back to the bed.
Sediment Load	The quantity of sediment moved past a particular cross-section in a specified time by estuarine flow.
Semi-diurnal	A twice-daily variation, eg. two high waters per day.
Shear Strength	The capacity of the bed sediments to resist shear stresses caused by flowing water without the movement of bed sediments. The shear strength of the bed depends upon bed material, degree of compaction, armouring,
Shear Stress	The stress exerted on the bed of an estuary by flowing water. The faster the velocity of flow the greater the shear stress.
Shoals	Shallow areas in an estuary created by the deposition and build-up of sediments.
Slack Water	The period of still water before the flood tide begins to ebb (high water slack) or the ebb tide begins to flood (low water slack).

Spring Tides	Tides with the greatest range in a monthly cycle, which occur when the Sun, Moon and Earth are in alignment (the gravitational effects of the Moon and Sun act in concert on the ocean)
SS	Suspended Solids
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage Hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Storm Surge	The increase in coastal water levels caused by the barometric and wind set-up effects of storms. Barometric set-up refers to the increase in coastal water levels associated with the lower atmospheric pressures characteristic of storms. Wind set-up refers to the increase in coastal water levels caused by an onshore wind driving water shorewards and piling it up against the coast.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Suspended Sediment Load	That portion of the total sediment load held in suspension by turbulent velocity fluctuations and transported by flowing water.
Tidal Amplification	The increase in the tidal range at upstream locations caused by the tidal resonance of the estuarine water body, or by a narrowing of the estuary channel.
Tidal Exchange	The proportion of the tidal prism that is flushed away and replaced with 'fresh' coastal water each tide cycle.
Tidal Excursion	The distance travelled by a water particle from low water slack to high water slack and vice versa.
Tidal Lag	The delay between the state of the tide at the estuary mouth (eg. high water slack) and the same state of tide at an upstream location.
Tidal Limit	The most upstream location where a tidal rise and fall of water levels is discernible. The location of the tidal limit changes with freshwater inflows and tidal range.

Tidal Planes	A series of water levels that define standard tides, eg. 'Mean High Water Spring' (MHWS) refers to the average high water level of Spring Tides.
Tidal Prism	The total volume of water moving past a fixed point in an estuary during each flood tide or ebb tide.
Tidal Propagation	The movement of the tidal wave into and out of an estuary.
Tidal Range	The difference between successive high water and low water levels. Tidal range is maximum during Spring Tides and minimum during Neap Tides.
Tidally Varying Models	Numerical models that predict estuarine behaviour within a tidal cycle, ie, the temporal resolution is of the order of minutes or hours.
Tides	The regular rise and fall in sea level in response to the gravitational attraction of the Sun, Moon and Earth.
Topography	A surface which defines the ground level of a chosen area.
Training Walls	Walls constructed at the entrances of estuaries to improve navigability by providing a persistently open entrance.
Tributary	Catchment, stream or river which flows into a larger river, lake or water body
Turbidity	A measure of the ability of water to absorb light.
T_z (Zero Crossing Period)	The average period of waves in a train of waves observed at a location.
Velocity Shear	The differential movement of neighbouring parcels of water brought about by frictional resistance within the flow, or at a boundary. Velocity shear causes dispersive mixing, the greater the shear (velocity gradient), the greater the mixing.
Wind Shear	The stress exerted on the water's surface by wind blowing over the water. Wind shear causes the water to pile up against downwind shores and generates secondary currents.

* Terminology in this Glossary has been derived or adapted from the NSW Government *Floodplain Development Manual*, 2005, and *Estuary Management Manual*, 1992, where available.