Estuary Planning Levels

Woollahra Coastal Zone Management Plan (Stage 1)

LJ3011

Prepared for
Woollahra Municipal Council

April 2015

Cardno
Shaping the Future

Contact Information

Cardno (NSW/ACT) Pty Ltd
ABN 95 001 145 035

Level 9, The Forum
203 Pacific Highway St Leonards NSW 2065

Telephone: 61 2 9496 7700
Facsimile: 61 2 9439 5170
International: 61 2 9496 7700

sydney@cardno.com.au
www.cardno.com

Document Information

Prepared for	Woollahra Municipal Council
Project Name	Woollahra Coastal Zone Management Plan (Stage 1)
File Reference	R001 EPL v4.docx
Job Reference	LJ3011
Date	April 2015

Document Control

Version	Date	Description of Revision	Prepared By	Prepared	Reviewed By	Reviewed
1	18/10/2013	Draft	Emma Maratea & Chris Beadle	ERM CJB	Doug Treloar & Louise Collier	PDT LCC
2	27/11/2013	Final Draft	Tanja Mackenzie	TJM	Doug Treloar	PDT
3	04/08/2014	Draft for Public Exhibition	Chris Beadle	CJB	Tanja Mackenzie	TJM
4	17/04/2015	Final	Tanja Mackenzie	TJM	Tanja Mackenzie	TJM

Version	Reason for Issue	Approved for Release By	Approved	Approved Date	Release
1	Council Review	Tanja Mackenzie	TJM	22/10/2013	
2	Council Review	Tanja Mackenzie	TJM	27/11/2013	
3	For Public Exhibition	Tanja Mackenzie	TJM	04/08/2014	
4	Final Report	Tanja Mackenzie	TJM	17/04/2015	

Table of Contents

Appendices

Tables

Figures

Glossary & Abbreviations

Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average recurrence interval (ARI)	The long-term average number of years between the occurrence of an event as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year-ARI flood event will occur on average once every 20 years. ARI is a way of expressing the likelihood of occurrence of an event that occurs rarely.
Barometric Setup	Mean sea level (MSL) rises in areas of low atmospheric pressure and falls in areas of high pressure.
Benchmarks	A standard by which something can be measured or judged. For example, predicted amounts of sea level rise to incorporate into planning considerations.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Crest level	The level in metres Australian Height Datum (mAHD) of the top of a particular foreshore type.
Coastal processes	Coastal processes are the set of mechanisms that operate at the land-water interface. These processes incorporate sediment transport and are governed by factors such as tide, wave and wind energy.
Coastal Zone	The coastal zone is the interface between the land and ocean. In NSW the coastal zone is defined by mapping prepared under the *Coastal Protection Act 1979* (Greater Metropolitan Region Maps 10, 11, 12 and 13).
Design storm event	A significant event to be considered in the planning process.
Development	As defined in the *Environmental Planning and Assessment Act 1979* (EP&A Act). New development refers to development of a completely different nature to that associated with the former land use, e.g. the urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. Infill development refers to the development of vacant blocks of land that are generally surrounded by already developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development Redevelopment refers to rebuilding in an area, for example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services. Conditions such as minimum floor levels may be imposed on infill development.
El Niño-Southern Oscillation (ENSO)	The term El Niño-Southern Oscillation (ENSO) describes a climatic cycle which oscillates between El Niño and La Niña conditions. It occurs due to changes in the strength of the Walker Circulation over the equatorial south Pacific. During El Niño conditions, which occur every three to eight years, drier conditions prevail, and average sea surface temperatures and sea levels are both lower. During La Niña conditions in Australia are generally wetter, and sea surface temperatures and average sea levels are both higher.
Estuarine Inundation Risk	Also, referred to as foreshore inundation risk. Foreshore inundation from a very high tide, combined with the effects of a storm event.
Fetch	The horizontal distance over which a wind blows in generating waves.
Foreshore	The area of land that interacts with the ocean or waterway.
Foreshore type	The nature of the foreshore at any given location, e.g. retaining wall, sandy beach, rocky foreshore.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.

Flood planning levels	The combinations of flood levels (derived from significant historical flood events or floods of specific ARIs) and freeboards selected for floodplain risk management purposes.
Flood Risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk is divided into three types, existing, future and continuing risks as described below: ▪ Existing flood risk is the risk a community is exposed to as a result of its location on the floodplain. ▪ Future flood risk is the risk a community may be exposed to as a result of new development on the floodplain. ▪ Continuing flood risk is the risk a community is exposed to after floodplain risk management measures have been implemented.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the estuarine planning level.
Geographical information system (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Hazard	A situation that poses a level of threat to life, health, property, or the environment.
High Tide	The maximum height reached by a rising tide. The high water is due to the periodic tidal forces and the effects of meteorological, hydrologic, and/or oceanographic conditions.
Highest Astronomical Tide (HAT)	The highest level of water which can be predicted to occur under any combination of astronomical conditions.
Joint Occurrence	The occurrence of two or more processes at any given point in time. With respect to coastal processes, joint occurrence could include the simultaneous occurrence of high astronomical tides, storm surges and wind-waves which would lead to highly elevated water levels.
Mean High Water Springs (MHWS)	The MHWS is the highest level which spring tides reach on the average over a period of time (usually several years).
Mean Low Water Springs (MLWS)	The MLWS is the lowest level which spring tides reach on the average over a time period (usually several years).
Mean Sea Level (MSL)	MSL is a measure of the average height of the ocean's surface such as the halfway point between the mean high tide and the mean low tide. At present, mean sea level is approximately equivalent to 0 mAHD.
Probability	A statistical measure of the expected frequency or occurrence of an event (e.g. flooding).
Rip rap	Rock material used to armour a shoreline (or other structure) and provide protection from wave attack and erosion.
Sea Level Rise (SLR)	A rise in the level of the ocean surface that is projected to occur in the future.
Section 149 Certificate	Under Section 149 of the *Environmental Planning and Assessment Act 1979* (EP&A Act), a local council will, upon application, issue a certificate providing information about planning controls or property affectations relating to any piece of land within the council area. A certificate issued under Section 149(2), which is compulsory in the sale of the property, provides information about the zoning of the property, the relevant state and local planning controls and other property affectations such as land contamination, road widening and whether or not flood-related development controls apply to the property. A Section 149(5) certificate provides additional advisory information that Council may be aware of on that land.
Storm surge	The increase in coastal water level caused by the effects of storms. Storm surge consists of three components: the increase in water level caused by the reduction in barometric pressure (barometric set-up or IBE), the increase in water level caused by the action of wind blowing over the sea surface (wind set-up), and the increase in water level caused by the piling up of waves against the coast (wave set-up).
Storm Tide Level	Storm tide is different from storm surge in that it includes all the elements of storm surge (IBE, wave set-up and wind set-up) as well as the astronomical tidal level.
Tidal Flood Risk	Potential danger to personal safety and potential damage to property resulting from tidal inundation from a waterway onto surrounding areas within a floodplain.

Topography	A surface which defines the ground level of a chosen area.
Wave Breaking	As waves increase in height through the shoaling process, the crest of the wave tends to speed up relative to the rest of the wave. Waves break when the speed of the crest exceeds the speed of the advance of the wave as a whole. Waves can break in three modes: spilling, surging and plunging.
Wave Run-up	The vertical distance above mean water level reached by the uprush of water from waves across a beach or up a structure.
Wave Set-up	The increase in water level within the surf zone above mean still water level caused by the breaking action of waves.

1 Introduction

The majority of the Australian population inhabits the coastal zone. The coastal zone of the Woollahra Local Government Area (LGA) is no exception, with the foreshore of Sydney Harbour being dominated by urban development. Inundation of the coastal zone (and subsequent impacts on the urban development within this zone) can be caused by large waves and elevated water levels associated with a range of coastal and oceanographic process responses to severe ocean storms. This is referred to as 'Estuarine Inundation Risk'. The nature and extent of the coastal inundation is dependent on the interactions between the ocean processes and the land; thus, an understanding of the interactions between the ocean and the land is essential to identifying the hazards within coastal zones.

In order to protect future development within the coastal zone from inundation under the majority of conditions, it is necessary to ensure appropriate development controls are incorporated into proposed developments. Estuary Planning Levels (EPLs) are applied as a method for managing inundation risk along the foreshore. EPLs are applied under the *Environmental Planning and Assessment Act 1979*.

Cardno (NSW/ACT) Pty Ltd (hereafter referred to as Cardno) have been engaged by Woollahra Municipal Council to calculate water levels and provide mapping to represent this periodic inundation using best available shoreline terrain data and estimates of elevated estuarine water levels. Council proposes to use the planning levels presented in this document to assist with the application of development controls.

EPLs calculated as part of the current study reflect the likely elevated water levels along the Woollahra LGA foreshore that generally occur during an intense ocean storm (that may occur, on average, once in a generation, or less frequently). Estimates of elevated water levels are based on the current understanding of the regional and local coastal processes.

The extent of the study area, the Woollahra LGA, is shown in **Figure 1-1**.

1.1 Planning Context

Appropriate building floor levels for the purposes of design and construction that are estimated from best available information on significantly elevated water levels (i.e. occurring very infrequently) associated with catchment flooding and ocean processes can often be obtained from NSW councils. Floor levels are commonly set to minimise the potential for inundation during severe inundation events.

Woollahra Municipal Council's existing approach to managing estuarine inundation risk is set out in the *Draft Flood Risk Development Control Plan* (DCP) (Woollahra Council, 2004). The draft DCP identified the use of planning levels as an appropriate management measure for managing risk along the foreshore of the Woollahra LGA.

The Draft DCP currently requires all proposed developments on properties fronting Sydney Harbour with any part of their land below 2.3 mAHD to undertake a foreshore inundation study or assessment of estuarine inundation risk and to determine the flood levels and appropriate estuarine planning levels (referred to in this document as EPLs).

As part of this study, a database of site-specific EPLs has been developed based on best available information for all properties affected by estuarine inundation risk. If adopted by Council, individual property owners / developers will no longer be required to undertake site specific wave climate and water level assessments to determine appropriate floor levels. However, they will still need to consider property-specific foreshore types and crest levels, and how these factors will affect the EPL for the site (e.g. a ground level survey to datum AHD by a registered surveyor).

It is understood that the EPLs will be applied to future Development Applications on affected properties in the Woollahra LGA via an appropriate development control.

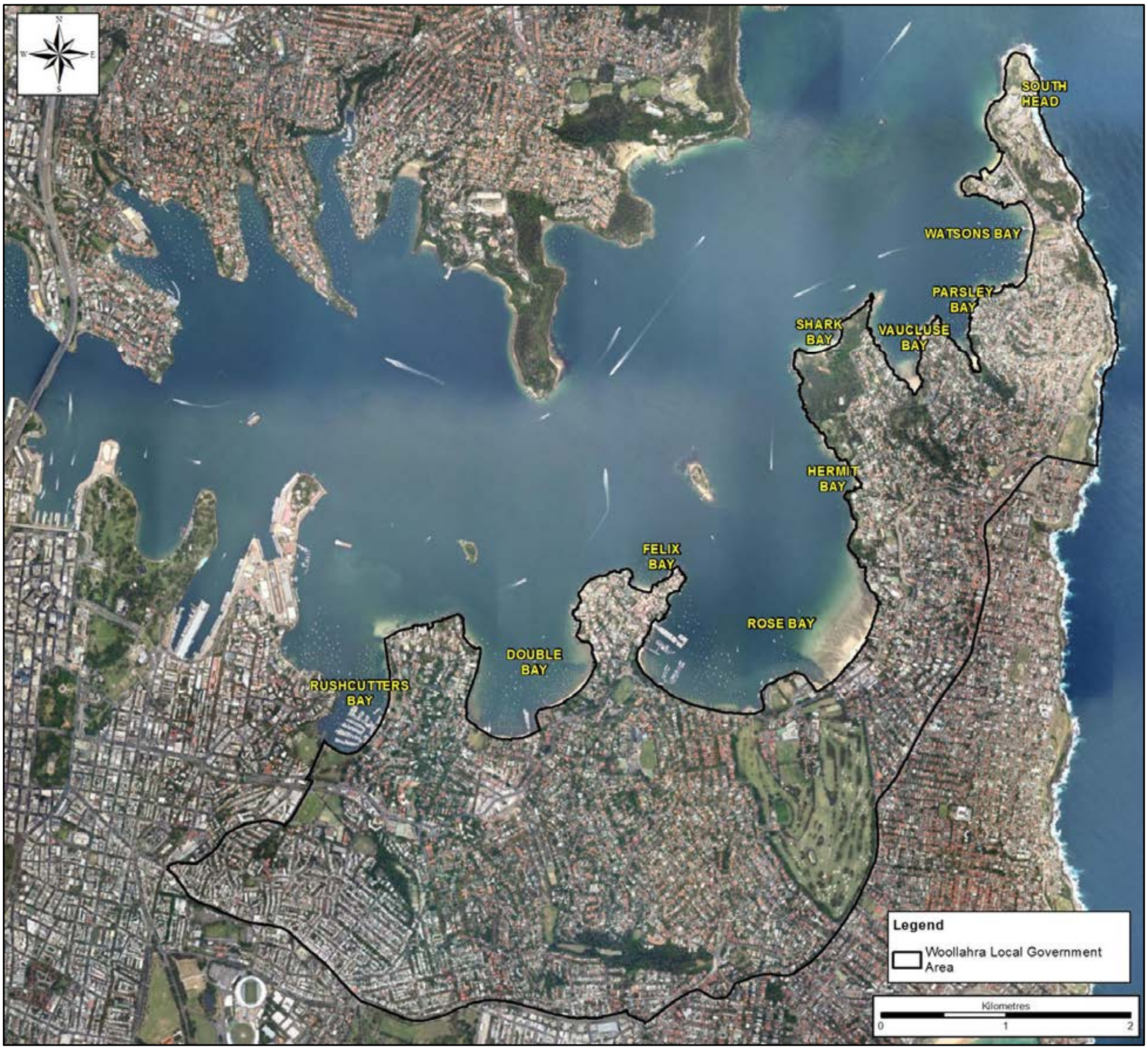


Figure 1-1 Study Area

1.2 Project Scope

This study aims to develop a property database of EPLs, including a range of projected sea level rise (SLR) scenarios and possible freeboards, to assist Council in setting appropriate planning levels for future development in the foreshore zone.

The key aims of this study are to:

> Define the 100-years Average Recurrence Interval (ARI) storm tide levels along the study area foreshore. This storm tide level is comprised of:
  - The astronomical tide, and
  - Meteorological / oceanographic processes including the barometric, wind and wave set-up;

> Define local design wave parameters along the study area foreshore;

> Define realistic wave and water level joint occurrence conditions;

> Define wave run-up and overtopping for a range of foreshore locations and foreshore types;

> Using the outcomes of the storm tide and wave investigations, define the EPL at each affected property for existing sea levels, and 0.4 and 0.9 m SLR conditions; and

> Apply a range of possible freeboards to the EPLs in a database for use by Council and developers.

2 Processes Influencing Estuarine Inundation

2.1 Overview of Processes

To calculate appropriate EPLs it is necessary to understand the oceanographic, estuarine and coastal processes affecting the foreshore. The following processes have been considered in the determination of EPLs for the Woollahra LGA:

> Regional processes (open coast beyond the Harbour - ocean scale of hundreds of kilometres);

> Local processes (within Sydney Harbour - scale of a few kilometres); and

> Site specific processes (scale of tens of metres).

These processes are outlined schematically in **Figure 2-1** and described in more detail in the following sections.

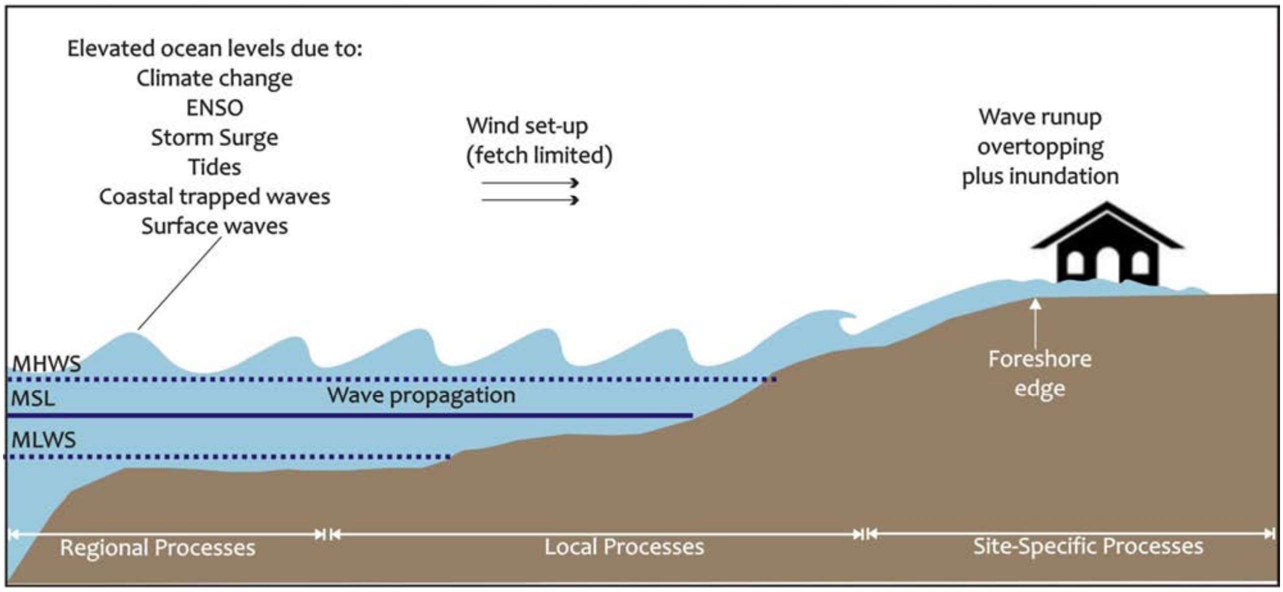


Figure 2-1 Processes Affecting Estuarine Planning Levels

2.2 Regional Processes

Regional oceanographic processes relate to those ocean processes that are influenced by energy inputs causing sea level fluctuations over the larger scales of the NSW coastal waters and that essentially affect coastal waters between Wollongong and Newcastle simultaneously (i.e. hundreds of kilometres of coastline). Coastal water levels in the study area region can be influenced by the following regional oceanographic processes:

> Astronomical tides;

> Meteorological / oceanographic processes:

- Storm surge (which is comprised of barometric set-up and wind set-up),
- Ocean waves (which contribute to wave set-up),
- Coastal trapped waves,
- The El Niño-Southern Oscillation (ENSO),
- Meteorological oscillations, and
- Climate change (e.g. SLR).

> Tectonic processes (e.g. due to movement of tectonic plates; not considered in this assessment).

At times, these individual factors interact in complex ways to elevate water levels significantly above normal tidal levels. Storms with low central atmospheric pressure (resulting in elevation of water due to barometric "set-up"), strong onshore winds (resulting in elevation of water due to wind "set-up") and large waves superimposed on spring (or king) tides, are the most common cause of elevated water levels (NSW Government, 1990). This is shown diagrammatically in **Figure 2-2**.

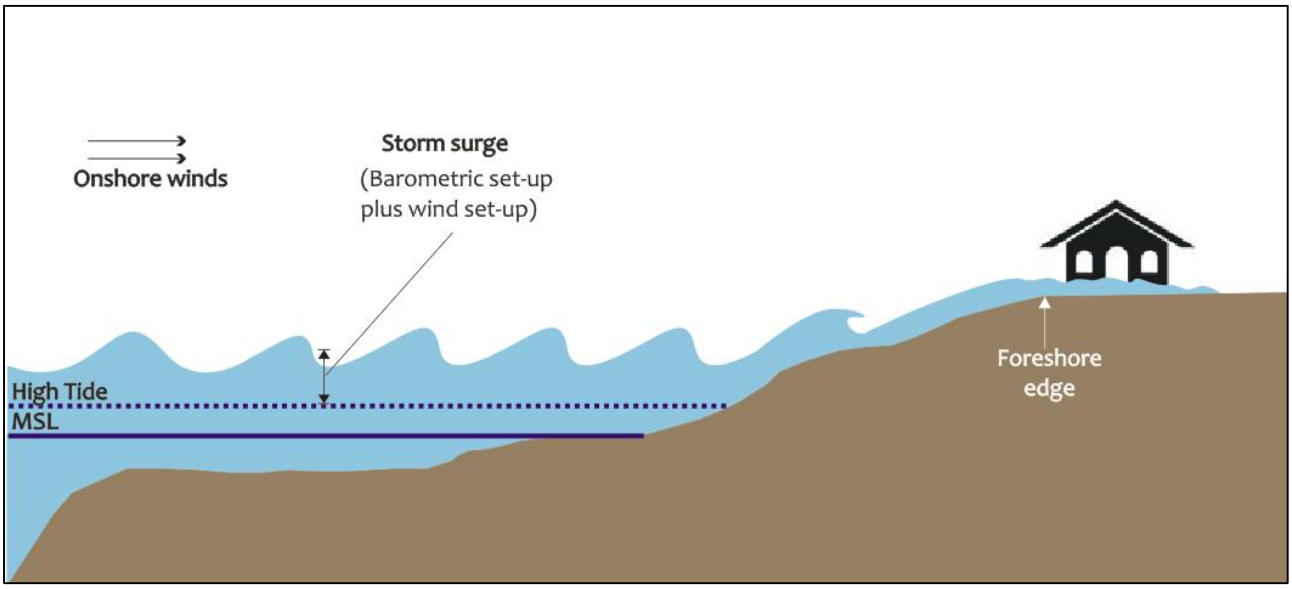


Figure 2-2 Dominant Regional Processes

Determining a regional elevated water level for planning purposes depends on the probability of that water level occurring and the associated risk associated. Planning benchmarks are generally determined on the basis of an average recurrence interval (ARI), which relates to the probability of a particular water level occurring. Department of Planning (2007) advises that for flood prone land, unless there are exceptional circumstances, councils should adopt the 100-years ARI flood levels for planning of residential development. This relates to the water levels associated with a catchment storm event that has the probability of occurring approximately once every 100 years. This design storm recurrence may also be applied to the derivation of elevated estuarine water levels.

SLR associated with climate change is predicted to have an effect on estuarine water levels in the future.

2.3 Local Processes

Within the context of this study, local processes are those that cause variations in 'elevated local water levels' within Sydney Harbour. Water levels within Sydney Harbour will be influenced by local variations as a result of both wind strength and direction, and waves, (which may comprise either local harbour wind waves or ocean waves that propagate into the Harbour).

2.3.1 Local Wind Set-up

The same wind that adds to the regional storm surge in the form of wind set-up over the ocean will also cause further variation in the water level through wind set-up developed within Sydney Harbour. This wind set-up, however, is much smaller and is limited by the distance of water (fetch) over which the wind blows.

2.3.2 Local Wave Height

As discussed in **Section 2.2** ocean storms can contribute to elevated water levels along the coastline. In the vicinity of Sydney, these ocean storms generally come from the east-north-east to south sector. Local wind generated waves can contribute to the elevated water levels as a result of ocean storms. The highest local wind generated waves will occur during storms that have north to easterly winds. In this way the two processes (regional and local) may or may not be strongly correlated and the likelihood that the highest ocean water levels and highest local wind-generated waves occur together (joint occurrence) will be very rare on the westward and northward-facing shorelines of the study area.

Cardno (2015) has shown that for the eastern end of the study site (from Sydney Harbour entrance to Nielsen Park), swell penetration from the Tasman Sea will dominate the local wave climate, whereas west of this swell penetration zone, the wave climate will be dominated by local waves generated by north-north westerly to north-northeasterly winds within the Harbour itself.

Furthermore, swell wave heights will vary depending on the location along the Sydney Harbour shoreline. This is because, as waves propagate from the deeper ocean into shallow water within the Harbour, the waves may undergo changes caused by refraction, shoaling, bed friction, wave breaking and (to some extent) diffraction.

2.4 Site Specific Processes

Site specific processes within the context of this study relate to the processes at the foreshore. The physical factors that will affect the elevated water level will be the nature of the foreshore (e.g. whether the foreshore comprises a retaining wall or a sandy beach, referred to in this report as “foreshore type”) and the crest level (height) in the back-beach area of the foreshore.

As a wave reaches the foreshore an ‘up-rush’ of water onto the foreshore will occur; this is called wave breaking and run-up. The height of wave run-up is affected by the nature of the foreshore. Should wave run-up be large, wave overtopping of the back-beach may occur, which results in the temporary inundation of the area immediately landward of the foreshore crest. For the purposes of this study, the inland extent of the wave inundation is assumed to be 40 m from the foreshore crest for locations affected by swell waves, but less (15 m) in areas affected by local sea waves only. These assumptions have been based on observations made at similar foreshore conditions at Gosford during the June 2007 storm event.

These processes are shown below in **Figure 2-3**.

Detailed discussion of possible wave run-up mechanisms and their calculation is provided in **Section 4.4**.

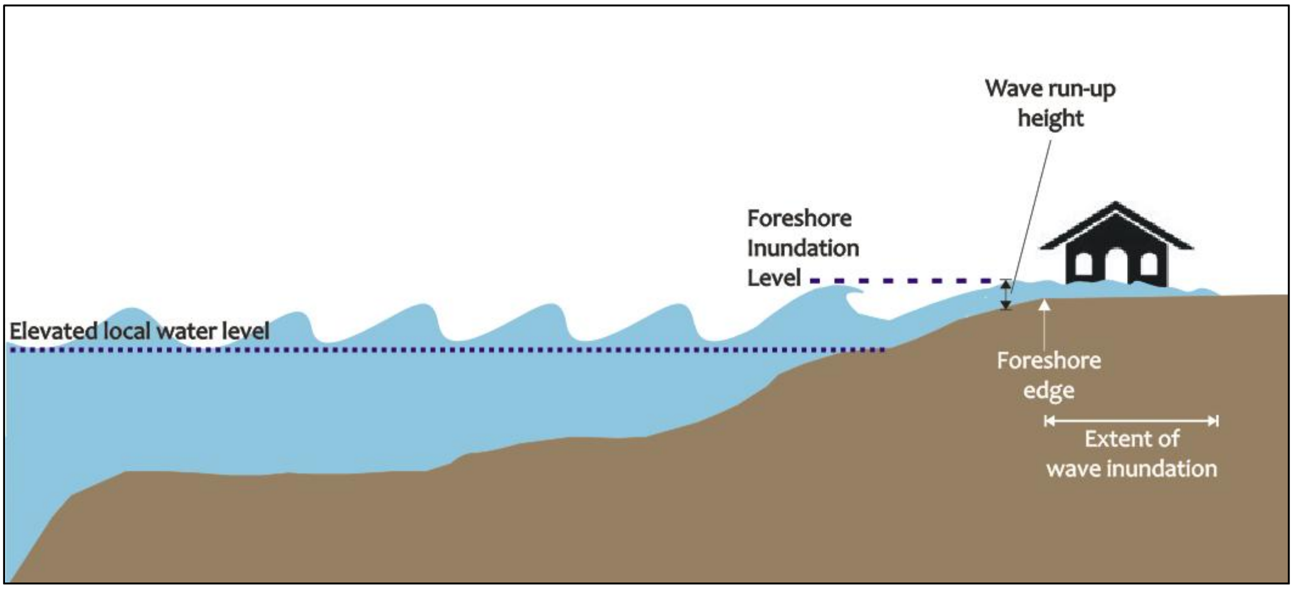


Figure 2-3 Site Specific Processes

3 Calculation of Estuary Planning Levels

3.1 Overview

To manage estuarine inundation risk along the Woollahra LGA foreshore of Sydney Harbour, EPLs have been calculated for use in Woollahra Council's planning and development assessment processes. This has been achieved by accounting for and calculating the following water level components:

> Identifying the regional 100-years ARI storm tide level and incorporating SLR (**Section 3.2**);

> Calculating the local wind set-up and local wave climate (wind waves and swell, depending upon location) within Sydney Harbour (**Section 3.3**);

> Calculating wave run-up and overtopping (**Section 3.4**), which requires:

- Identification of the typical foreshore types in this LGA, and
- Calculation of the reduction in overtopping wave heights as a result of distance from the foreshore back-beach; and

> Applying a freeboard to allow for any uncertainties primarily associated with local wave and wind action (**Section 3.5**).

The components of the EPLs are shown diagrammatically in **Figure 3-1** and are discussed in more detail in the sections below.

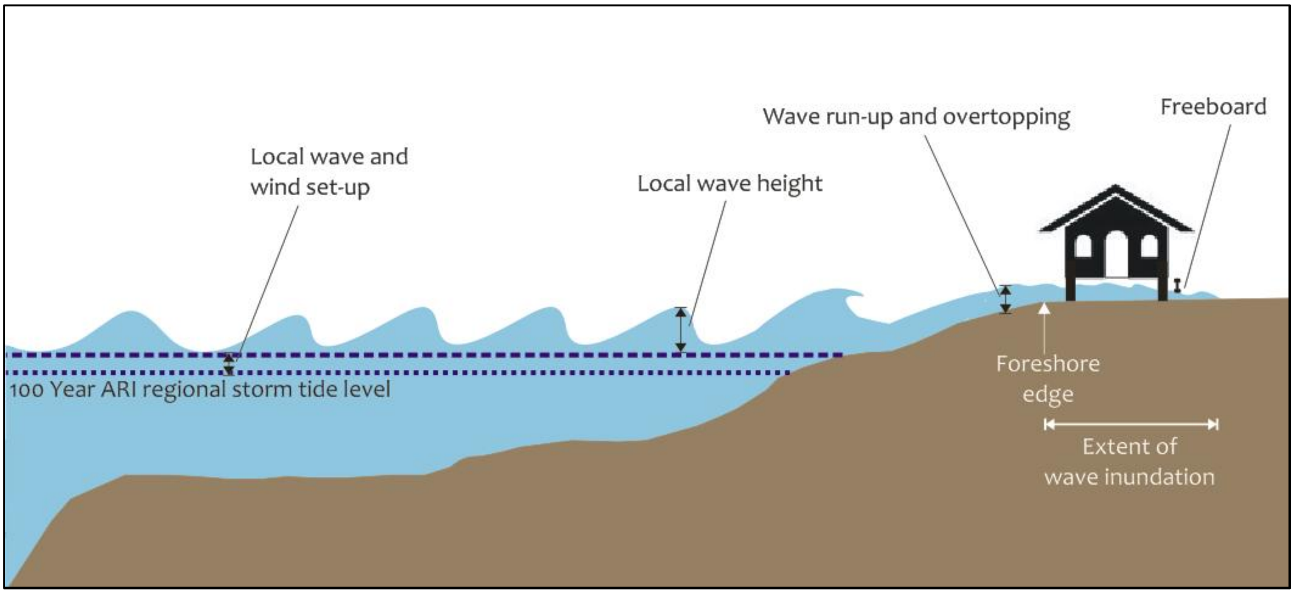


Figure 3-1 Estuary Planning Level Components

3.2 Regional Storm Tide Level and Sea Level Rise

For the purposes of determining the storm tide level component of the EPL, the design still water levels presented in DECCW (2010) were adopted for the present day and the SLR scenarios. This is consistent with the approach adopted by CSIRO (2012), who prepared a regional investigation of storm tide for Sydney and surrounds. The DECCW (2010) design still water levels for Fort Denison are presented in **Table 3-1**. These water levels include a SLR component (in the Tasman Sea) of 0.4 m for 2050 and 0.9 m for 2100.

Table 3-1 Design Still Water Levels (mAHD) at Fort Denison from DECCW (2010)

ARI (years)	Existing	2050	2100
1	1.24	1.58	2.08
50	1.42	1.75	2.25
100	1.44	1.78	2.28

It is noted, however, that the water levels observed at Fort Denison will not necessarily occur at all locations around Sydney Harbour due to local conditions. Key local conditions that vary include orientation of the foreshore and distance from the Harbour entrance amongst others, and hence the relative exposure to ocean swell and/or local sea (wind) waves and wind itself. When selecting a design case upon which to calculate local wave conditions, it is necessary to consider the likelihood of waves arriving at the shoreline at the same time as the peak 100-years ARI ocean water level.

To assess the potential for local water level variation, Cardno (2015) conducted a validation exercise to assess the difference between the Fort Denison and Rose Bay water levels for the May 1997 design storm event modelled by CSIRO (2012), which adopted the design still water levels from DECCW (2010). The results showed that modelled water levels at Fort Denison and Rose Bay were generally equivalent, with slightly reduced water levels at Rose Bay, in the order of a few centimetres. This demonstrated that there is some potential for design water levels along the Woollahra LGA foreshore to differ from those at Fort Denison, which may lead to a minor overestimation or underestimation when determining EPLs at shoreline locations in the study area if the Fort Denison based design still water levels are applied.

Hence, Council commissioned Cardno to undertake some additional detailed hydrodynamic modelling as part of this EPL study in order to determine site specific design water levels at a series of locations along the Woollahra LGA foreshore.

Numerical modelling simulations for the development of site specific EPLs were undertaken using the Delft3D modelling system (Deltares, V4.00, August 2011). The Delft3D modelling system has been applied to hydrodynamic and wave investigations at many international locations, as well as within Australia by Cardno, including Port Botany (Sydney), Cairns Navy Base (Queensland), Brisbane Water (NSW), New Caledonia, and Exmouth Gulf in Western Australia. The Delft3D modelling system includes wind, pressure, tide and wave forcing, three dimensional currents, stratification, sediment transport and water quality descriptions and is capable of using irregular rectilinear or curvilinear coordinates.

For this study Cardno implemented its fully calibrated and verified 2-Dimensional Delft3D model of Port Jackson (Cardno, 2010). This comprises a curvilinear grid with resolution along the Woollahra LGA foreshore of approximately 25-50 m (**Figure 3-2**).

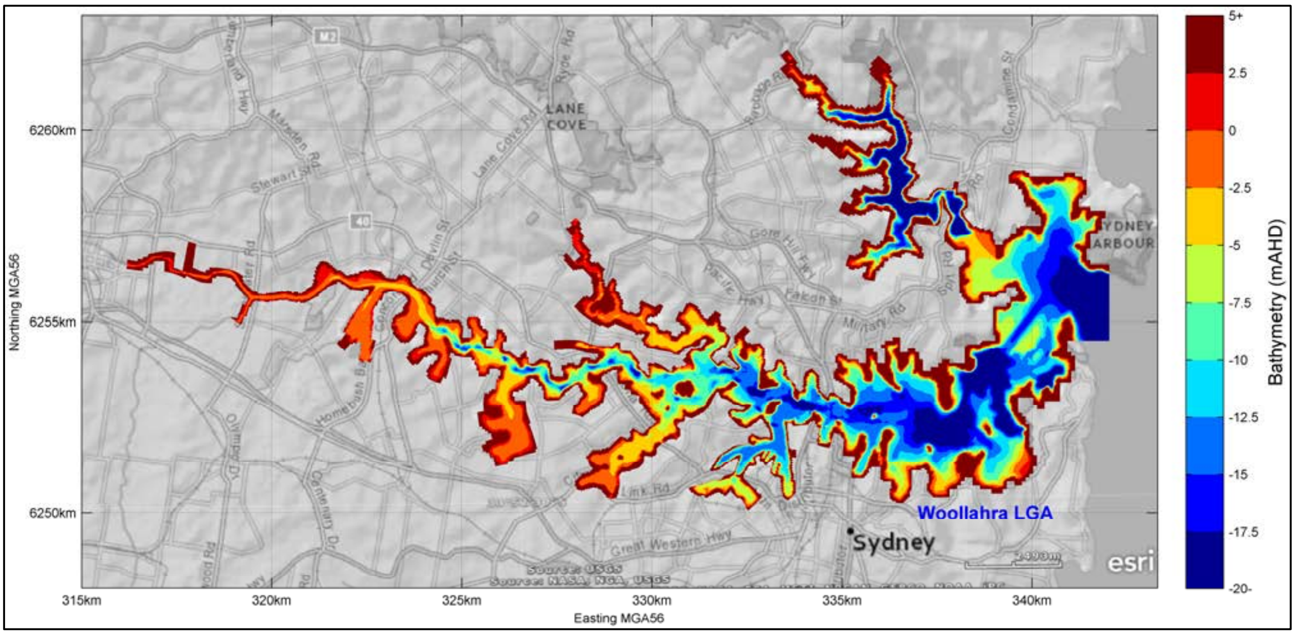


Figure 3-2 Hydrodynamic Model Grid of Sydney Harbour

3.3 Local Wind Set-up and Local Wave Climate

The SWAN wave model was used to investigate the development of wave climate along the Woollahra LGA foreshore. This model system was developed at the Delft Technical University and includes wind input, (local sea cases), combined sea and swell, offshore wave parameters (swell cases), refraction, shoaling, non-linear wave-wave interaction, a full directional spectral description of wave propagation, bed friction, white capping, currents and wave breaking. It can include nesting of finer grid areas within an overall coarser grid model.

To account for the local variations in wind set-up and wave height along the foreshore, the wind set-up and wave heights were calculated at 163 locations along the foreshore (see **Figure 3-3**). These locations represent areas of similar wave and wind conditions. The design wave climate was determined at each of these foreshore locations through the use of the same wave hindcast modelling methodology as described in Cardno (2015).

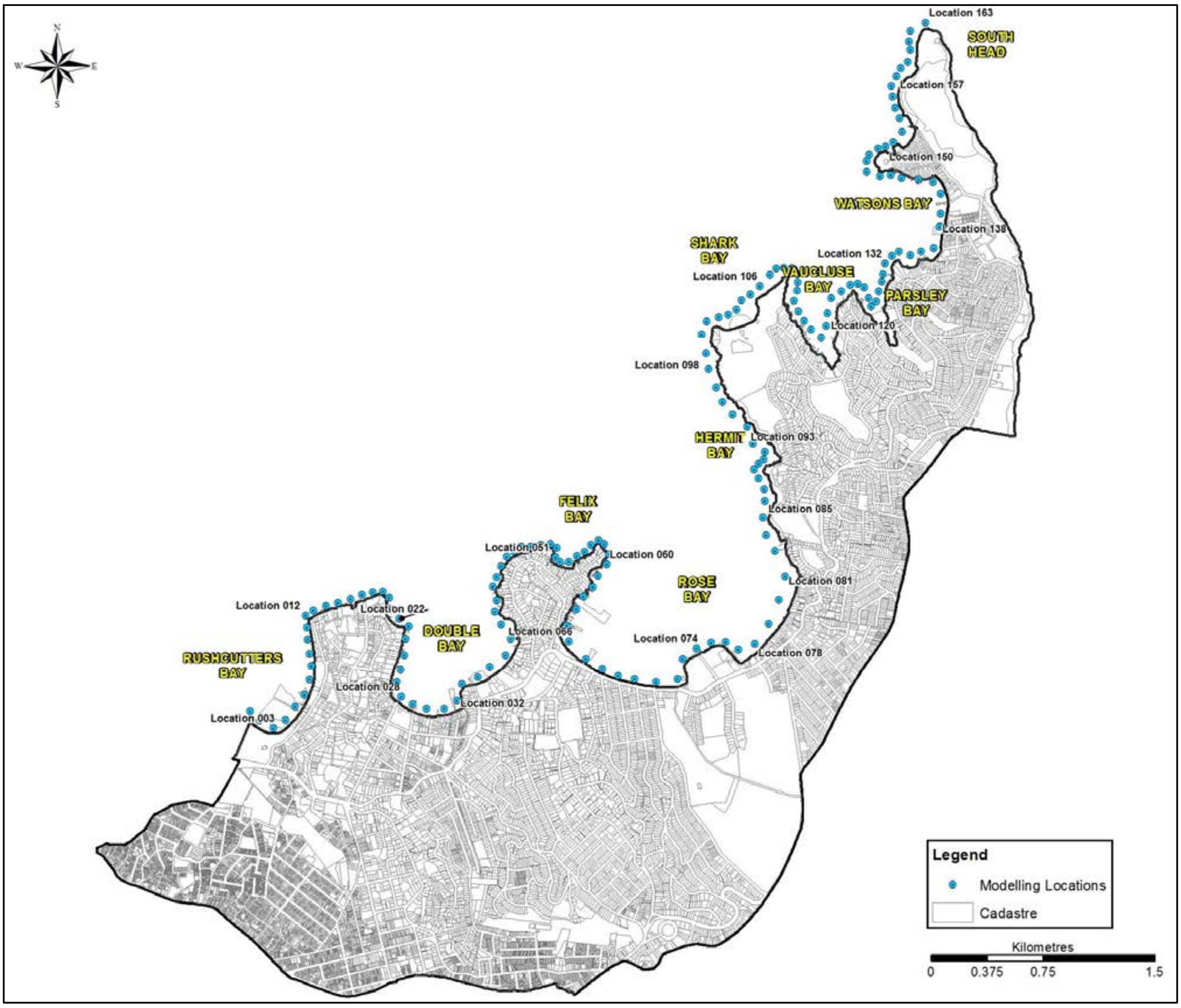


Figure 3-3 Foreshore Model Output Locations (Delft3D)

Wind set-up values were determined by simulating the effects of a suite of wind speeds for eight directional sectors (from North through South at 45^{o} sectors and back to North). Extremal analysis of Sydney Airport wind data was obtained from Cardno (2013) for wind speeds for both 20 and 100-years ARI for each of these eight directional sectors. Simulations of resulting wind set-up were then conducted for each wind speed ARI and direction case (16 simulations in total). Each simulation was completed over a 12-hour period with a spring tidal range boundary condition, peaking at 0.94 mAHD (approximately the 1% exceedance level at Woollahra), to provide a realistic estimations of the dynamic wind/tide effects over a non-stationary high water level surface. Wind speeds peaked for a six-hour period to coincide with the peak water level around the Woollahra foreshore. This has been found to provide a slightly lower wind set-up than simulations undertaken with static water levels in other project sites, including large estuary areas such as Brisbane Water, Gosford.

Wind duration is important to the development of wind generated set-up. In reality, the critical wind duration that causes the maximum wind set-up at a given location would change in line with the variation of fetch lengths and depths in the individual directions. When the matter of actual wind speed and direction duration is considered this combination is unlikely to persist for more than six hour in any one combined condition. Hence a six-hour peak wind duration was applied, which is likely to allow the maximum wind set-up to occur while also ensuring that phasing with the high tide is incorporated.

Model input is typically based on the 10-minute average wind speed and direction parameters as they may vary with time. The Delft3D hydrodynamic model specifies this wind parameter for model input. Cardno (2013) identifies that 10-minute average wind speed data will be slightly higher than 3-hour duration average wind speed data. Adopting the 10-minute average data along with a six-hour peak duration provides a conservative outcome, which for the definition of planning levels, is an appropriate position.

Results of the local wind set-up and local wave condition modelling, as extracted for 163 locations around the Woollahra foreshore (see **Figure 3-2**), are tabulated in **Appendix A**. These results show that, as expected, wind set-up is slightly higher at the study site foreshore regions (relative to Fort Denison) for winds from the westerly to northerly directions. For the Rushcutters Bay and Double Bay regions, north to north-westerly winds produce the highest wind set-up relative to Fort Denison, with these differences being in the order of 1-5 cm for 100-years ARI winds. For the study site region east of and including Rose Bay, westerly winds produce the highest wind set-up at the study site. The results show that this increase in wind set-up is in the order of 3-10 cm across the foreshore for 100-years ARI westerly winds, with the highest values occurring at the eastern end of Rose Bay, near Dumaresq Reserve. These wind directions will also be those that cause the highest coincident wind waves at these sites.

These results show that where strong north to westerly winds occur, applying the design water level of Fort Denison to the study site may underestimate the local storm tide (and hence estuary planning) levels in some Woollahra foreshore areas by up to 0.1 m. As such, there is a need to assess the joint occurrence of such winds with realistic storm tide levels.

These results also show that for winds from the easterly to southerly sectors, the wind set-up values at the study site shorelines are slightly lower than the set-up at Fort Denison. For the Rushcutters Bay and Double Bay regions, south to south-easterly winds produce the lowest wind set-up relative to Fort Denison, with these differences in the order of 2-6 cm for 100-years ARI winds. For the study site region east of and including Rose Bay, easterly winds produce the lowest wind set-up at the study site relative to Fort Denison. The results show that this decrease in wind set-up is in the order of 4-10 cm (relative to Fort Denison) across the foreshore for 100-years ARI easterly winds.

Hence, west of Nielsen Park, 100-years ARI wave conditions are combined with the 20-years ARI design water level at Fort Denison, plus the additional water level increment (wind set-up) caused by the onshore winds. For those locations east of (and including) Nielsen Park, the 100-years ARI storm tide at Fort Denison is combined with 100-years ARI wave conditions (propagating from the offshore direction of east), minus the negative wind set-up caused by the offshore winds at Watsons Bay, for example.

The joint occurrence conditions used in the calculation of the EPLs are shown in **Table 3-2**.

Table 3-2 Joint Occurrence Conditions for Calculation of 100-years ARI Estuary Planning Levels

Location	ARI Water Level (years)	ARI Wind Condition (years)	Wind Direction	Source of 100-years ARI Waves
West of Nielsen Park (Local Sea Zone)	20	100	NW to N	Local Sea (Wind Driven)
East of Nielsen Park (Offshore Swell Zone)	100	100	E to SE	Offshore Swell Penetration

3.4 Wave Run-up and Overtopping

The height of wave run-up and the depth of overtopping are dependent on the foreshore type (edge treatment) and the level of the foreshore edge (crest level).

3.4.1 Wave Run-up and Overtopping Mechanisms

In defining the wave run-up level, three mechanisms of wave run-up were identified, namely:

> Wave run-up without overtopping of the edge treatment crest. Where this condition occurs, no EPL is required;

> Wave run-up rising above the edge treatment crest, thereby resulting in wave overtopping; and

> Wave overtopping when the storm tide level (plus local wind and wave set-up) is above the edge treatment crest.

Wave set-up influences wave run-up and is included implicitly in wave run-up calculation. 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 waves progress shoreward across the surf zone. Goda (2000) provides an approximation of this set-up based on the significant wave height (Hs) or the breaking wave height (Hb) near the shoreline, whichever is smaller. The calculation of wave set-up was implicitly included in the calculation of the wave run-up heights.

Note that where neighbouring properties have different edge treatments, overtopping water from the less protected property may propagate onto the more protected property. In that circumstance, the more protected property may require some protective structure to be incorporated into at least some of the separating boundary fence.

3.4.1.1 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 (CEM, 2002), was adopted. The equation for this calculation is as follows.

<u>Wave Run-up on a Sloping Wall;</u>

$$Level = STL(+lwws) + R_{u2\%}$$

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

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

H_s - significant wave height

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

STL - Storm Tide Level

lwws - local wind and wave setup

<u>Wave Run-up on a Vertical Wall</u>

$$Level = STL + H_s$$

It is described as a robust approximation developed using extensive measurements of model run-up data (CEM, 2002). Should the run-up level not exceed the defined crest level, then the EPL is considered to simply be the storm tide level plus the run-up height (including SLR plus the selected freeboard).

The definition of run-up on a vertical wall is quite different to a smooth slope. For a smooth, impermeable, continuous vertical wall the run-up level can be approximated as the wave height above the storm tide level (plus local wind and wave set-up), or approximately two times the crest level above the storm tide level (plus local wind and wave set-up). This is derived from linear wave theory which is suitable for short period waves.

The mechanism of wave run-up with no overtopping is shown graphically in **Figure 3-4**.

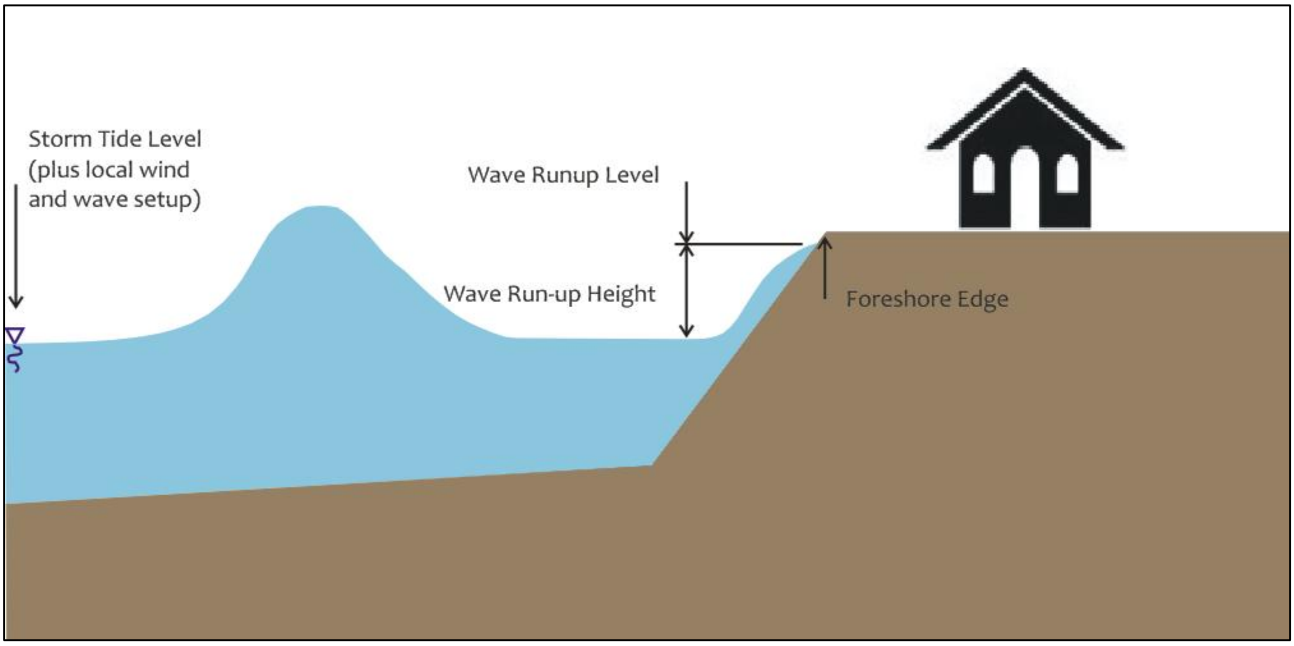


Figure 3-4 Wave Run-up with No Overtopping

3.4.1.2 Wave Run-up with Overtopping

Once the crest level is reached by the wave, the mechanism of run-up is no longer applicable by itself 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 landward area. This transmitted wave can be defined using an algorithm as defined in the Shoreline Protection Manual (CERC, 1984). The equation is as follows.

<u>Wave Run-up and Overtopping of a Sloped Wall</u>

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

Where: $H_{TO} = K_{TO} \times H_s$,

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

C = 0.51 for transmitted wave at the crest

K_{TO} - Transmitted overtopping wave coefficient

R_c - The vertical difference between the crest level and the still water level

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

H_{TO} - Transmitted overtopping wave height

<u>Wave Run-up and Overtopping of a Vertical Wall</u>

$$Level = STL + H_s$$

Where: *STL* - Storm Tide Level

The run-up level can then simply be defined as the height of the transmitted wave (i.e. overtopping wave height) added to the crest level (plus the freeboard). Note though, that local wind wave propagation over land is much less than it is for swell and this is accounted for by applying a reduction factor as the wave propagates inland, this is discussed in **Section 3.3.3**.

The mechanism of wave run-up with overtopping is shown graphically in **Figure 3-5**.

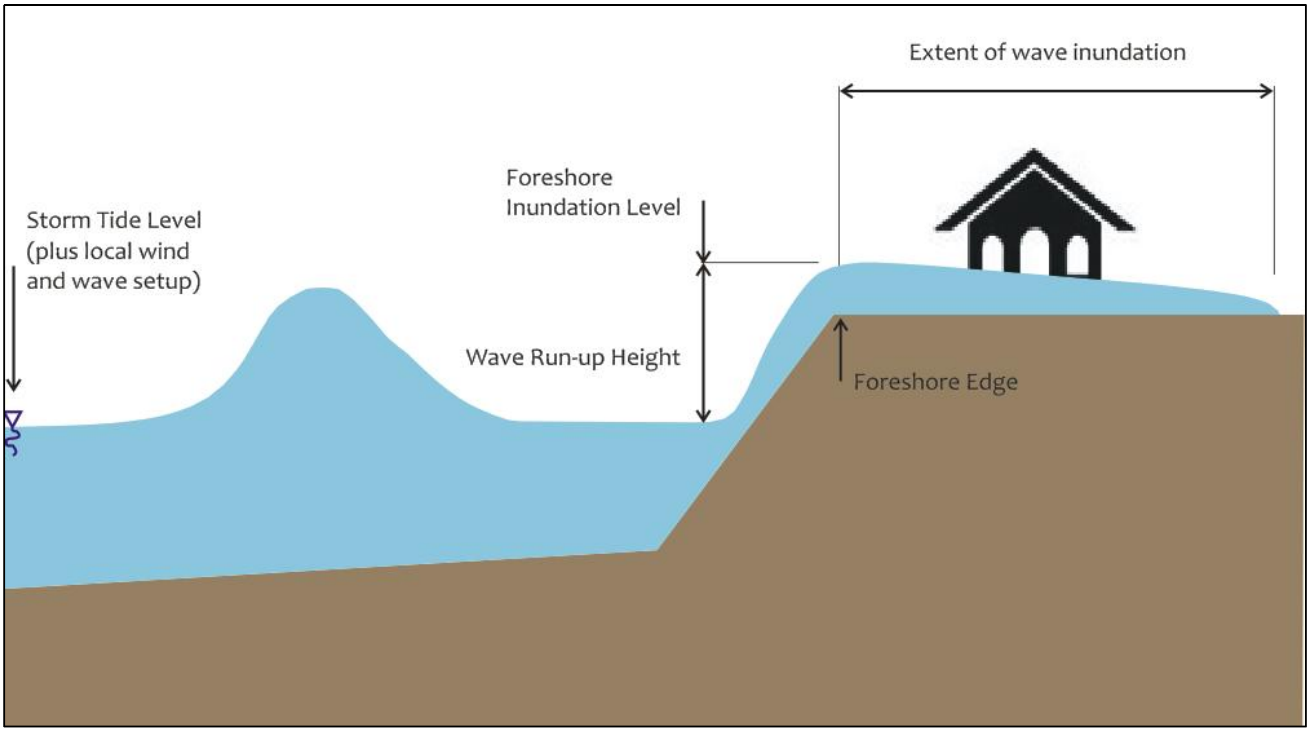


Figure 3-5 Wave Run-up with Overtopping

3.4.1.3 Overtopping when Still Water Level is above the Crest

Should the storm tide level (plus local wind and wave set-up) be above the foreshore crest level, then waves are able to directly surge over the foreshore crest and onto the foreshore areas, albeit with some attenuation due to the reduction in depth below the wave. Studies undertaken by the Public Works Department (2001) define the height of this surge as half the approaching wave height above the storm tide level (plus local wind and wave set-up). The equation is as follows:

$$Level = STL(+lwws) + \frac{H_s}{2}$$

Where: H_s - significant wave height

STL - Storm Tide Level

lwws - local wind and wave setup

The mechanism of overtopping when the storm tide level (plus local wind and wave setup) is above the crest is shown graphically in **Figure 3-6**.

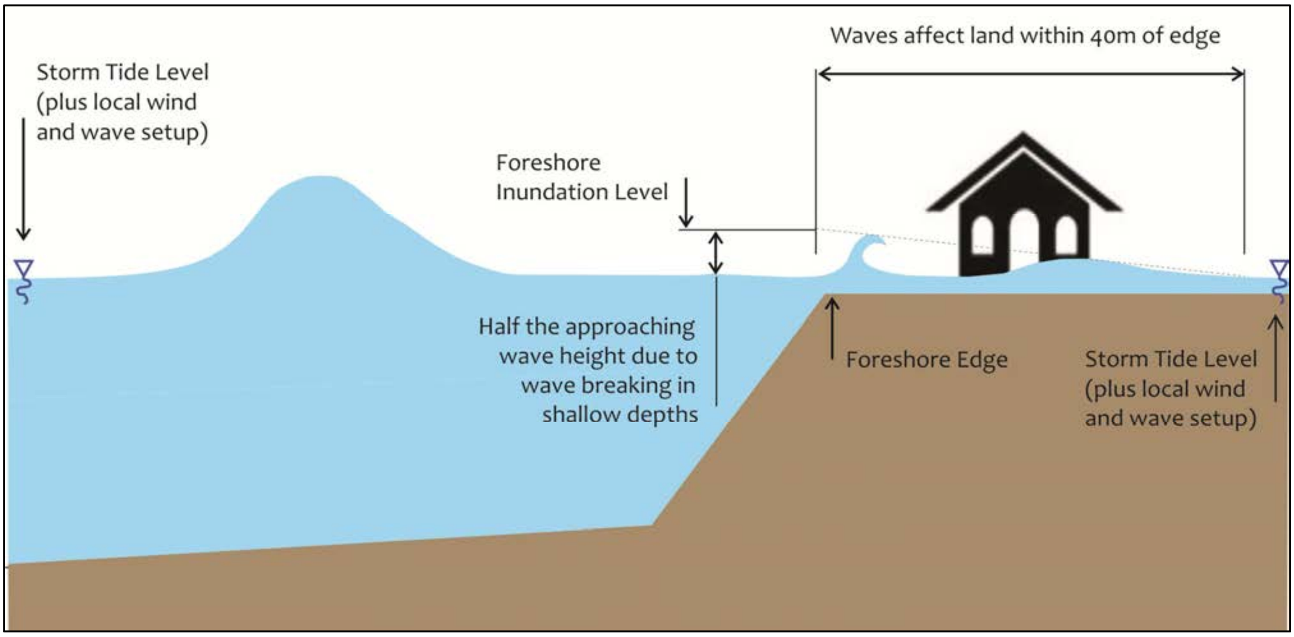


Figure 3-6 Overtopping when Storm Tide Level (Plus Local Wind and Wave Set-up) is above the Crest

3.4.2 Foreshore Edge Types

Field inspections were undertaken of the foreshore from late February to early March 2013. Photographs were taken using a GPS camera to capture the foreshore character and typical foreshore types were subsequently identified. Photograph locations were then compiled in a GIS and observed foreshore types were spatially delineated.

The field inspection demonstrated that the predominant foreshore types for the Woollahra LGA include:

> Vertical seawalls;

> Rocky foreshores;

> Sandy slopes, and

> Grassy/vegetated slopes.

It should be noted that these represent the predominant foreshore types and are not intended to represent the full range of foreshore types for all properties.

Property owners or developers have the opportunity to select the appropriate foreshore type for their property when calculating an EPL. Based on these observations, a set of typical foreshore types was adopted for the EPL database, namely:

> 1 in 8 natural slope (representing grassed and sandy gently sloping foreshores);

> 1 in 3 rocky shoreline (representing natural rocky foreshore or sloped rip rap); and

> Vertical seawall (e.g. block work or other retaining walls).

The magnitude of wave run-up is also dependant on the type of foreshore surface. Generally, the higher the porosity or roughness of the foreshore surface, the lower the run-up height is. Hence, the algorithms adopted for run-up calculations for each of these three foreshore types incorporated reduction coefficients in accordance with the published literature (CEM, 2002). They are presented in **Table 3-3**.

Table 3-3 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	0.9

Type of Edge Treatment Surface	Reduction Factor for $R_{u2\%}$
Rocky shoreline	0.6

For each of these foreshore types, calculations were undertaken for three back beach crest levels, being:

> 1.5 mAHD;

> 2.0 mAHD; and

> 2.5 mAHD.

3.4.3 Inland Extent of Wave Overtopping

The EPL applied to a development also depends on the distance of the development (building) from the foreshore edge. The landward reduction of wave inundation cannot be estimated with great confidence, and has been based on Cardno's observations of wave overtopping during the June 2007 storm in Brisbane Water, Gosford. It is assumed that wave run-up diminishes to zero at a point inland from the edge structure. The inland extent of the wave inundation is assumed to be 40 m for ocean swell waves and 15 m for local wind waves overtopping from the foreshore crest.

The EPL therefore includes wave run-up and overtopping values over this 40 m/15 m wide landward extent. Seaward of this area, the EPL has been based on the calculated storm tide level plus local wind and wave set-up for the appropriate foreshore location, where this is above ground level. This means that at the foreshore, the EPL is set to the "maximum EPL" and at 40 m/15 m from the foreshore the EPL is set at the local (still) water level. A linear interpolation has been used to calculate the EPL between 0 m and 40 m/15 m from the foreshore.

It should be noted that where a property slopes steeply back from the foreshore, the wave inundation may only affect a small portion of the property.

3.5 Freeboard

The estimation of all of the components that make up the EPL (**Sections 3.2-3.4**) 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 is normally the largest water level component, other than astronomical tide.

It is common practice to take some precaution over this uncertainty. This is generally achieved through the application of a freeboard.

To assist Council in determining an appropriate freeboard, the following freeboards have been included in the property database (**Appendix B**):

> + 0.0 m freeboard;

> + 0.3 m freeboard;

> + 0.5 m freeboard; and

> Variable freeboard (in this case, properties for which wave run-up is greater than or equal to 1.3 m, there is no freeboard allowance. All other properties have a 0.3 m freeboard).

Prior to explicit incorporation of provision for SLR in planning levels, a freeboard of 0.5 m has commonly been adopted in NSW, incorporating a 0.3 m freeboard with an additional 0.2 m to account for potential SLR (much less than the current predicted SLR).

For the current study, Cardno recommends a freeboard of 0.3 m for the 2050 and 2100 scenarios, and 0.5 m for the present day case with no SLR component. This approach has been adopted in calculation of the EPLs in the database (**Appendix B**; electronic database).

4 Properties Affected by Estuary Planning Levels

4.1 Identifying Affected Properties

Those properties affected by EPLs include properties along the foreshore with ground levels below the EPLs (excluding a freeboard), with minimum ground levels determined based on Airborne Laser Scanning (ALS) survey provided by Council (captured in 2007).

Affected properties have been identified for the following conditions:

> Existing conditions:
  - +0 m freeboard,
  - +0.3 m freeboard,
  - +0.5 m freeboard, and
  - Variable freeboard (as described in **Section 3.5**).

> 0.4 m SLR:
  - +0 m freeboard,
  - +0.3 m freeboard,
  - +0.5 m freeboard, and
  - Variable freeboard (as described in **Section 3.5**).

> 0.9 m SLR:
  - +0 m freeboard,
  - +0.3 m freeboard,
  - +0.5 m freeboard, and
  - Variable freeboard (as described in **Section 3.5**).

4.2 Properties Affected by Estuarine Planning Levels

A summary of the number of properties (as defined by cadastral lots) affected by EPLs under the various scenarios has been provided in **Table 4-1** and the inundation extents have been mapped in **Figures 4.1-4.10** of **Appendix C**. It should be noted that the information in the table and accompanying figures does not include those properties that are above the inundation extent, but within the freeboard extent.

The EPLs for all properties falling within the inundation extent are provided in a Property Database in **Appendix B** (electronic database).

Table 4-1 Properties Affected by Estuarine Inundation Risk

Scenario	Number of Properties Affected
Existing conditions	462
+0.4 m SLR	542
+0.9 m SLR	722

The Property Database identifies the EPLs for each specific allotment falling within the inundation extent for each of the possible site specific foreshore types (natural slope, rocky shoreline, and vertical seawall), and in the case of seawalls, for three possible seawall crest levels (1.5, 2.0 and 2.5 mAHD). In identifying the appropriate EPL for a specific allotment, the user would consider the site specific foreshore type and read off the corresponding EPL for the allotment.

This is generally a simple process, noting that there is a need to consider the potential range of scenarios whereby allotments do not fall neatly within these categories, and that these also need to be considered in identifying the appropriate EPL to manage the risk of estuarine inundation for a specific site. In general, this issue relates primarily to sites with seawalls, and specifically to properties whereby the seawall crest level falls:

> Between two of the three seawall crest levels identified in the Property Database, or

> Falls outside of the range of possible seawall crest levels.

Where, for example, a specific allotment has a seawall with a crest level of 1.7 mAHD, the appropriate EPL for that allotment could be determined by either:

> Reading off the EPLs for the site for a 1.5 mAHD and 2.0 mAHD high seawall and adopting the higher of the two levels; or

> Interpolating the two EPLs to develop a site specific EPL taking into account the seawall crest level of 1.7 mAHD.

In the event that inspection of the EPL Property Database shows that overtopping does not occur at the site for a seawall of 2.0 mAHD, but does occur for a seawall of 1.5 mAHD height, then it is considered reasonable to either adopt the EPL from the Property Database for the 1.5 mAHD seawall, or to seek a site-specific assessment by a qualified coastal engineer to determine an appropriate EPL, taking into account the seawall crest level of 1.7 mAHD and the incident wave data and other water level base data for the site.

Considering the second scenario outlined above, it may be the case that, for the allotment in question, the seawall crest level is either less than 1.5 mAHD or greater than 2.5 mAHD, and therefore it is not possible to interpolate between values to determine the appropriate EPL. If the Property Database identifies that the allotment is not subject to inundation at 2.5 mAHD, then the site will not be at risk of inundation, provided that the crest level of the seawall protecting the property is greater than 2.5 mAHD for its entire seaward boundary, and that of neighbouring properties. However, if the seawall crest level is lower than 1.5 mAHD, a site specific EPL may need to be determined by a qualified coastal engineer, adopting the wave and water level data provided in **Appendix A**.

It is recommended that Council prescribe in their DCP the appropriate approaches to cover off these different scenarios.

5 Assumptions and Qualifications

This document has been prepared using spatial information, reports, policy documents and legislation as referenced in the text, and assumes this available information is accurate at the time of report preparation.

The property analyses undertaken in this project have been based on cadastral boundaries supplied by Crown Lands and regional land survey data captured via aerial laser survey (ALS) and provided to Cardno for use by Woollahra Municipal Council. The vertical accuracy of the ALS data may vary between 0 m and 0.15 m. If required, property owners can evaluate the effect of these levels on their properties against the EPLs by obtaining a site specific ground survey of their properties, including the public foreshore area.

6 References

Cardno (2010) *Estuarine Planning Levels Study - Foreshore Region of Leichhardt Local Government Area.* Prepared for Leichardt Municipal Council, April 2010.

Cardno (2015) *Woollahra Coastal Zone Management Plan Stage 1*. LJ3011/R2771. Prepared for Woollahra Council, April 2015.

Cardno (2013) *Metocean Study for the Caltex Wharf, Kurnell.* Prepared for Caltex Australia, March 2013. Not publicly available.

CEM (2002) *Coastal Engineering Manual*. U.S. Army Corps of Engineers, Engineer Manual 1110-2-1100, Washington D.C.

Coastal Engineering Research Centre (1984) *Shoreline Protection Manual, 4th edition.* U.S. Department of the Army, Washington, D.C.

Chief Scientist and Engineer (2012) *Assessment of the Science Behind the NSW Government's Sea Level Rise Planning Benchmarks.* NSW Government.

CSIRO and Sydney Coastal Councils Group (2012) *Mapping and Responding to Coastal Inundation. Stage 1 – Modelling and Mapping of Coastal Inundation Under Future Sea Level Rise.*

DECCW (2010) Coastal Risk Management Guide. Incorporating Sea Level Rise Benchmarks in Coastal Risk Assessments. Prepared by the NSW Department of Environment, Climate Change and Water.

Department of Planning (2007) *Planning Circular 07-003. New Guideline and Changes to Section 117 Direction and EP&A Regulation on Flood Prone Land*. NSW Government.

Goda, Y. (2000) *Random Seas and Design of Maritime Structures*. World Scientific, Volume 15.

NSW Government (1990) *Coastline Management Manual*.

NSW Government (2005) *Floodplain Development Manual*.

Public Works Department (2001) *Wallis Lake Floodplain Management Study, Foreshore Flooding Assessment.* Manly Hydraulics Laboratory. MHL Report 1023.

de Waal, J. P., and van der Meer, J. W. 1992. *Wave Run-Up and Overtopping on Coastal Structures*. Proceedings of the 23rd International Coastal Engineering Conference, American Society of Civil Engineers, Vol 2, pp 1758-1771.

Woollahra Coastal Zone Management Plan (Stage 1)

APPENDIX A

WIND SETUP MODELLING RESULTS

Cardno
Shaping the Future

Table A-1 – Delft3D Hydrodynamic Modelling Results for 20-Years-ARI Wind Setup Values (relative to Fort Denison)

Region	Loc. ID	N	NE	E	SE	S	SW	W	NW	Max. Set-up	Dir of Max. Set-up	Min. Set-up	Dir of Min. Set-up
Rushcutters Bay	001	0.02	0.01	0.00	-0.02	-0.05	-0.02	0.00	0.02	0.02	N	-0.05	S
Rushcutters Bay	002	0.02	0.01	0.00	-0.02	-0.05	-0.02	0.00	0.02	0.02	NW	-0.05	S
Rushcutters Bay	003	0.02	0.01	0.00	-0.02	-0.05	-0.02	0.01	0.02	0.02	NW	-0.05	S
Rushcutters Bay	004	0.02	0.01	-0.01	-0.02	-0.05	-0.01	0.01	0.02	0.02	NW	-0.05	S
Rushcutters Bay	005	0.02	0.01	-0.01	-0.02	-0.05	-0.01	0.01	0.02	0.02	NW	-0.05	S
Rushcutters Bay	006	0.01	0.00	-0.01	-0.02	-0.04	-0.01	0.01	0.02	0.02	NW	-0.04	S
Rushcutters Bay	007	0.01	0.00	-0.01	-0.02	-0.03	-0.01	0.02	0.02	0.02	NW	-0.03	S
Rushcutters Bay	008	0.01	0.00	-0.01	-0.02	-0.03	0.00	0.02	0.02	0.02	NW	-0.03	S
Rushcutters Bay	009	0.01	0.00	-0.01	-0.02	-0.03	0.00	0.02	0.01	0.02	W	-0.03	S
Rushcutters Bay	010	0.01	0.00	-0.01	-0.02	-0.03	0.00	0.02	0.01	0.02	W	-0.03	S
Rushcutters Bay	011	0.00	0.00	-0.01	-0.01	-0.03	0.00	0.01	0.01	0.01	W	-0.03	S
Rushcutters Bay	012	0.00	0.00	-0.01	-0.01	-0.03	-0.01	0.01	0.00	0.01	W	-0.03	S
Rushcutters Bay	013	0.00	0.00	-0.01	-0.01	-0.03	-0.01	0.00	0.00	0.00	N	-0.03	S
Darling Point	014	0.00	-0.01	-0.01	-0.01	-0.02	-0.01	0.00	0.00	0.00	N	-0.02	S
Darling Point	015	0.00	0.00	-0.01	-0.01	-0.02	0.00	0.02	0.01	0.02	W	-0.02	S
Darling Point	016	0.00	0.00	-0.01	-0.01	-0.02	-0.01	0.00	0.00	0.00	NW	-0.02	S
Darling Point	017	0.00	0.00	-0.01	-0.01	-0.02	0.00	0.01	0.01	0.01	W	-0.02	S
Darling Point	018	0.00	-0.01	-0.01	-0.02	-0.02	0.00	0.01	0.00	0.01	W	-0.02	S
Darling Point	019	0.00	-0.01	-0.01	-0.02	-0.02	-0.01	-0.01	0.00	0.00	N	-0.02	S
Darling Point	020	0.00	0.00	-0.01	-0.01	-0.02	0.00	0.01	0.01	0.01	W	-0.02	S
Double Bay	021	0.00	0.00	-0.01	-0.01	-0.02	0.00	0.01	0.01	0.01	W	-0.02	S
Double Bay	022	0.00	0.00	-0.01	-0.01	-0.02	0.00	0.01	0.01	0.01	W	-0.02	S
Double Bay	023	0.00	0.00	-0.01	-0.01	-0.02	0.00	0.01	0.00	0.01	W	-0.02	S
Double Bay	024	0.00	0.00	-0.01	-0.01	-0.03	0.00	0.01	0.01	0.01	W	-0.03	S
Double Bay	025	0.00	0.00	0.00	-0.01	-0.02	-0.01	0.01	0.01	0.01	W	-0.02	S
Double Bay	026	0.01	0.00	0.00	-0.01	-0.03	-0.01	0.01	0.01	0.01	NW	-0.03	S
Double Bay	027	0.01	0.01	0.00	-0.01	-0.03	-0.02	0.00	0.01	0.01	NE	-0.03	S
Double Bay	028	0.01	0.01	0.00	-0.01	-0.04	-0.02	0.01	0.01	0.01	NW	-0.04	S
Double Bay	029	0.01	0.01	0.00	-0.02	-0.04	-0.01	0.01	0.01	0.01	NW	-0.04	S
Double Bay	030	0.01	0.01	0.00	-0.02	-0.05	-0.01	0.02	0.02	0.02	NW	-0.05	S
Double Bay	031	0.01	0.00	-0.01	-0.02	-0.05	-0.01	0.03	0.02	0.03	W	-0.05	S
Double Bay	032	0.01	0.00	-0.01	-0.02	-0.04	0.00	0.02	0.02	0.02	W	-0.04	S
Double Bay	033	0.01	0.00	-0.01	-0.02	-0.04	0.00	0.02	0.02	0.02	W	-0.04	S
Double Bay	034	0.01	0.00	-0.01	-0.02	-0.04	0.00	0.03	0.02	0.03	W	-0.04	S
Double Bay	035	0.01	0.00	-0.01	-0.02	-0.03	0.01	0.03	0.02	0.03	W	-0.03	S
Double Bay	036	0.01	0.00	-0.01	-0.02	-0.03	0.01	0.03	0.02	0.03	W	-0.03	S
Double Bay	037	0.01	-0.01	-0.01	-0.02	-0.02	0.01	0.03	0.02	0.03	W	-0.02	SE
Double Bay	038	0.00	-0.01	-0.01	-0.02	-0.02	0.01	0.03	0.01	0.03	W	-0.02	S
Double Bay	039	0.00	-0.01	-0.01	-0.02	-0.03	0.01	0.02	0.01	0.02	W	-0.03	S
Double Bay	040	0.00	-0.01	-0.01	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	S
Double Bay	041	0.00	-0.01	-0.01	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	S
Double Bay	042	0.00	-0.01	-0.01	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	SE

Region	Loc. ID	N	NE	E	SE	S	SW	W	NW	Max. Set-up	Dir of Max. Set-up	Min. Set-up	Dir of Min. Set-up
Double Bay	043	0.00	-0.01	-0.01	-0.02	-0.01	0.01	0.01	0.01	0.01	W	-0.02	SE
Point Piper	044	0.00	-0.01	-0.01	-0.02	-0.02	0.00	0.01	0.01	0.01	W	-0.02	S
Point Piper	045	0.00	-0.01	-0.01	-0.02	-0.02	0.00	0.01	0.01	0.01	W	-0.02	S
Point Piper	046	0.00	-0.01	-0.01	-0.02	-0.02	0.00	0.01	0.01	0.01	W	-0.02	S
Point Piper	047	0.00	-0.01	-0.01	-0.02	-0.02	0.00	0.01	0.01	0.01	W	-0.02	S
Point Piper	048	0.00	-0.01	-0.01	-0.02	-0.02	0.00	0.01	0.01	0.01	W	-0.02	SE
Point Piper	049	0.00	-0.01	-0.01	-0.02	-0.02	0.00	0.02	0.01	0.02	W	-0.02	SE
Point Piper	050	0.00	-0.01	-0.02	-0.02	-0.02	0.00	0.02	0.01	0.02	W	-0.02	SE
Point Piper	051	0.00	-0.01	-0.01	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	S
Point Piper	052	0.00	-0.01	-0.01	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	S
Point Piper	053	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	S
Point Piper	054	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	S
Point Piper	055	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	SE
Point Piper	056	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	SE
Point Piper	057	0.00	-0.01	-0.02	-0.02	-0.01	0.01	0.02	0.01	0.02	W	-0.02	SE
Point Piper	058	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	SE
Point Piper	059	0.00	-0.01	-0.02	-0.02	-0.02	0.00	0.02	0.01	0.02	W	-0.02	SE
Rose Bay	060	0.00	-0.01	-0.02	-0.02	-0.02	0.00	0.02	0.01	0.02	W	-0.02	S
Rose Bay	061	0.00	-0.01	-0.02	-0.02	-0.02	0.00	0.02	0.01	0.02	W	-0.02	S
Rose Bay	062	0.00	-0.01	-0.02	-0.02	-0.02	0.00	0.02	0.01	0.02	W	-0.02	S
Rose Bay	063	0.00	-0.01	-0.01	-0.02	-0.02	0.00	0.01	0.00	0.01	W	-0.02	S
Rose Bay	064	0.00	-0.01	-0.01	-0.02	-0.02	0.00	0.01	0.01	0.01	W	-0.02	S
Rose Bay	065	0.00	0.00	-0.01	-0.02	-0.02	0.00	0.01	0.01	0.01	W	-0.02	S
Rose Bay	066	0.01	0.00	-0.01	-0.02	-0.05	-0.01	0.01	0.01	0.01	NW	-0.05	S
Rose Bay	067	0.01	0.00	-0.01	-0.02	-0.04	-0.01	0.01	0.01	0.01	NW	-0.04	S
Rose Bay	068	0.01	0.00	-0.01	-0.03	-0.09	-0.02	0.02	0.02	0.02	NW	-0.09	S
Rose Bay	069	0.01	-0.01	-0.02	-0.03	-0.04	0.00	0.02	0.01	0.02	W	-0.04	S
Rose Bay	070	0.01	-0.01	-0.02	-0.03	-0.04	0.00	0.02	0.01	0.02	W	-0.04	S
Rose Bay	071	0.01	-0.01	-0.02	-0.03	-0.04	0.00	0.03	0.02	0.03	W	-0.04	S
Rose Bay	072	0.01	-0.01	-0.02	-0.03	-0.04	0.01	0.03	0.02	0.03	W	-0.04	S
Rose Bay	073	0.00	-0.01	-0.02	-0.03	-0.03	0.00	0.02	0.01	0.02	W	-0.03	S
Rose Bay	074	0.00	-0.01	-0.02	-0.03	-0.03	0.01	0.03	0.02	0.03	W	-0.03	S
Rose Bay	075	0.01	-0.01	-0.02	-0.03	-0.03	0.01	0.03	0.02	0.03	W	-0.03	S
Rose Bay	076	0.02	0.00	-0.03	-0.04	-0.04	0.02	0.05	0.03	0.05	W	-0.04	S
Rose Bay	077	0.01	-0.01	-0.03	-0.04	-0.06	0.01	0.05	0.04	0.05	W	-0.06	S
Rose Bay	078	0.02	-0.01	-0.03	-0.06	-0.08	0.03	0.07	0.05	0.07	W	-0.08	S
Rose Bay	079	0.01	-0.02	-0.04	-0.05	-0.02	0.04	0.08	0.04	0.08	W	-0.05	SE
Rose Bay	080	0.00	-0.02	-0.03	-0.04	-0.03	0.03	0.06	0.03	0.06	W	-0.04	SE
Rose Bay	081	0.00	-0.02	-0.03	-0.03	0.00	0.04	0.05	0.02	0.05	W	-0.03	SE
Rose Bay	082	-0.01	-0.02	-0.03	-0.03	0.00	0.03	0.04	0.02	0.04	W	-0.03	SE
Rose Bay	083	-0.01	-0.02	-0.02	-0.03	-0.02	0.02	0.04	0.01	0.04	W	-0.03	SE
Vaucluse	084	-0.01	-0.02	-0.02	-0.03	-0.03	0.01	0.03	0.01	0.03	W	-0.03	SE
Vaucluse	085	-0.01	-0.02	-0.02	-0.02	-0.01	0.02	0.03	0.01	0.03	W	-0.02	SE
Vaucluse	086	-0.01	-0.02	-0.02	-0.02	0.00	0.02	0.03	0.01	0.03	W	-0.02	E

Region	Loc. ID	N	NE	E	SE	S	SW	W	NW	Max. Set-up	Dir of Max. Set-up	Min. Set-up	Dir of Min. Set-up
Vaucluse	087	-0.01	-0.02	-0.02	-0.02	-0.01	0.02	0.03	0.01	0.03	W	-0.02	E
Vaucluse	088	-0.01	-0.02	-0.02	-0.02	-0.01	0.01	0.03	0.01	0.03	W	-0.02	SE
Vaucluse	089	-0.01	-0.02	-0.02	-0.02	-0.01	0.02	0.03	0.01	0.03	W	-0.02	E
Vaucluse	090	-0.01	-0.02	-0.02	-0.02	-0.01	0.02	0.03	0.01	0.03	W	-0.02	SE
Vaucluse	091	-0.01	-0.02	-0.02	-0.02	-0.01	0.02	0.03	0.01	0.03	W	-0.02	E
Vaucluse	092	-0.01	-0.02	-0.02	-0.02	-0.01	0.02	0.03	0.00	0.03	W	-0.02	E
Vaucluse	093	-0.01	-0.02	-0.02	-0.02	-0.02	0.01	0.03	0.01	0.03	W	-0.02	E
Vaucluse	094	-0.01	-0.02	-0.02	-0.02	-0.01	0.01	0.02	0.01	0.02	W	-0.02	E
Vaucluse	095	-0.01	-0.02	-0.02	-0.02	-0.01	0.01	0.02	0.00	0.02	W	-0.02	E
Vaucluse	096	-0.01	-0.02	-0.02	-0.02	-0.01	0.01	0.02	0.00	0.02	W	-0.02	E
Vaucluse	097	-0.01	-0.02	-0.02	-0.02	0.00	0.01	0.02	0.00	0.02	W	-0.02	E
Vaucluse	098	-0.01	-0.02	-0.02	-0.02	-0.01	0.01	0.02	0.00	0.02	W	-0.02	SE
Neilson Park	099	-0.01	-0.02	-0.02	-0.02	-0.01	0.01	0.02	0.00	0.02	W	-0.02	SE
Neilson Park	100	-0.02	-0.02	-0.03	-0.02	-0.02	0.00	0.01	0.00	0.01	W	-0.03	E
Neilson Park	101	-0.01	-0.02	-0.02	-0.02	-0.01	0.01	0.02	0.00	0.02	W	-0.02	E
Neilson Park	102	-0.01	-0.02	-0.02	-0.02	-0.01	0.01	0.02	0.00	0.02	W	-0.02	E
Neilson Park	103	-0.01	-0.02	-0.03	-0.03	-0.02	0.01	0.03	0.01	0.03	W	-0.03	SE
Neilson Park	104	-0.01	-0.02	-0.03	-0.02	-0.01	0.01	0.02	0.00	0.02	W	-0.03	E
Neilson Park	105	-0.02	-0.02	-0.03	-0.02	-0.02	0.00	0.02	0.00	0.02	W	-0.03	E
Neilson Park	106	-0.02	-0.02	-0.03	-0.02	-0.01	0.01	0.02	0.00	0.02	W	-0.03	E
Neilson Park	107	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Neilson Park	108	-0.02	-0.03	-0.03	-0.03	-0.01	0.01	0.02	0.00	0.02	W	-0.03	E
Neilson Park	109	-0.02	-0.03	-0.03	-0.03	0.00	0.02	0.02	0.00	0.02	W	-0.03	E
Vaucluse/Parsley Bay	110	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Vaucluse/Parsley Bay	111	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Vaucluse/Parsley Bay	112	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Vaucluse/Parsley Bay	113	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Vaucluse/Parsley Bay	114	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Vaucluse/Parsley Bay	115	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Vaucluse/Parsley Bay	116	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Vaucluse/Parsley Bay	117	-0.01	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Vaucluse/Parsley Bay	118	-0.01	-0.03	-0.03	-0.03	-0.02	0.01	0.03	0.01	0.03	W	-0.03	SE
Vaucluse/Parsley Bay	119	-0.01	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.01	0.03	W	-0.03	E
Vaucluse/Parsley Bay	120	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Vaucluse/Parsley Bay	121	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Vaucluse/Parsley Bay	122	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Vaucluse/Parsley Bay	123	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Vaucluse/Parsley Bay	124	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Watsons Bay	125	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Watsons Bay	126	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Watsons Bay	127	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Watsons Bay	128	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Watsons Bay	129	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Watsons Bay	130	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E

Region	Loc. ID	N	NE	E	SE	S	SW	W	NW	Max. Set-up	Dir of Max. Set-up	Min. Set-up	Dir of Min. Set-up
Watsons Bay	131	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Watsons Bay	132	-0.02	-0.03	-0.03	-0.03	0.00	0.02	0.03	0.00	0.03	W	-0.03	E
Watsons Bay	133	-0.02	-0.03	-0.03	-0.03	0.00	0.02	0.03	0.00	0.03	W	-0.03	E
Watsons Bay	134	-0.02	-0.03	-0.04	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.04	E
Watsons Bay	135	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Watsons Bay	136	-0.02	-0.03	-0.03	-0.03	-0.01	0.03	0.04	0.01	0.04	W	-0.03	E
Watsons Bay	137	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.01	0.04	W	-0.04	E
Watsons Bay	138	-0.02	-0.03	-0.03	-0.04	-0.01	0.02	0.04	0.01	0.04	W	-0.04	SE
Watsons Bay	139	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.00	0.04	W	-0.04	E
Watsons Bay	140	-0.02	-0.03	-0.04	-0.03	0.01	0.03	0.04	0.00	0.04	W	-0.04	E
Watsons Bay	141	-0.02	-0.03	-0.04	-0.03	0.01	0.03	0.04	0.00	0.04	W	-0.04	E
Watsons Bay	142	-0.02	-0.03	-0.03	-0.03	0.01	0.03	0.03	0.00	0.03	W	-0.03	E
Watsons Bay	143	-0.02	-0.03	-0.03	-0.03	0.00	0.03	0.03	0.00	0.03	W	-0.03	E
Watsons Bay	144	-0.02	-0.03	-0.03	-0.03	0.01	0.03	0.03	0.00	0.03	W	-0.03	E
Watsons Bay	145	-0.02	-0.03	-0.03	-0.03	0.00	0.02	0.03	0.00	0.03	W	-0.03	E
Camp Cove	146	-0.02	-0.03	-0.04	-0.03	0.00	0.02	0.03	0.00	0.03	W	-0.04	E
Camp Cove	147	-0.02	-0.03	-0.03	-0.03	0.00	0.02	0.03	0.00	0.03	W	-0.03	E
Camp Cove	148	-0.02	-0.03	-0.04	-0.03	0.00	0.02	0.03	0.00	0.03	W	-0.04	E
Camp Cove	149	-0.03	-0.04	-0.04	-0.03	0.00	0.02	0.03	0.00	0.03	W	-0.04	E
Camp Cove	150	-0.03	-0.03	-0.04	-0.03	0.01	0.02	0.03	0.00	0.03	W	-0.04	E
Camp Cove	151	-0.02	-0.03	-0.04	-0.04	0.01	0.03	0.03	0.00	0.03	W	-0.04	E
Camp Cove	152	-0.03	-0.04	-0.04	-0.03	0.02	0.03	0.03	0.00	0.03	W	-0.04	E
Camp Cove	153	-0.03	-0.04	-0.04	-0.03	0.01	0.03	0.03	0.00	0.03	W	-0.04	E
Camp Cove	154	-0.03	-0.04	-0.04	-0.03	0.01	0.03	0.03	0.00	0.03	W	-0.04	NE
Camp Cove	155	-0.03	-0.04	-0.04	-0.03	0.01	0.02	0.03	-0.01	0.03	W	-0.04	E
Camp Cove	156	-0.03	-0.04	-0.04	-0.03	0.01	0.02	0.03	-0.01	0.03	W	-0.04	NE
Camp Cove	157	-0.03	-0.04	-0.04	-0.03	0.00	0.02	0.03	-0.01	0.03	W	-0.04	NE
Harbour Entrance	158	-0.03	-0.04	-0.04	-0.03	0.01	0.03	0.03	-0.01	0.03	W	-0.04	NE
Harbour Entrance	159	-0.03	0.06	-0.04	-0.03	0.02	0.03	0.03	-0.01	0.06	NE	-0.04	E
Harbour Entrance	160	-0.03	-0.04	-0.04	-0.03	0.02	0.03	0.03	-0.01	0.03	W	-0.04	NE
Harbour Entrance	161	-0.03	-0.04	-0.04	-0.04	0.00	0.01	0.02	-0.01	0.02	W	-0.04	NE
Harbour Entrance	162	-0.03	-0.04	-0.04	-0.03	0.01	0.02	0.02	-0.01	0.02	W	-0.04	NE
Harbour Entrance	163	-0.03	-0.04	-0.04	-0.03	0.01	0.02	0.02	-0.01	0.02	W	-0.04	NE

Table A-2 – Delft3D Hydrodynamic Modelling Results for 100-Years-ARI Wind Setup Values (relative to Fort Denison)

Region	Loc. ID	N	NE	E	SE	S	SW	W	NW	Max. Set-up	Dir of Max. Set-up	Min. Set-up	Dir of Min. Set-up
Rushcutters Bay	001	0.02	0.01	0.00	-0.02	-0.05	-0.02	0.00	0.02	0.02	N	-0.05	S
Rushcutters Bay	002	0.02	0.01	0.00	-0.02	-0.06	-0.02	0.01	0.02	0.02	NW	-0.06	S
Rushcutters Bay	003	0.02	0.01	0.00	-0.02	-0.06	-0.02	0.01	0.02	0.02	NW	-0.06	S
Rushcutters Bay	004	0.02	0.01	0.00	-0.02	-0.06	-0.02	0.01	0.02	0.02	NW	-0.06	S
Rushcutters Bay	005	0.02	0.01	0.00	-0.02	-0.06	-0.01	0.02	0.02	0.02	NW	-0.06	S
Rushcutters Bay	006	0.01	0.01	-0.01	-0.02	-0.05	-0.01	0.02	0.02	0.02	NW	-0.05	S
Rushcutters Bay	007	0.01	0.01	-0.01	-0.02	-0.04	-0.01	0.02	0.02	0.02	W	-0.04	S
Rushcutters Bay	008	0.01	0.00	-0.01	-0.02	-0.04	0.00	0.02	0.02	0.02	W	-0.04	S
Rushcutters Bay	009	0.01	0.00	-0.01	-0.02	-0.04	0.00	0.02	0.02	0.02	W	-0.04	S
Rushcutters Bay	010	0.01	0.00	-0.01	-0.02	-0.03	0.00	0.02	0.01	0.02	W	-0.03	S
Rushcutters Bay	011	0.01	0.00	-0.01	-0.01	-0.03	0.00	0.02	0.01	0.02	W	-0.03	S
Rushcutters Bay	012	0.01	0.00	-0.01	-0.01	-0.03	-0.01	0.01	0.00	0.01	W	-0.03	S
Rushcutters Bay	013	0.00	-0.01	-0.01	-0.01	-0.03	-0.02	0.00	0.00	0.00	N	-0.03	S
Darling Point	014	0.00	-0.01	-0.02	-0.02	-0.03	-0.02	0.00	0.00	0.00	N	-0.03	S
Darling Point	015	0.01	0.00	-0.01	-0.02	-0.03	0.00	0.03	0.01	0.03	W	-0.03	S
Darling Point	016	0.00	0.00	-0.01	-0.01	-0.02	-0.01	0.00	0.00	0.00	W	-0.02	S
Darling Point	017	0.00	0.00	-0.01	-0.02	-0.02	0.00	0.01	0.01	0.01	W	-0.02	S
Darling Point	018	0.00	-0.01	-0.02	-0.02	-0.02	0.00	0.01	0.01	0.01	W	-0.02	SE
Darling Point	019	0.00	-0.01	-0.02	-0.02	-0.03	-0.01	-0.01	0.00	0.00	N	-0.03	S
Darling Point	020	0.00	-0.01	-0.01	-0.02	-0.03	0.00	0.01	0.01	0.01	W	-0.03	S
Double Bay	021	0.00	0.00	-0.01	-0.02	-0.02	0.00	0.01	0.01	0.01	W	-0.02	S
Double Bay	022	0.00	0.00	-0.01	-0.02	-0.03	0.00	0.01	0.01	0.01	W	-0.03	S
Double Bay	023	0.00	0.00	-0.01	-0.02	-0.03	0.00	0.01	0.00	0.01	W	-0.03	S
Double Bay	024	0.01	0.00	-0.01	-0.02	-0.03	0.00	0.01	0.01	0.01	W	-0.03	S
Double Bay	025	0.01	0.00	-0.01	-0.01	-0.03	-0.01	0.01	0.01	0.01	W	-0.03	S
Double Bay	026	0.01	0.01	0.00	-0.01	-0.04	-0.01	0.01	0.01	0.01	W	-0.04	S
Double Bay	027	0.01	0.01	0.00	-0.01	-0.04	-0.02	0.00	0.01	0.01	NW	-0.04	S
Double Bay	028	0.01	0.01	0.00	-0.02	-0.05	-0.02	0.01	0.02	0.02	NW	-0.05	S
Double Bay	029	0.01	0.01	0.00	-0.02	-0.05	-0.01	0.02	0.02	0.02	NW	-0.05	S
Double Bay	030	0.02	0.01	-0.01	-0.02	-0.06	-0.01	0.02	0.02	0.02	W	-0.06	S
Double Bay	031	0.02	0.01	-0.01	-0.03	-0.05	0.00	0.03	0.03	0.03	W	-0.05	S
Double Bay	032	0.01	0.00	-0.01	-0.03	-0.05	0.00	0.03	0.02	0.03	W	-0.05	S
Double Bay	033	0.01	0.00	-0.02	-0.03	-0.04	0.00	0.03	0.02	0.03	W	-0.04	S
Double Bay	034	0.01	0.00	-0.02	-0.03	-0.04	0.00	0.04	0.02	0.04	W	-0.04	S
Double Bay	035	0.01	0.00	-0.02	-0.03	-0.04	0.01	0.04	0.02	0.04	W	-0.04	S
Double Bay	036	0.01	0.00	-0.02	-0.03	-0.03	0.01	0.05	0.02	0.05	W	-0.03	S
Double Bay	037	0.01	0.00	-0.02	-0.03	-0.02	0.02	0.05	0.02	0.05	W	-0.03	SE
Double Bay	038	0.00	0.00	-0.02	-0.02	-0.03	0.01	0.04	0.01	0.04	W	-0.03	S
Double Bay	039	0.00	-0.01	-0.02	-0.02	-0.03	0.01	0.03	0.01	0.03	W	-0.03	S
Double Bay	040	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.03	0.01	0.03	W	-0.02	SE
Double Bay	041	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.03	0.01	0.03	W	-0.02	SE

Region	Loc. ID	N	NE	E	SE	S	SW	W	NW	Max. Set-up	Dir of Max. Set-up	Min. Set-up	Dir of Min. Set-up
Double Bay	042	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	SE
Double Bay	043	0.00	-0.01	-0.02	-0.02	-0.01	0.01	0.02	0.01	0.02	W	-0.02	SE
Point Piper	044	0.00	-0.01	-0.02	-0.02	-0.02	0.00	0.02	0.01	0.02	W	-0.02	S
Point Piper	045	0.00	-0.01	-0.02	-0.02	-0.02	0.00	0.02	0.01	0.02	W	-0.02	S
Point Piper	046	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	SE
Point Piper	047	0.00	-0.01	-0.02	-0.02	-0.02	0.00	0.02	0.01	0.02	W	-0.02	S
Point Piper	048	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	SE
Point Piper	049	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	SE
Point Piper	050	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	SE
Point Piper	051	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.03	0.01	0.03	W	-0.02	SE
Point Piper	052	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.03	0.01	0.03	W	-0.02	SE
Point Piper	053	0.00	-0.01	-0.02	-0.02	-0.03	0.01	0.03	0.02	0.03	W	-0.03	S
Point Piper	054	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.03	0.01	0.03	W	-0.02	SE
Point Piper	055	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.03	0.01	0.03	W	-0.02	SE
Point Piper	056	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.03	0.01	0.03	W	-0.02	SE
Point Piper	057	0.00	-0.01	-0.02	-0.02	-0.01	0.01	0.03	0.01	0.03	W	-0.02	SE
Point Piper	058	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	SE
Point Piper	059	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.03	0.01	0.03	W	-0.02	SE
Rose Bay	060	0.00	-0.01	-0.02	-0.03	-0.02	0.01	0.03	0.01	0.03	W	-0.03	SE
Rose Bay	061	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.02	0.01	0.02	W	-0.02	SE
Rose Bay	062	0.00	-0.01	-0.02	-0.02	-0.03	0.01	0.02	0.01	0.02	W	-0.03	S
Rose Bay	063	0.00	-0.01	-0.01	-0.02	-0.02	0.00	0.01	0.00	0.01	W	-0.02	S
Rose Bay	064	0.00	-0.01	-0.01	-0.02	-0.03	0.00	0.01	0.01	0.01	W	-0.03	S
Rose Bay	065	0.01	0.00	-0.01	-0.02	-0.03	0.00	0.01	0.01	0.01	W	-0.03	S
Rose Bay	066	0.01	0.00	-0.01	-0.03	-0.05	-0.02	0.01	0.02	0.02	NW	-0.05	S
Rose Bay	067	0.01	0.00	-0.01	-0.03	-0.06	-0.01	0.01	0.02	0.02	NW	-0.06	S
Rose Bay	068	0.02	0.01	-0.02	-0.04	-0.18	-0.03	0.02	0.03	0.03	NW	-0.18	S
Rose Bay	069	0.01	0.00	-0.02	-0.03	-0.05	0.00	0.03	0.02	0.03	W	-0.05	S
Rose Bay	070	0.01	-0.01	-0.02	-0.03	-0.05	0.00	0.03	0.02	0.03	W	-0.05	S
Rose Bay	071	0.01	0.00	-0.02	-0.03	-0.05	0.00	0.04	0.02	0.04	W	-0.05	S
Rose Bay	072	0.01	-0.01	-0.02	-0.03	-0.05	0.01	0.04	0.02	0.04	W	-0.05	S
Rose Bay	073	0.00	-0.01	-0.02	-0.03	-0.04	0.00	0.03	0.02	0.03	W	-0.04	S
Rose Bay	074	0.00	-0.01	-0.02	-0.03	-0.04	0.01	0.04	0.02	0.04	W	-0.04	S
Rose Bay	075	0.01	-0.01	-0.02	-0.04	-0.04	0.01	0.05	0.03	0.05	W	-0.04	S
Rose Bay	076	0.02	0.00	-0.03	-0.05	-0.05	0.02	0.06	0.04	0.06	W	-0.05	S
Rose Bay	077	0.01	-0.01	-0.04	-0.05	-0.07	0.02	0.07	0.04	0.07	W	-0.07	S
Rose Bay	078	0.02	-0.01	-0.04	-0.07	-0.10	0.03	0.10	0.06	0.10	W	-0.10	S
Rose Bay	079	0.02	-0.02	-0.05	-0.07	-0.03	0.05	0.10	0.05	0.10	W	-0.07	SE
Rose Bay	080	0.00	-0.02	-0.04	-0.05	-0.03	0.04	0.08	0.03	0.08	W	-0.05	SE
Rose Bay	081	0.00	-0.02	-0.03	-0.04	0.00	0.05	0.08	0.03	0.08	W	-0.04	SE
Rose Bay	082	0.00	-0.02	-0.03	-0.03	0.01	0.04	0.06	0.02	0.06	W	-0.03	E
Rose Bay	083	-0.01	-0.02	-0.03	-0.03	-0.01	0.03	0.05	0.01	0.05	W	-0.03	SE
Vaucluse	084	-0.01	-0.02	-0.03	-0.03	-0.03	0.02	0.04	0.01	0.04	W	-0.03	SE
Vaucluse	085	-0.01	-0.02	-0.03	-0.03	-0.01	0.02	0.04	0.01	0.04	W	-0.03	SE

Region	Loc. ID	N	NE	E	SE	S	SW	W	NW	Max. Set-up	Dir of Max. Set-up	Min. Set-up	Dir of Min. Set-up
Vaucluse	086	-0.01	-0.02	-0.03	-0.03	0.00	0.03	0.04	0.01	0.04	W	-0.03	E
Vaucluse	087	-0.01	-0.02	-0.03	-0.03	-0.01	0.03	0.04	0.01	0.04	W	-0.03	SE
Vaucluse	088	-0.01	-0.02	-0.03	-0.03	-0.01	0.02	0.04	0.01	0.04	W	-0.03	SE
Vaucluse	089	-0.01	-0.02	-0.03	-0.03	-0.01	0.02	0.04	0.01	0.04	W	-0.03	SE
Vaucluse	090	-0.01	-0.02	-0.03	-0.03	-0.01	0.03	0.04	0.01	0.04	W	-0.03	E
Vaucluse	091	-0.01	-0.02	-0.03	-0.03	0.00	0.03	0.04	0.01	0.04	W	-0.03	E
Vaucluse	092	-0.01	-0.02	-0.03	-0.02	0.00	0.03	0.04	0.01	0.04	W	-0.03	E
Vaucluse	093	-0.01	-0.02	-0.03	-0.03	-0.01	0.02	0.04	0.01	0.04	W	-0.03	E
Vaucluse	094	-0.01	-0.02	-0.03	-0.03	-0.01	0.02	0.04	0.01	0.04	W	-0.03	E
Vaucluse	095	-0.01	-0.02	-0.03	-0.02	-0.01	0.02	0.03	0.01	0.03	W	-0.03	E
Vaucluse	096	-0.01	-0.02	-0.03	-0.02	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Vaucluse	097	-0.01	-0.02	-0.03	-0.02	0.00	0.02	0.03	0.01	0.03	W	-0.03	E
Vaucluse	098	-0.01	-0.02	-0.03	-0.02	0.00	0.02	0.03	0.00	0.03	W	-0.03	E
Neilson Park	099	-0.01	-0.02	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	SE
Neilson Park	100	-0.02	-0.03	-0.03	-0.03	-0.02	0.00	0.02	0.00	0.02	W	-0.03	E
Neilson Park	101	-0.01	-0.02	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Neilson Park	102	-0.01	-0.02	-0.03	-0.03	-0.01	0.02	0.03	0.00	0.03	W	-0.03	E
Neilson Park	103	-0.01	-0.02	-0.03	-0.03	-0.02	0.02	0.04	0.01	0.04	W	-0.03	E
Neilson Park	104	-0.01	-0.02	-0.03	-0.03	-0.01	0.02	0.04	0.00	0.04	W	-0.03	E
Neilson Park	105	-0.01	-0.02	-0.03	-0.03	-0.02	0.01	0.03	0.00	0.03	W	-0.03	E
Neilson Park	106	-0.02	-0.02	-0.03	-0.03	-0.01	0.02	0.04	0.00	0.04	W	-0.03	E
Neilson Park	107	-0.02	-0.03	-0.03	-0.03	0.00	0.02	0.04	0.00	0.04	W	-0.03	E
Neilson Park	108	-0.02	-0.03	-0.03	-0.03	0.00	0.02	0.04	0.00	0.04	W	-0.03	E
Neilson Park	109	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.00	0.04	W	-0.04	E
Vaucluse/Parsley Bay	110	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.00	0.04	W	-0.04	E
Vaucluse/Parsley Bay	111	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.00	0.04	W	-0.04	E
Vaucluse/Parsley Bay	112	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.00	0.04	W	-0.04	E
Vaucluse/Parsley Bay	113	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.00	0.04	W	-0.04	E
Vaucluse/Parsley Bay	114	-0.02	-0.03	-0.03	-0.03	0.00	0.03	0.04	0.00	0.04	W	-0.03	E
Vaucluse/Parsley Bay	115	-0.02	-0.03	-0.03	-0.03	-0.01	0.02	0.04	0.00	0.04	W	-0.03	E
Vaucluse/Parsley Bay	116	-0.02	-0.03	-0.03	-0.03	-0.01	0.03	0.04	0.00	0.04	W	-0.03	E
Vaucluse/Parsley Bay	117	-0.01	-0.03	-0.03	-0.03	-0.01	0.03	0.04	0.01	0.04	W	-0.03	E
Vaucluse/Parsley Bay	118	-0.01	-0.03	-0.03	-0.04	-0.02	0.02	0.05	0.01	0.05	W	-0.04	SE
Vaucluse/Parsley Bay	119	-0.01	-0.03	-0.03	-0.03	-0.01	0.03	0.05	0.01	0.05	W	-0.03	E
Vaucluse/Parsley Bay	120	-0.02	-0.03	-0.04	-0.03	-0.01	0.03	0.04	0.01	0.04	W	-0.04	E
Vaucluse/Parsley Bay	121	-0.02	-0.03	-0.04	-0.03	-0.01	0.02	0.04	0.00	0.04	W	-0.04	E
Vaucluse/Parsley Bay	122	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.00	0.04	W	-0.04	E
Vaucluse/Parsley Bay	123	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.00	0.04	W	-0.04	E
Vaucluse/Parsley Bay	124	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.00	0.04	W	-0.04	E
Watsons Bay	125	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.00	0.04	W	-0.04	E
Watsons Bay	126	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.01	0.04	W	-0.04	E
Watsons Bay	127	-0.02	-0.03	-0.04	-0.03	-0.01	0.03	0.04	0.01	0.04	W	-0.04	E
Watsons Bay	128	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.01	0.04	W	-0.04	E
Watsons Bay	129	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.01	0.04	W	-0.04	E

Region	Loc. ID	N	NE	E	SE	S	SW	W	NW	Max. Set-up	Dir of Max. Set-up	Min. Set-up	Dir of Min. Set-up
Watsons Bay	130	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.05	0.01	0.05	W	-0.04	E
Watsons Bay	131	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.05	0.01	0.05	W	-0.04	E
Watsons Bay	132	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.05	0.00	0.05	W	-0.04	E
Watsons Bay	133	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.05	0.00	0.05	W	-0.04	E
Watsons Bay	134	-0.02	-0.03	-0.04	-0.04	0.00	0.03	0.04	0.00	0.04	W	-0.04	E
Watsons Bay	135	-0.02	-0.03	-0.04	-0.03	0.00	0.03	0.04	0.00	0.04	W	-0.04	E
Watsons Bay	136	-0.02	-0.03	-0.04	-0.04	0.00	0.04	0.06	0.01	0.06	W	-0.04	E
Watsons Bay	137	-0.02	-0.03	-0.04	-0.04	0.00	0.04	0.05	0.01	0.05	W	-0.04	E
Watsons Bay	138	-0.02	-0.03	-0.04	-0.04	0.00	0.03	0.06	0.01	0.06	W	-0.04	E
Watsons Bay	139	-0.02	-0.03	-0.04	-0.03	0.01	0.04	0.05	0.01	0.05	W	-0.04	E
Watsons Bay	140	-0.02	-0.03	-0.04	-0.03	0.01	0.04	0.06	0.01	0.06	W	-0.04	E
Watsons Bay	141	-0.02	-0.03	-0.04	-0.03	0.02	0.04	0.06	0.01	0.06	W	-0.04	E
Watsons Bay	142	-0.02	-0.03	-0.04	-0.03	0.02	0.04	0.05	0.00	0.05	W	-0.04	E
Watsons Bay	143	-0.02	-0.03	-0.04	-0.03	0.01	0.04	0.05	0.00	0.05	W	-0.04	E
Watsons Bay	144	-0.02	-0.03	-0.04	-0.03	0.02	0.04	0.05	0.00	0.05	W	-0.04	E
Watsons Bay	145	-0.02	-0.03	-0.04	-0.03	0.01	0.04	0.05	0.00	0.05	W	-0.04	E
Camp Cove	146	-0.02	-0.03	-0.04	-0.04	0.01	0.04	0.05	0.00	0.05	W	-0.04	E
Camp Cove	147	-0.02	-0.03	-0.04	-0.04	0.01	0.04	0.04	0.00	0.04	W	-0.04	E
Camp Cove	148	-0.03	-0.04	-0.04	-0.04	0.01	0.03	0.04	0.00	0.04	W	-0.04	E
Camp Cove	149	-0.03	-0.04	-0.04	-0.04	0.02	0.04	0.04	0.00	0.04	W	-0.04	E
Camp Cove	150	-0.03	-0.04	-0.04	-0.04	0.02	0.04	0.05	0.00	0.05	W	-0.04	E
Camp Cove	151	-0.02	-0.04	-0.04	-0.04	0.02	0.04	0.05	0.00	0.05	W	-0.04	E
Camp Cove	152	-0.03	-0.04	-0.04	-0.04	0.03	0.05	0.05	0.00	0.05	W	-0.04	E
Camp Cove	153	-0.03	-0.04	-0.04	-0.04	0.03	0.05	0.05	0.00	0.05	W	-0.04	E
Camp Cove	154	-0.03	-0.04	-0.04	-0.03	0.02	0.04	0.05	0.00	0.05	W	-0.04	E
Camp Cove	155	-0.03	-0.04	-0.04	-0.03	0.02	0.04	0.04	0.00	0.04	W	-0.04	E
Camp Cove	156	-0.03	-0.04	-0.04	-0.04	0.02	0.04	0.04	-0.01	0.04	W	-0.04	E
Camp Cove	157	-0.03	-0.04	-0.04	-0.04	0.02	0.04	0.04	-0.01	0.04	W	-0.04	E
Harbour Entrance	158	-0.03	-0.04	-0.04	-0.03	0.03	0.04	0.05	-0.01	0.05	W	-0.04	E
Harbour Entrance	159	-0.03	-0.04	-0.05	-0.03	0.03	0.04	0.05	-0.01	0.05	W	-0.05	E
Harbour Entrance	160	-0.03	-0.04	-0.05	-0.03	0.03	0.04	0.05	-0.01	0.05	W	-0.05	E
Harbour Entrance	161	-0.04	-0.04	-0.05	-0.04	0.01	0.03	0.04	-0.01	0.04	W	-0.05	E
Harbour Entrance	162	-0.04	-0.04	-0.05	-0.03	0.03	0.03	0.04	-0.01	0.04	W	-0.05	E
Harbour Entrance	163	-0.04	-0.05	-0.05	-0.03	0.03	0.03	0.03	-0.01	0.03	W	-0.05	E

APPENDIX B

PROPERTY DATABASE

Woollahra Coastal Zone Management Plan (Stage 1)

APPENDIX C
ESTUARINE INUNDATION EXTENT MAPPING

Cardno
Shaping the Future

Estuarine Inundation Risk Extents

WOOLLAHRA
ESTUARY PLANNING LEVELS

ZONE 2

Legend

- Cadastre
- Present Day Estuarine Inundation Risk

N
W E
S

FIGURE 4.1

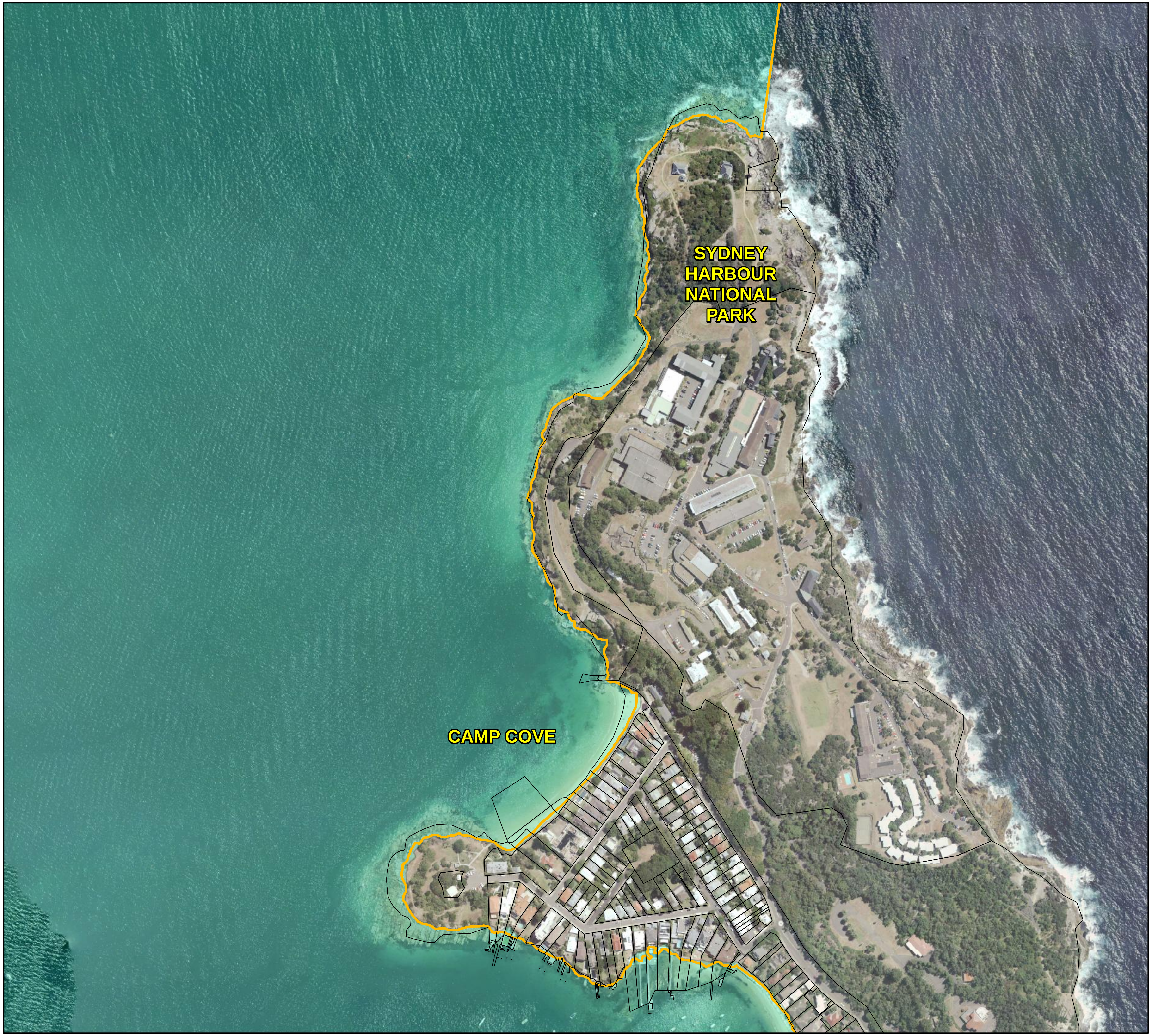
1:5,000 Scale at A3

Metres
0 125 250

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-08-04
Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Project: LJ3011
Map: G4001 - Zone 2 - Present Day Inundation Extents.mxd 02

Aerial imagery supplied by Woollahra Council (2011).



Estuarine Inundation Risk Extents

WOOLLAHRA
ESTUARY PLANNING LEVELS

ZONE 2

Legend

Cadastre

2050 Estuarine Inundation Risk Contour (+0.4 m SLR)

2100 Estuarine Inundation Risk (+0.9 m SLR)

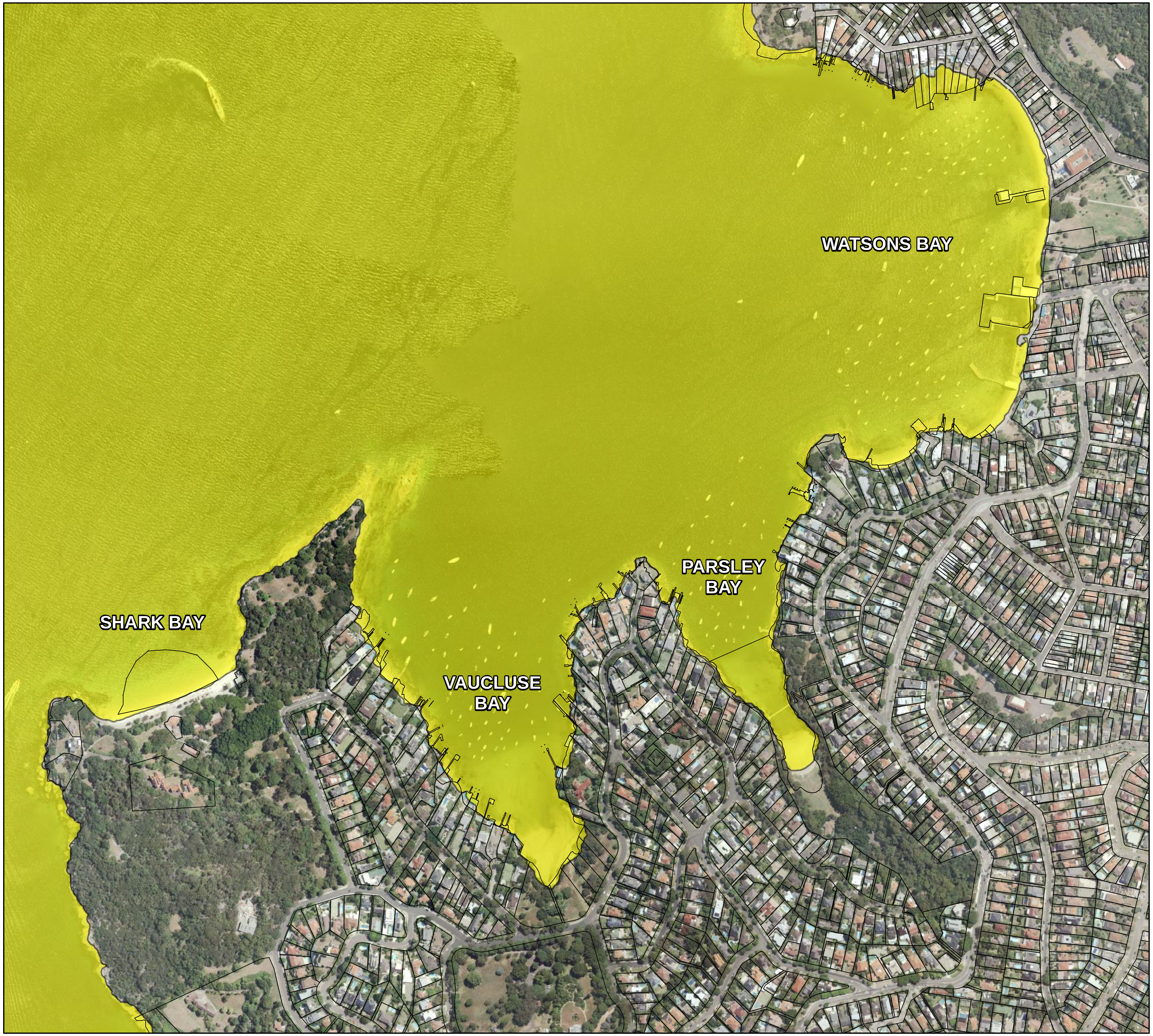
N
W E
S

FIGURE 4.2

1:5,000 Scale at A3

Metres
0 125 250

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-08-04
Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Project: LJ3011
Map: G4002 - Zone 2- 2050_2100 Inundation Extents.mxd 02
Aerial imagery supplied by Woollahra Council (2011).



WOOLLAHRA MUNICIPAL COUNCIL

Estuarine Inundation Risk Extents

WOOLLAHRA
ESTUARY PLANNING LEVELS

ZONE 3

Legend

Cadastre

Present Day Estuarine Inundation Risk

N W E S

FIGURE 4.3

1:7,000 Scale at A3

Metres
0 250 500

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-08-04
Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Project: LJ3011
Map: G4003 - Zone 3 - Present Day Inundation Extents.mxd 02
Aerial imagery supplied by Woollahra Council (2011).

WOOLLAHRA MUNICIPAL COUNCIL

Estuarine Inundation Risk Extents

WOOLLAHRA
ESTUARY PLANNING LEVELS

ZONE 3

Legend

- Cadastre
- 2050 Estuarine Inundation Risk Contour (+0.4 m SLR)
- 2100 Estuarine Inundation Risk (+0.9 m SLR)

N
W E
S

FIGURE 4.4

1:7,000 Scale at A3

Metres
0 250 500

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-08-04
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ3011
Map: G4004 - Zone 3 - 2050_2100 Inundation Extents.mxd 02

Aerial imagery supplied by Woollahra Council (2011).

WOOLLAHRA MUNICIPAL COUNCIL

Estuarine Inundation Risk Extents

WOOLLAHRA
ESTUARY PLANNING LEVELS

ZONE 4

Legend

Cadastre

Present Day Estuarine Inundation Risk

N
W E
S

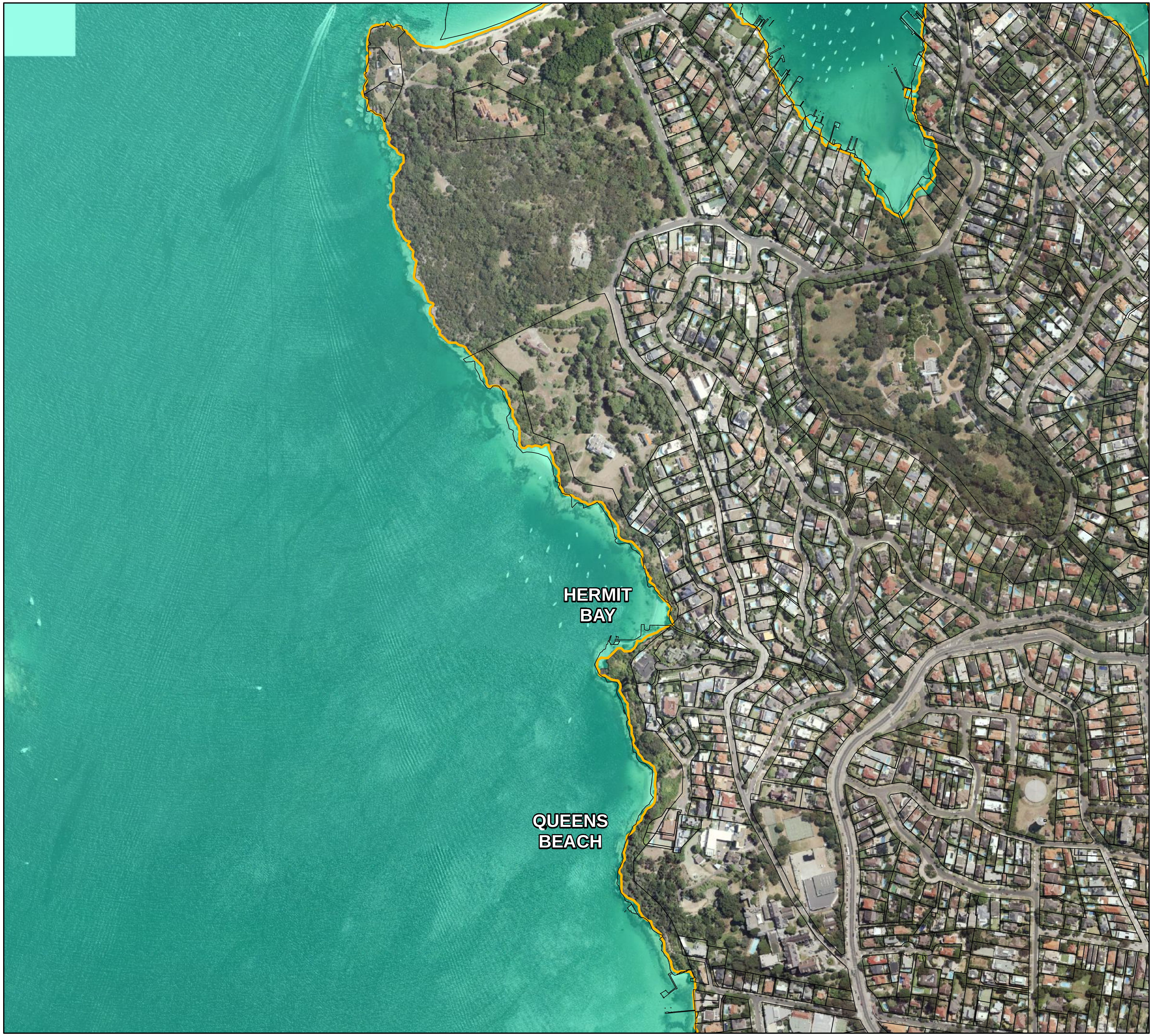
FIGURE 4.5

1:5,500 Scale at A3

Metres
0 180 360

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-08-04
Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Project: LJ3011
Map: G4005 - Zone 4- Present Day Inundation Extents.mxd 02
Aerial imagery supplied by Woollahra Council (2011).



WOOLLAHRA MUNICIPAL COUNCIL

Estuarine Inundation Risk Extents

WOOLLAHRA
ESTUARY PLANNING LEVELS

ZONE 4

Legend

- Cadastre
- 2050 Estuarine Inundation Risk Contour (+0.4 m SLR)
- 2100 Estuarine Inundation Risk (+0.9 m SLR)

N
W E
S

FIGURE 4.6

1:5,500 Scale at A3

Metres
0 180 360

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-08-04
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ3011
Map: G4006 - Zone 4- 2050_2100 Inundation Extents.mxd 02
Aerial imagery supplied by Woollahra Council (2011).

Estuarine Inundation Risk Extents

WOOLLAHRA
ESTUARY PLANNING LEVELS

ZONE 5 - EAST

Legend

- Cadastre
- Present Day Estuarine Inundation Risk

FIGURE 4.7

1:8,000 Scale at A3

Metres
0 250 500

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-08-04
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ3011
Map: G4007 - Zone 5_1 Present Day Inundation Extents.mxd 02

Aerial imagery supplied by Woollahra Council (2011).

Estuarine Inundation Risk Extents

WOOLLAHRA
ESTUARY PLANNING LEVELS

ZONE 5 - EAST

Legend

- Cadastre
- 2050 Estuarine Inundation Risk Contour (+0.4 m SLR)
- 2100 Estuarine Inundation Risk (+0.9 m SLR)

N
W E
S

FIGURE 4.8

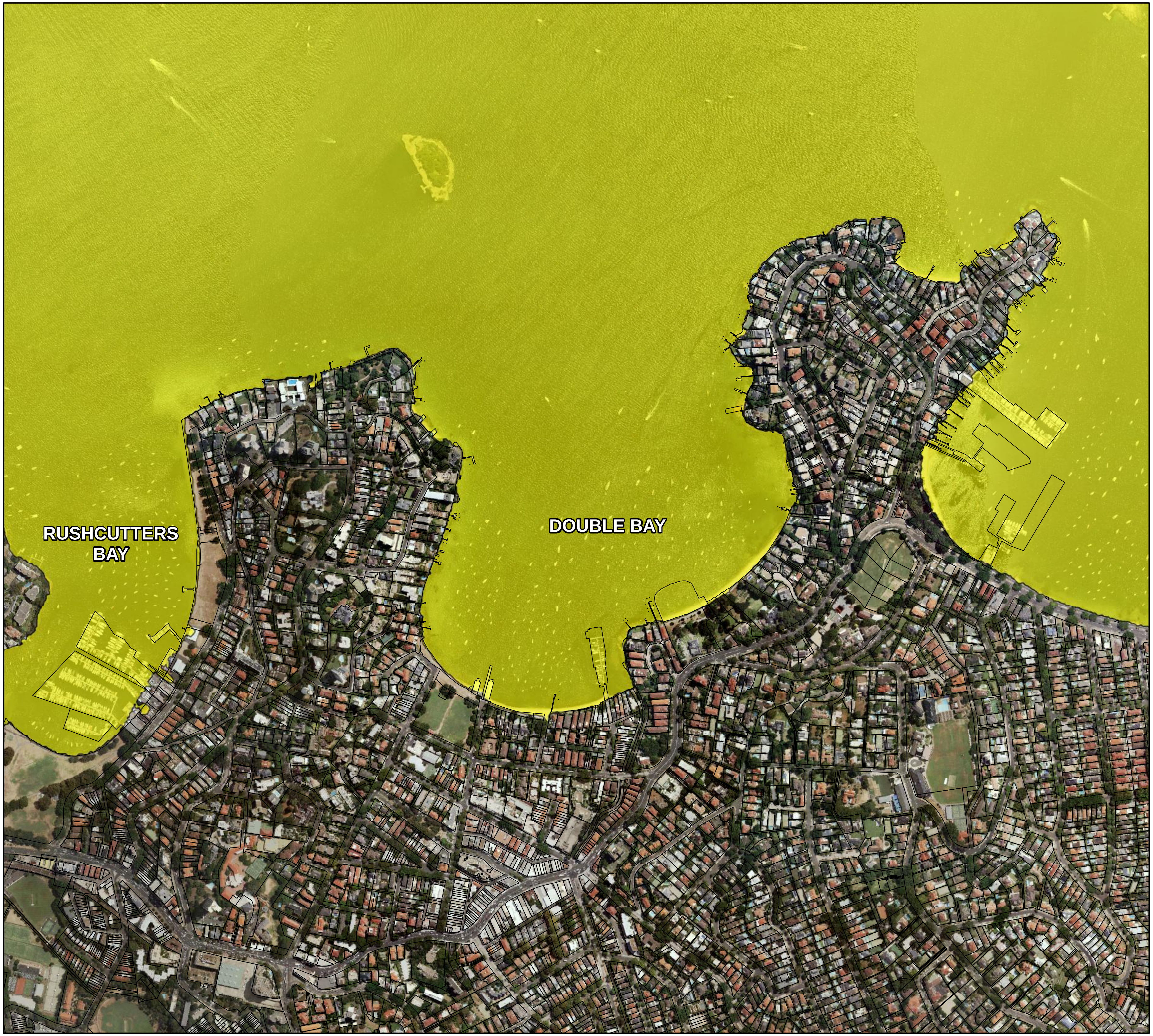
1:8,000 Scale at A3

Metres
0 250 500

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-08-04
Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Project: LJ3011
Map: G4008 - Zone 5_1 2050_2100 Inundation Extents.mxd 02

Aerial imagery supplied by Woollahra Council (2011).



WOOLLAHRA MUNICIPAL COUNCIL

Estuarine Inundation Risk Extents

WOOLLAHRA
ESTUARY PLANNING LEVELS

ZONE 5 - WEST

Legend

- Cadastre
- Present Day Estuarine Inundation Risk

N S E W

FIGURE 4.9

1:10,000 Scale at A3

Metres
0 275 550

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-08-04
Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Project: LJ3011
Map: G4009 - Zone 5_2 - Present Day Inundation Extents.mxd 02

Aerial imagery supplied by Woollahra Council (2011).

Estuarine Inundation Risk Extents

WOOLLAHRA
ESTUARY PLANNING LEVELS

ZONE 5 - WEST

Legend

- Cadastre
- 2050 Estuarine Inundation Risk Contour (+0.4 m SLR)
- 2100 Estuarine Inundation Risk Contour (+0.9 m SLR)

N
W E
S

FIGURE 4.10

1:8,500 Scale at A3

Metres
0 230 460

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-08-05
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ3011
Map: G4010- Zone 5_2 - 2050_2100 Inundation Extents.mxd 02

Aerial imagery supplied by Woollahra Council (2011).