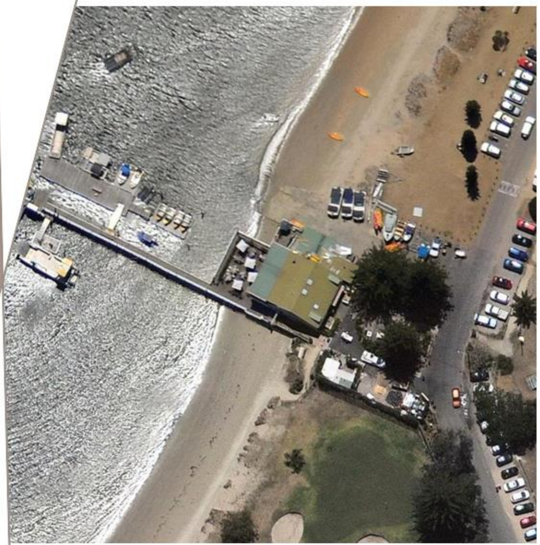

Coastal Engineering Assessment and Estuarine Risk Management Report

Prepared for
London Lakes Partnership

6 May 2021

Contact Information

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

Level 9 - The Forum
203 Pacific Highway
St Leonards NSW 2065
Australia

www.cardno.com
Phone +61 2 9496 7700
Fax +61 2 9496 7748

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Author(s):

Name: Doug Treloar – FIE Aust., NER 254510
Job title: Senior Principal Coastal Engineer

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Approved By:

Name: Chris Scraggs
Job title: Principal Coastal Engineer

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1 Introduction

1.1 Background

Cardno (NSW/ACT) Pty Ltd have been engaged by London Lakes Partnership (LLP), who plan to undertake demolition and renovations to the restaurant, boat-hire facilities and deck areas (The Superstructure), on their leased property at the Barrenjoey Boat House Wharf, Palm Beach. They also plan to upgrade the marina facilities under a separate application. The work will involve an almost complete demolition of the Superstructure and pier replacement under it as required, other than a few piers that are in sound condition.

Appendix A presents architectural plans provided by their Builder, Blue Pacific Constructions Pty Ltd (BPC), and includes a site survey undertaken in February 2018 and updated in August 2019. The survey shows the gazetted Mean High Water Mark (MHWM) and that the Superstructure on the seaward side all lies within Crown Lands leased area on the water, whereas the outside seating area east of the main restaurant entrance is located on Council land. The renovation plans were prepared by Canvas Architecture & Design. Slightly earlier plans were used by Cardno for this Coastal Engineering Risk Assessment Report, but later changes do not affect the outcomes of the investigations presented herein. Some of the recent changes relate to enhanced beach and dune improvement works, but not levels.

Figure 1.1 provides a locality plan of the site. Note that the survey includes beach levels, which will be needed for design and construction of replacement works, including below and along parts of the building. Note that Council has recently constructed a cut sand-stone block seawall near the back beach area to the south – extending south about 20m from the edge of the southern deck area. Some details of the design, particularly the base level of the works, have been provided by Council. These steps are shown on **Figure 1.2** and the form of steps-Boat House junction, as best can be seen, in **Figure 1.3**. This seawall and steps were constructed following the storm of June 2016 when significant beach erosion occurred in the area of the seawall/steps.

The plan is to demolish and raise the existing facilities such as decks, toilets, a stairway and food processing areas to improve the overall restaurant, seaplane and boat hire operations and improve the satisfaction of patrons and employees. No areas are intended for accommodation and the upstairs areas provide office facilities for general operation. The remaining wharf and boat-berth areas lying seaward of the Boat House outer deck/wharf itself are not included in these proposed works except for raising of the large wharf immediately in front of the Superstructure by 200mm; noting that recent repairs have been made to those separate facilities following the major ocean storm in June 2016. The section of the wharf on the southern side of the building needs to be demolished and reinstated because of the poor condition of the joists and bearers; noting that the balcony on the first floor is supported by it. Council has attached their recently constructed stone-block seawall to the piers using H4 sleepers, which are not appropriate in the marine environment.

Appendix B provides some history of the site and includes condition reports prepared by Blue Pacific Constructions Pty Ltd – before June 2016. The building is old and was developed in a piece-meal fashion. The seaward deck level is 1.8m AHD and hence is currently not affected by the 50-years average recurrence interval (ARI) storm tide level of 1.47m AHD; but occasionally by high tides and ocean swell, such as in June 2016, when some damage to the structure, together with shoreline erosion, occurred. Deck boards have been loosened by wave action in the past – they are currently nailed to the deck beams/bearers below; with some nails obviously lifted. A higher upper-deck at 2.5m AHD and closer to the restaurant and along the southern side to the back of the building is accessed from the lower, seaward deck by steps and also the arrival area.

Northern Beaches (formerly Pittwater) Council requires that the lessees must submit an independent wave action and tidal inundation report and assessment to Council in the form of adequate qualitative and quantitative detail addressing estuarine planning level information, the management of estuarine risk and other criteria (where applicable), as they affect the subject building, land and its surroundings. The report is to address the issues presented in Council's P21 DCP Part B, see **Appendix C**. A definition of estuarine planning levels (EPL) is presented on Page 7 of Appendix 7 of P21 DCP prepared by the then Pittwater Council, see **Appendix D**.

This report has been prepared by Cardno to address these matters and it is based on site visits first undertaken at 1530 hours on 17 November 2015, and subsequent visits following the June 2016 storm damage, in early March 2018 and on 28 January 2020, together with the Cardno report 'Pittwater Foreshore Floodplain Mapping of Sea level Rise Impacts' prepared for Pittwater Council – Report LJ2882/R2658v4-Final Report, 30 January, 2012. This risk management report has been prepared in accordance with Pittwater Council's P21 DCP and includes all of the required data.

1.2 Site Visits

The initial site visit occurred at a time near mid-tide – +0.8m LAT as recorded by the Manly Hydraulics Laboratory web-site; in the company of BPC – Mr Peter Heber. Although there was a NE sea breeze blowing, as demonstrated by wind waves that were observable offshore, wave conditions were calm at the site. **Figure 1.4** provides a view of the shoreline immediately to the south, as it was then, and shows that there was some localised shoreline damage and construction of ad hoc protection works, and that beach access near the southern side of the building was ad hoc and probably unsafe. However, **Figures 1.5a** and **1.5b** show that in general the beach/shoreline either side of the building and slightly further away shows no similar effects, but also indicate that the existing infrastructure has some effect on local coastal processes. The dominant swell wave conditions that affect the shoreline will, on average, have wave crests near-parallel to the shoreline (near the shoreline) – with little net longshore transport to the south; except during major storms – as demonstrated by **Figure 1.5b**. These structures have been in place for decades, and even though the boat-ramp and boat hire facilities located on the northern side of the Boat House itself stand on the beach, there is little groyne effect; the visible widening at the Boat House likely being affected also by the wave climate shadow arising from the marina pontoons, which are on separate title.

Figure 1.6 describes the swell wave direction at the site.

Figures 1.7a and **1.7b** describe the pile and headstock/beam/bearer structure supporting the outer/lower deck. Pile spacing is about 2.7 m with aged timber piles of 0.3 m diameter.

Figures 1.8a and **1.8b** describe the underside pile/column support system of the decks and restaurant area. Some of these are in poor condition and will require re-instatement/replacement and checking/re-fixing of beams/purlins to the pile/column supports to accommodate wave uplift forces. These photographs also show that there are 'loosely' placed electricity cables and suspended water/sewerage pipelines. These services will need to be replaced (electricity cables) and checked for stability (water/sewerage) pipelines under the new, raised decks.

Images shown in **Appendix E** describe the landward edge of the shoreline that underlies the landward/eastward side of the restaurant area. There is no structure-specific scour identifiable at this shoreline, which is offered some protection by the ad hoc rubble/stone that has been placed in this area. Similar work is shown in **Figure 1.9** near the boat ramp on the northern side. Inspection of the paved area at the entrance to the restaurant shows no damage that might be attributable to shoreline erosion/scour at the shoreline below. **Appendix E** also shows the extent of cabling and pipework beneath the building.

2 Review of Existing Information and Assessment

2.1 General

LLP, through Blue Pacific Constructions, have requested that the EPL for re-design and re-construction of the Superstructure at the Boat House Wharf be based on 2070, including projected sea level rise. This has been interpolated from the 2050 and 2100 data presented in Cardno (2012). This planning period is based on the likely design life of some of the proposed marine works. Design principals have been based on AS4997-2005 for Design of Maritime Structures because the Superstructure is seaward of the gazetted MHWM and is classified as a normal commercial wharf structure. The design criterion of 50 years operational life has been adopted to limit access issues to the building and any effects on three significant Norfolk Island pines; noting that by 2100 a 100-years ARI storm would inundate the access roadway.

As per AS4997, Section 3.1:

'*For wharves and jetties in locations subject to local river flooding or storm surge situations, the design may allow for periodic inundation during such events. Such structures should be able to withstand lateral loads and uplift from elevated water levels including flood effects from the design flood event.*

Where overtopping of deck structures by waves would result in disproportionate level of damage to the superstructure above main deck level, means to prevent water damage to the property should be incorporated into the design.'

Note also that the re-furbished Superstructure could be raised after 50 years, above the new piers, bearers and joists that would be installed – if the building is still in use at 2070.

2.2 EPL Assessment

In terms of the Lawson and Treloar (now Cardno)/Cardno (2004, 2012) reports, the site is on Station/Barrenjoey Beach. That report provides estuary planning levels (EPL) and the nominally appropriate case for this project is the 50-years (from 2020) ARI storm and water level conditions for 2070. This level is 2.1m AHD (2.05m) at the Boat House – excluding freeboard and wave run-up and overtopping, which are addressed separately. This is the closest example site included in Cardno (2004, 2012). This level includes 0.6m of projected sea level rise to 2070.

Cardno's (2004, 2012) EPL study for Pittwater Council provided general planning level advice based on precincts and a range of back-beach types and crest levels for 2010, 2050 and 2100, including the related projected sea level rises. Wave data for 100-years ARI conditions were included also. These are intended for on-land development, generally, but can be applied to boat-sheds, for example.

Because of the type of structure at the Boat House, a planning period to 2070 has been adopted. Furthermore, there is a mixture of back beach types and a back-beach level of about 2.5m AHD; considering also the fact that the main structure is predominantly over water and is not intended for habitable space.

Cardno has taken the responsible course of determining a site/project specific EPL analysis, coupled with site specific wave overtopping and run-up levels and overtopping wave heights.

Hence an appropriate still water EPL of 2.05m at 2070 has been determined and then wave overtopping and uplift/horizontal forces determined. The equivalent EPL on the land near the front entrance then is 2.05m AHD + 0.4m (overtopping) + 0.3m (freeboard) = 2.75m AHD. This is just below the sealed top of the waste-water pump-out and holding tank (2.9m AHD), and for the appropriate 2070 planning period for this re-development project is consistent with the 3.05m AHD 2100 EPL – see below.

2.3 Estuarine Risk Management

The EPL assessed above complies with Appendix 7 of Pittwater 21 DCP. Note that:

- This is not a residential development under Appendix 7 and Pittwater 21 DCP clauses 3.8 and 3.9.
- The storage of dangerous goods and sewerage systems are all above the EPL.

2.4 Flooding

In terms of flooding at 2100, the EPL is 2.35m AHD (still water level) + 0.4m (overtopping) + 0.3m (freeboard) = 3.05m AHD; noting that the building is not habitable. Note that the foot-print of the proposed re-development will not change and the works will not affect nearby sites any more than they might do at present. The surrounding land area would be inundated by intermittent wave overtopping, including the access road in this design 2100 flooding scenario. Note that the new restaurant access decks will be above the existing ground level and allow flow beneath them, thereby allowing overtopping seawater to return seaward partially below the new deck. If needed, refuge could be taken in the upstairs office area, but this flooding could only occur at high tide and there would be ample storm warning – likely a major ECL. The interior restaurant floor level at 2.8m AHD will not flood at 2070, noting that the front and back doors to the restaurant must be sealed – EPL at 2070 is 2.75m AHD, to prevent minor wave wetting that might be caused by wave overtopping. The doors may be sealed by keeping available a plank that has rubber seals along the bottom and side edges and which can be firmly fixed to the insides of the door-frames when needed. Some minor leakage would still likely occur.

The lower deck and some other service areas would be inundated. Electrical outlets to be at 1.5m above floor levels on the lower deck and 1m above floor levels at other locations below 2.8m AHD. For levels at 2.8m AHD or above, outlets should be set 200mm above floor level. The main meter box will be installed at about 1.5m above ground lev el – about 4m AHD and will include automatic circuit breakers.

Moreover, the proposed development, having the same foot-print will not change the current coastal processes or flood levels – no change in foot-print. Removal of the marina facilities on the northern side may reduce the small salient at the site.

The refurbished seaward deck, raised to 2.04m AHD from 1.8m AHD, will be marginally inundated in this design EPL condition, but with significant wave overtopping. This area may suffer damage in rare severe storms, but can be repaired after storm abatement. The rear, or upper deck, restaurant interior and entrance area on the eastern side are all to be at 2.8m AHD, which is above the 2070 EPL, but can be marginally affected by severe storms – uplift addressed separately. The separate boat-hire office (floor level 2.5m AHD) and store shed (floor level 2.8m AHD) also will not be directly inundated. It is not practical to raise the front, lower deck more than the proposed 0.2m up to 2.04m for overall access reasons.

The back beach level shown on the site survey is about 2.5m AHD. Hence the car park, outdoor seating and outdoor kitchen facilities area would not be inundated by ‘still water’ at 2070 in the design storm event; but wave overtopping would cause some inundation, which could flow back into the restaurant area. Hence the front door of the restaurant will need to be sealed well.

The related design wave condition is Hs=1.5m with a zero crossing period of 10.2 seconds. This is an ocean wave that may propagate from the Tasman Sea to the site in a rare storm, most likely with an offshore direction of east to east north-east. These waves could cause considerable uplift force on the floors and decks of the building, and wave overtopping north and south of the building would extend up to 40m inland. The overtopping flow may be up to 0.4m deep at the shoreline with speeds in the order of 0.6 to 0.8m/s; and would be dangerous. However, ample warning of these storm conditions would be available, and in these circumstances the building and site would need to vacated.

The access road to the north and south has levels of about 2.4 to 2.6m AHD and will flood in a future very severe storm with projected sea level rise.

The property boundary between Crown Lands and Council is defined by the gazetted MHWM, which is 1.17m AHD – based on the astronomical tide, that is, it excludes SLR and meteorological effects.

Existing levels on the bitumen and packed sand in front of the Boat House building vary from about 2.5m AHD at the landward side of the restaurant building and rise to 2.8m AHD towards the access road.

The redevelopment project includes a wastewater pump-out and holding tank, as well as a grease trap located in the facilities area east of the entrance to the restaurant. It has a sealed opening/access-point that is set at 2.9m AHD and is needed for maintenance access. The site specific EPL for this area is 2.75m AHD, including 0.3m freeboard. The area will be affected by intermittent wave overtopping in the 50-years planning period design scenario to 2070. Although some splashing would occur at the access point, there will be no identifiable sea water influx to the tanks. Setting these openings higher is not appropriate or needed. In due course this ‘manhole’ entry point can be raised as projected SLR may occur.

Hence, the nearshore/onshore design EPL is 2.75m AHD = (2.1m AHD + 0.3m freeboard + 0.4m inundation by wave overtopping). This is a site specific calculation, noting that the back-beach level is higher than the 2m AHD included in Cardno (2004, 2012) for wave overtopping calculations.

None of these areas is habitable.

2.5 Design Criteria

2.5.1 Storm Tide and Wave Activity

The level of risk to structures along the foreshore is governed by the severity of waves in combination with the still water level at the time near the peak design storm event. Higher water levels provide greater ability for waves to impinge upon the foreshore and affect coastal structures. **Figure 2.1** describes the important coastal processes at the site.

Cardno (2012) [*Pittwater Foreshore Floodplain Mapping of Sea Level Rise Impacts*], provides wave height, period, elevated water levels and wave run-up data throughout the Pittwater estuary for the 100-years Average Recurrence Interval (ARI). Lower return period water levels were taken from other engineering analysis of tide and surge levels at Fort Denison (OEH, 2012). The 50-years ARI significant wave height was calculated to be 1.5 m at this site, but this wave condition would likely involve significant nearshore wave breaking of the highest waves – greater than Hs.

It is also appropriate to determine a site specific EPL.

2.5.2 Wave Run-Up

The level of wave run-up achieved relative to the still water level is dependent on the foreshore type and the height of the foreshore edge (crest level of natural shoreline or a structure). At this site it is generally restricted by the decks and floor of the restaurant, but would overtop the back-beach areas to the north and south of the building. This process would also involve wave uplift forces under the decks.

2.5.3 Freeboard

In this context, freeboard is the distance between still water level and deck level. It is likely that the floors of the decks and restaurant will be affected by wave uplift and lateral forces. These forces depend upon floor level, wave parameters and water level. Hence a range of conditions can occur and wave uplift forces must be calculated for those cases in order to determine the design loading – not necessarily the highest wave.

2.5.4 Wave Height Reduction

Because of the relatively low level of the Boat House decks and floor, and the difficulty of constructing a deck and pile system that can resist wave uplift forces, both in holding the wooden deck boards to the bearers/beams, and then in the supporting piles-in-sand resistance to the applied wave uplift loads, it was decided to include wave screens on the seaward faces of the Boat House decks, as shown in **Figure 2.2**. These two wave screen segments (shown in pink), will reduce incident wave heights propagating beneath some of the deck areas, and therefore wave uplift loads. This figure also indicates the typical direction of ocean swell at the Boat House – based upon inspection of NearMap images. This wave direction affects the areas where the wave screens reduce wave heights and wave uplift. The proposed screens are discussed in **Section 2.3**. No screen sections are proposed in the shore normal direction; so that longshore pedestrian traffic is not hindered at low tide and so that longshore sediment transport is not affected, other than by the existing boat hire facilities that 'sit on the beach'. However, it is likely that the reduced lee-side wave conditions behind the screens will lead to some minor sand accumulation on the landward sides of the two screen sections.

Because of the building's existing design (to be basically replaced), and existing site conditions, only wave loads at 50-years ARI can be accommodated – noting that this is a re-build/re-furbishment/replacement project. **Figure 2.3** provides a map of calculated wave uplift forces for two cases, namely 0.0m SLR and a nominal SLR of 0.2m; and then for the latter case with the re-furbished decks being constructed of a mesh with 46% apertures. The spatial variation in these wave uplift loads is based on the presence/non-presence of a wave screen and the direction of design wave approach. More frequent, but smaller wind waves will occur also, but not with elevated ocean levels.

The re-furbished deck/floor areas will need to withstand these loads, preferably including 0.2 m SLR; at least in part. It is understood, (pers. comm. Heber – Treloar), that the condition of the existing piles is very poor and that new driven piles at 3 m centres are proposed to provide 30 kN each of uplift resistance, allowing scour to -1m AHD during a future very severe storm – noting that less scour occurred in the severe storm of June 2016.

2.6 Wave Transmission and Uplift Forces

From discussions with the builder (BPC), wave uplift forces greater than about 8 kN/m^2 may not be accommodated by the existing decking/flooring system, even when deck planks are replaced, raised and fixed with screws instead of the present nail system. Hence a system to reduce wave propagation beneath the decks is proposed. Reducing the wave height propagating below the decks and restaurant will also reduce the risk of scour at the shoreline, which is protected presently by ad hoc rock, see **Appendix E**, and wave loads on service ducts suspended below the floors. This wave screen structure would be formed of vertical, closely spaced planks of 200mm width and 100 mm thickness and inter-plank gaps of 25 mm. They would be fixed to a separate line of piles structure and near the top and base by bolts to additional inter-pile beam supports – likely needing new, deeper piles. Base level of the screens to be -0.5m AHD (to allow for storm-caused scour), and which is below the present-day seabed sand level of about -0.1m AHD in this area (but it will vary), see the survey in **Appendix A**. There is likely to be some marine growth in these gaps up to a level of about 0.5 m AHD, based on on-site marine growth observations. This growth can be removed using abrasive processes or anti-fouling paint (of an environmentally acceptable type). However, the effect of marine growth will be to cause some reduction in wave transmission below the decks. Note that the screen planks will be treated hardwood and monitoring of their condition by the lessee will be required, together with maintenance as needed.

A wave height transmission coefficient of about 0.4 would be achieved – see **Appendix F**, Figure 9. The plan extents of these three structures would be as shown on **Figure 2.2**. One of the wave screen elements would be shore normal along the outer northern side of the building. This screen would not impede any small rate of longshore sediment transport to the south, but would reduce wave uplift for design in the pink rectangle near this screen to 3.5kPa – applied universally over the rectangle; see below and reference to **Figure 2.3**. There would be no shore normal increase in pile density so that any existing longshore transport would not be affected. The nearly shore-normal wave propagation direction at the site ensures that there will be some leakage of wave energy past the ends of the screens by diffraction. This process will have an effect on nearshore wave direction and needs attention, see below. **Figures 1.5a** and **1.5b** show that there is very little, if any, long shore sediment transport at this site – little accumulation on the up-drift, northern side. The supporting piles will need to be driven well below -1m AHD to allow for possible scour and the design wave loads on the screen and transmitted to the piles.

The wave height transmitted below the deck will then become 0.6m (Hs) – except where there are small gaps. There will also be a reflected wave of about 0.8m Hs – see Figure 10 of **Appendix F**. This reflected wave would combine with the incident ocean waves to cause greater effective wave heights seaward of the wave screen, but with the reflected waves diminishing in height due to diffraction as they propagate offshore. Note that incident and reflected wave heights are combined on an energy basis, not by direct addition, except right at the screen where coherence is high.

There are areas of seagrass lying seaward of the Boat House and proposed outer wave screen. Based on previous investigations undertaken in southern Botany Bay, Cardno has established that a threshold seabed shear stress of 1N/m^2, a water particle speed of about 1m/s, can damage seagrass. At this site and water depths, this condition occurs when incident wave height (Hs) exceeds 0.8m. Based on wave climate investigations described in Lawson and Treloar (2003), this wave height occurs about once every 8 years at the Boat House. The wave reflection coefficient from the wave screen has been determined to be about 0.65 and the incident wave direction is indicated on **Figure 2.2**. Hence 'a beam' of reflected waves will form as shown on **Figure 2.4**, with smaller waves beyond the 'edges' of the beam. These waves will diffract and become smaller as they propagate seaward from the wave screen – hence the combined, on an energy basis, incident and reflected waves become smaller. Cardno has estimated diffraction coefficients based on Goda (2000) and re-estimated the average recurrence intervals of these combined waves near the jetty (20m from the wave screen) and at 50m from the screen. The outcome is that, at the closer location, the Hs=0.8m threshold conditions would occur more frequently, every 7 years, on average, but with no identifiable change at 50m from the wave screen, see **Figure 2.4**. Hence the patch of Posidonia shown on **Figure 2.4** is not affected wave the wave reflections and the Zostera identified closer to screen in the 20m range is sparse.

Wave uplift forces will depend upon deck/floor levels, water level and incident wave heights. **Figure 2.3** describes the design wave uplift forces for present-day sea level and for a nominal SLR of 0.2 m for 50-years ARI storm conditions. Note that these loads have been prepared for impervious deck areas as well as the proposed fibre glass composite material 38mm thick with 6mm apertures – 46% porosity. This deck material reduces wave uplift forces, by allowing upward flow through the apertures and is understood to provide a safe walking platform. **Appendix G** shows structural drawings of the proposed cut-off wall along the landward side of the restaurant.

Note that with a design water level of 2.1m AHD (50-years ARI excluding freeboard and wave-caused inundation), see **Section 2.1**, and a seaward deck level of 2.04m AHD, there will be wave overtopping of the seaward/lower deck in this adopted design scenario – depth limited wave heights on the deck. There would be intermittent waves of height in the order of 0.3 m height propagating across the seaward/lower deck. This area would not be safe in these conditions and significant damage to deck furniture may be expected, and possibly the deck itself.

Note that this is somewhat better than the present situation because of the raised deck, proposed wave screen and porous deck material.

2.6.1 Horizontal Wave Impact Forces

The wave screens will be subjected to landward and seaward directed horizontal wave loads. These forces have been calculated to be 24 kN/m along each wave screen for both 0.0 and 0.2 m SLR; the difference between these cases is small and depends more on the adopted design wave-water level scenario and water level differences between the seaward and leeward sides of the screens than an estimated difference in water level and wave height. No account of horizontal load-reduction arising from the screen gaps has been considered – hence slightly conservative. This distributed load will be applied via the wave screen support structure to the piles and deck beams at a level of 1 m AHD.

Structural elements such as the walls, stairs and piles can be subject to high loads due to waves breaking or slamming onto them as they become submerged. The force is defined as:

$$Fs = 0.5\, Cs.\rho.A.u^2 \qquad (1)$$

where A is the area of the vertical surface subject to the wave crest, u is the peak horizontal fluid velocity in the wave crest, and Cs is a ‘slamming coefficient’ in the range 2 – 20 (Tickell, 1994).

The orbital velocity near the incident wave crest has been calculated to be 2.3 m/s using a high-order numerical wave theory solution (Fenton, 1999). This corresponds to a slamming force of between 4 and 20 kN/m^2 of structure surface area exposed to oncoming waves. Considering the relatively sheltered aspect of the site, and the overall shape of the sections presented to the on-coming waves, it is more likely that the impact forces will be at the low end of the range considered. Hence a uniform load of 4 kN/m is to be applied at 2.2m AHD along the seaward-facing wall and doors at the rear of the lower deck, and along the boat hire office and store shed seaward walls. Along the landward side (rear) and southern side of the upper deck/restaurant building of the Boat House, a wave caused horizontal load of 1 kN/m is to be applied at a level of 2.9m AHD.

Along the northern and southern sides of the Boat House, wave loads can be considered to be applied as moving 10m long moving wave crest bands of 1kN/m at 2.2m AHD; the latter by wave diffraction.

The wave loads on these structures are in addition to wind loads, for example, and are to applied simultaneously, albeit peak wind gusts are unlikely to occur at the same time as peak wave loads.

Piles beneath the building, assuming 0.4m diameter with some marine growth, will be subject to horizontal wave loads of 2 kN on each pile – drag force, applied at 1 m AHD.

For design purposes, vertical and horizontal loads should be applied simultaneously.

2.7 Additional Safety Considerations

The conditions presented above would be expected to last for less than 6 hours because water level is dominated by the astronomical tide and wind direction changes over such a duration. Although this represents a relatively small amount of time in comparison to the overall length of the year, we advise the following safety considerations should be taken in to account:

- The location, aspect and exposure of the Boat House to oncoming storm waves makes it unsuitable for habitation purposes, noting that there is no intention for that;
- Exterior power fittings should be at 1.5m above the lower deck level and 1m above deck levels in other exterior areas and the boat hire office to avoid contact with splashing waves. Within the restaurant and ancillary buildings power points can be 0.3m above finished floor levels, and
- The potential for component fatigue (wear and tear) should be recognised for the less severe, but more frequent, wave impact loadings, notably on the proposed wave screen elements.

2.8 Shoreline Protection

Construction of the wave screens will have some effect on wave heights and directions at the shoreline. There is likely to be a tendency for minor sand accumulation at the shoreline beneath the Boat House because of this localised change in nearshore wave direction – similar, but to a smaller degree to shoreline plan feature shown in **Figure 1.5**. This tendency would be accompanied by a potential for very minor beach width reduction to the immediate north and south. On the northern side this is prevented (protected by the existing boat ramp). On the southern side there is evidence of historical shoreline erosion and effects on the Boat House, see **Figure 1.4**.

The site visit undertaken in January 2020 showed that Council has recently constructed a cut sand-stone block seawall near the back beach area to the south – extending south about 20m from the edge of the southern deck/walkway area. Few details of the design, particularly the base level of the works have been provided by Council. These steps are shown on **Figure 1.2** and the form of the steps-Boat House junction, as best can be seen, in **Figure 1.3**.

Cardno had previously advised that the Boat House lessees should consider replacing the then existing ad hoc works on the southern side with a more formal stepped block wall of the type shown in **Figure 2.5**; which is located further south in Pittwater and protects part of a Council Reserve area. This type of wall reduces wave overtopping to some extent and provides safe beach access – which was then not the case at the Boat House. It would need to include shore normal turn-backs constructed from PVC sheet piling, or other material, to prevent out-flanking and sub-structure sand loss. The toe of this wall was advised to be set at -1m AHD.

Note that **Figure 2.3** shows proposed PVC sheet piling (shown in red), along the rear of the Boat House restaurant area, which is advised to prevent sand loss from beneath the restaurant and rear paved area that is presently only nominally protected by ad hoc rock works. Additionally, a similar PVC wall is required along the northern side of Council's seawall to prevent potential loss of fill from beneath/behind these steps, see **Figure 2.3**. Some details of Council's wall are presented in **Appendix H**. These steps/seawall have been constructed on Crown Land.

The base of the constructed wall has been set at 0.5m below the beach level on site at the time of construction, which was about 1.3m AHD; a base level of about 0.8m AHD for the stone blocks. This is much higher than Cardno's previous advice that the toe level should be set at -1m AHD to allow for future scour and shoreline recession that may occur as a result of projected sea level rise.

It will be necessary to excavate close to this wall as part of grease-trap and sewerage tank installation. In order to prevent collapse of Council's stepped seawall, it is proposed to install a contiguous closely-spaced or sheet pile wall landward of it, without causing damage to the seawall. The project engineer will need to determine the base level of the piles to withstand soil/rock pressure , and also the lateral extent of the driven piles, probably assuming a stable sand slope of 25 degrees – to be confirmed.

This area underwent significant erosion damage in June 2016. **Figure 2.6** presents images of the shoreline in the vicinity of the boathouse before and after that storm event. It shows that storm erosion from that event resulted in a horizontal erosion of the vegetated foredune of around 4 to 5 metres. **Figure 2.7** depicts the position of the Cardno proposed seawall relative to the June 2016 eroded beach face at the site. It shows that storm erosion did not occur below about 0.5 m AHD at the proposed seawall and a base constructed at -1 m AHD will provide a stable, level base for long term stability. Furthermore, that figure shows the position of the proposed Cardno seawall relative to an eroded shoreline under a future sea level rise scenario of 0.4 m that also incorporates around 5.5 m of associated long term shoreline recession (based on the Bruun rule, 1960). It shows that even under future shoreline recession and storm erosion (to that timeframe) the toe of the proposed Cardno seawall would be unlikely to be undermined. However, the recently constructed Council seawall with a base level at about 0.8m AHD would be liable to significant damage by undermining. Future outflanking and/or undermining could occur; hence the inclusion of the PVC sheet pile cut-off wall along the northern side of Council steps.

The Boat House refurbishment proposal includes replacing an ad hoc back of beach rock revetment that lies under the existing building with a non-visible engineered rock revetment with two layers of rock (D_{50} = 0.2m), toe level at 0.5m AHD, crest at underside of the upper deck, batter1V:2H. A Texcel 600R geotextile fabric would be placed below the rocks. The seabed level here is about 1.5m AHD, so this structure would be generally covered by natural beach sand and only act/become exposed in rare, very severe storms. Note that this rock size assumes that the proposed wave screen will be built. Without that structure, the rock size will need to be larger. This buried rock structure would need to be built early in the project whilst the front area was ‘peeled-back’.

The landside Ecology and Integration to Public Space report prepared by Kingfisher (2020) advises that revegetation works be undertaken on Council land to the immediate north of the Boat House development. This work would assist with dune stabilisation by reducing wind-blown sand losses and helping to reduce future storm-caused shoreline erosion. Nevertheless, Cardno advises the inclusion of a cut-off sheet pile wall on the northern side of the building, as shown on **Figure 2.3**, to prevent future possible outflanking.

3 Conclusions and Recommendations

3.1 General

The proposed additions and modifications/demolition and rebuild works at the Boat House, Palm Beach, will have little effect on estuarine/shoreline processes. No habitable areas are proposed.

This building has been developed in stages and some existing deck levels are lower than Council's estuary planning levels. Hence, significant still water and wave inundation would occur in a future very severe ocean storm, noting that storm damage occurred at the site and to the building in June 2016.

The decks will need to be designed to withstand significant wave uplift forces and horizontal loads. It is proposed that the uplift loads be reduced in part by constructing a timber wave screen along the outer rows of piles (to be replaced by new screw piles), in order to reduce wave penetration beneath the decks and hence uplift forces and damage to the shoreline beneath the building. These wave screens will be subject to significant horizontal (landward and seaward) design loads, together with some fatigue loading. Additionally, porous decking is proposed to reduce uplift load.

Horizontal wave and wave uplift loads have been determined and included within this report.

It is advised that all exterior deck electrical fittings be installed at least 1.5 m/1 m above the lower/upper deck levels and that the design engineer ensures that a horizontal load of 3 kN/m is to be applied at 2.2m AHD along the seaward-facing wall and doors at the rear of the lower deck, and along the boat hire office and store shed. This requirement is set to limit wave entry to the restaurant and other internal areas. Lateral wave loads are to applied also along the northern walls and piles.

In a future design storm, wave overtopping of the shoreline and back-beach areas to the north and south of the rebuilt Boat House would lead to potential intermittent inflow of overtopping seawater to the restaurant area through the front door. Hence the architect will need to consider sealing all doors against intermittent wave overtopping flows during the design future ocean storm.

Note that the lower deck facilities could suffer significant damage and the restaurant would suffer some wave damage during a major storm; and would need to be vacated in the event of an imminent, future very severe storm.

In the longer term, based on projected sea level rises, the access road may become inundated by storm tide to a depth of about 0.3 to 0.4m; posing evacuation concerns; albeit adequate warning should be available.

3.2 Coastal Risk Design Requirements

The following section summarises the design requirements arising from this Coastal Risk Management study:

1. Demolish and replace all dilapidated elements
2. Adopt the site-specific EPL of 2.8m AHD
3. Raise the seaward deck to 2.04m AHD
4. Raise the boat-shop area floor by 0.5m and store perishable items above 2.5m AHD
5. Seal the front and back door(s) to prevent wave overtopping flow from entering the restaurant, **Section 2.3**
6. Include wave screens along the seaward sides of the lower deck and the outer northern deck as shown in **Figure 2.2** and **Figure 2.3**, details in **Section 2.3**
7. Apply deck uplift loads as presented in **Figure 2.3**
8. Apply design horizontal loads to the wave screens and supports and piles as specified in **Section 2.3.1**
9. Include a cut-off wall along the landward sides of the restaurant
10. Include/adopt the additional safety recommendations of **Section 2**, including for electrical works

11. During construction, install closely placed piles landward of the new rock-block seawall and steps constructed on the southern side by Council to prevent landward collapse of the wall during construction of the sewer trap and grease-trap tanks.
12. Adopt the revegetation works advised by Kingfish
13. From about 2045, prepare an evacuation plan when a very high tide is predicted to occur with a severe East Coast Low storm, noting that there would be ample time for this procedure.

3.3 Impacts of the Proposed Works

Based on the foregoing investigations and the Construction Plan, I advise that:

- Piling will cause minimal seabed disturbance and suspended sediment plumes.
- Construction of the wave baffle wall will cause minimal disturbance to the seabed and surrounding environment because its construction will be undertaken using hand-excavation up to a maximum depth off 500mm and would be undertaken at low tide; supported by DPI Fisheries and Cardno's Aquatic report. The majority of the works, apart from the pile driving, will be land based as described in the Construction Plan.
- The rear-of-building sheet pile cut-off wall will cause minimal disturbance as a result of the pile driving activity, together with minimal excavation for top-of-wall concrete encasement. This will be a land based activity as described in the Construction Plan.
- The type of construction will be a conventional timber wharf and deck structure in order to minimise the effects on the marine environment and maintain the existing style of building at this historic site.
- There will be no net increase in turbidity caused by this proposal. At some stages of the tide waves will break at the proposed wave screen, whereas at present this process occurs slightly further inshore. The wave wall is located in the inter-tidal zone, so fines that may have been present at the line of the wave screen will have been winnowed out of the beach face there during previous severe storms. Although wave reflection at the wave screen will cause large waves there, the increased, localised wave agitation will quickly winnow any remaining deeper fines from the sand column. There will be no identifiable or quantifiable local or regional siltation arising from that change.
- Long shore drift in this area is slow and will occur mainly landward of the wave wall. Removal of one existing building wall on the northern side of the structure will re-instate part of this process. Any sand build-up on the northern side of the short (6m) length of shore-normal wave screen will be small – about 6m x 4m x0.5m thick, and sand bypassing will develop quickly.
- The upgraded sewerage system and dangerous goods storage area will generally eliminate the shoreline and estuarine habitat risk exposure from those items.
- The proposed dune stabilisation works that extend up to 25m north of the Boat House will reduce aeolian sand losses and reduce the risk of coastal erosion and regenerate the natural environment there.

4 References

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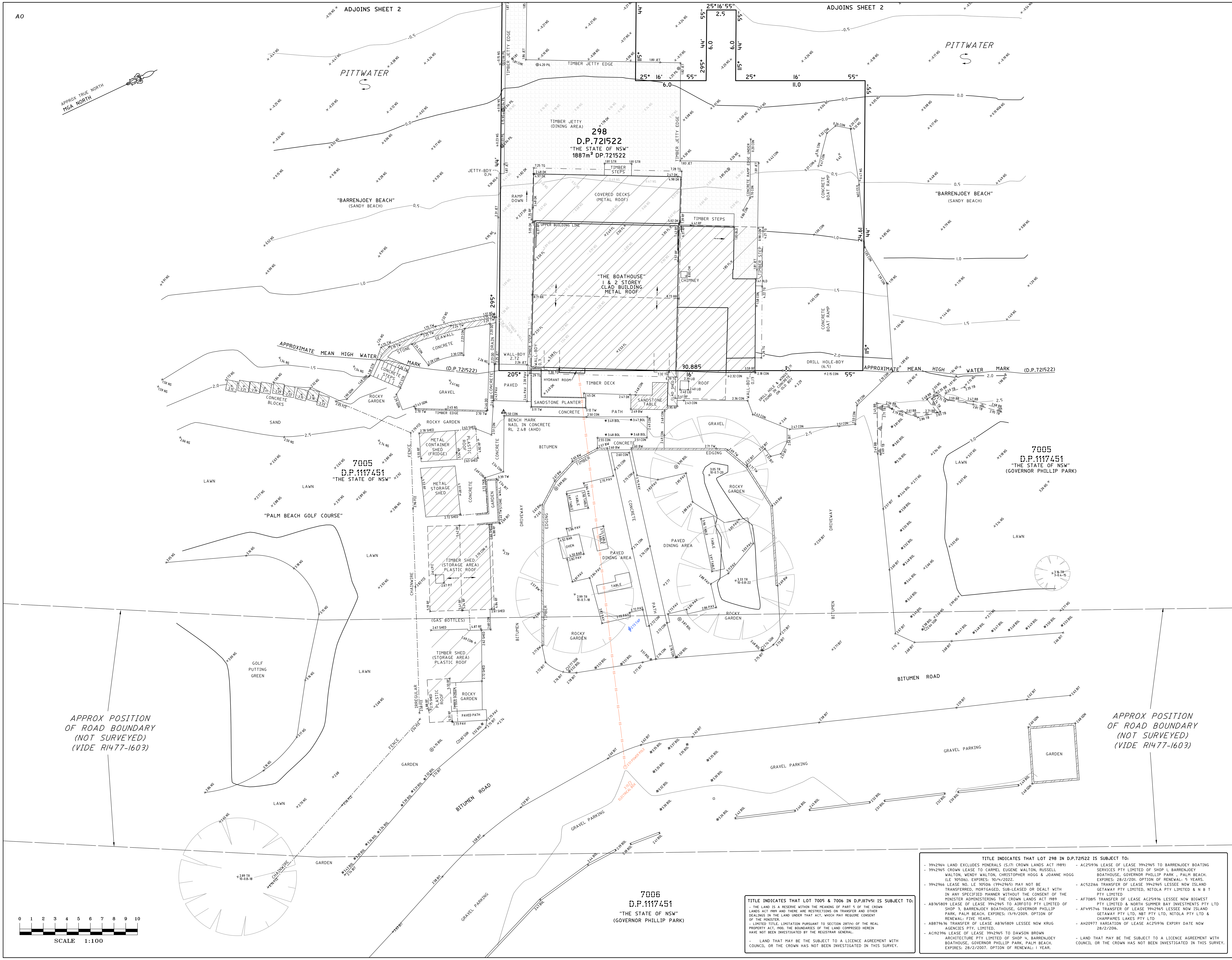
APPENDIX

A

RENOVATION ARCHITECTURAL PLANS



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- AB879636 TRANSFER OF LEASE AB365809 LESSEE NOW KRUG AGENCIES PTY. LIMITED.
- AC192396 LEASE OF LEASE 3942965 TO DAWSON BROWN ARCHITECTURE PTY LIMITED OF SHOP 4, BARRENJOEY BOATHOUSE, GOVERNOR PHILLIP PARK, PALM BEACH. EXPIRES: 28/2/2007. OPTION OF RENEWAL: 1 YEAR.
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VERTICAL DATUM:
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B.M. ADOPTED: PM 11657
R.L. 2.171 (ORDER L2)
SOURCE: S.C.I.M.S. (02/02/18)

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SURVEY PLAN

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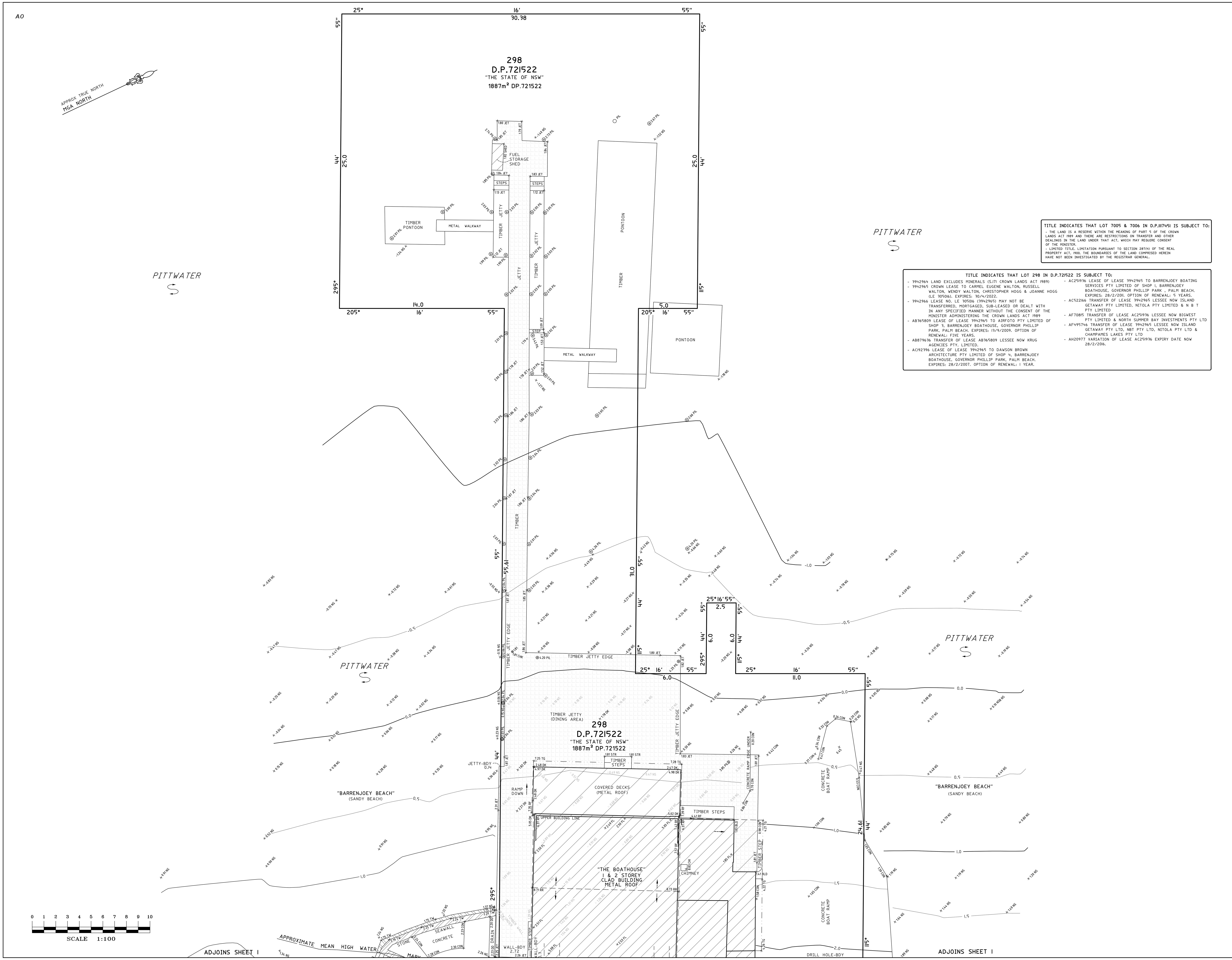
C.M.S. Surveyors Pty Limited
ACN: 096 240 201
PO Box 463 Dee Why
NSW 2099
2/99A South Creek Road,
Dee Why NSW 2099
Telephone: (02) 9971 4802
Facsimile: (02) 9971 4822
E-mail: info@cmssurveyors.com.au

LGA: NORTHERN BEACHES		SHEET 1 OF 2	
SURVEYED L.J.	DRAWN R.N./GP	CHECKED L.J.	APPROVED S.M./MDL
SURVEY INSTRUCTION 17534C	SCALE 1:100 @ A0	DATE OF SURVEY 05/02/18-17/07/18 12/06/19-19/08/19	
DRAWING NAME 17534detail		ISSUE 1	
CAD FILE 17534Cdetail 1.dwg			



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PO Box 463 Dee Why NSW 2099
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Facsimile: (02) 9971 4822
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17534C	1:100 @ A0	05/02/18-17/07/18 12/06/19-19/08/19

DRAWING NAME	ISSUE
17534detail	1

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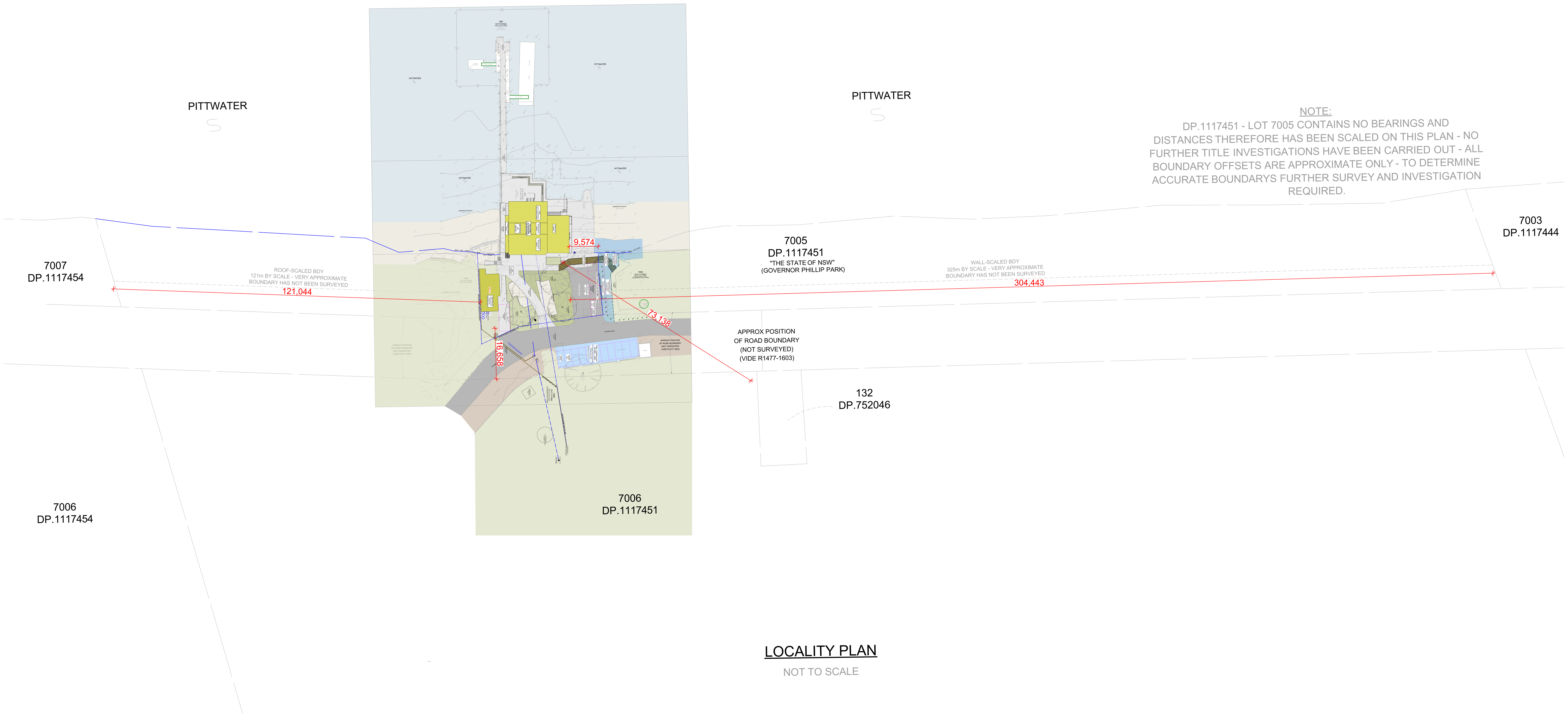
SHEET NUMBER	SHEET NAME
DA00	Addendum as requested by BCA Consultant
DA00	COVER
DA01	SITE ANALYSIS PLAN
DA02	SITE PLAN
DA03	DEMOLITION PLAN
DA04	SITE & GROUND PLAN
DA05	SITE & GROUND PLAN 1:200
DA06	PROPOSED GROUND FLOOR PLAN - A3
DA07	PROPOSED ANCILLARY BUILDING GROUND FLOO...
DA08	PROPOSED FIRST FLOOR PLAN
DA09	NORTH / EAST ELEVATIONS
DA10	SOUTH / WEST ELEVATIONS
DA11	THE BOATHOUSE LONG & CROSS SECTION
DA12	PROPOSED PUBLIC ACCESS ON CROWN LEASE L...
DA13	WASTE MANAGEMENT PLAN
DA14	PROPOSED OUTLINE NEW & EXISTING SERVICES
DA15	WINTER SOLSTICE 9 AM
DA16	WINTER SOLSTICE 12 PM
DA17	WINTER SOLSTICE 3 PM
DA18	NOTIFICATION PLANS SHEET 1
DA19	NOTIFICATION PLANS SHEET 2

THE BOATHOUSE PALM BEACH

NOTE:
LOT 7005 IN DP.1117451 AND ROAD RESERVE HAVE BEEN ADDED BY SCALE ONLY AND IS VERY APPROXIMATE - NO SURVEY OF THESE BOUNDARYS HAS BEEN UNDERTAKEN AT THIS DATE.

IF ACCURATE SURVEY BOUNDARY OFFSETS ARE REQUIRED THEN FURTHER SURVEY MUST BE UNDERTAKEN.



LOCALITY PLAN

NOT TO SCALE

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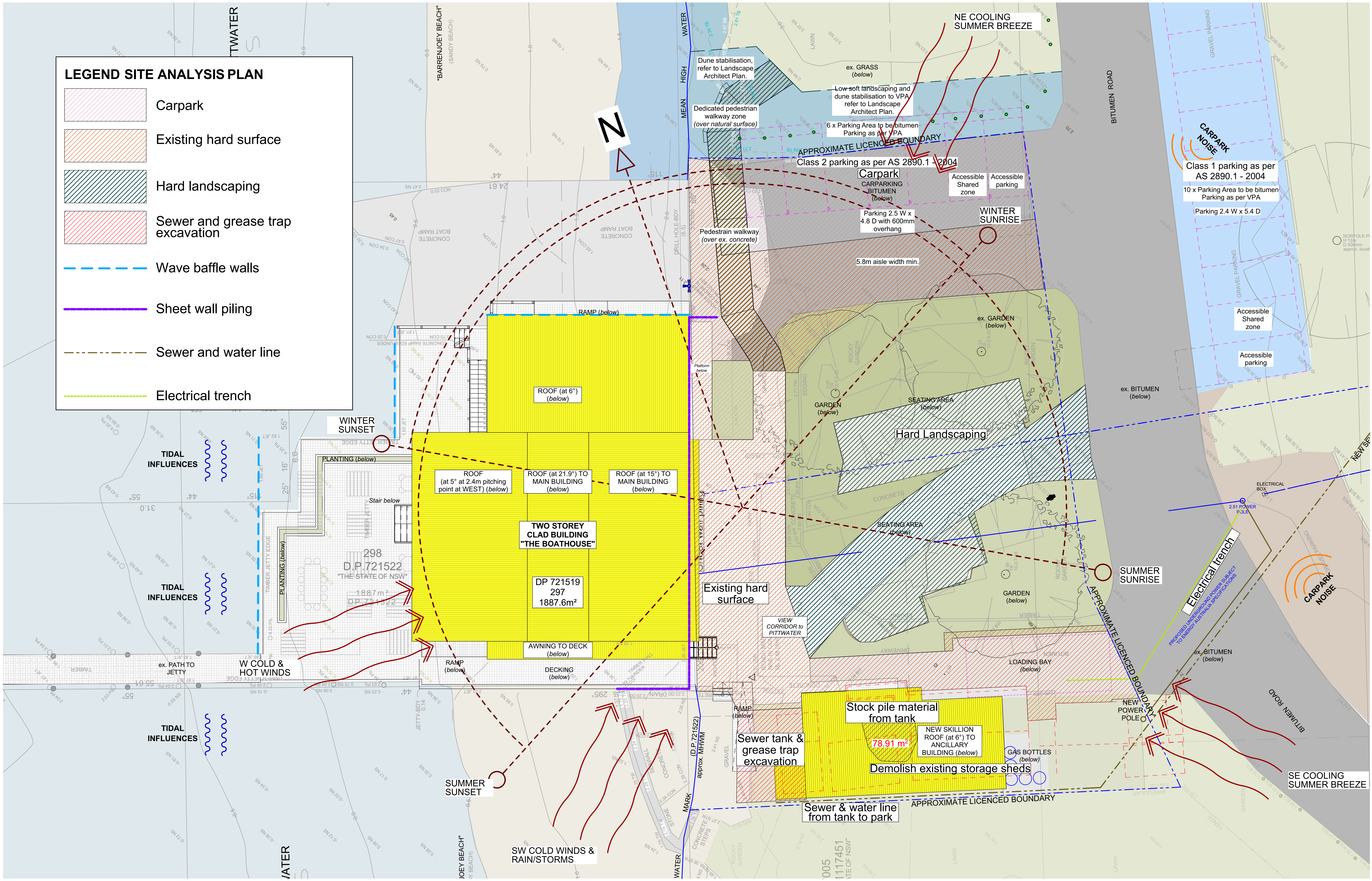
THE BOATHOUSE
PALM BEACH

Canvas Architecture & Design
ABN 80 154 221 722
21 Endeavour Drive
BEACON HILL NSW 2100
Roslyn Miller
NSW REG: 9453 BARCH (HONS I)
roslyn@canvasarch.com.au 0405 60 11 30

Drawing Name	Drawing Scale	Layout ID
Addendum as requested by BCA Consultant	**1:500**	**DA00**
	Drawn **RM**	**30/01/2021 DEVELOPMENT APPLICATION**

N



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ABN 80 154 221 722
21 Endeavour Drive
BEACON HILL NSW 2100
Roslyn Miller
NSW REG: 9453 BARCH (HONS I)
roslyn@canvasarch.com.au 0405 60 11 30

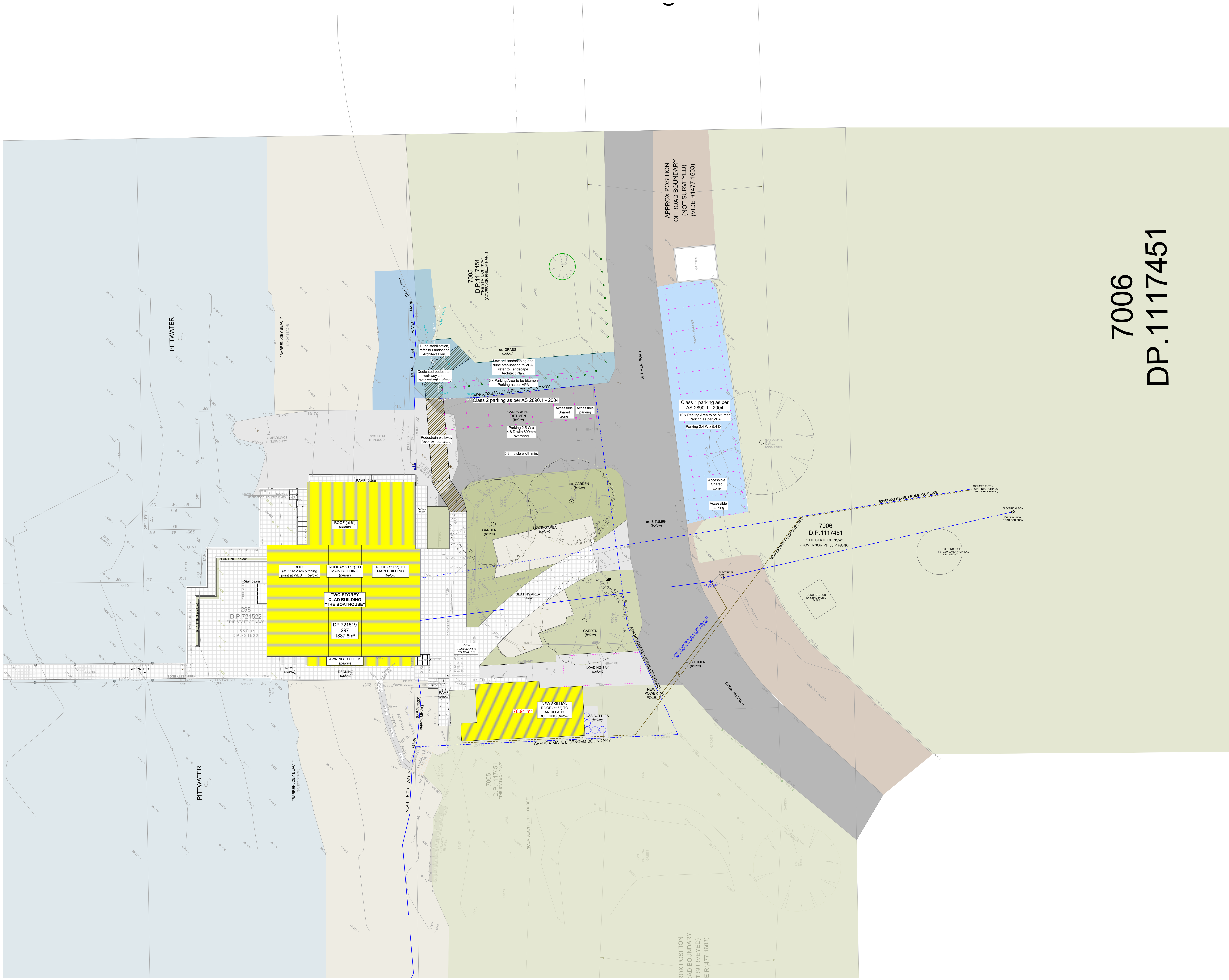
Drawing Name
SITE ANALYSIS PLAN

Drawing Scale
1:200

Drawn
RM

Layout ID
DA01
30/01/2021 DEVELOPMENT APPLICATION

N



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ABN 80 154 221 722
21 Endeavour Drive
BEACON HILL NSW 2100
Roslyn Miller
NSW REG: 9453 BARCH (HONS I)
roslyn@canvasarch.com.au 0405 60 11 30

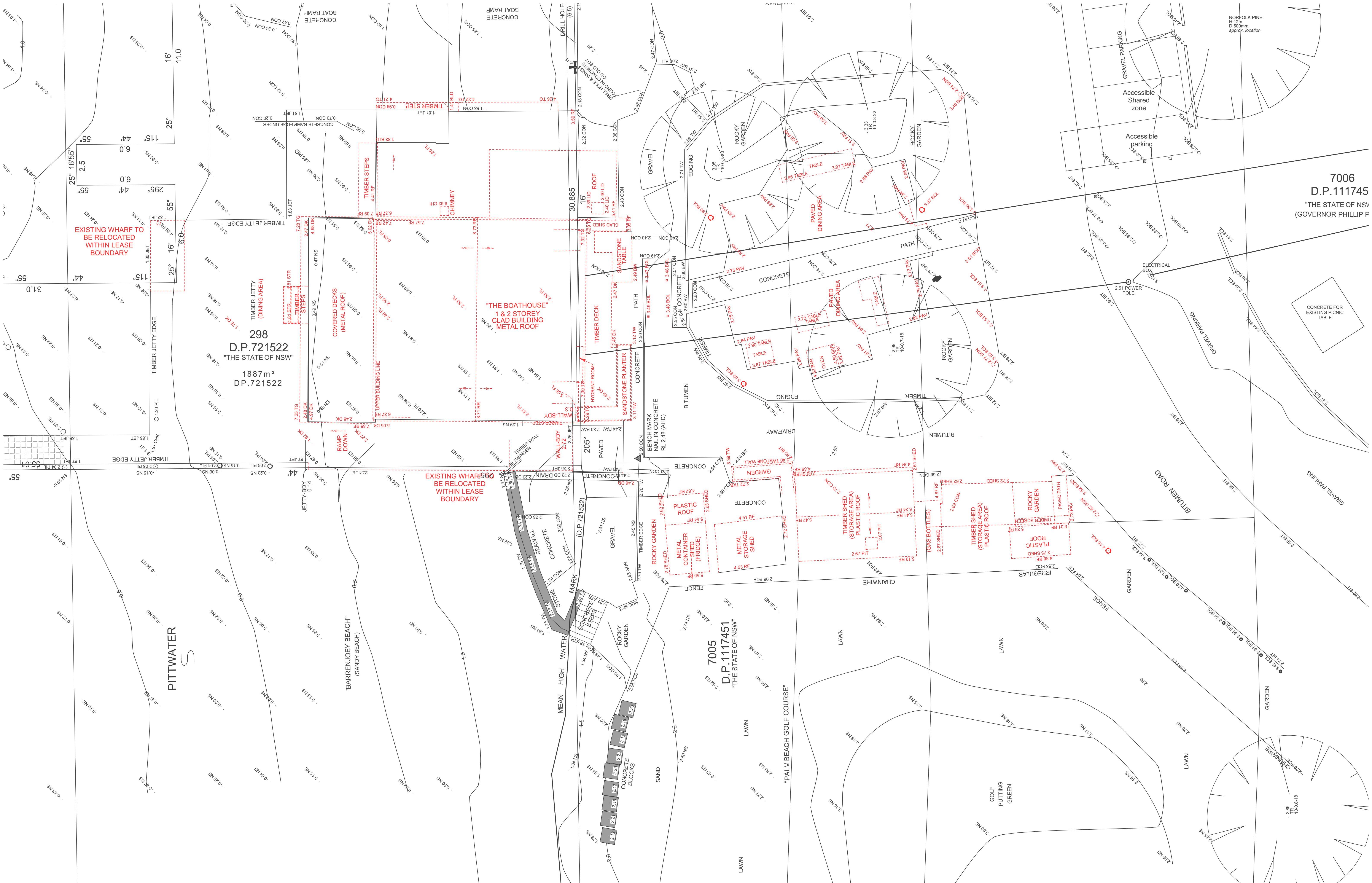
Drawing Name
SITE PLAN

Drawing Scale
1:200

Drawn
RM

Layout ID
DA02
30/01/2021 DEVELOPMENT APPLICATION

N



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21 Endeavour Drive
BEACON HILL NSW 2100
Roslyn Miller
NSW REG: 9453 BARCH (HONS I)
roslyn@canvasarch.com.au 0405 60 11 30

Drawing Name
DEMOLITION PLAN

Drawing Scale
1:200

Drawn
RM

Layout ID
DA03
30/01/2021 DEVELOPMENT APPLICATION

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roslyn@canvasarch.com.au 0405 60 11 30

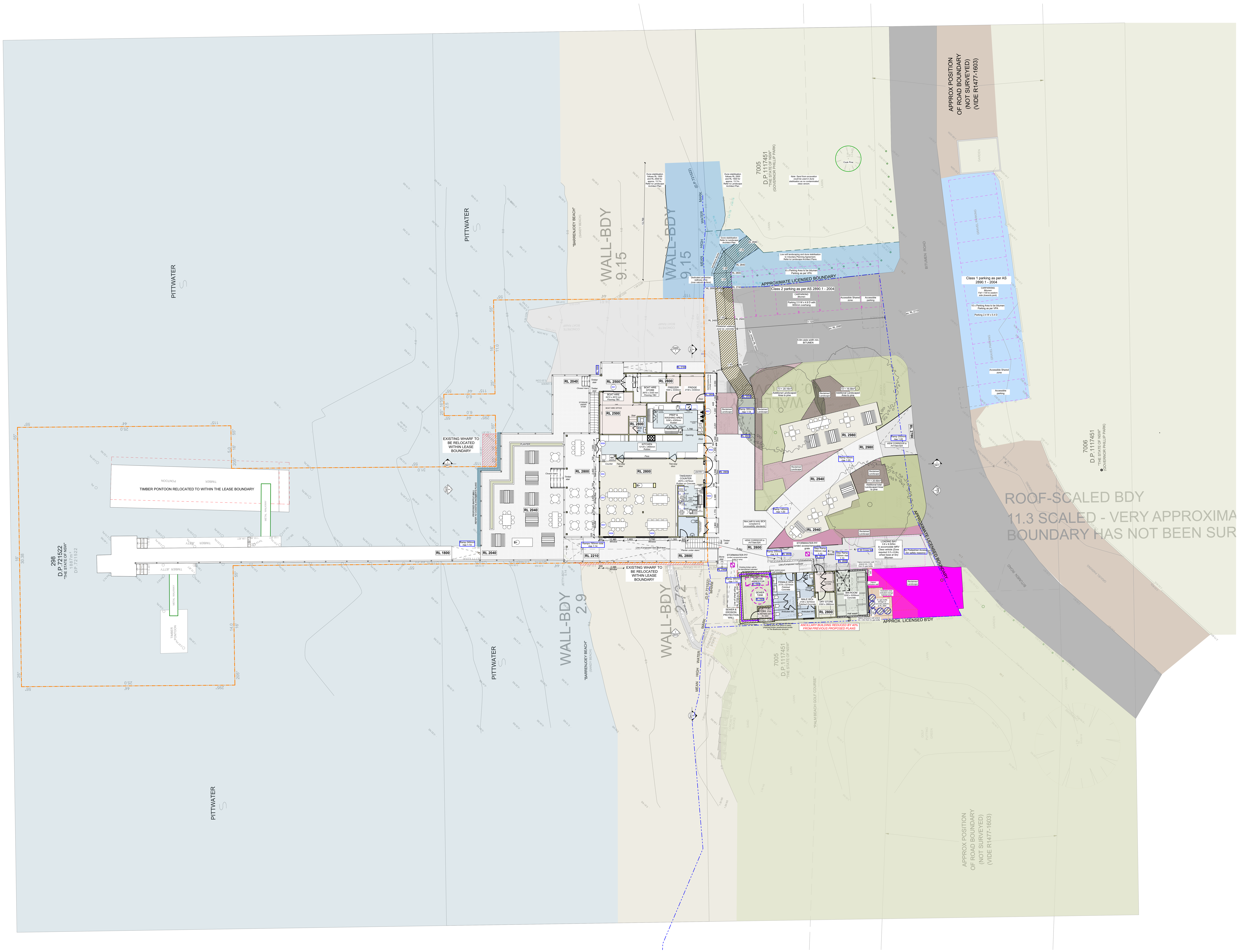
Drawing Name
SITE & GROUND PLAN

Drawing Scale
1:100

Drawn
RM

Layout ID
DA04
30/01/2021 DEVELOPMENT APPLICATION

N



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ABN 80 154 221 722
21 Endeavour Drive
BEACON HILL NSW 2100
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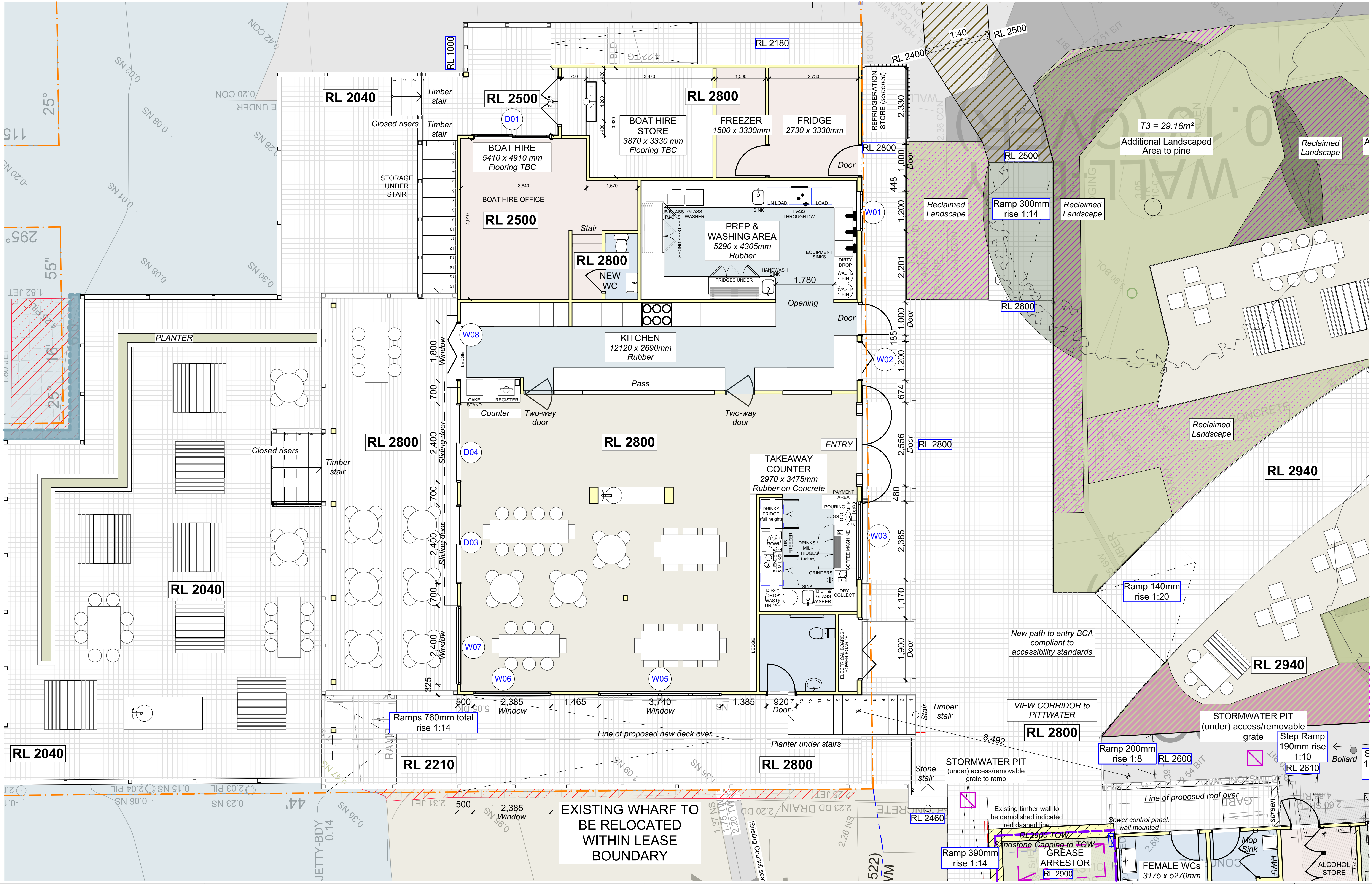
Drawing Name
SITE & GROUND PLAN 1:200

Drawing Scale
1:200

Drawn
RM

Layout ID
DA05
30/01/2021 DEVELOPMENT APPLICATION

N



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ABN 80 154 221 722
21 Endeavour Drive
BEACON HILL NSW 2100
Roslyn Miller
NSW REG: 9453 BARCH (HONS I)
roslyn@canvasarch.com.au 0405 60 11 30

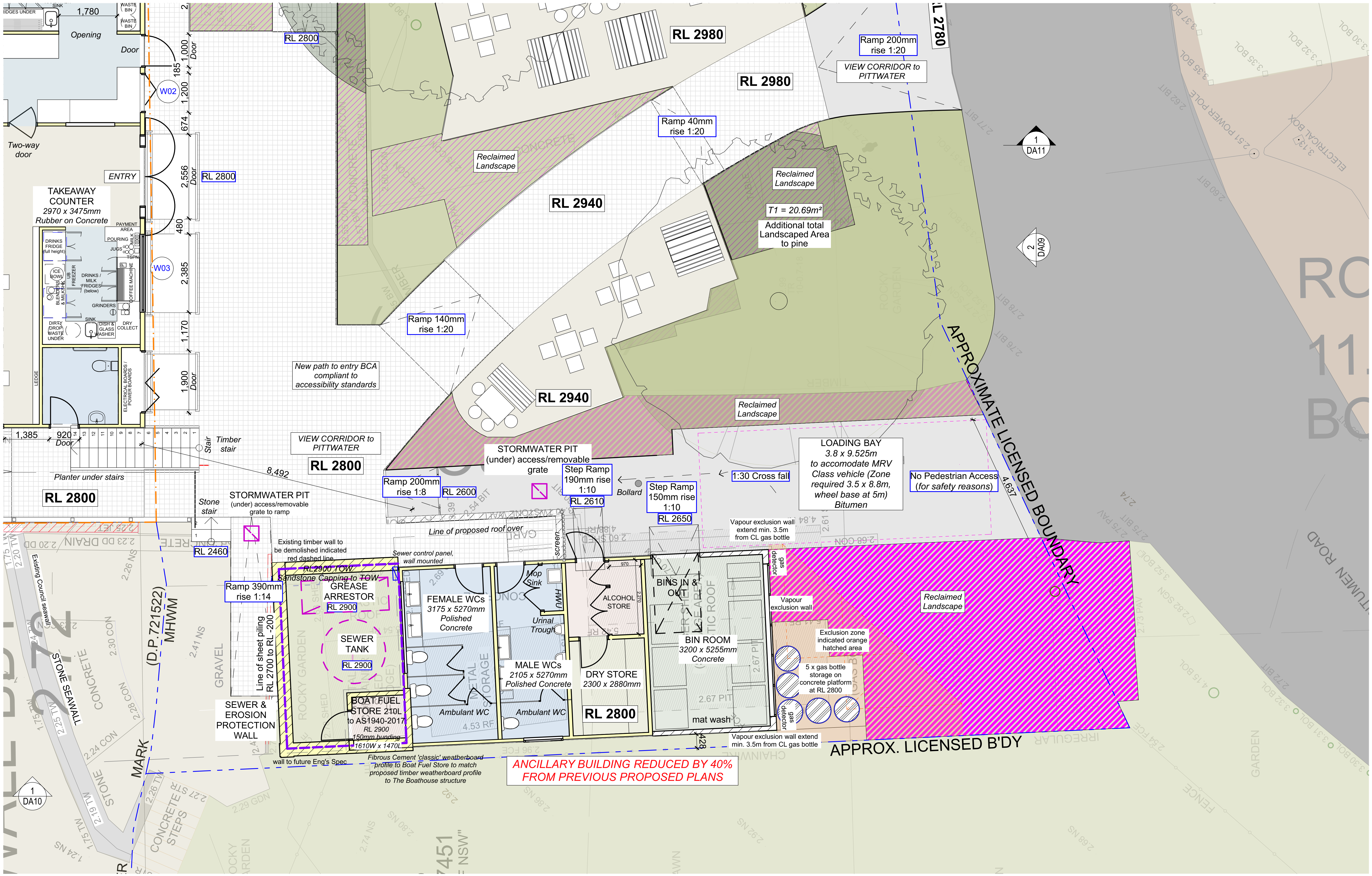
Drawing Name
PROPOSED GROUND FLOOR PLAN - A3

Drawing Scale
1:100

Drawn
RM

Layout ID
DA06
30/01/2021 DEVELOPMENT APPLICATION

N



NOTES (NOT FOR CONSTRUCTION)

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21 Endeavour Drive
BEACON HILL NSW 2100
Roslyn Miller
NSW REG: 9453 BARCH (HONS I)
roslyn@canvasarch.com.au 0405 60 11 30

Drawing Name
PROPOSED ANCILLARY BUILDING GROUND FLOOR PLAN - A3

Drawing Scale
1:100

Drawn
RM

Layout ID
DA07

30/01/2021 DEVELOPMENT APPLICATION

N

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ABN 80 154 221 722
21 Endeavour Drive
BEACON HILL NSW 2100
Roslyn Miller
NSW REG: 9453 BARCH (HONS I)
roslyn@canvasarch.com.au 0405 60 11 30

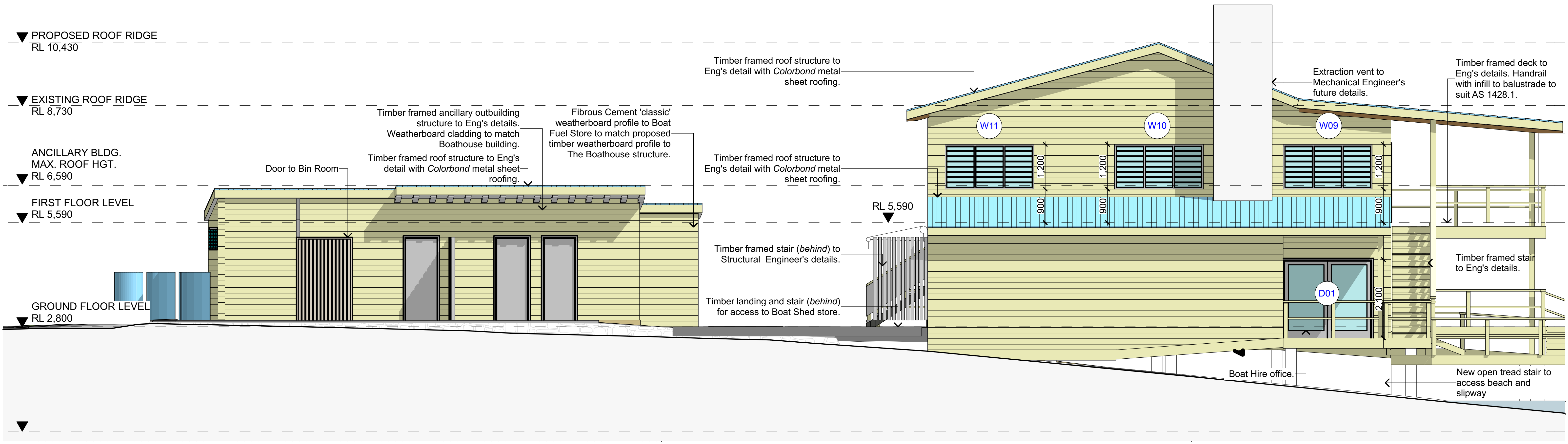
Drawing Name
PROPOSED FIRST FLOOR PLAN

Drawing Scale
1:100

Drawn
RM

Layout ID
DA08
30/01/2021 DEVELOPMENT APPLICATION

N



1 NORTH ELEVATION
1:100

2 EAST ELEVATION
1:100

NOTES (NOT FOR CONSTRUCTION)

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ABN 80 154 221 722
21 Endeavour Drive
BEACON HILL NSW 2100
Roslyn Miller
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roslyn@canvasarch.com.au 0405 60 11 30

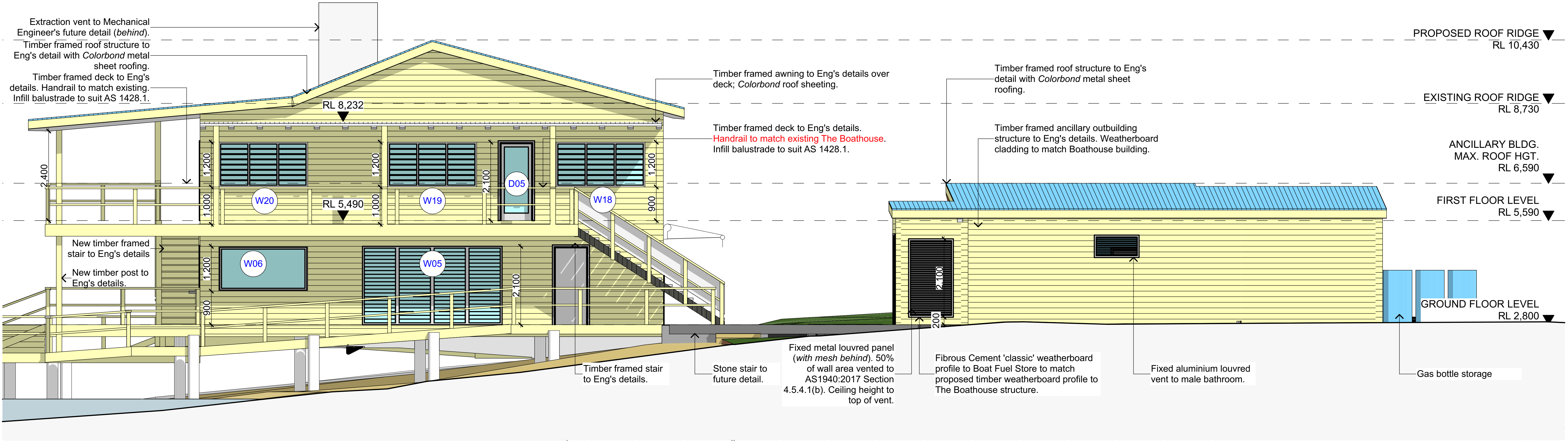
Drawing Name
NORTH / EAST ELEVATIONS

Drawing Scale
1:100

Drawn
RM

Layout ID
DA09

30/01/2021 DEVELOPMENT APPLICATION



1

SOUTH ELEVATION

1:100

2

WEST ELEVATION

1:100

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roslyn@canvasarch.com.au 0405 60 11 30

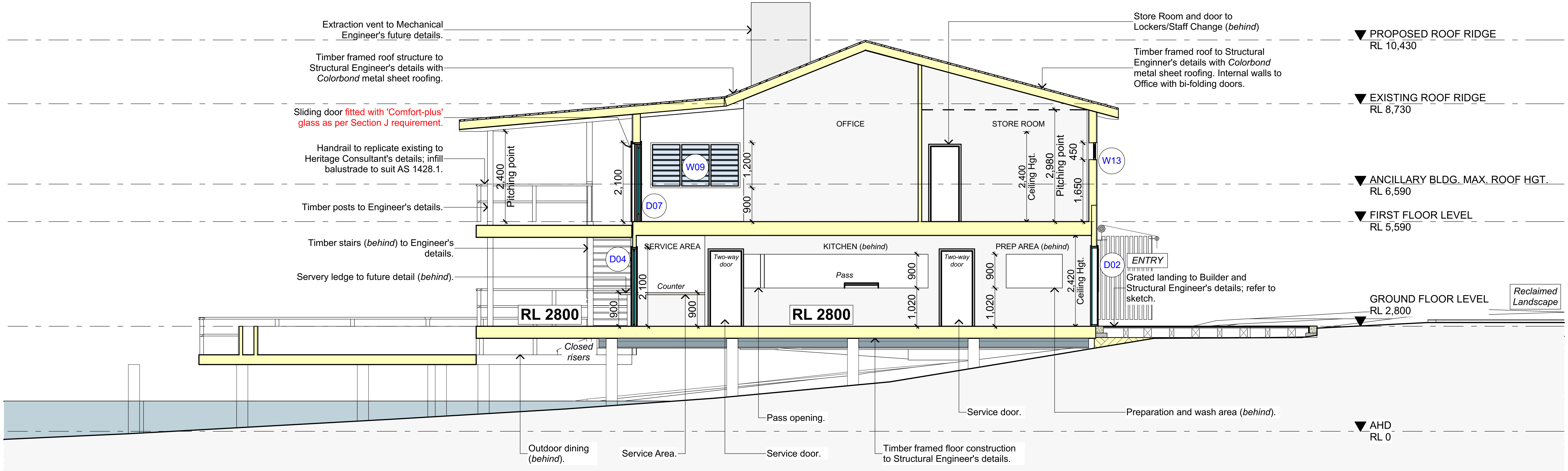
Drawing Name
SOUTH / WEST ELEVATIONS

Drawing Scale
1:100

Drawn
RM

Layout ID
DA10

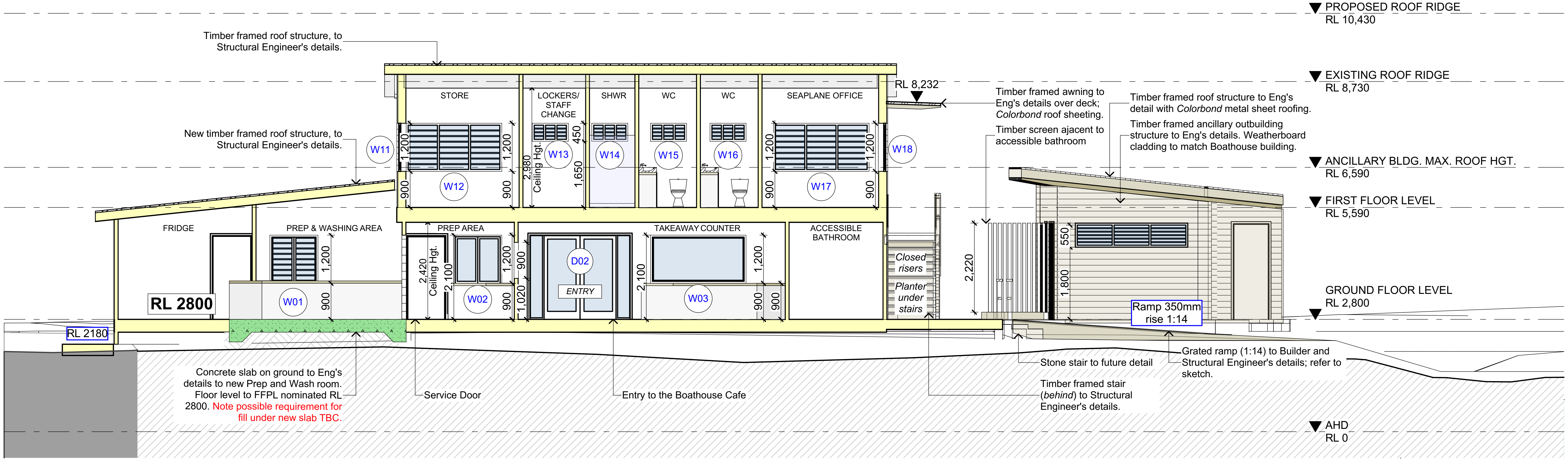
30/01/2021 DEVELOPMENT APPLICATION



1

S-01 Long Section

1:100



2

S-02 Cross Section

1:100

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ABN 80 154 221 722
21 Endeavour Drive
BEACON HILL NSW 2100
Roslyn Miller
NSW REG: 9453 BARCH (HONS I)
roslyn@canvasarch.com.au 0405 60 11 30

Drawing Name
THE BOATHOUSE LONG & CROSS SECTION

Drawing Scale
1:100

Drawn
RM

Layout ID
DA11

30/01/2021 DEVELOPMENT APPLICATION

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Roslyn Miller
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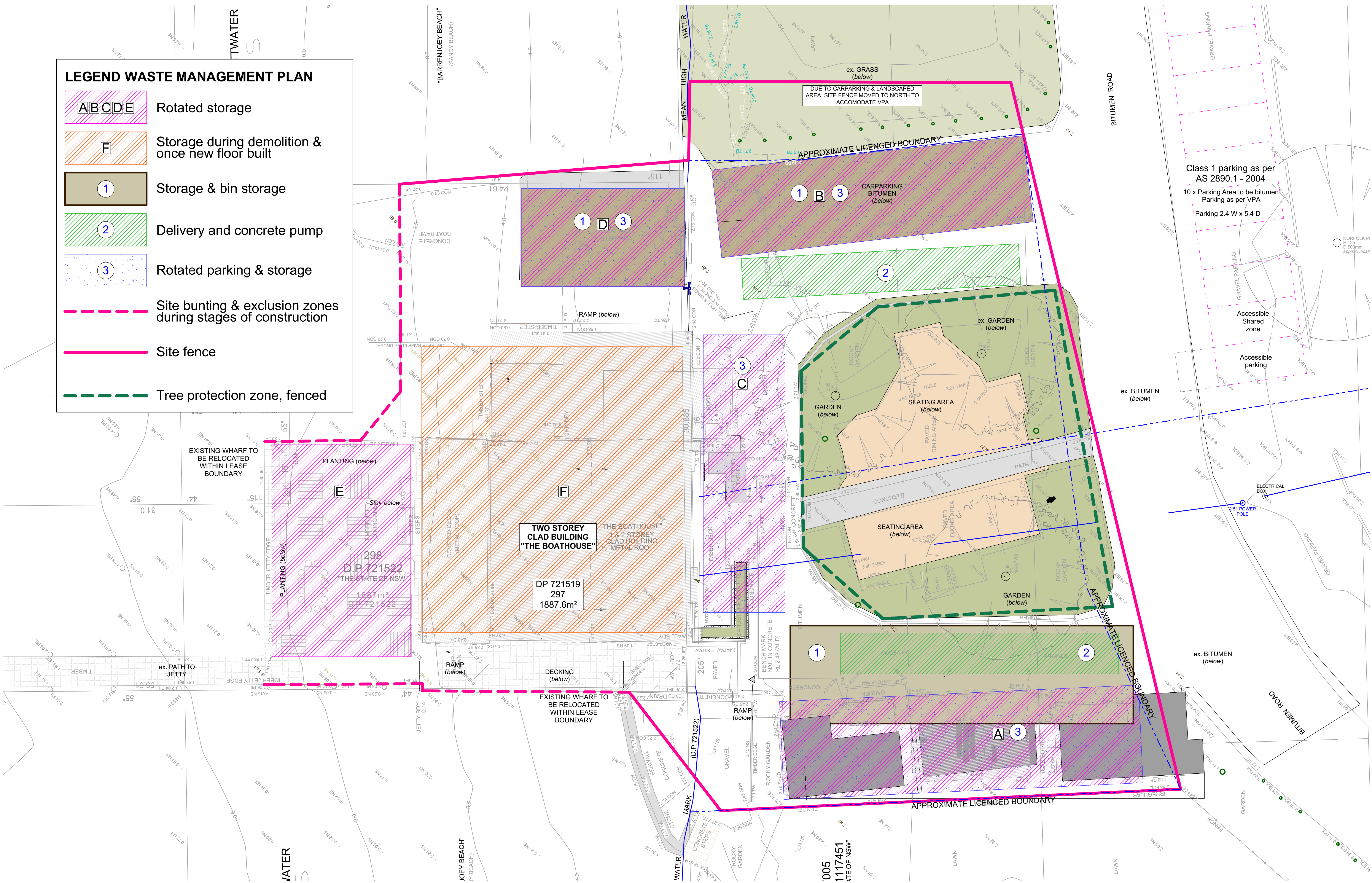
roslyn@canvasarch.com.au 0405 60 11 30

Drawing Name
PROPOSED PUBLIC ACCESS ON CROWN LEASE LAND

Drawing Scale
1:200

Drawn
RM

Layout ID



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21 Endeavour Drive
BEACON HILL NSW 2100
Roslyn Miller
NSW REG: 9453 BARCH (HONS I)
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Drawing Name
WASTE MANAGEMENT PLAN

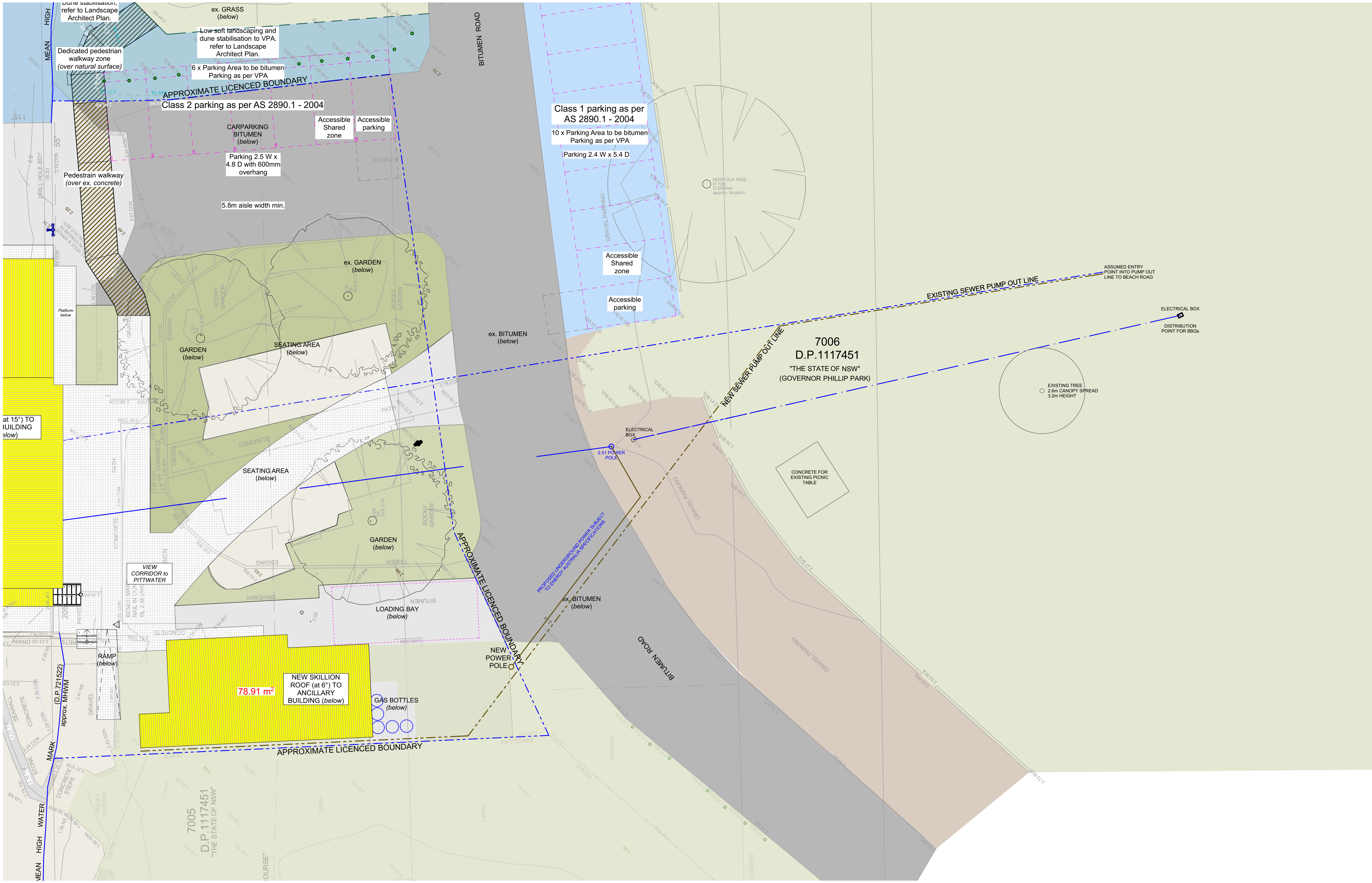
Drawing Scale
1:200

Drawn
RM

Layout ID
DA13

30/01/2021 DEVELOPMENT APPLICATION

N



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21 Endeavour Drive
BEACON HILL NSW 2100
Roslyn Miller
NSW REG: 9453 BARCH (HONS I)
roslyn@canvasarch.com.au 0405 60 11 30

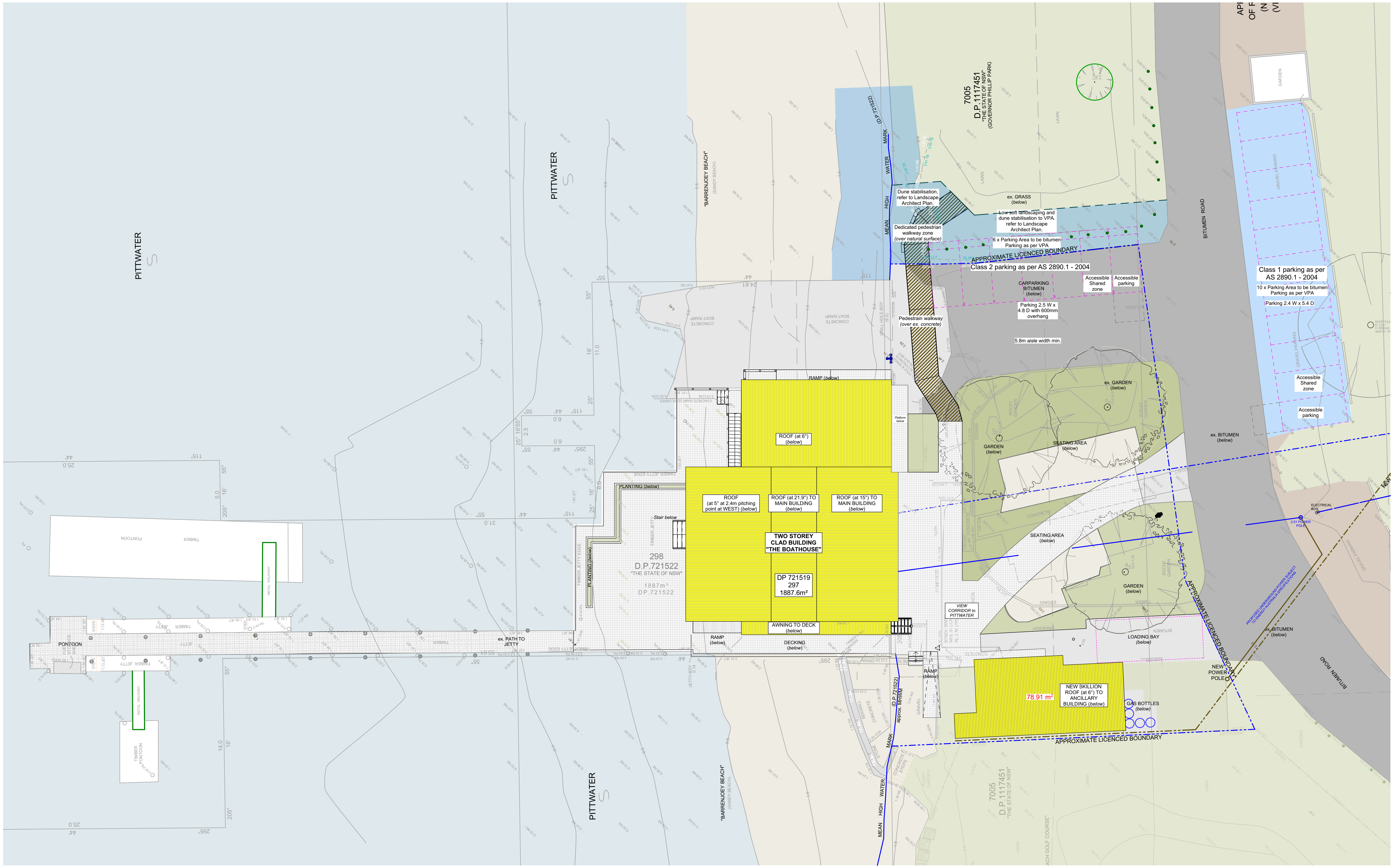
Drawing Name
PROPOSED OUTLINE NEW & EXISTING SERVICES

Drawing Scale
1:200

Drawn
RM

Layout ID
DA14
30/01/2021 DEVELOPMENT APPLICATION

N



1

SITE / ROOF PLAN

1:300

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BEACON HILL NSW 2100
Roslyn Miller
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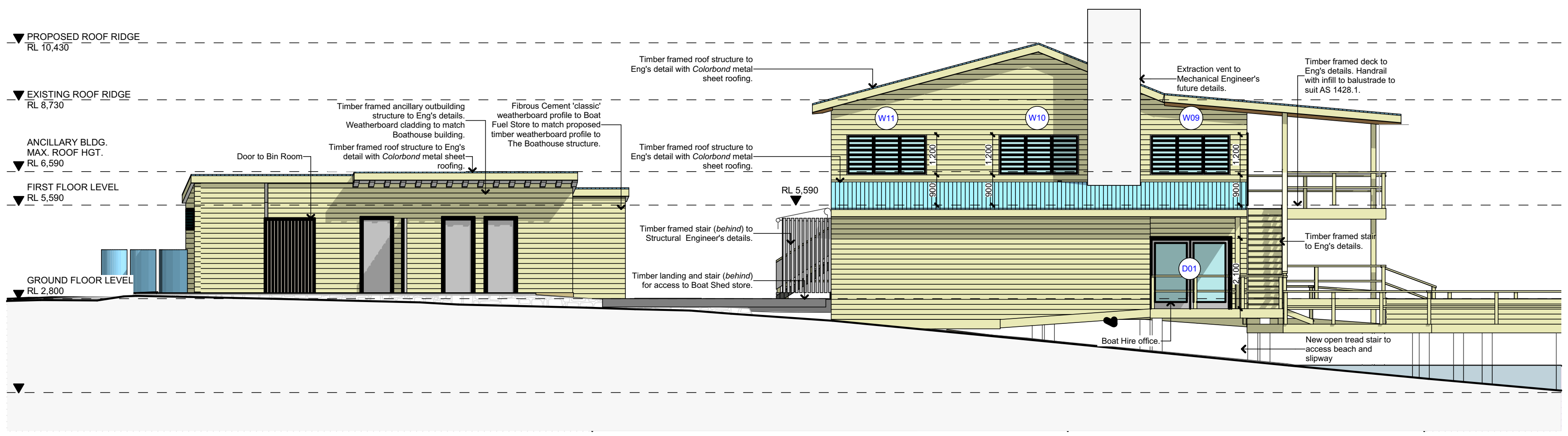
roslyn@canvasarch.com.au 0405 60 11 30

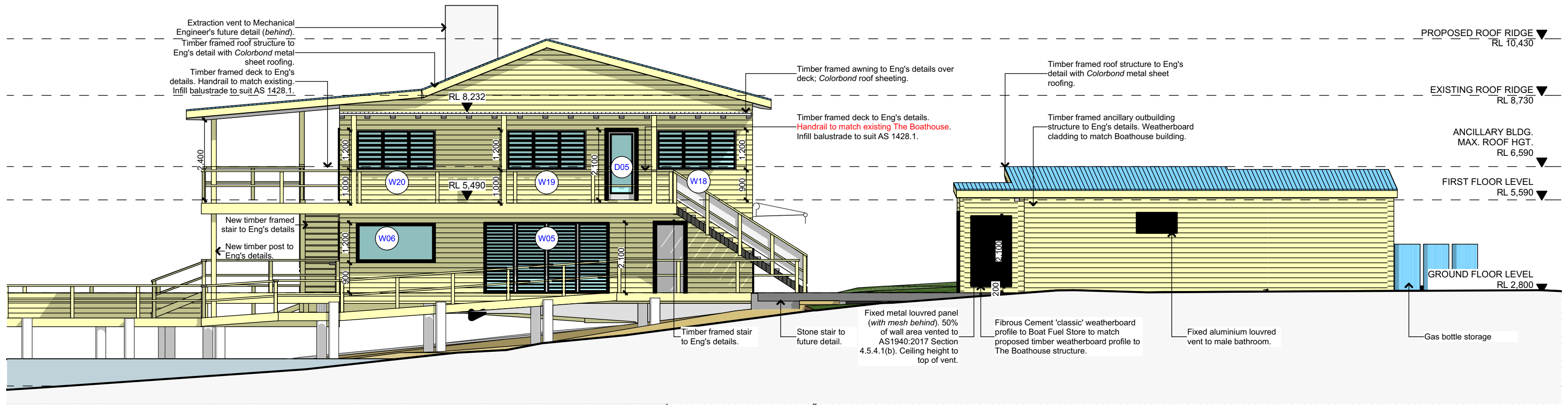
Drawing Name	Drawing Scale	Layout ID
NOTIFICATION PLANS SHEET 1	**1:300**	**DA18**
	Drawn **RM**	**30/01/2021 DEVELOPMENT APPLICATION**

N



1 NORTH ELEVATION 1:200

2 WEST ELEVATION 1:200



3 SOUTH ELEVATION 1:200

4 EAST ELEVATION 1:200

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21 Endeavour Drive
BEACON HILL NSW 2100
Roslyn Miller
NSW REG: 9453 BARCH (HONS I)
roslyn@canvasarch.com.au 0405 60 11 30

Drawing Name
NOTIFICATION PLANS SHEET 2

Drawing Scale
1:200

Drawn
RM

Layout ID
DA19
30/01/2021 DEVELOPMENT APPLICATION

N

APPENDIX

B

HISTORICAL INFORMATION

Blue Pacific Constructions Pty Ltd

P.O Box 626
Mona Vale NSW 2103

Tel/Fax: (02) 9918 5321
Mobile: 0410 594 809
bluepacificconst@bigpond.com
Lic No: 128426c

ABN 22 086 943240

Barrenjoey Boathouse, Station Beach (Palm Beach)

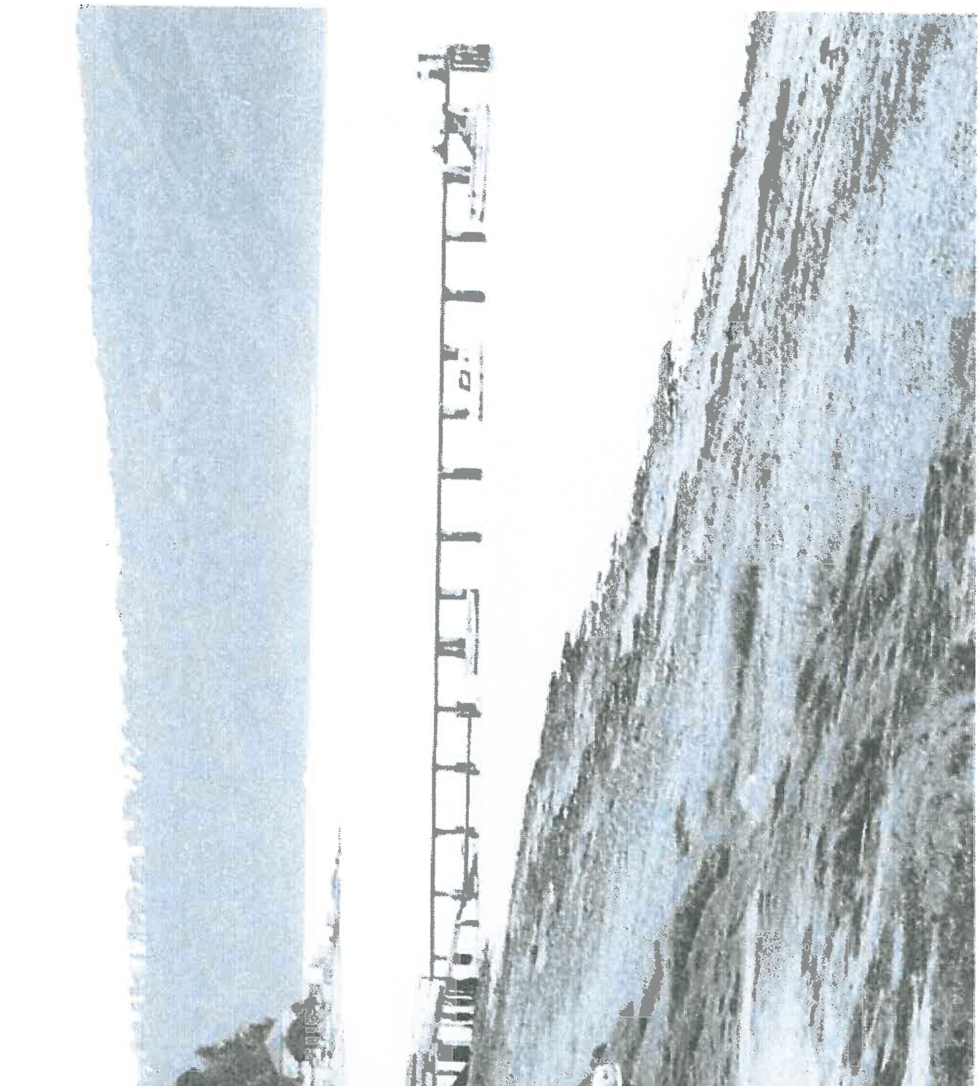
The construction was probably built towards the end of the Second World War and the wharf added around 1946.From various photos it was the original building two dormers on western side and gable roof and no annexes and no verandas. The major changes seem to have occurred in the mid 70s and minor ones such as front gables and small balconies post 1956

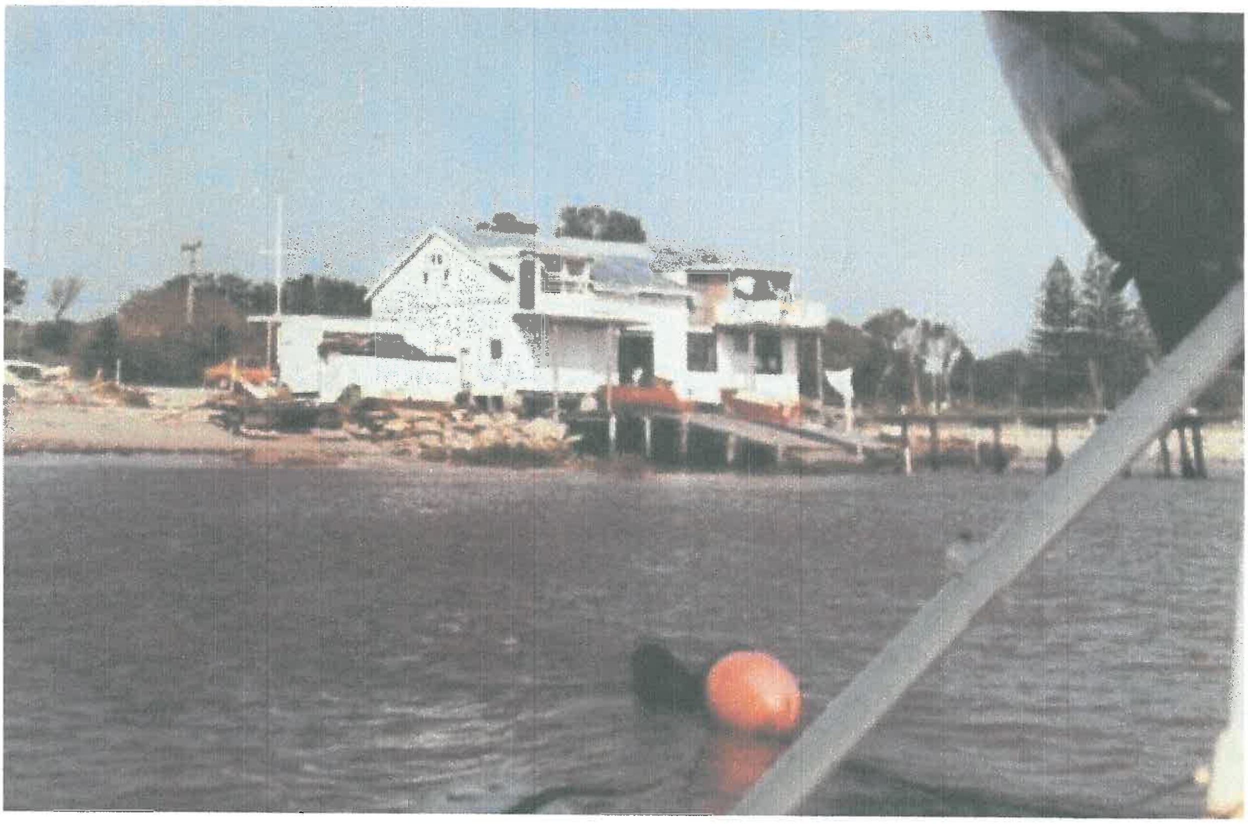
The original building had no accommodation upstairs it was from what has been gathered a sail loft. This matches with the truss system of Hardwood and long bolts 1/4, 2/4,3/4 and gable ends. There was a ramp from the front middle of the building running to the water to allow boats to be brought inside. The original wharf was a lot longer with fuel pumps at the end for refueling the ferries and boats that operated thru Pittwater and the Hawkesbury. Where the larger annex is on the side of the N/E corner there was a large sliding door that went thru to the underside of the top plate for the gable.

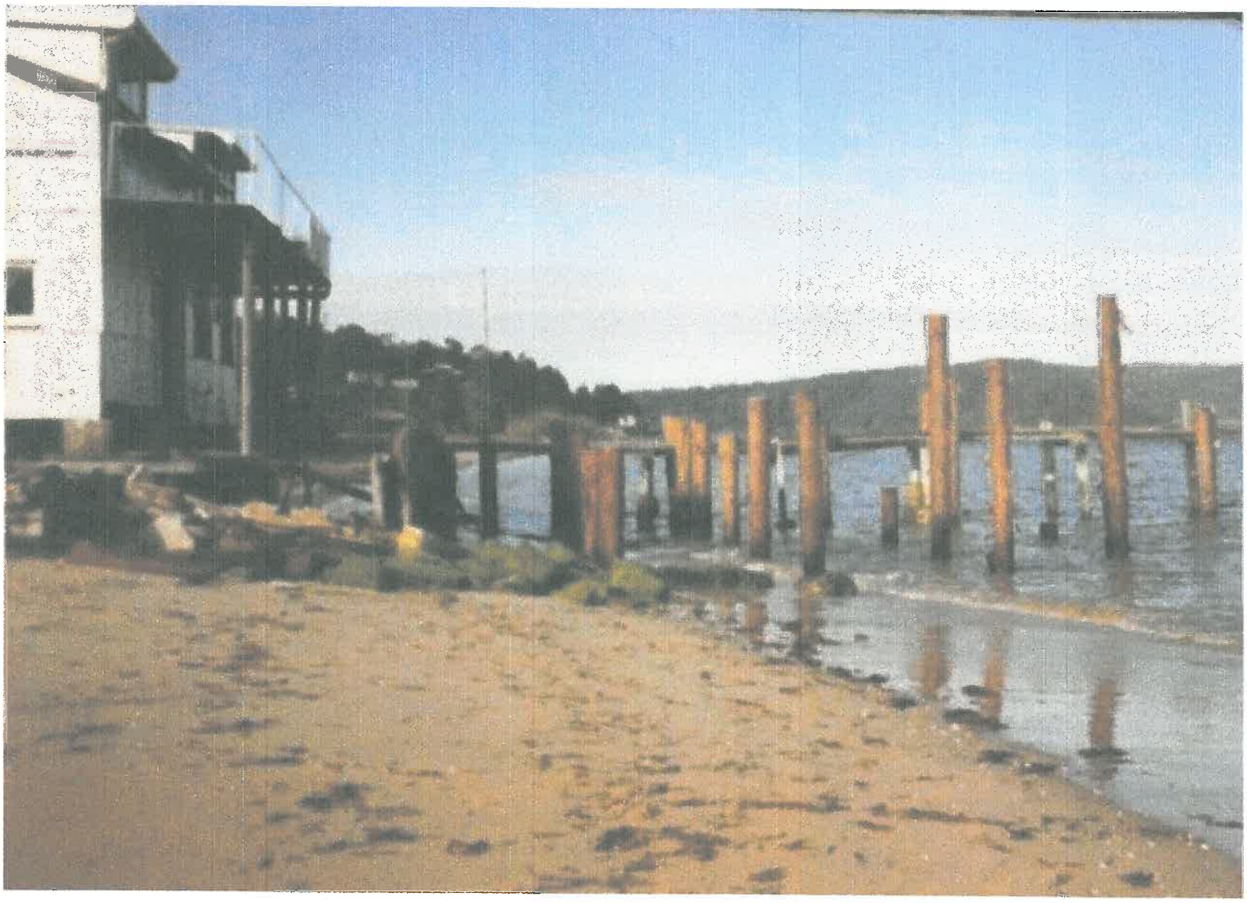
The piers are the original, except in 5 locations where they are timber. The existing timber frame in general seems to be original.
There are records of Warringah council replacing the rusty corrugate iron in the late 60s before considerable renovations took place in the mid 70s and later.
These renovations from what I have researched included the following

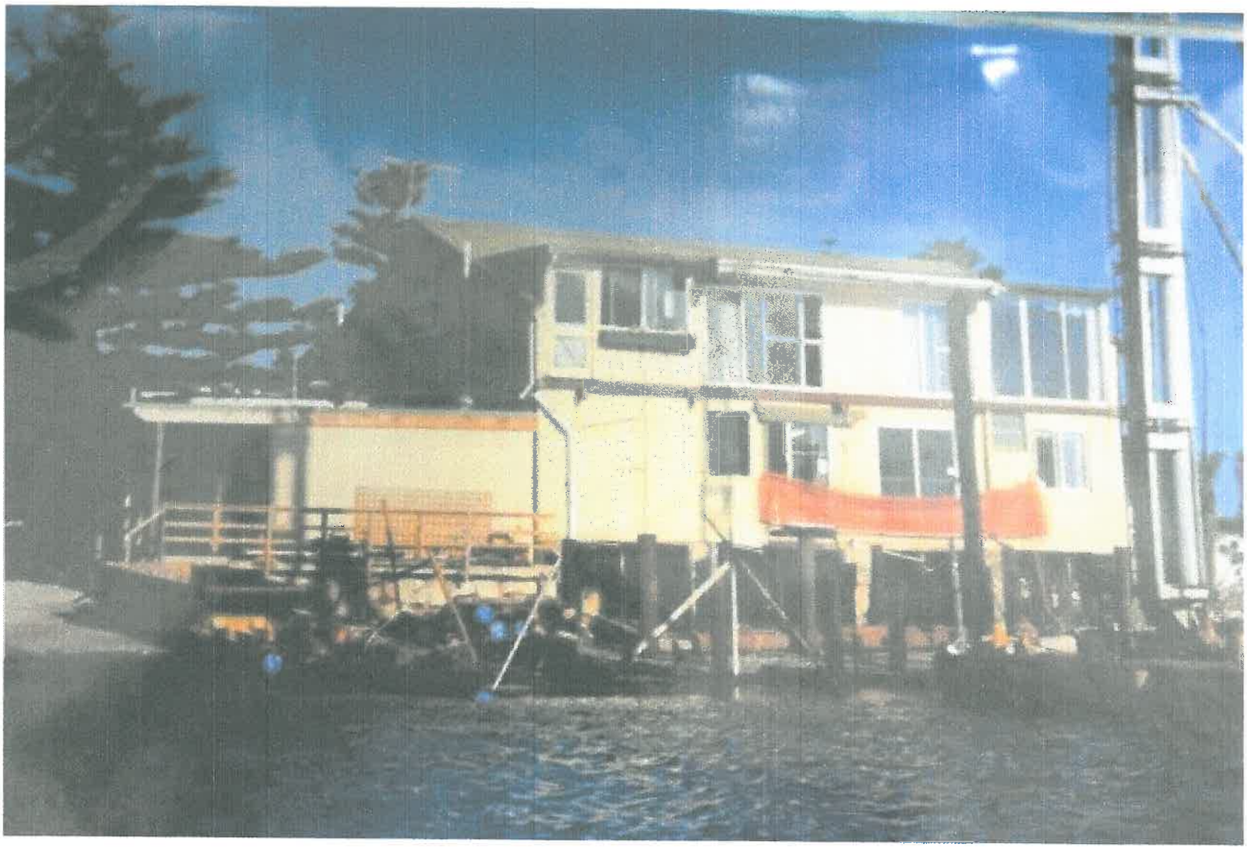
- Adding eastern and western side dormers
- Adding a 13 meter deck with slipway over the water for seaplanes
- Adding a front veranda behind deck for the lower storey
- Adding a front veranda to the 1st floor and then extending it later
- Turning the 1st floor into all accommodation
- Side annex's added to the building.
- Changes made by restaurant to accommodate the business

Please see following photos (photos from approx 62)









The building has not had any real major structural improvements since it was originally built except for floor lay out changes and verandas.

The structure was built using traditional building methods at the end of WW2 when materials where in short supply prior to the introduction of AS after Cyclone Tracy. To try and retrofit the whole building to current AS would be virtually impossible. However a number of actions to improve the building are feasible.

If we apply AS1170.2 (Design wind) consider the following

- Resistance to live and dead loads AS1170
- Provision to reasonable level of rigidity and stiffness to strong winds
- Resistance to max winds as per AS11702.2

Under AS4055 you would classify the building as N3 wind category

1 Currently the roof cladding is not screw down to acceptable screw profile and the roof flexes in a numbers of locations indicating the screws aren't into anything substantial. You can therefore assume the batons also don't comply along with tie downs of rafters to plates etc

APPENDIX

C

EXTRACT FROM PITTWATER DCP

The following applies to all development:

- All development or activities must be designed and constructed such that they will not increase the level of risk from estuarine processes for any people, assets or infrastructure in surrounding properties; they will not adversely affect estuarine processes; they will not be adversely affected by estuarine processes; and,

- All structural elements below the Estuarine Planning Level shall be constructed from flood compatible materials; and,
- All structures must be designed and constructed so that they will have a low risk of damage and instability due to wave action and tidal inundation; and,
- All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the Estuarine Planning Level; and,
- The storage of toxic or potentially polluting goods, materials or other products, which may be hazardous or pollute the waterway, is not permitted below the Estuarine Planning Level; and,
- For existing structures, a tolerance of up to minus 100mm may be applied to the Estuarine Planning Level in respect of compliance with these controls.
- To ensure Council's recommended flood evacuation strategy of 'shelter-in-place', it will need to be demonstrated that there is safe pedestrian access to a 'safe haven' above the Estuarine Planning Level.

<u>Wave Action and Tidal Inundation Mitigation Works</u>

Developments that propose mitigation works that modify the wave action or tidal inundation behaviour within the development site including the filling of land, the construction of retaining structures and the construction of wave protection walls may be permitted on a merit basis subject to demonstration through an Estuarine Risk Management Report that:

- The wave action or tidal inundation mitigation works do not have an adverse impact on any surrounding property or estuarine processes up to the Estuarine Planning Level; and,
- The wave action or tidal inundation mitigation works result in the protection of the existing and proposed development from inundation up to the Estuarine Planning Level.
- The wave action or tidal inundation mitigation works do not have an adverse impact on the environment. (This includes but is not limited to the altering of natural flow paths and the clearing of vegetation).

Where wave action or tidal inundation mitigation works are undertaken to protect the development from inundation as set out above, the application of the Estuarine Planning Level requirements of this control need not apply.

A Section 88B notation under the Conveyancing Act 1919 may be required to be placed on the title describing the location and type of wave action or tidal inundation mitigation works with a requirement for their retention and maintenance.

<u>Floor Levels - New Development and Additions</u>

All floor levels within the dwelling, including floor levels of the existing dwelling, but excluding open balconies (with open balustrades), shall be at, or above, or raised to the Estuarine Planning Level.

Floor Levels - Carparking Facilities

- **New enclosed garage:**

All floor levels shall be at or above the Estuarine Planning Level.

- **Basement (i.e. below natural ground level) garage:**

All access, ventilation and any other potential water entry points must be above the Estuarine Planning Level. A clearly signposted pedestrian access to a 'safe haven' above the Estuarine Planning Level, separate from the vehicular access ramps, shall be provided. The access ramp to the basement, where practical should not face the direction of wave action.

- **Open carpark areas and carports (including covered carpark areas):**

Are permissible at the existing ground level. Vehicle barriers or restraints are to be provided to prevent floating vehicles leaving the site where finished surface levels are more than 300mm below the Estuarine Planning Level.

Floor Levels - Boatshed Facilities

- **New boatshed:**

All floor levels shall be at or above the Estuarine Planning Level.

- **Basement (i.e. below natural ground level) boatshed facilities:**

All access and potential water entry points must be above the Estuarine Planning Level and a clearly signposted pedestrian access to a 'safe haven' above the Estuarine Planning Level, separate from the access ramps, shall be provided. The access ramp to the basement, where practical should not face the direction of wave action.

Variations

Innovative Design in Wave Action and Tidal inundation Protection Measures

Innovative and alternative design in wave action and tidal inundation protection measures may be permitted on a merit basis subject to demonstration through and Estuarine Risk Management Report that the protection measures can be achieved.

Alterations and Additions - Existing Dwelling - Retain existing floor level below Estuarine Planning Level

An alteration or addition to an existing residential dwelling may be permissible where existing floor levels are retained below the Estuarine Planning Level provided that:

- The total gross floor area (GFA) of any additions to the dwelling, at any point in time can only be increased to a maximum total area not exceeding 30m^2 if any part of the existing gross floor area (GFA) of the dwelling is below the Estuarine Planning Level; and,
- The floor levels of the addition must be at or above the Estuarine Planning Level; and,

- If the floor level of the existing dwelling is to be retained below the Estuarine Planning Level, the existing dwelling must be satisfactorily protected to minimise risk against wave action or tidal inundation; and,
- The addition must be designed and constructed such that it does not preclude the raising of the floor level of the existing structure to the Estuarine Planning Level when further additions are undertaken; and,
- Where a first floor addition to the dwelling is to be constructed the floor level of the first floor is to be of a height that allows for the internal ground floor of the existing dwelling to be either at or raised to the Estuarine Planning Level (whilst maintaining minimum floor to ceiling height requirements).

Floor Levels - Carparking Facilities - New Enclosed Garage

Consideration may be given to a floor level of an enclosed garage at or above 300mm below the Estuarine Planning Level where it can be demonstrated that:

- The enclosed garage is not connected internally to the dwelling; and
- The enclosed garage is to be used for car parking purposes only; and,
- The entrance to the garage does not face the direction of wave action.

Floor Levels - Boatshed Facilities

Consideration may be given on a merit basis to a floor level of a boatshed at a level lower than the Estuarine Planning Level where it can be demonstrated through an Estuarine Risk Management Report that the boatshed is structurally designed to withstand periodic wave action and tidal inundation up to the Estuarine Planning Level.

Advisory Notes

- For a detached Secondary Dwelling the controls for new development apply.

B3.8 Estuarine Hazard - Residential Development: Multi Unit Housing and Shop-Top Housing Development

Land to which this control applies

- Land identified on the Estuarine Hazard Map as affected by estuarine processes. - P21DCP-BCMDCP018

Uses to which this control applies

- Group Building
- Multi-Unit Housing
- Residential Flat Building (2 storey)
- Residential Flat Building (3 storey)
- Seniors Housing - SEPP (Housing for Seniors or People with a Disability) 2004
- Shop-Top Housing

Outcomes

Protection of people. (S)
Protection of the natural environment. (En)
Protection of private and public infrastructure and assets. (S)

Controls

Obtaining Estuarine Planning Level

To apply this control, the Estuarine Planning Level must first be established by:

- Obtaining Estuarine Planning Level Advice using the'Flood and Estuarine Levels Tool' from Council's Web site, or;
- An independent assessment undertaken by a Coastal Engineer (as defined in the Estuarine Risk Management Policy for Development in Pittwater contained in Appendix 7).

The Estuarine Planning Level may vary landward across the site based on foreshore edge treatment and distance from the foreshore edge.

The Estuarine Planning Level does not apply to Jetties, Bridging Ramps or Pontoons located on the seaward side of the foreshore edge.

Estuarine Risk Management Policy for Development in Pittwater

For additional information, applicants are referred to the Estuarine Risk Management Policy for Development in Pittwater contained in Appendix 7.

Protection of Development from Wave Action and Tidal Inundation

Development is to be protected from the effects of wave action or tidal inundation either by mitigation works to protect the development or ensuring that the floor levels of the development are at or above the Estuarine Planning Level.

General to all Development

The following applies to all development:

- All development or activities must be designed and constructed such that they will not increase the level of risk from estuarine processes for any people, assets or infrastructure in surrounding properties; they will not adversely affect estuarine processes; they will not be adversely affected by estuarine processes; and
- All structural elements below the Estuarine Planning Level shall be constructed from flood compatible materials; and,
- All structures must be designed and constructed so that they will have a low risk of damage and instability due to wave action and tidal inundation; and,
- All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the Estuarine Planning Level; and,
- The storage of toxic or potentially polluting goods, materials or other products, which may be hazardous or pollute the waterway, is not permitted to be stored below the Estuarine Planning Level; and,
- For existing structures, a tolerance of up to minus 100mm may be applied to the Estuarine Planning Level in respect of compliance with these controls.
- To ensure Council's recommended flood evacuation strategy of 'shelter-in-place', it will need to be demonstrated that there is safe pedestrian access to a 'safe haven' above the Estuarine Planning Level.

<u>Wave Action and Tidal Inundation Mitigation Works</u>

Developments that propose mitigation works that modify the wave action or tidal inundation behaviour within the development site including the filling of land, the construction of retaining structures and the construction of wave protection walls may be permitted on a merit basis subject to demonstration through an Estuarine Risk Management Report that:

- The wave action or tidal inundation works do not have an adverse impact on any surrounding property or estuarine processes up to the Estuarine Planning Level; and
- The wave action or tidal inundation mitigation works result in the protection of the existing and proposed development from inundation up to the Estuarine Planning Level.
- The wave action or tidal inundation mitigation works do not have an adverse impact on the environment (this includes but is not limited to the altering of natural flow paths and the clearing of vegetation).

Where wave action or tidal inundation mitigation works are undertaken to protect the development from inundation as set out above, the application of the Estuarine Planning Level requirements of this control need not apply.

A Section 88B notation under the Conveyancing Act 1919 may be required to be placed on the title describing the location and type of wave action or tidal inundation mitigation works with a requirement for their retention and maintenance.

<u>Floor Levels - New Development and Additions</u>

All floor levels within the development, excluding balconies (with open balustrades) are to be at, or above, or raised to the Estuarine Planning Level.

<u>Floor Levels - Carparking Facilities</u>

- **Enclosed garage or enclosed car park:**

All floor levels shall be at or above the Estuarine Planning Level.

- **Basement (i.e. below natural ground level) carparking facilities:**

All access, ventilation and any other potential water entry points must be above the Estuarine Planning Level. A clearly signposted pedestrian access to a 'safe haven' above the Estuarine Planning Level separate from the vehicular access ramps, shall be provided. The access ramp to the basement where practical should not face the direction of wave action.

- **Open carpark areas (including covered carpark areas) and carports used for residential carparking:**

All floor levels/pavement levels shall be at or above the Estuarine Planning Level.

- **Open carpark areas (including covered carpark areas) and carports used by visitors, staff and service delivery vehicles spaces:**

Are permissible at the existing ground level. Vehicle barriers or restraints are to be provided to prevent floating vehicles leaving where finished surface levels are more than 300mm below the Estuarine Planning Level.

<u>Floor Levels - Boatshed Facilities</u>

- **New boatshed:**

All floor levels shall be at or above the Estuarine Planning Level.

Basement (i.e. below natural ground level) boatshed facilities: All access and potential water entry points must be above the Estuarine Planning Level and a clearly signposted pedestrian access to a 'safe haven' above the Estuarine Planning Level , separate from the access ramps, shall be provided. The access ramp to the basement where practical should not face the direction of wave action.

Variations

<u>Innovative Designs in Wave Action and Tidal Inundation Protection Measures</u>

Innovative and alternative designs in wave action and tidal inundation protection measures may be permitted on a merit basis subject to demonstration through an Estuarine Risk Management Report that the protection measures can be achieved.

<u>Floor Levels - Boatshed Facilities</u>

Consideration may be given on a merit basis to a floor level of a boatshed at a level lower than the Estuarine Planning Level where it can be demonstrated through an Estuarine Risk Management Report that the boatshed is structurally designed to withstand periodic wave action and tidal inundation up to the Estuarine Planning Level.

B3.9 Estuarine Hazard - Business, Light Industrial and Other Development

Land to which this control applies

- Land identified on the Estuarine Hazard Map as affected by estuarine processes. - P21DCP-BCMDCP018

Uses to which this control applies

- Business Development - New Construction or Alterations and Additions
- Child Care Centre
- Hospital/Nursing Home
- Industrial Development - New Construction or Alterations and Additions
- Other Development/Land Use

Outcomes

Protection of people. (S)
Protection of the natural environment. (En)
Protection of private and public infrastructure and assets. (S)

Controls

Obtaining Estuarine Planning Level

To apply this control, the Estuarine Planning Level must first be established by:

- Obtaining 'Estuarine Planning Level Advice' using the 'Flood and Estuarine Levels Tool' from Council's Web site, or;
- An independent assessment undertaken by a Coastal Engineer (as defined in the Estuarine Risk Management Policy for Development in Pittwater contained in Appendix 7).

The Estuarine Planning Level may vary landward across the site based on foreshore edge treatment and distance from the foreshore edge.

The Estuarine Planning Level does not apply to Jetties, Bridging Ramps or Pontoons located on the seaward side of the foreshore edge.

Estuarine Risk Management Policy for Development in Pittwater

For additional information, applicants are referred to the Estuarine Risk Management Policy for Development in Pittwater contained in Appendix 7.

Protection of Development from Wave Action and Tidal Inundation

Development is to be protected from the effects of wave action or tidal inundation either by mitigation works to protect the development or ensuring that the floor levels of the development are at or above the Estuarine Planning Level.

General to all Development

The following applies to all development:

- All development or activities must be designed and constructed such that they will not increase the level of risk from estuarine processes for any people, assets or infrastructure in surrounding properties; they will not adversely affect estuarine processes; they will not be adversely affected by estuarine processes; and
- All structural elements below the Estuarine Planning Level shall be constructed from flood compatible materials; and,
- All structures must be designed and constructed so that they will have a low risk of damage and instability due to wave action and tidal inundation; and,
- All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the Estuarine Planning Level; and,
- The storage of toxic or potentially polluting goods, materials or other products, which may be hazardous or pollute the waterway, is not permitted to be stored below the Estuarine Planning Level; and,
- For existing structures, a tolerance of up to minus 100mm may be applied to the Estuarine Planning Level in respect of compliance with these controls.
- To ensure Council's recommended flood evacuation strategy of 'shelter-in-place' it will need to be demonstrated that there is safe pedestrian access to a 'safe haven' above the Estuarine Planning Level.

<u>Wave Action and Tidal Inundation Mitigation Works</u>

Developments that propose mitigation works that modify the wave action or tidal inundation behaviour within the development site including the filling of land, the construction of retaining structures and the construction of wave protection walls may be permitted on a merit basis subject to demonstration through an Estuarine Risk Management Report that:

- The wave action or tidal inundation mitigation works do not have an adverse impact on any surrounding property or estuarine processes up to the Estuarine Planning Level; and,
- The wave action or tidal inundation mitigation works result in the protection of the existing and the proposed development from inundation up to the Estuarine Planning Level; and
- The wave action or tidal inundation mitigation works do not have an adverse impact on the environment. (This includes but is not limited to the altering of natural flow paths and the clearing of vegetation).

Where wave action or tidal inundation mitigation works are undertaken to protect the development from inundation as set out above the application of the Estuarine Planning Level requirements of this control need not apply.

A Section 88B notation under the Conveyancing Act 1919 may be required to be placed on the title describing the location and type of wave action or tidal inundation mitigation works with a requirement for their retention and maintenance.

<u>Floor Levels - New Development and Additions</u>

All floor levels within the development, excluding balconies (with open balustrades) are to be at or above, or raised to the Estuarine Planning Level.

<u>Floor Levels - Carparking Facilities</u>

- **Enclosed garage or enclosed car park**: All floor levels shall be at or above the Estuarine Planning Level.
- **Basement (i.e. below natural ground level) carparking facilities:** All access, ventilation and any other potential water entry points must be above the Estuarine Planning Level. A clearly signposted pedestrian access to a 'safe haven' above the Estuarine Planning Level separate from the vehicle access ramps, shall be provided. The access ramp to the basement, where practical should not face the direction of wave action.
- **Open carpark areas (including covered carpark areas) and carports**: Are permissible at the existing ground level. Vehicle barriers or restraints are to be provided to prevent floating vehicles leaving the site where finished surface levels are more than 300mm below the Estuarine Planning Level.

<u>Floor Levels - Boatshed Facilities</u>

- **New boatshed:**

All floor levels shall be at or above the Estuarine Planning Level.

- **Basement (i.e. below natural ground level) boatshed facilities:**

All access and potential water entry points must be above the Estuarine Planning Level. A clearly signposted pedestrian access to a 'safe haven' above the Estuarine Planning Level separate from the access ramps, shall be provided. The access ramp to the basement, where practical should not face the direction of wave action.

Variations

<u>Innovative Designs in Wave Action and tidal Inundation Protection Measures</u>
Innovative and alternative designs in wave action and tidal inundation protection measures may be permitted on a merit basis subject to demonstration through an Estuarine Risk Management Report that the protection measures can be achieved

<u>Floor Levels - Change of Use and Alterations and Additions for Existing Premises - Business and Light Industrial Development Only</u>
Where constructing the floor level at the Estuarine Planning Level or raising the floor level of the existing development to the Estuarine Planning Level may be difficult to achieve, due to practical, heritage or other constraints, consideration may be given to a floor level at a level lower that the Estuarine Planning Level for the non-residential component of the development, subject to demonstration through a Estuarine Risk Management Report that all precautions have been taken to minimise risk from the effect of wave action and tidal inundation up to the Estuarine Planning Level.

<u>Floor Levels - Boatshed Facilities</u>

Consideration may be given on a merit basis to a floor level of a boatshed at a level lower than the Estuarine Planning Level where it can be demonstrated through an Estuarine Risk Management Report that the boatshed is structurally designed to withstand periodic wave action and tidal inundation up to the Estuarine Planning Level.

B3.10 Estuarine Hazard - Land Subdivision

Land to which this control applies

- Land identified on the Estuarine Hazard Map as affected by estuarine processes. - P21DCP-BCMDCP018

Uses to which this control applies

- Subdivision (Additional Lots - Excludes Dual Occupancy)
- Subdivision (Boundary Adjustment)

Outcomes

Protection of people. (S)
Protection of the natural environment. (En)
Protection of private and public infrastructure and assets. (S)

Controls

Obtaining Estuarine Planning Level

To apply this control, the Estuarine Planning Level must first be established by:

- Obtaining Estuarine Planning Level Advice using the 'Flood and Estuarine Levels Tool' from Council's Web site, or;
- An independent assessment undertaken by a Coastal Engineer (as defined in the Estuarine Risk Management Policy for Development in Pittwater contained in Appendix 7).

The Estuarine Planning Level may vary landward across the site based on foreshore edge treatment and distance from the foreshore edge.

The Estuarine Planning Level does not apply to Jetties, Bridging Ramps or Pontoons located on the seaward side of the foreshore edge.

Estuarine Risk Management Policy for Development in Pittwater

For additional information, applicants are referred to the Estuarine Risk Management Policy for Development in Pittwater contained in Appendix 7.

Protection of Development from Wave Action and Tidal Inundation

Development is to be protected from the effects of wave action or tidal inundation either by mitigation works to protect the development or ensuring that the floor levels of the development are at or above the Estuarine Planning Level.

General to all Development

The following applies to all development:

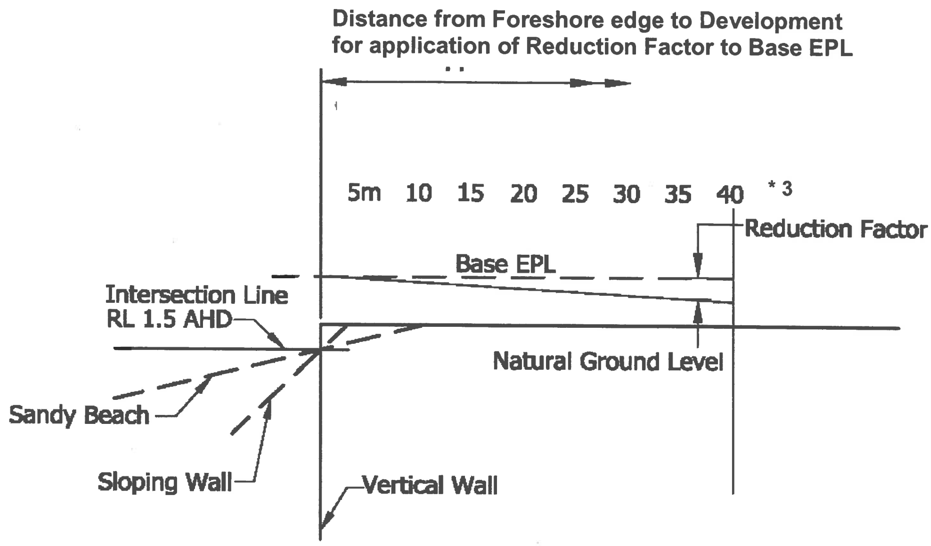
- All development or activities must be designed and constructed such that they will not increase the level of risk from estuarine processes for any people,

APPENDIX

D

ESTUARY PLANNING LEVEL

5.2 Figure 1: Diagrammatic Representation for determining of Estuarine Planning Level (EPL)



EPL = Base EPL*1 - Reduction Factor*2

*1 Base EPL is function of existing or proposed edge treatment

1. Sandy Beach
2. Vertical Wall, crest at 1.5m AHD
3. Vertical Wall, crest at 2.0m AHD
4. Sloping Rock Wall
5. Sloping Smooth Wall

* 2 Reduction Factor based on distance to development from foreshore edge treatment.

* 3. For EPL's further than 40 m from the foreshore edge, there is no further reduction in EPL.

Property Estuarine Planning Level Advice is available from the 'Flood and Estuarine Levels Tool' at Council's Web Site

APPENDIX

E

PHOTOGRAPHS OF ROCK BACK WALL UNDER STRUCTURE

Estuarine Risk Management Report

Rock Back Wall under Structure
Photo 1

Appendix E.1

Estuarine Risk Management Report

Rock Back Wall under Structure
Photo 2

Appendix E.2

Estuarine Risk Management Report

Rock Back Wall under Structure
Photo 3

Appendix E.3

APPENDIX

F

HYDRAULIC RESEARCH ON THE CLOSELY SPACED PILE BREAKWATER

CHAPTER 50

HYDRAULIC RESEARCH ON THE CLOSELY SPACED PILE BREAKWATER

Taizo HAYASHI, Professor
Masataro HATTORI, Associate Professor
Department of Civil Engineering
Chuo University, Tokyo

and

Tokutaro KANO, Technical Adviser
Masujiro SHIRAI, Project Chief
Technical Research Institute
Taisei Construction Company, Ltd., Tokyo

ABSTRACT

Hydraulic properties of a row of closely spaced circular piles as a breakwater have been studied both theoretically and experimentally. A theory is presented for the transmission of waves past the breakwater and also for the thrust and bending moment to be exerted by the waves upon each pile in the breakwater. Laboratory experiment has been made on a model structure. A pretty close agreement is shown in the comparison between the theory and the experiment with respect to the transmission coefficient and the bending moment distribution.

Special emphasis is laid on the remarkable rate of decrease of the thrust and bending moment to be exerted on each pile in the breakwater with the increase of the space of the piles. In taking this economical aspect of this structure into consideration, the closely spaced pile breakwater has been concluded as a promising type of breakwater of comparatively light structure.

INTROCUCTION

A possible type of breakwater consists of a row of closely spaced circular piles [1, 2]. Such a type of structure will sometimes be very convenient from the standpoint of construction. A question arises to what extent such a structure will interfere with the normal propagation of waves and to what extent the thrust and moment exerted by waves upon each pile in the structure will be reduced by the spacing of the piles. The purpose of this paper is to develop the theory of such a structure and to conduct laboratory tests on a model structure under various wave conditions.

THEORY

Wave transmission. Consider a single row of piles of diameter D and space between piles b(Fig. 1). It is observed from the experiments that the piles work like a kind of screen to the transmission of the incoming waves and, consequently, the velocity distribution of water particles caused by the waves becomes vertically more uniform than in the case of a vertical wall. In taking account of this property of the relatively uniform velocity distribution of water particles in front of the closely spaced pile breakwater, and for the sake of mathematical simplicity, we assume that the waves near the breakwater are long waves.

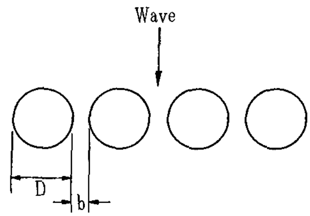


Fig. 1.

Then, the velocities caused by an incident wave, a reflected wave and a transmitted wave are respectively expressed as follows:

$$v_I = \sqrt{g/h} \cdot \eta_I \qquad \text{..........(1)}$$

$$v_R = - \sqrt{g/h} \cdot \eta_R \qquad \text{..........(2)}$$

$$v_T = \sqrt{g/h} \cdot \eta_T \qquad \text{..........(3)}$$

in which η is the surface ordinate of waves (Fig. 2 at the end of this paper), v is the velocity of water particle, h is the water depth measured form the still water level, g is the acceleration of gravity, and, I, R and T are suffixes referring to an incident wave, a reflected wave and a transmitted wave, respectively.

Neglecting the effect of the wave height at the breakwater, the equation of continuity is written as follows:

$$v_I h + v_R h = v_T h$$

from which we find

$$v_I + v_R = v_T \qquad \text{..........(4)}$$

The velocity of jet discharging from a space between any two adjacent piles is given by the Bernoulli's theorem as

$$V = C_v \sqrt{2g\ (\eta_I + \eta_R - \eta_T)} \Big/ \sqrt{1 - \left(\frac{b}{D+b}\right)^2} \qquad \text{.........(5)}$$

in which V is the jet velocity, and C_v is the coefficient of velocity of the jet. The term appeared in the denominator in the right member of the above equation represents the effect of the velocity of approach to the jet.

On the other hand, from the equation of continuity behind the breakwater, we have the relation

$$V \cdot C_c\ b\ h = v_T \cdot (D+b)\ h \qquad \text{..........(6)}$$

in which C_c is the coefficient of contraction of the jet.

Thus, from Eqs. (5) and (6) we obtain

$$v_T = C\frac{b}{D+b}\sqrt{2g\,(\eta_I + \eta_R - \eta_T)}\Big/\sqrt{1-\left(\frac{b}{D+b}\right)^2} \quad \text{........(7)}$$

in which C ($= C_v\,C_c$) is the coefficient of discharge of each space of piles.

At the instant of collision of the crest of the incident wave against the breakwater, from Eqs. (1), (2), (3), (4) and (7) we find the following relations:

$$v_I = \sqrt{g/h}\cdot H_I/2 \quad \text{.............(8)}$$

$$v_R = -\sqrt{g/h}\cdot H_R/2 \quad \text{.............(9)}$$

$$v_T = \sqrt{g/h}\cdot H_T/2 \quad \text{............(10)}$$

$$v_I + v_R = v_T \quad \text{............(11)}$$

$$v_T = C\frac{b}{D+b}\cdot\sqrt{g\,(H_I + H_R - H_T)}\Big/\sqrt{1-\left(\frac{b}{D+b}\right)^2} \quad \text{.........(12)}$$

in which H represents the wave height measured vertically from trough to crest. From these five equations we can determine five unknown quantities, v_I, v_R, v_T, H_R and H_T, as the functions of H_I. The expressions of H_T and H_R thus determined are as follows:

$$H_T = 4h\varepsilon\left[-\varepsilon + \sqrt{\varepsilon^2 + (H_I/2h)}\right] \quad \text{.............(13)}$$

$$H_R = H_I - H_T \quad \text{.............(14)}$$

in which

$$\varepsilon = C\frac{b}{D+b}\Big/\sqrt{1-\left(\frac{b}{D+b}\right)^2} \quad \text{.............(15)}$$

Denoting the coefficients of wave transmission and wave reflection by r_T and r_R, respectively, those coefficients are given by

$$r_T = H_T / H_I \quad \text{.............(16)}$$

and

$$r_R = H_R / H_I \quad \text{.............(17)}$$

Substituting these relations into Eqs. (13) and (14), we obtain

$$r_T = 4(h/H_I)\varepsilon\left[-\varepsilon + \sqrt{\varepsilon^2 + (H_I/2h)}\right] \quad \text{.............(18)}$$

$$r_R = 1 - r_T \quad \text{.............(19)}$$

Figures 3 and 5 at the end of this paper illustrate the magnitude of r_T and r_R with respect to b/D for various values of h/H_I, in the cases of C=1 and C = 0.9, respectively.

Transmitted wave energy, reflected wave energy and loss energy. From the equation of continuity of wave energy at the breakwater we have the relation

$$E_I = E_T + E_R + E_{Loss} \quad \text{.............(20)}$$

in which E_T is the transmitted wave energy per wave lenght per unit width of wave, E_R is the reflected wave energy per wave length per unit width of wave, and E_{Loss} is the loss wave energy per unit wave length per unit width of wave. In taking account of the relation

$$E = (1/2)\rho g L H^2$$

Eq. (20) can be rewritten as follows:

$$\frac{E_{Loss}}{E_I} = 1 - r_T^2 - r_R^2 = 2r_T(1-r_T) \quad ....(21)$$

The above relation is illustrated in Figs. 4 and 6, in the cases of C = 1 and C = 0.9, respectively.

Wave force acting on each pile. Assuming

$$\eta_I = (H_I/2)\sin(kx - \sigma t) \quad ....(22)$$

the reflected wave is expressed by

$$\eta_R = r_R (H_I/2)\sin(kx + \sigma t) \quad ....(23)$$

These two waves make the wave pressure in a vertical plane just in front of the closely spaced pile breakwater as illustrated in Fig. 7.

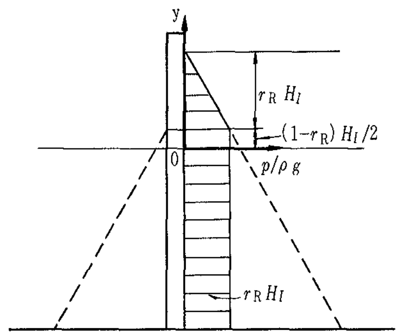


Fig. 7.

The thrust exerted on each pile by the wave pressure shown in Fig. 7 can be determined from the momentum equation below, formulated with respect to the water in the shaded part of Fig. 8.

$$\int \rho V C_c b \left[V - \frac{C_c b}{D+b} V \right] dy = \int p\,(D+b)dy - F \quad ....(24)$$

in which F is the total thrust exerted upon each pile. From Eq. (24) we obtain the relation

$$\frac{dF}{dy} = p\,(D+b) - \rho C_c b\left(1 - \frac{C_c b}{D+b}\right)V^2$$

$$\fallingdotseq p\,(D+b) - \rho C_c b\left(1 - \frac{b}{D+b}\right)V^2 \quad ....(25)$$

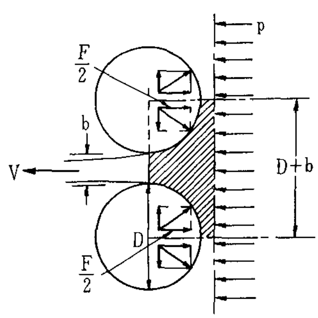


Fig. 8.

On the other hand, the jet velocity V is determined by the Bernoulli's theorem as follows:

For $-h \leqq y \leqq (1-r_R)H_I/2$

$$V = C_v \sqrt{2g\left(\frac{H_I}{2} + \frac{H_R}{2} - \frac{H_T}{2}\right)} \Big/ \sqrt{1 - \left(\frac{C_c b}{D+b}\right)^2}$$

$$= C_v \sqrt{2g \cdot r_R H_I} \Big/ \sqrt{1 - \left(\frac{C_c b}{D+b}\right)^2}$$

$$\fallingdotseq C_v \sqrt{2g \cdot r_R H_I} \Big/ \sqrt{1 - \left(\frac{b}{D+b}\right)^2} \qquad \text{..........(26)}$$

and for $(1 - r_R)\, H_I/2 \leqq y \leqq (1 + r_R)\, H_I/2$

$$V = C_v \sqrt{2g\left(\frac{H_I}{2} + \frac{H_R}{2} - y\right)} \Big/ \sqrt{1 - \left(\frac{C_c b}{D+b}\right)^2}$$

$$= C_v \sqrt{2g\,[(1 - r_R)(H_I/2) + r_R H_I - y]} \Big/ \sqrt{1 - \left(\frac{C_c b}{D+b}\right)^2}$$

$$\fallingdotseq C_v \sqrt{2g\,[(1 - r_R)(H_I/2) + r_R H_I - y]} \Big/ \sqrt{1 - \left(\frac{b}{D+b}\right)^2} \qquad \text{..........(27)}$$

Thus, the total thrust exerted upon a pile in the closely spaced pile breakwater is obtained as follows:

$$F = \int_{-h}^{(1 - r_R)\, H_I/2} \frac{dF}{dy}\, dy + \int_{(1 - r_R)\, H_I/2}^{(1 + r_R)\, H_I/2} \frac{dF}{dy}\, dy$$

$$= \frac{1 + (b/D)(3 - 2C_c C_v^2) + 2(b/D)^2\, (1 - C_c C_v^2)}{1 + (2b/D)}\, r_R \cdot \frac{1}{2}\left(1 + \frac{2h}{H_I}\right) \rho\, g\, D\, H_I^2$$

$$= \frac{D + (3 - 2C)\, b}{D + 2b}\, r_R \cdot \frac{1}{2}\left(1 + \frac{2h}{H_I}\right) \rho\, g\, D\, H_I^2 \qquad \text{........(28)}$$

Bending moment about the bottom of the pile. The moment distribution is given by the following expressions:

For $-h \leqq y \leqq (1 - r_R)\, H_I/2$

$$M = \int_{y}^{(1 - r_R)\, H_I/2} \frac{dF}{d\xi} \cdot (\xi - y)\, d\xi + \int_{(1 - r_R)\, H_I/2}^{(1 + r_R)\, H_I/2} \frac{dF}{d\xi} \cdot (\xi - y)\, d\xi$$

$$= \frac{1}{8} \rho\, g\, D\, H_I^3 \cdot \frac{D + (3 - 2C)b}{D + 2b}\, r_R \left[\frac{r_R^2}{3} + \left(1 - \frac{2y}{H_I}\right)^2\right] \qquad \text{.....(29)}$$

and for $(1 - r_R)\, H_I/2 \leqq y \leqq (1 + r_R)\, H_I/2$

$$M = \int_{y}^{(1 + r_R)\, H_I/2} \frac{dF}{d\xi} \cdot (\xi - y)\, d\xi$$

$$= \frac{1}{48} \rho g D H_I^3 \cdot \frac{D + (3 - 2C)b}{D + 2b} \left[1 + r_R - \frac{2y}{H_I} \right]^3 \qquad (30)$$

The bending moment about the bottom of the pile, i. e. the mamimum bending moment on the pile, M_{max}, is determined from Eq. (29) as

$$M_{max} = \frac{1}{8} \rho g H_I^3 D \cdot \frac{D + (3 - 2C)b}{D + 2b} r_R \left[\frac{r_R^2}{3} + (1 + \frac{2h}{H_I})^2 \right] \qquad (31)$$

In the case of non-spaced pile breakwater, i. e. in the case when b = 0, it is seen from Eqs. (15), (18) and (19) that r_R becomes unity. The magnitude of M_{max} in that case, which is denoted by M_{max0}, is given by

$$M_{max0} = \frac{1}{8} \rho g H_I^3 D \cdot \left[\frac{1}{3} + (1 + \frac{2h}{H_I})^2 \right] \qquad (32)$$

Thus, we obtain the relation

$$\frac{M_{max}}{M_{max0}} = \frac{D + (3 - 2C)b}{D + 2b} r_R \left[\frac{r_R^2}{3} + (1 + \frac{2h}{H_I})^2 \right] \Bigg/ \left[\frac{1}{3} + (1 + \frac{2h}{H_I})^2 \right] \qquad (33)$$

The above relation is illustrated in Figs. 4 and 6 in the cases of C = 1 and 0.9, respectively.

EXPERIMENTAL EQUIPMENT AND PROCEDURES

Experiments were conducted in the 0.80m wide by 0.70m deep by 30m long wave channel at the Hydraulic Laboratory of Chuo University, Tokyo.

The closely spaced pile breakwater at the experiments consisted of 60.5mm diameter steel pipes (Photo. 1). One of the pipes was made of brass and was divided into twenty-two short tubes, each tubes having the dimension 60mmø x 30mm. A flat steel bar 87cm long, 4cm wide and 6mm thick, was put through those tubes and built in the bottom of the wave channel. Each tube was attached to this bar with a pair of screws, on which bar wire strain gauges were attached for the measurement of the moment distribution (Photo. 2). The gaps of those tubes were covered by vinyl tape in such a way that no water could enter the brass pipe. Static calibration curves of this brass pipe for the bending moments at various elevations were made by pushing a point in the upper part of the flat steel bar fixed in this pipe horizontally to the "harbour-side" with a small screw-jack which was connected with a ring-type compression link.

For the experiment of the non-spaced pile breakwater, semicircular pieces attached on a steel plate were used (Photo.3)

The depth of water and the period of waves were 40cm and 1.7sec, respectively, in all runs. For the experiment of the coefficients of reflection and transmission, the test range of incident wave characteristics was H_I = 18.6~3.9cm, and consequently, h/H_I = 2.15~10.3 and H_I/L = 0.061 ~ 0.013. For the experiment of the bending moment distribution, all runs were made at an incident wave height of 16cm.

The wave characteristics were measured by resistance elements of the parallel wire type and recorded with an oscillograph. Before and after each run, gages were calibrated, the calibration having been made by moving the gages up or down. The measurements taken from the wave records were based on the average values obtained from the first three or four fully developed waves. The bending moments at various elevations of the brass pipe were recorded also with an oscillograph.

EXPERIMENTAL RESULTS

The coefficients of wave transmission and wave reflection. These coefficients obtained from the experiments, together with the theory calculated with eqs. (15), (18) and (19), are shown in Figs. 9 and 10. The thin lines show the theory when the coefficient of discharge of jet is unity, and the heavy lines show the theory when the same coefficient is 0.9. It is seen from Fig. 9 that the agreement between the theory and the experiment with respect to the transmission coefficient is pretty good. As to the reflection coefficient, however, it appears from Fig. 10 that there is difference between the theory and the experiment. Main reason for this difference may be attributed to the loss of wave energy in front of the breakwater, and the improvement in the theory with respect to this point may be needed.

Moment distribution. Comparisons of the theory and experiment are shown in Fig. 11. Equations (29), (30), (32), (15), (18) and (19), with the value of $C = 0.9$, were used to calculate the dimensionless moment distribution of pile. It appears that the agreement between the theory and experiment is pretty close.

CONCLUSIONS

It seems that the theory developed in this paper can predict the wave transmission coefficient and the moment distribution adequately for engineering design purposes.

The wave transmission coefficient and the ratio of the maximum bending moment on a pile in the closely spaced pile breakwater to that in the case of non-spaced pile breakwater are illustrated in Figs. 3~6. The rate of decrease of this ratio with the increase of the value of b/D is remarkable. For example, for $C = 1$, $b/D = 0.05$ and $h/H_I = 2$, the magnitude of r_T and that of M_{max}/M_{max0} is read 0.174 and 0.786, respectively, and for $C = 1$, $b/D = 0.075$ and $h/H_I = 2$, r_T and M_{max}/M_{max0} are read 0.243 and 0.704, respectively. In taking account of this remarkable rate of decrease of the maximum bending moment with the increase of the value of b/D, the closely spaced pile breakwater may be concluded as an economical and useful type when it is adopted in the places where the transmitted waves of the wave height less than a certain limit are permissible.

ACKNOWLEDGEMENTS

The authors are grateful to Mr. Shigeru Yoshida, Postgraduate Student at Chuo University and to Mr. Katsumi Ito, who was a student at the same university, for their assistance and cooperation in the experiments.

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[1] Castello, R. D., Damping of water waves by vertical circular cylinders, Transactions, American Geophysical Union, Vol. 33, No. 4, Aug. 1952, pp. 513-519.

[2] Wiegel, R. L., Closely spaced piles as a breakwater, Dock and Harbour Authority, Sept. 1961, p. 150.

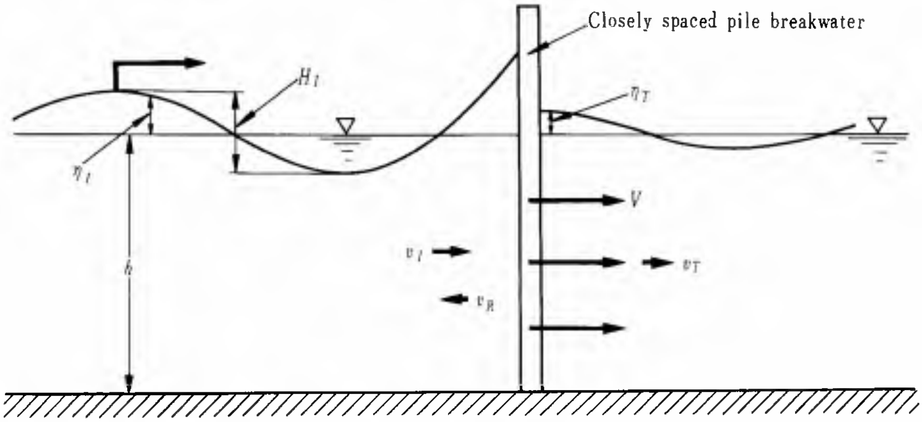


Fig. 2. Symbols.

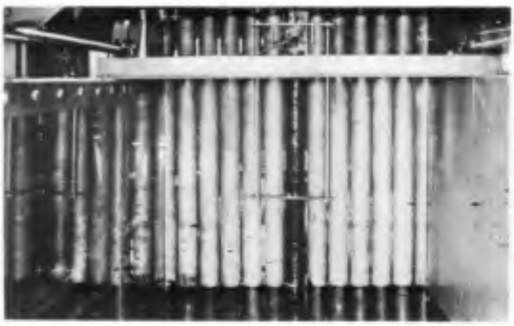


Photo. 1. Model of the closely spaced pile breakwater.

Photo. 2. Pile for the measurement of moment distribution.

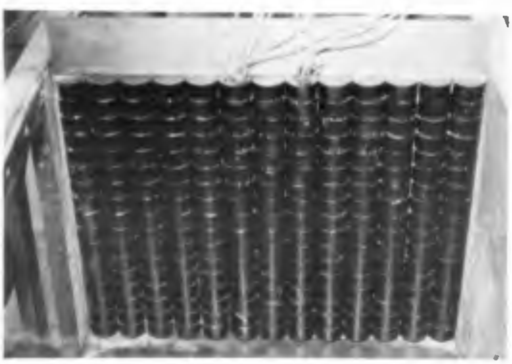


Photo. 3. Model of the non-spaced pile breakwater.

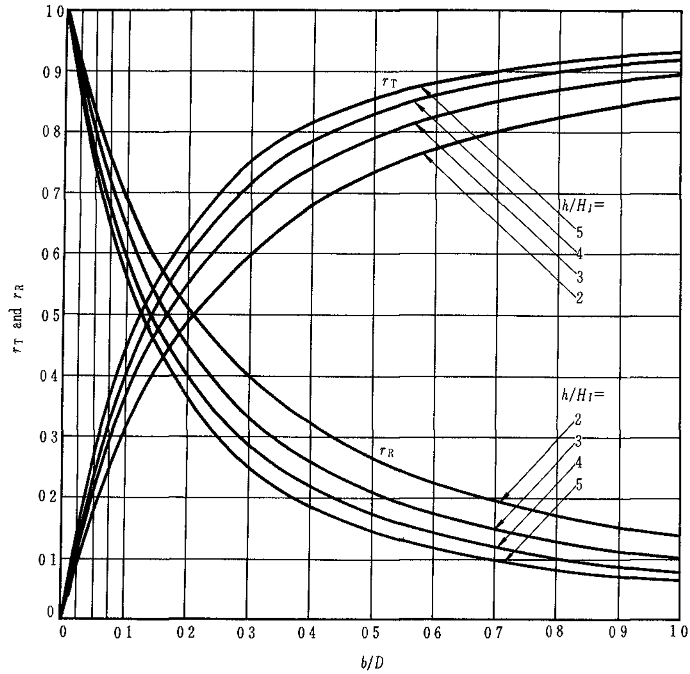


Fig. 3. Coefficients of wave transmission and wave reflection in the case of C = 1.

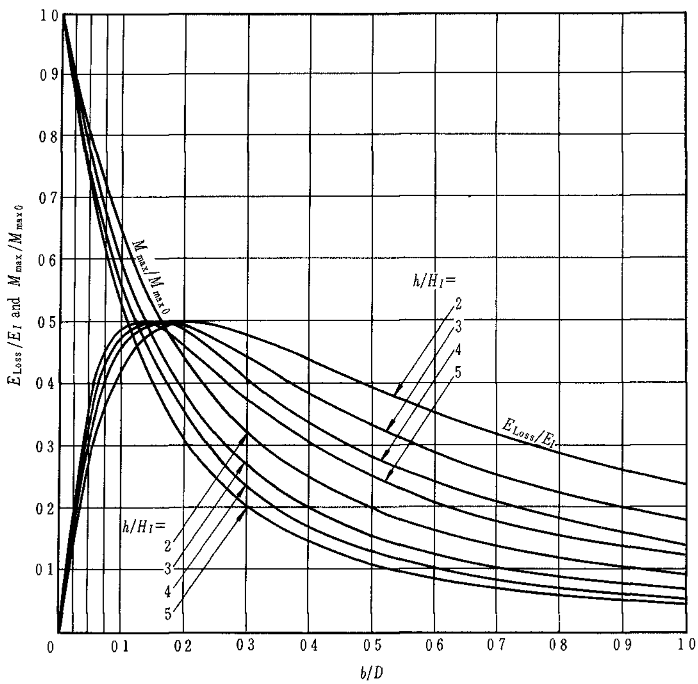


Fig. 4. E_{Loss}/E_I and $M_{max}/\overline{M}_{max0}$ in the case of C = 1.

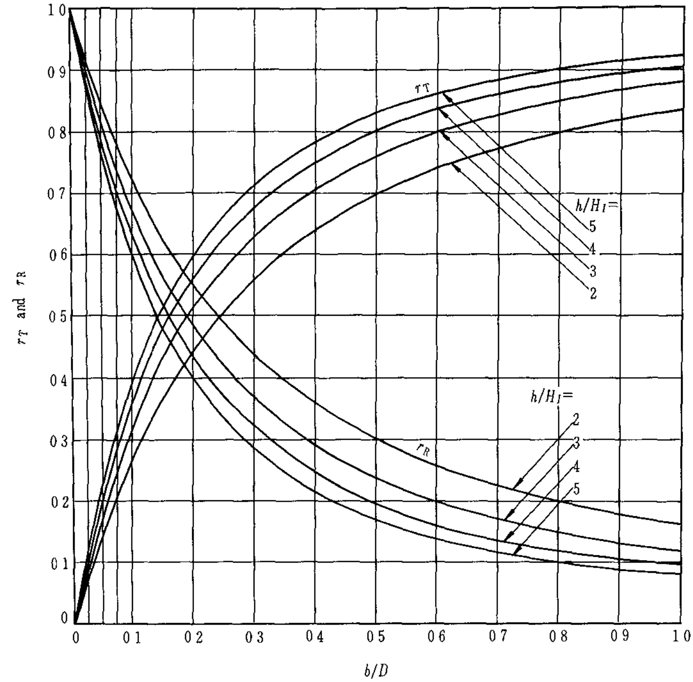


Fig. 5. Coefficients of wave transmission and wave reflection in the case of C = 0.9.

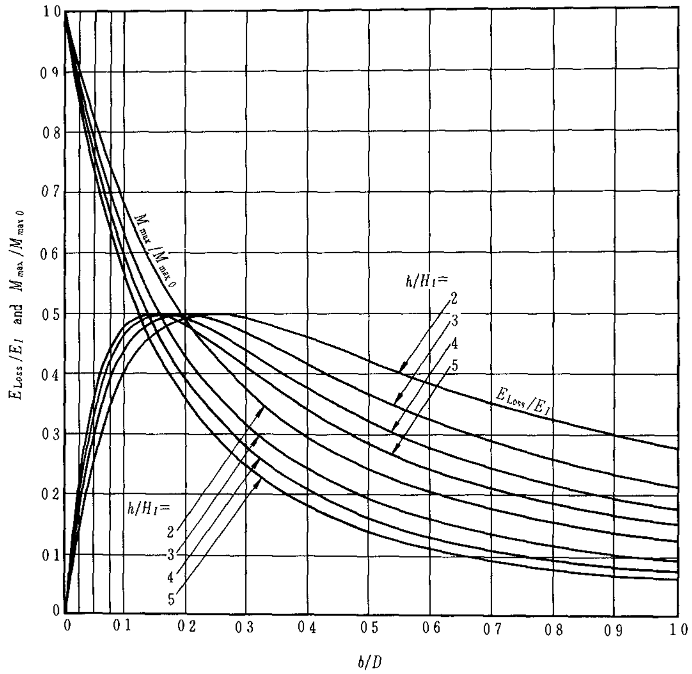


Fig. 6. E_{Loss}/E_I and M_{max}/M_{max0} in the case of C = 0.9.

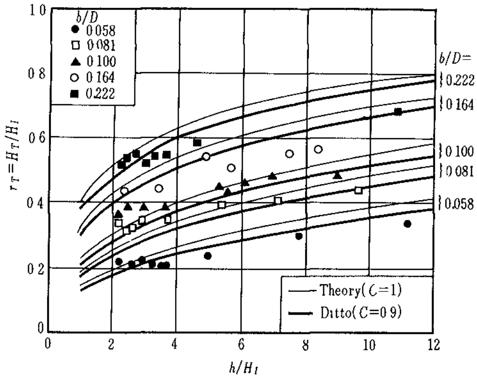


Fig. 9. Coefficient of wave transmission.

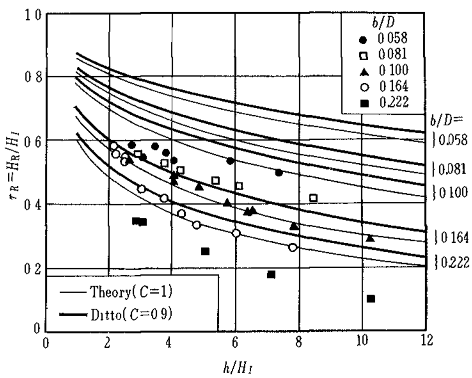


Fig. 10. Coefficient of wave reflection.

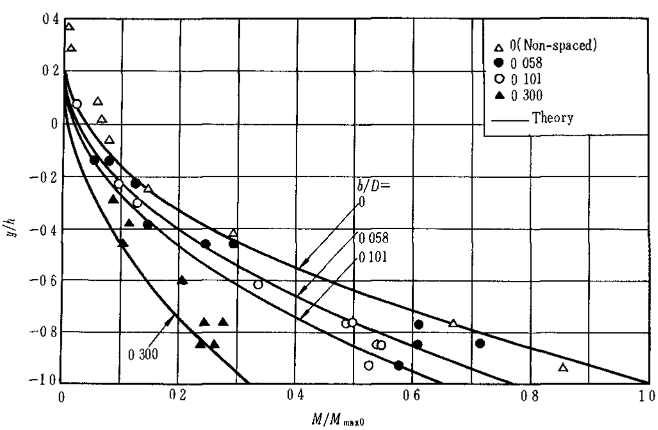
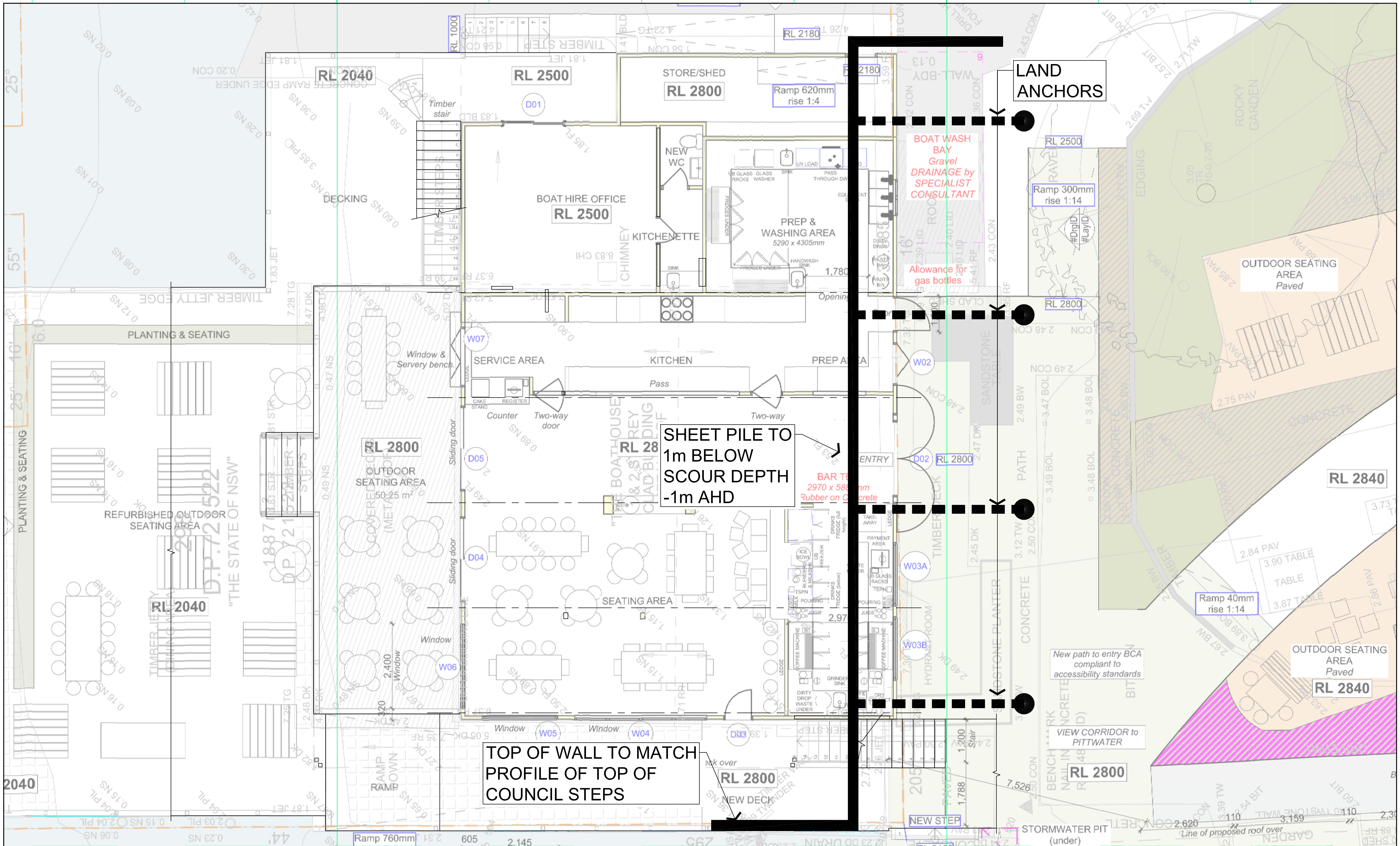


Fig. 11. Dimensionless moment distributions of pile.

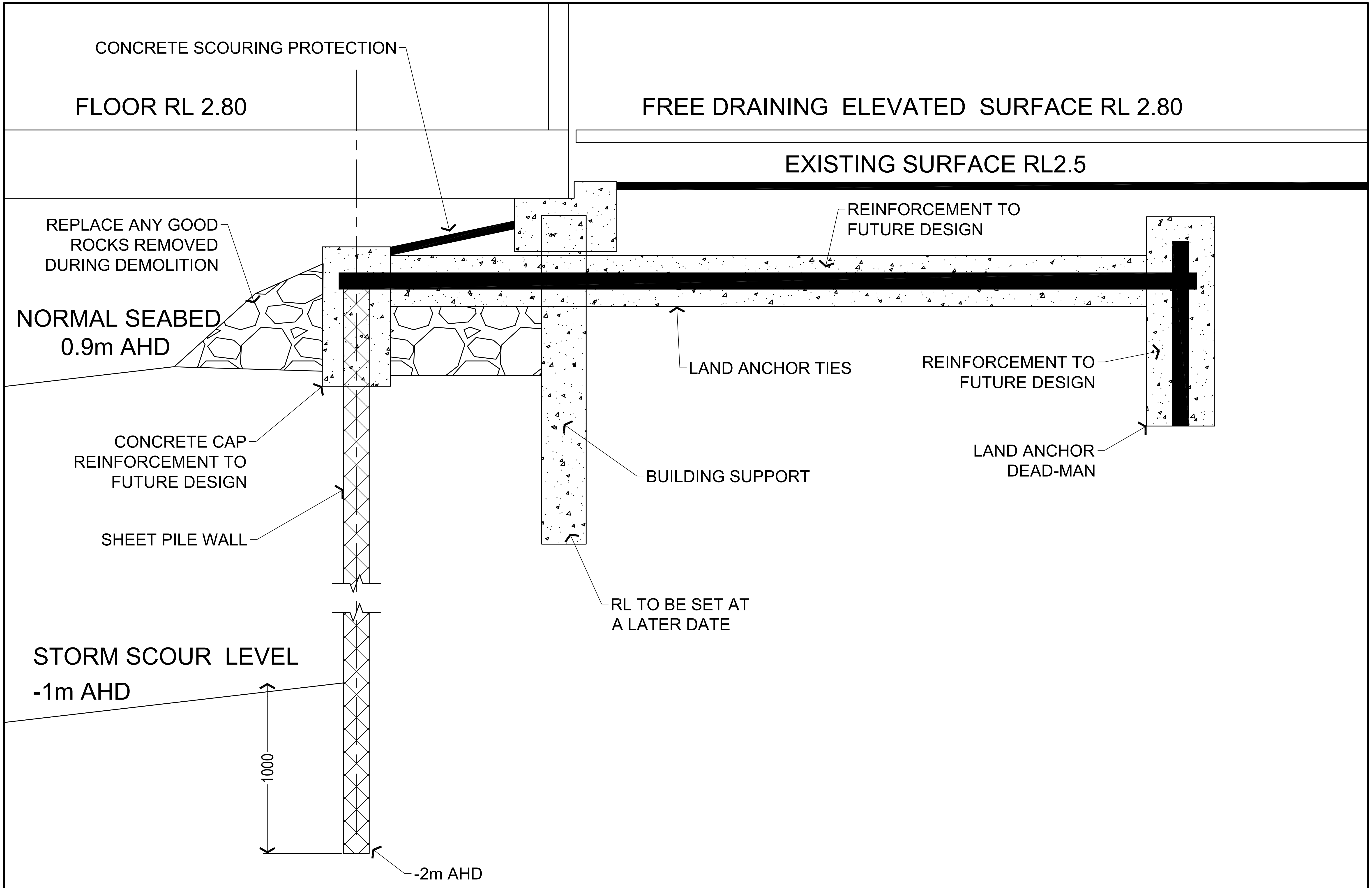
APPENDIX

G

ENGINEERING DRAWINGS



McKEE & ASSOCIATES PTY LTD STRUCTURAL ENGINEERS 12 Niven Place Belrose 2085 ABN 71 003 894 111 mckeepl@bigpond.net.au 0419 733 366	PROPOSED DEVELOPMENT 1191 BARRENJOEY RD PALM BEACH STORM EROSION PROTECTION WALL	Scale	Print Date 03/03/2020	Rev Date 03.03.20	Size	Rev
		Purpose CONCEPT		PROJECT 25722	Dwg EPW01	



G. McKee	McKEE & ASSOCIATES PTY LTD STRUCTURAL ENGINEERS 12 Niven Place Belrose 2085 ABN 71 003 894 111 mckeepl@bigpond.net.au 0419 733 366	PROPOSED DEVELOPMENT 1191 BARRENJOEY RD PALM BEACH	Scale	Print Date 03/03/2020	Rev Date 03.03.20	Size	Rev.
		STORM EROSION PROTECTION WALL	Purpose CONCEPT		PROJECT 25722	Dwg EPW02	

APPENDIX

H

COUNCIL SEAWALL

Aerial Map provided by Nearmap

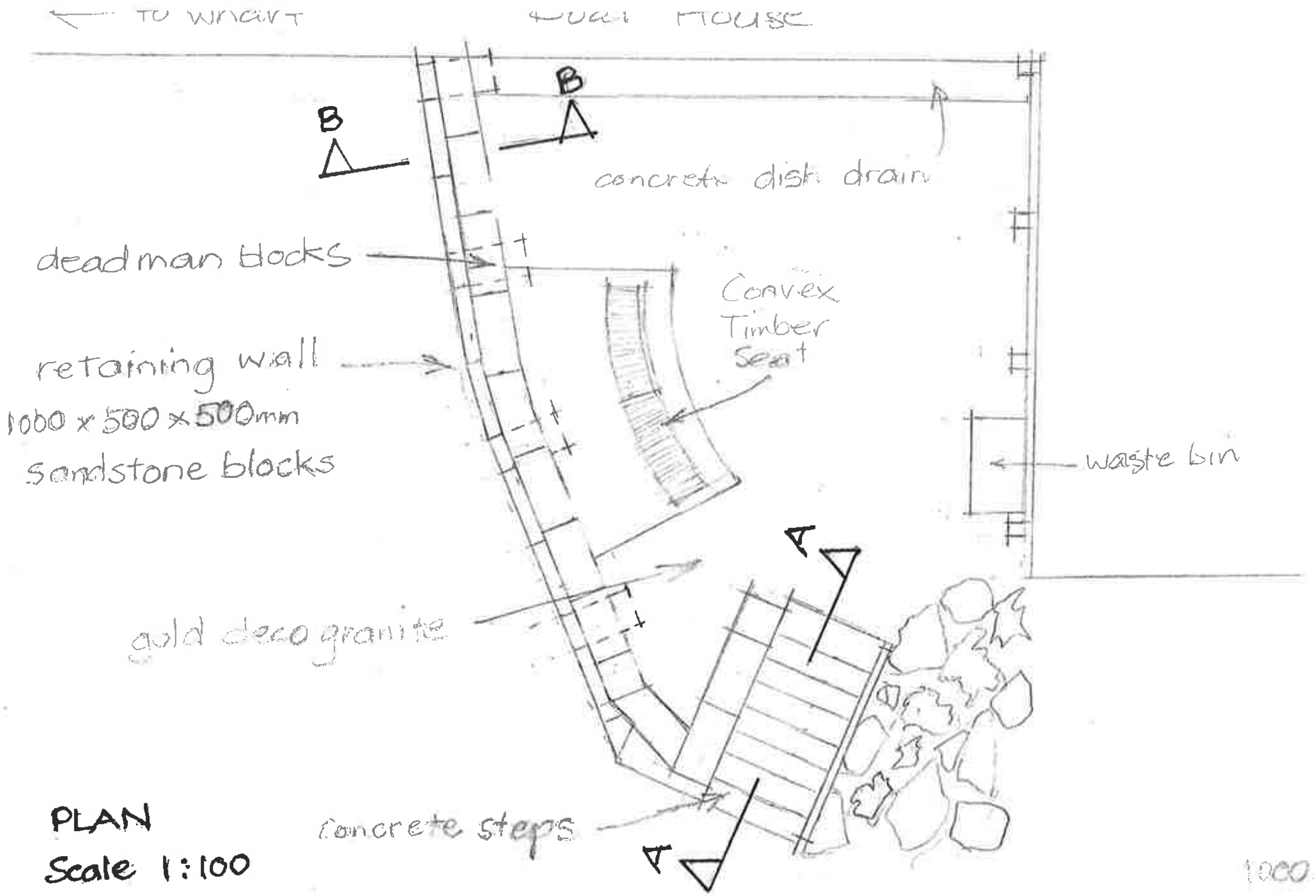
northern beaches council

STATION BEACH (SOUTH), PALM BEACH DOG OFF-LEASH AREA PROPOSAL

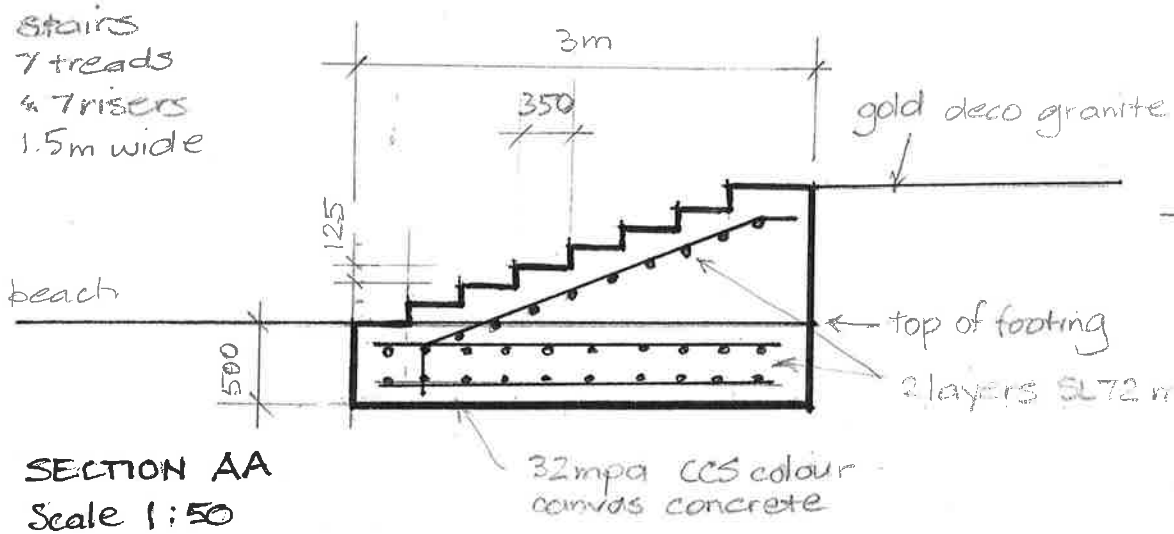
Concept Plan

November 2018 Not to Scale

STATION BEACH (South)
Seating and Stairs Adjacent to Boat House



PLAN
Scale 1:100



SECTION AA
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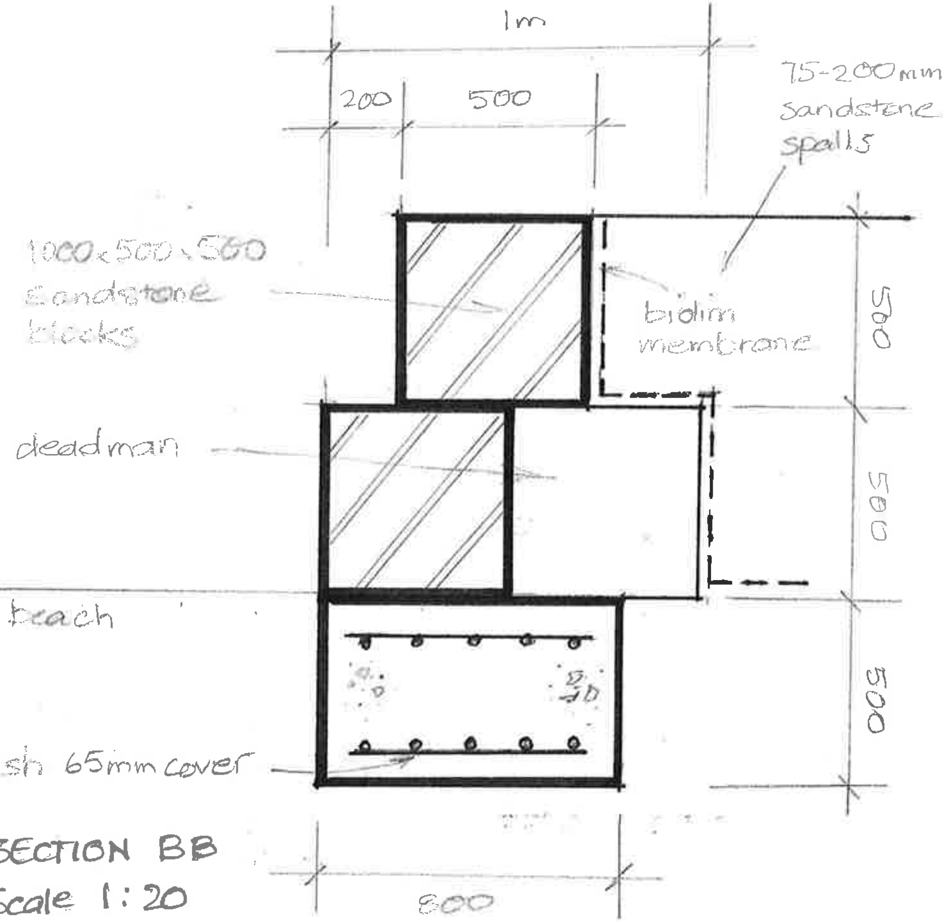

SECTION BB
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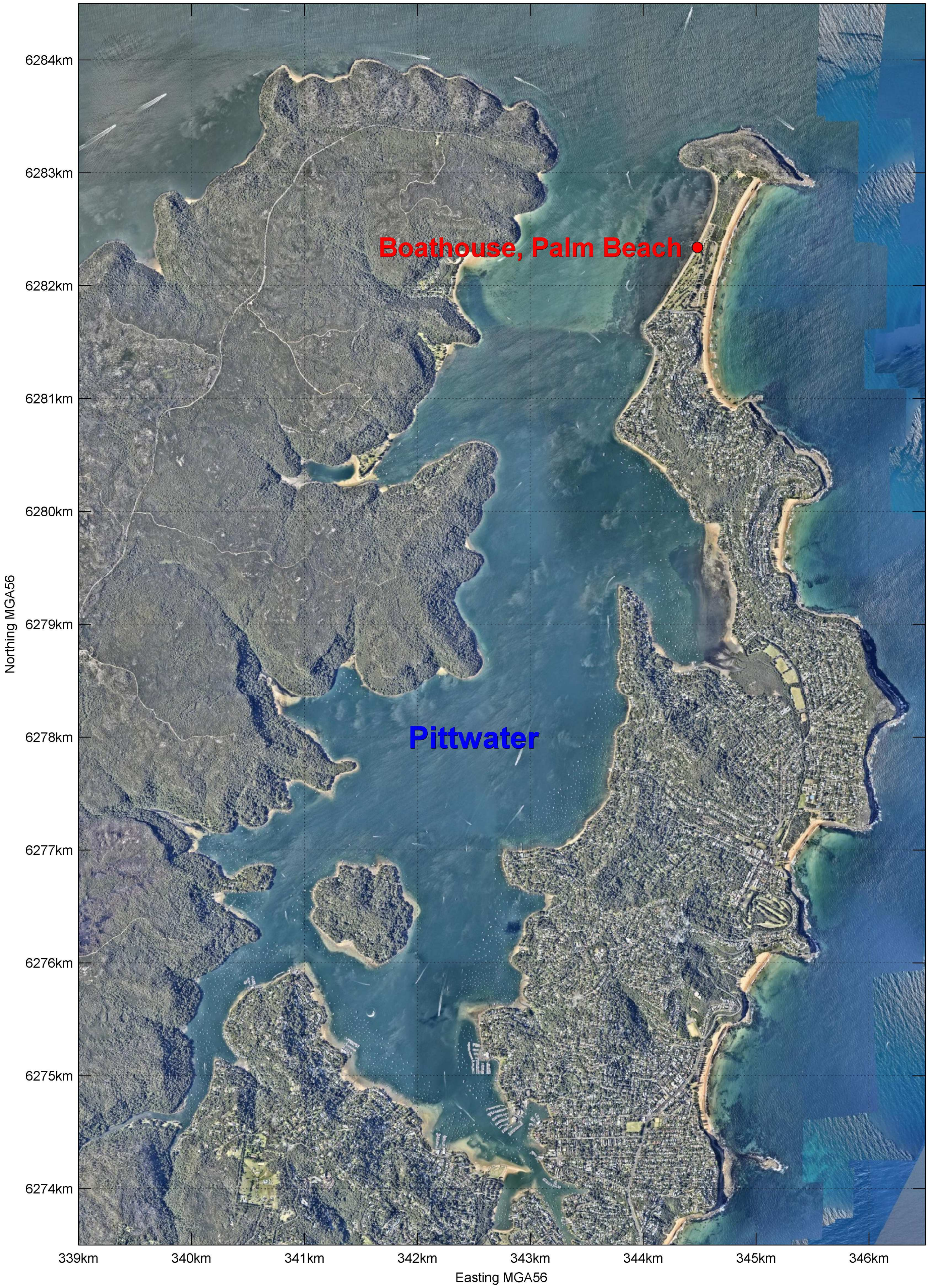

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Estuarine Risk Management Report

Locality Plan

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Figure 1.1

Estuarine Risk Management Report

Sandstone Block Seawall
Looking South from Boat House

Figure 1.2

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Estuarine Risk Management Report

Sandstone Block Seawall
Junction at Boat House

Figure 1.3

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Estuarine Risk Management Report

Photo of Shoreline Condition
South of Boat House

Figure 1.4

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Nearmap Aerial
October 2012

Figure 1.5a

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Nearmap Aerial
October 2015

Figure 1.5b

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Swell Approaching the Study Area

Figure 1.6

Estuarine Risk Management Report

Photo of Support Structures
Lower Deck – Photo 1

Figure 1.7a

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Estuarine Risk Management Report

Photo of Support Structures
Lower Deck – Photo 2

Figure 1.7b

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Estuarine Risk Management Report

Photo of Support Structures
Upper Deck – Photo 1

Figure 1.8a

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Photo of Support Structures
Upper Deck – Photo 2

Figure 1.8b

Estuarine Risk Management Report
Photo of Rubble under Lower Deck

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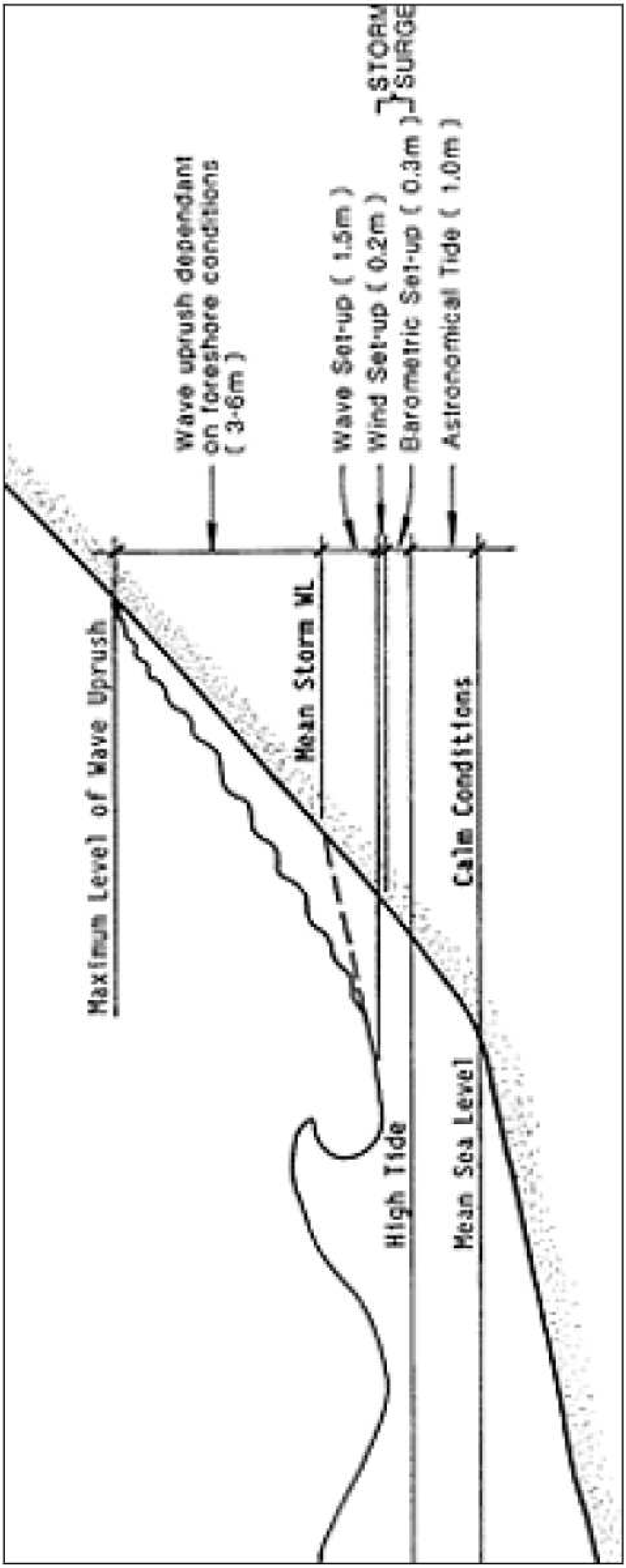
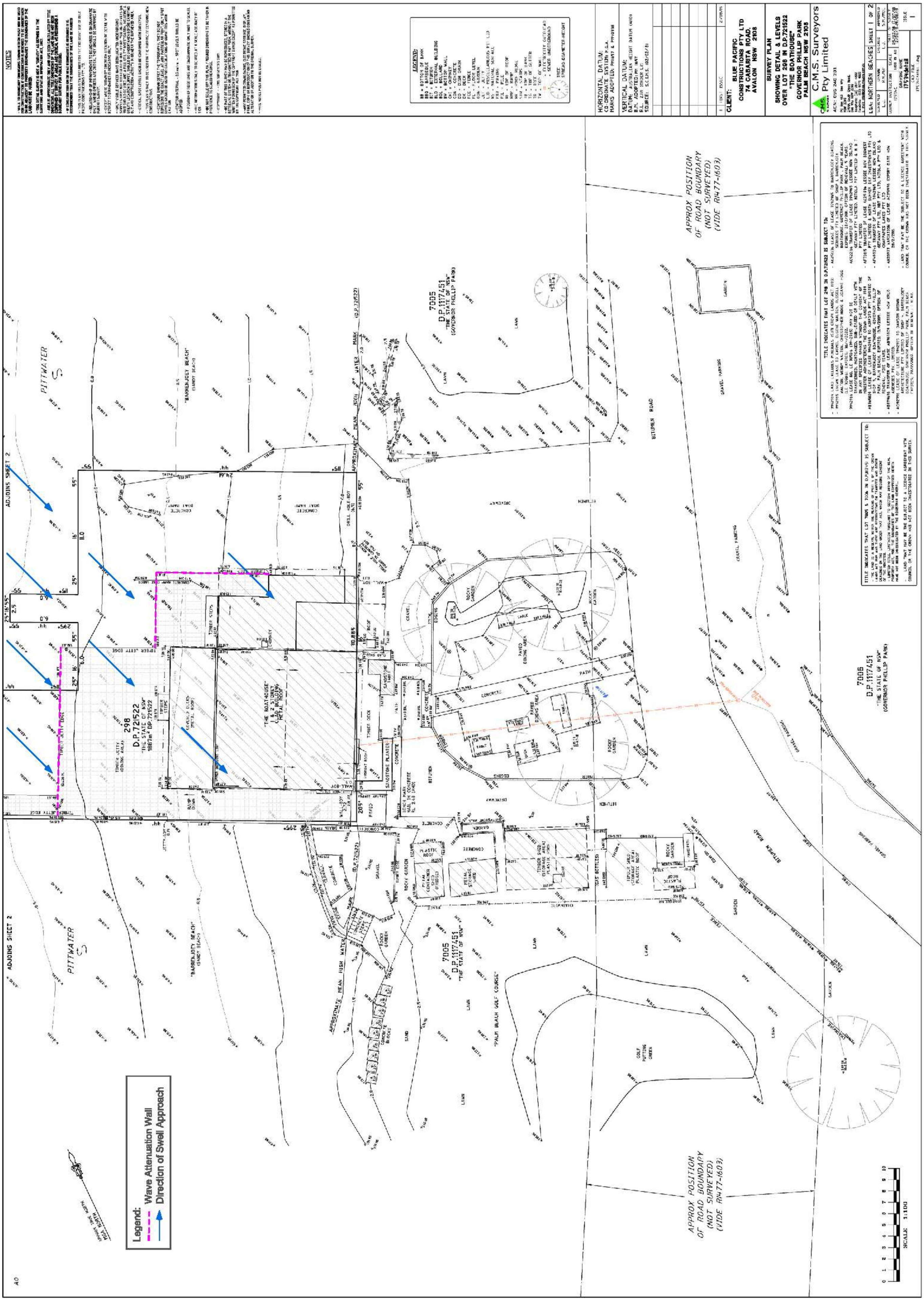
Figure 1.9



Wave uprush dependant on foreshore conditions (3-6m)
Wave Set-up (1.5m)
Wind Set-up (0.2m)
Barometric Set-up (0.3m)
STORM SURGE
Astronomical Tide (1.0m)
Maximum Level of Wave Uprush
Mean Storm WL
Calm Conditions
High Tide
Mean Sea Level



Estuarine Risk Management Report
Proposed Wave Screens

Figure 2.2

Legend
PVC Sheet Piling (To Depth Below -1 m AHD)
Wave Attenuation Walls
kPa = Including 0.2 m of SLR
kPa = For Present Day Sea Level
kPa = Including 0.2 m of SL (Porous Deck)
Direction of Mean Wave Energy
PITTWATER
14 kPa
6 kPa
9.5 kPa
3.5 kPa
2 kPa
9 kPa
6 kPa


Indicative Locations of Seagrasses
PALM BEACH
Legend
Study Area
Impact Area
The Property
59916081_MarineVegHab2020
Hal-1
Hal-2
Hal-2, Zos-2
Pos-2
Pos-2, Zos-2
Pos-3
Zos-2
Zos-2, Hal-2
Zos-2, Pos-2, Hal-1
FIGURE 3-1
1:350 Scale at A3
Cardno
8/7
8/8

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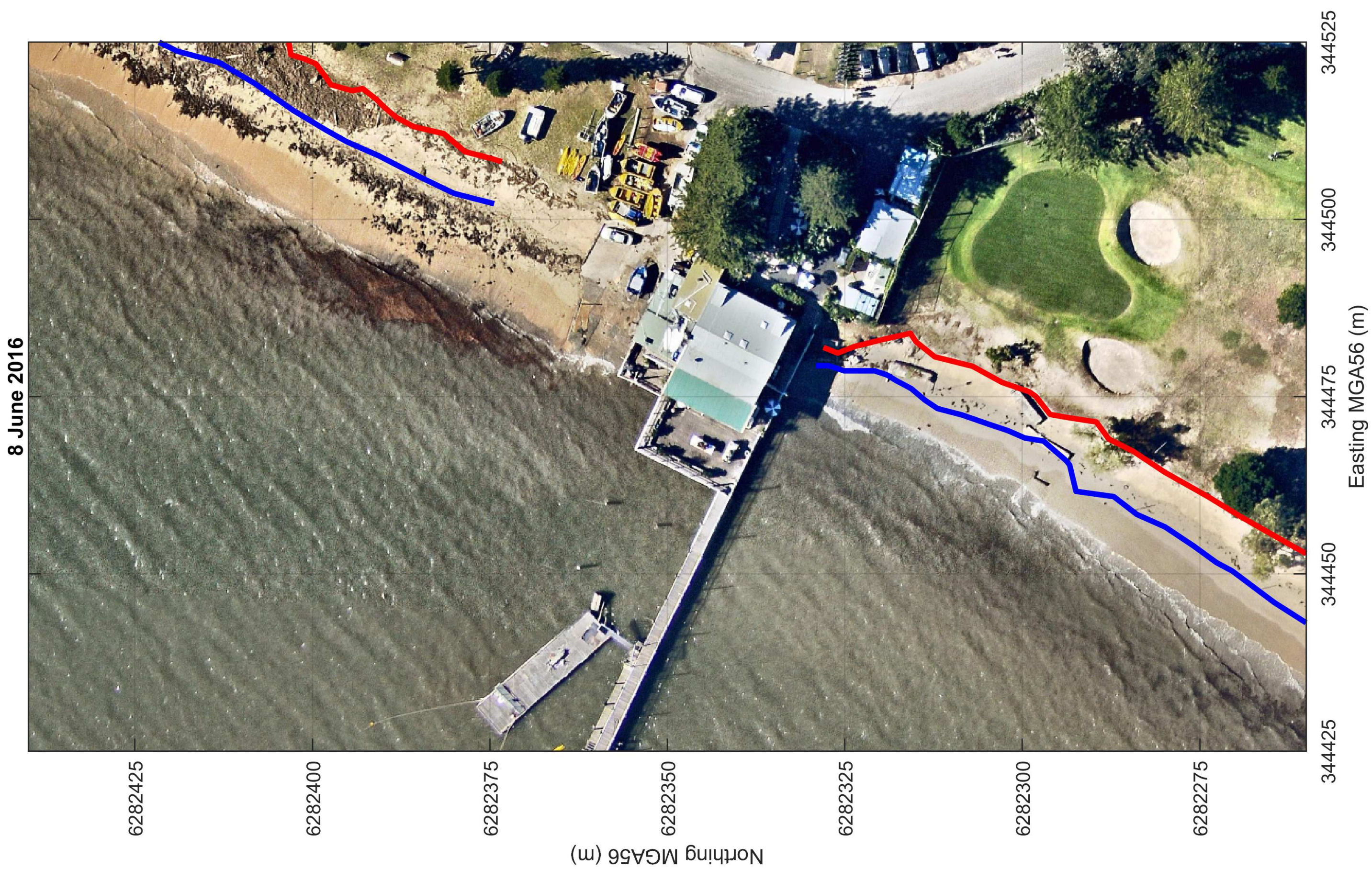
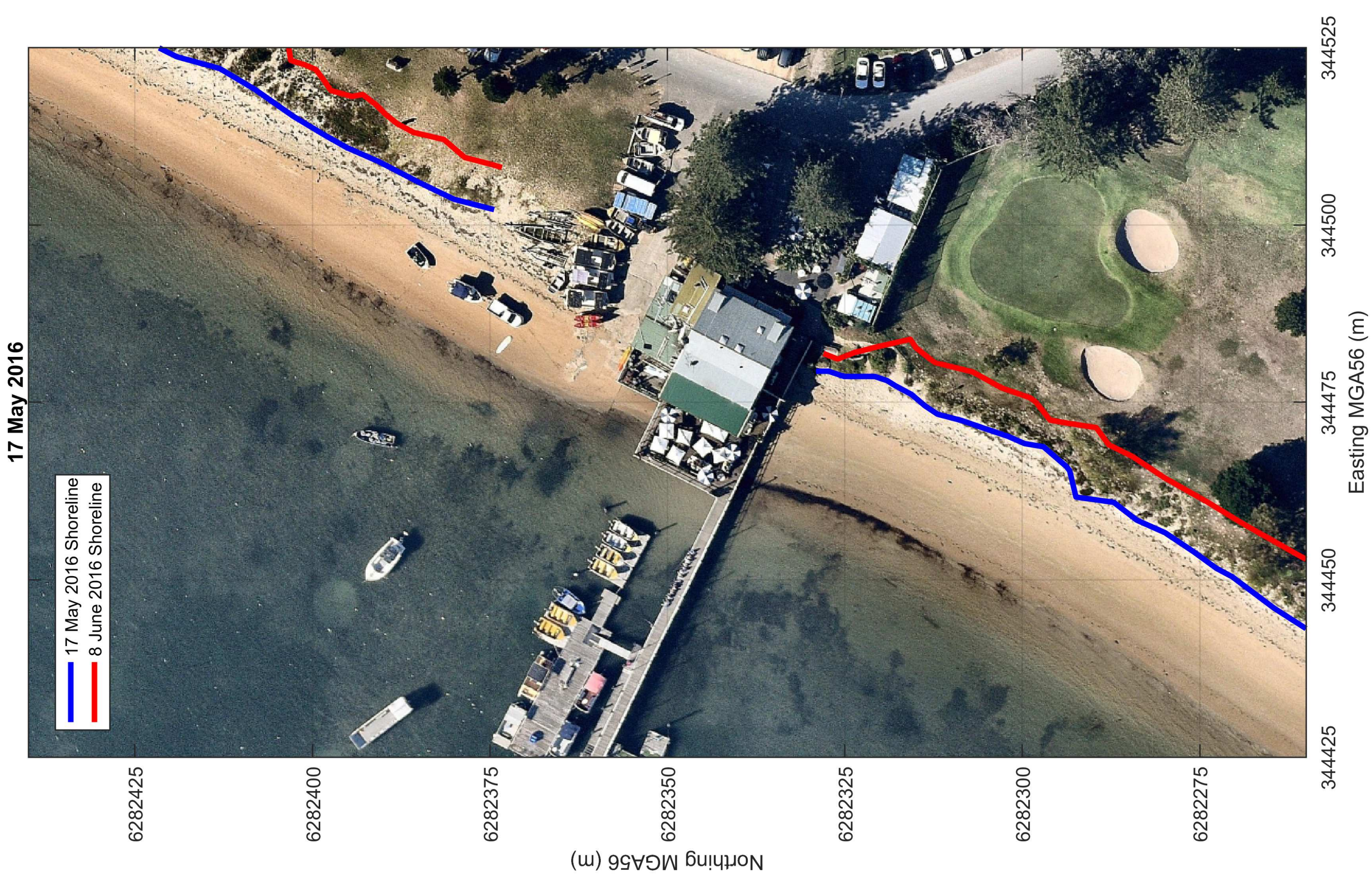
Estuarine Risk Management Report
Stepped Block Wall
Pittwater

Figure 2.5





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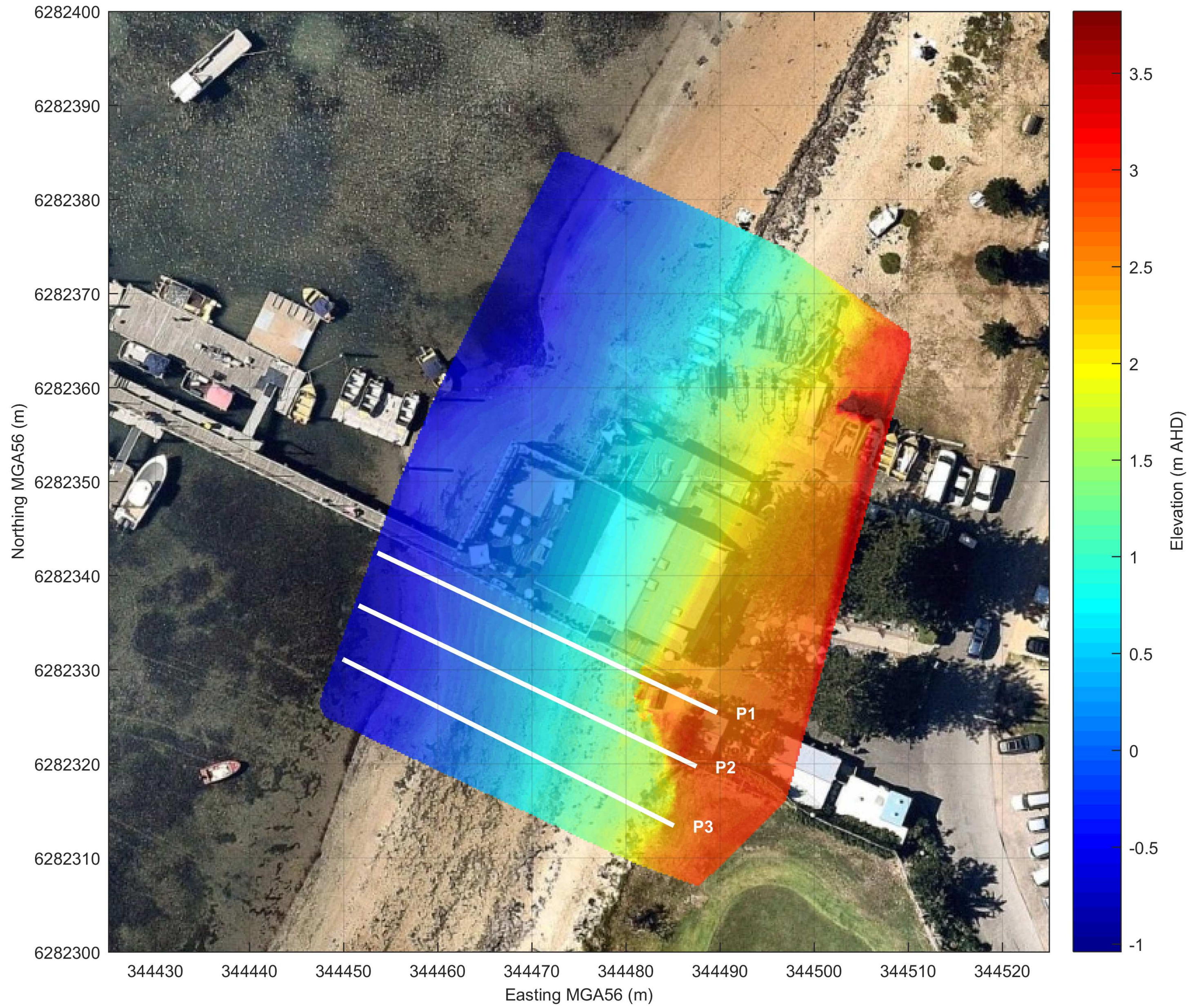
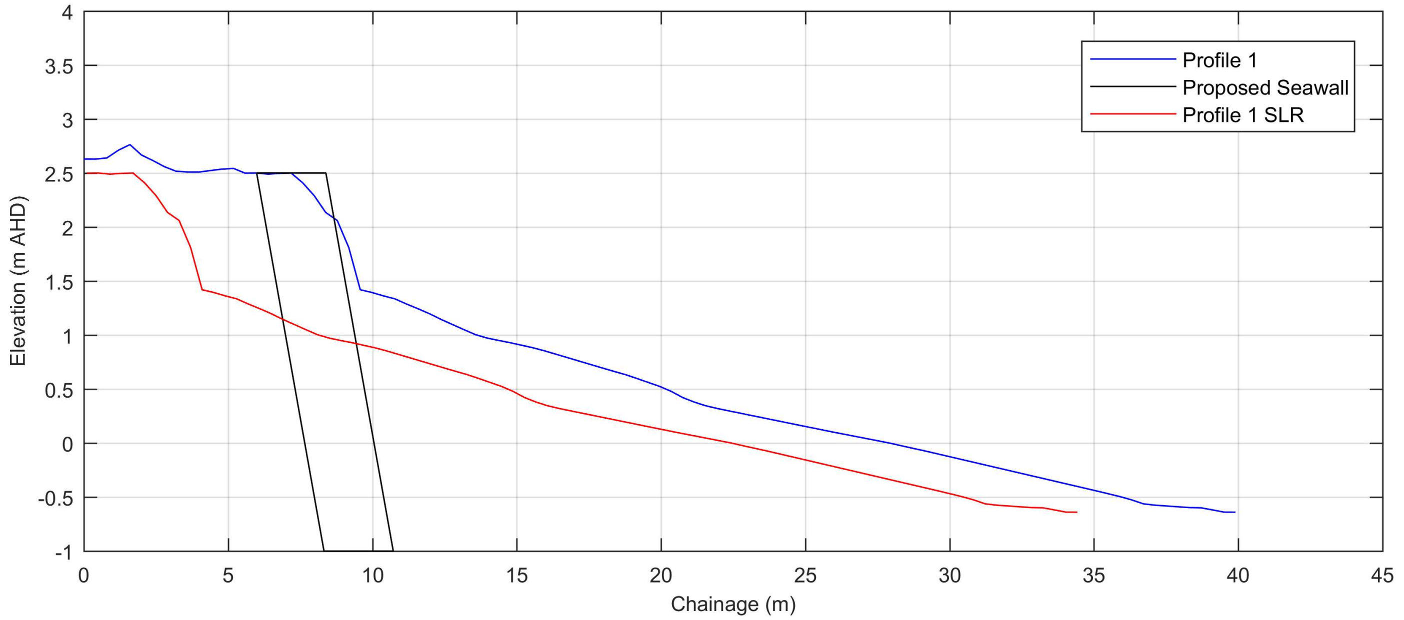
Shoreline Erosion Incurred During the 2016 East Coast Low Event

Figure 2.6





Estuarine Risk Management Report

Proposed Seawall (Cardno) and Beac Profile

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Figure 2.7