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GEOMORPHIC IMPACT ASSESEMENT

Astoria Group Pty Ltd

martens consulting engineers

Geomorphic Impact Assessment For Proposed Seawall, Arrawarra Caravan Park, Arrawarra, NSW.

ENVIRONMENTAL

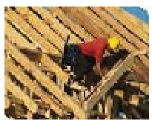
WATER

WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT MANAGEMENT



P0601565JR01_v3
January 2007

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Document and Distribution Status

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Revision No.	Status	Release Date	Document Location					
			File Copy	MA Library	Client	Void	Void	Void
A	Final	24/1/07	1E, 1P		1P			

Distribution Types: F = Fax, H = hard copy, P = PDF document, E = Other electronic format. Digits indicate number of document copies.

All enquiries regarding this project are to be directed to the Project Manager.

Contents

1 Introduction

1.1 Background

The Arrawarra Caravan Park, Coffs Harbour, NSW, is situated on a prograding barrier at the confluence of Arrawarra and Yarrawarra Creek, which flow directly into the ocean. The system made up by the immediate area is known as a wave dominated estuary and thus is an environmentally sensitive and ecologically significant part of the coastal setting.

The Caravan Park is currently partially protected by a poorly designed and degraded, variable height vertical rock gabion sea wall.

This report discusses the current site geomorphic setting, the geomorphic risks to the site and the current impacts of the existing sea wall. The need for a seawall will be established and suitable environmental protection requirements are provided.

1.2 Development Proposal

Astoria Group Pty Ltd proposes to extend and repair an existing sea wall at Arrawarra Caravan Park (Lot 12 DP 835612 and Lot 1 DP 789002) (the 'site'). The proposed development design by de Groot & Benson Pty Ltd is shown in Attachment A. Features of the proposed sea wall are summarised below;

- CH 0 - 25 – Scour protection involving rock over filter fabric to protect zone from ongoing scour caused by stormwater pipe.
- CH 25 – 120 – Rock rubble sea wall, slope 1:2 (1:1 maximum) with a concrete path on top. Riparian bank vegetation on the top of the bank is retained and larger boulders are placed at the toe to prevent scour. Seawall approximately 3.0mAHD in height.
- CH 120 – 130 – Only large boulders placed at bottom of banks as toe protection to reduce undercutting. Swamp Mahogany and Figs to remain.
- CH 130-180 – Rock rubble sea wall with a slope of 1:1. Large boulders placed at the toe.
- CH 180 – 210 – Rock gabions to be retained with selected large boulders at the toe. Rock rubble sea wall to continue to a height of approximately 3.0mAHD.

- CH 210 – 380 – The existing gabion sea wall is to be retained and maintained.

- CH 380 – 480 – Existing riparian vegetation at creek edge to be retained. Toe protection by large rocks will be used in between vegetation where erosion is evident.

We understand that the sea wall works are intended to stabilise the Yarrawarra and Arrawarra Creek banks which form the northern, eastern and southern boundaries of the caravan park.

1.3 Existing Sea wall

The current revetment structure is made up of rock gabion baskets that extend from chainage 175m to 380m. This wall has begun to deteriorate and in some places has completely corroded freeing rip rap. Some warping and settlement is also occurring as a result of wave attack sediment redistribution at the wall toe and tidal influences.

Minor bed sediment erosion (toe scour) was observed along parts of the gabion wall particularly along the eastern boundary where Arrawarra Creek flows entirely along the wall. Small bed scour pools were observed at each end of the existing wall, notably on the Arrawarra reach. Scour behind the existing gabion wall was observed between chainages 175 to 210. Erosion is localised and no impacts were observed at distance from the existing sea wall. However, erosion indicates that the present wall will need to be replaced sometime in the near future.

2 Site Description

2.1 Location

Arrawarra Caravan Park is located on Arrawarra Beach Road, Arrawarra. The site is situated on the southern end of Corindi Beach at the confluence of Arrawarra Creek, to the south, and Yarrawarra Creek, to the north, 30km north of Coffs Harbour (SMEC, 2003). Arrawarra Creek then flows into the Pacific Ocean some 200m further downstream.

Yarrawarra Creek has the smallest catchment area of the two, totalling 842 ha. This area includes a swampy / wetland zone located upstream behind the sand dunes of Corindi Beach. There are two smaller tributaries which join Yarrawarra Creek in the south east at chainage 40 metres. The Arrawarra Creek catchment has a total area of 925 ha which is well-vegetated with little urban development. Together these areas have evolved into a complex estuarine environment.

2.2 Geomorphic Context

2.2.1 Historical Investigation of gradual imperceptible change / catastrophic change

A historical analysis of air photos was conducted by Martens and Associates (2006) in order to establish whether gradual imperceptible change / catastrophic change to the creek bank position had occurred in the past 60 years. Air photos from 1994, 1984, 1976, 1964 and 1956 were analysed using a CAD software system. Control points were established and an attempt to rectify photographs was made. The rectification process proved difficult due to some photogrammetric distortion. It was therefore not possible to accurately determine the amount of land gained or lost over time. However, our somewhat more subjective view on the matter on the basis of visual assessment of aerial photographic sequence available as follows:

1. There is likely to have been a reasonably rapid shift in creek bank position on the Yarrawarra creek side of the park.

2. There is unlikely to have been a reasonably rapid shift in creek bank position on the Arrawarra creek side of the park. The creek bank here appears to be relatively mobile and appears to be dominated by a significant and shifting sand deposit. The historical aerial photographic analysis did not reveal any

significant creek bank vegetation on this side of the park which had been 'suddenly' removed.

2.2.2 *General*

The Arrawarra estuary is wave dominated where the central basin between the inner and outer barrier has been infilled by sediment derived from both catchment and marine sources. Wave-dominated estuaries occur on exposed coastlines with a relatively small tidal influence (Roy *et. al.*, 2001). The outer barrier (supra-tidal barrier) creates a constricted entrance that allows exchange of water between this central basin and the sea. At the head of a wave dominated estuary is a fluvial bayhead delta that extends into the central basin and is constructed from terrigenous material from the catchment deposited at the river mouth.

The evolution of wave dominated estuaries is characterised by infilling of the central basin (Roy *et. al.* 1980). As they evolve and 'mature' a flood tide delta propagates landward while the fluvial bayhead delta propagates seaward (Roy, 1984). Flood tide deltas are typically found in the entrances of wave-dominated estuaries, adjacent to the barrier and are formed by the redistribution of sediment by tidal flows. Sediments usually comprise of moderately to well-sorted quartz-rich sand and both flood and ebb-orientated bedforms can occur.

When given sufficient time and constant sediment supply, wave dominated estuaries have the potential to evolve into wave dominated deltas (Heap *et. al.*, In Press). This occurs when the central basin is completely infilled and terrigenous material is exported directly to the ocean rather than being trapped. The entrances of wave dominated deltas are relatively narrow due to constriction by the outer barrier and, due to the high river influence, are rarely closed. During the later stages of evolution this tidal inlet increases, allowing more efficient delivery of fluvial sediment. Remnant central basin features then slowly infill and become swamp areas. As a consequence the overall gross morphology of wave dominated deltas are relatively stable and may persist over long periods of time with little change (Heap *et. al.*, In Press).

2.2.3 *Geomorphic Features*

At present, the high degree of sediment infilling of the Arrawarra Estuary indicates that it is mature, demonstrating characteristics typical of a wave dominated estuary nearing a wave dominated delta. A geomorphic plan and sedimentary section of the Arrawarra Estuary are provided in Attachment B where a 1x1 km area has been used to define the local 'study area'. The Arrawarra Caravan Park currently exists on an Inner 'prograding' Barrier made up of sands and other sediments dating at least back to the Pleistocene. According to Roy and Thom (1981), Inner Barriers are characterised by the tendency of sediments to weakly cement together and discolour to greys and browns. This together with its rock-like character leads to its common name *coffee rock* and, during recent site inspections was observed to be exposed along the right bank of the Yarrawarra Creek.

The separation of this Inner barrier with the present Outer Barrier has formed the extensive estuarine channel system between them (Roy and Thom, 1981) containing mudflats, saltmarsh and mangrove habitats.

The zone immediately upstream and downstream of the Arrawarra/Yarrawarra Creek confluence is dominated by a flood tide delta. In the case of this site, this tidal impact has been considerably reduced due to a large deposit of sand at the Creek mouth blocking the tidal inlet.

2.2.4 Geomorphic Map

A geomorphic map of the 1km² study area was devised on the basis of the 1994 and 2002 aerial, photographs, site inspection and available geotechnical data. A geomorphic map and sedimentary section are provided in Attachment B. This shows locations of geomorphic units characteristic of this type of estuarine environment. Table 1 below summarises geomorphic units for the study area.

Table 1: Summary of geomorphic units found in study area.

Units	Area (ha)	Location	Function/Description
Inner Barrier (Bi)	16.00	Landward of outer barrier systems	Build up of sand sediments dating back to the Pleistocene which have begun to cement and form coffee rock. Often well vegetated.
Floodplain silts and swamp deposits (FP)	34.00	Between the inner and outer barrier system	Formed by infilling of the original central basin. Deposited marine and terrigenous material creating estuarine habitats.
Flood Tide Delta (FTD)	4.00	Entrance of the estuary	Formed by redistribution of sediment by tidal movement and waves in and out of entrance – mainly quartz rich sand. Currently blocking tidal flow to creek.
Basin (B)	2.00	Area between inner and outer barrier	Forms between inner and outer barrier. Low energy environment with organic rich sands and muds, infauna, epifauna and no vegetation.
Intertidal Flats (IT)	1.20	Flat, saturated parts of central basin (from mean sea level to mean high water spring elevations)	Environment supports habitat such as mangroves, saltmarsh and mud flats. Concentrations of organic material is high. Has a high degree of productive flora and fauna communities.
Outer Barrier (Bo)	14.00	Landward of the active shoreface. Constricts entrance to creek mouth	Consists of vegetation, a berm and dunes. Intermittently closes estuarine environment and allows for sediment infilling.
Rocky outcrop (RO)	2.00	South east headland of study area	Exposed rocks with shallow soils supporting heath and scrub vegetation.
Active Shoreface (AS)	11.00	In front of the outer barrier system and flood tide delta	Active deposition and erosion of marine sediments by wave and tidal action. Very little impacts by ebb tides.
Bar (BR)	0.25	Offshore, parallel to the active shoreface.	Deposition of sand offshore by littoral drift.
Ocean (O)	16.00	-	-

2.3 Wave Climate

The east coast of NSW comes under the east coast swell wave climate (Short, 1999). This zone receives waves from five sources, a number of which directly affect the Coffs Harbour region.

The most significant of these sources are east coast cyclones and tropical cyclones. On average, approximately ten east and south-east coast cyclones per year produce the highest waves arriving as sea, and then as swell from the east, while three to four north east tropical cyclones a year produce moderate to high east coast swell conditions in late summer. Other sources include easterly winds, produced by the dominant sub-tropical high pressure system, producing short easterly waves; and summer north-east sea breeze winds which produce short, steep waves on 40% of summer days.

Based on data obtained from the Bureau of Meteorology and GPATS, The Weather Co. (2005) state the mean significant wave height for northern NSW is approximately 1.1m with a peak wave period of 8 seconds from the south east.

We note that this site is exposed to significant wave energy during high storm events. This is particularly the case at the east and south east portion of the site. Wave attack can result in a number of significant site impacts such as:

- Loss of current sea wall
- Coastal retreat
- Foreshore scour
- Vegetation loss

We have classified risk zones for the park. These are presented in Attachment B. We consider that the risk of wave attack in these areas is moderate to high.

2.4 Tides

The Coffs Harbour region experiences ocean tides close to that of the Sydney region, with an average high tide of approximately 1.15 ISWL and an average low tide of approximately 0.6 ISWL (Bureau of Meteorology, 2006). Estuaries, being considerably smaller bodies of water, do not produce a response to astronomical forcing, however when connected to the sea, tidal currents of the deeper ocean which enter and leave the region force tidal movement (Tomczak, 2000). These tides are known as co-oscillation tides. Co-oscillation tides have a phase and amplitude close to that of the deep ocean tides, however due to flow constriction by outer barriers or flood tide deltas tides are often attenuated. As a further consequence of this constriction, tidal flow within an estuary may be moderate to stronger than usual ocean tides as flow is forced to rush through the narrow tidal outlet (Tomczak, 2000).

In the case of the Arrawarra estuary, the impact of ocean tides is considerably reduced due to the large sand deposit formed by the flood tide delta and outer barrier. This significantly reduces tidal inflow to the estuary. Minor tidal bed forms were observed within the creek bed, although recent site inspection revealed no significant ebb tidal features. This has created a low energy environment, particularly in the middle of the estuary.

2.5 Flooding

Both rainfall and heavy seas may affect flooding in the Arrawarra/Yarrawarra Creek (SMEC, 2003). These two factors are not necessarily independent from each other as both can occur from the same weather system. Intense low pressure systems offshore are the mechanism driving large amounts of moist air, and hence heavy rainfall, to the coast. However, heavy rainfall can occur without the occurrence of heavy seas (SMEC, 2003). Historical records indicate that six out of the ten most severe rainfall events at Arrawarra since 1940 were coincident with heavy seas. However, some of the most severe storm events recorded on the north coast of NSW were not associated with highest ranked rainfall event (SMEC, 2003).

To date, a maximum observed flood level of 2.6mAHD at the eastern boundary and 2.7mAHD at the northern boundary has been recorded (Umwelt, 2003).

A 1 in 100 year ARI flood study has been undertaken by SMEC (2003). Although unlikely, modelling was carried out with the 1:100 year ARI rainfall event occurring simultaneously with the maximum significant ocean wave height. The modelling indicated that the key determinant of flood level is wave height generated by storm surges, which may result in a peak tailwater level of 3.0mAHD adjacent to the site. A simultaneous peak discharge event would increase flood levels to 3.02mAHD.

The Arrawarra Caravan Park site is relatively flat with levels over the site vary from 4.5mAHD to approximately 1.2mAHD. These results indicate that flooding may cause the partial inundation of the site. However, this will generally be restricted to times of high tailwater conditions (SMEC, 2003).

We note that the northern portion of the park is exposed to considerably high flow velocities during high stage flooding. This has already led to bank erosion and undercutting. Our view is that the northern portion of the park is under active erosion pressure. The high risk zones have been delineated in Attachment B. Bank support works are required in this zone to ensure that further catastrophic as well as gradual bank retreat is prevented and the park is secured.

2.6 Sedimentology

Geotechnical investigation carried out by de Groot & Benson Pty Ltd (2006) found the soil profile along the creek banks to be reasonably consistent. The general profile is predominately alluvial sand above 0.5mAHD over residual clays. This sand, specifically, is fine to medium sub-angular dune and beach sand.

Along Yarrawarra Creek, the exposed bank shows a fractured band of Coffee Rock between 1.5mAHD and 0.5mAHD, typical of Pleistocene deposits making up an Inner Barrier. This rock was found to be only weakly cemented (de Groot & Benson Pty Ltd, 2006).

The underlying clay was found to either be residual or ancient alluvial in deposition and light to dark grey of medium to high plasticity. A thin zone of soft super-saturated clay lies immediately below the sand; however underneath this the clays were well consolidated. No underlying rock exists within the profile and so must exist below -3.0mAHD (de Groot & Benson Pty Ltd, 2006).

Channel bed sediments were generally observed to consist of fine to medium grained sands and silty clays. Specifically, the creek bed comprises of loose alluvial sands below which the surface 0.5m of underlying clay is soft, however these stiffen with depth (de Groot & Benson Pty Ltd, 2006). Some surface organic sands were observed in low energy portions of the site.

Geotechnical information for the study site is summarised below in Table 2.

Table 2: Summary of geotechnical testing within Arrawarra Caravan Park Site.

Elevation (mAHD)	Description	Consistency / Density
0.5 to 4.0	Alluvial sands	Fine to medium sub-angular dune/beach sand. Loose to medium density with some silt and clays.
0.5 to 1.5	Coffee Rock	Discontinuous weakly cemented indurated sands. Deposits from the Pleistocene.

0.5 to 0.0	Super-saturated clays	A thin zone of soft and unconsolidated clays immediately below sand. Variable thickness
0.0 to -0.5	Soft to fine clays	Well consolidated, medium to high plasticity with depth.
-0.5 to -1.0	Stiff clays	Dark grey clays with increasingly red mottling and stiffness with depth.

2.7 Water Quality

Visual inspection suggests water quality conditions are generally good with perhaps some stormwater pollution. We understand from the NSW EPA (2004) that previous monitoring of the area indicated that the creek passed the swimming water quality guidelines only once in the seven months of the 2002-2003 swimming season. Elevated bacterial levels were routinely measured at the site and, although the source of pollution was inconclusive, levels were at their highest during rainfall events. This suggests the source of contamination was related to wet weather such as urban stormwater runoff (EPA, 2004).

Offshore storm events producing large swell conditions causes the deposition of large quantities of sand onshore. This occasionally results in sediment closing the mouth of the estuary to tidal flows which may subsequently cause periods of extremely low water quality in Arrawarra Creek, particularly during summer months (DNR, 2006). Recent site inspections showed the creek mouth to be closed and revealed algal blooms along Arrawarra Creek indicating elevated levels of nutrients and water temperatures.

2.8 Riparian Vegetation

A significant portion of the Arrawarra/Yarrawarra Creek banks are presently protected by the existing rock gabion sea wall. Chainage 0 – 170 and 380 - 480 is currently either unprotected, or protected by either bank vegetation or, to a lesser degree, toe coffee rock exposures.

We understand that a number of the riparian trees have ecological value. These include Swamp Mahogany (*Eucalyptus robusta*), Broad-Leaved Paperbark (*Melaleuca quinquenervia)*, Swamp Oak (*Casuarina glauca*) and Figs *(Ficus sp.)*. Due to local disturbance, much of the riparian vegetation has been taken over by weed species, namely Lantana, and introduced grasses (Eco logic Australia Pty Ltd, 2006).

Field investigations revealed that a number of these trees are slumping and are in danger of falling into the creek. This indicates that these zones are experiencing bank undercutting, slope instability and erosion caused by fluvial impacts on the channel banks. As shown on the Risk map appended in Attachment B, these unprotected zones are under a moderate risk of erosion caused by fluvial impacts.

2.9 Habitat

Wave dominated deltas, such as the Arrawarra Estuary, typically support 'euryhaline' esturine species as well as transient visitors from marine environments. The high energy environment is dominated by habitats such as intertidal mudflats, salt marshes and mangroves (Roy *et. al.*, 2003).

The most common aquatic environment within the study site is sand and mud flats. These support a diverse assemblage of benthic invertebrates which inturn support a range of fish and wading birds (Eco Logic Australia Pty Ltd, 2006). The mud flat ecosystem thus forms an important part of the local food chain.

Mangrove and saltmarsh vegetation also occur in the immediate site area. Recent site inspections by Ecologic Australia (2006) demonstrated that these two vegetation types provide an important habitat for a range of aquatic fauna including fish, crustaceans, molluscs and act as a feeding ground for wading birds. Mangroves and saltmarsh also act as an important buffer and filter within the environment for sediments and nutrients, and contribute a large amount of organic matter to the system (Eco Logic Australia Pty Ltd, 2006).

The site also contains a number of instream habitats within Arrawarra and Yarrawarra Creeks. These include large woody debris, rocky and sandy channel beds and scour pools and are most prevalent along the southern bank of Yarrawarra Creek (Eco Logic Australia Pty Ltd, 2006). These areas often become a refuge for fish and other organisms during periods of low flow, as well as a substrate for colonisation and providing shelter.

The vegetation structures within the caravan park lack structural complexity and so have a relatively low habitat value. Remnant trees, particularly Swamp Mahogany (*Eucalyptus robusta)* could potentially provide an important food source to birds and mammals, particularly over winter whilst they are flowering. Vegetation to the north, south and east of Arrawarra Creek is structurally more diverse and are so more likely to provide habitat for terrestrial fauna (Eco logic Australia Pty Ltd, 2006).

2.10 Coastal Morphodynamics

Coastal morphodynamics involves the interaction of waves, tides and currents with coastal topography involving sediment transport (Short, 1999). In the case of the Arrawarra estuary, the interaction of coastal, estuarine and fluvial processes have resulted in the formation of current morphology. The following brief comments are made in relation to coastal morphodynamics:

- The estuary is nearing 'maturity' being largely infilled by a significant flood tide delta. This process is continuing.

- Coastal processes largely dominate over fluvial processes in the eastern portion of the site. At present, further southward barrier progression is restricted due to the Arrawarra headland which acts as a local structural control. The eastern portion of the site is at the greatest risk of coastal retreat during high wave energy events.

- Fluvial processes largely dominate over the south-western and northern portions of the site. Bank erosion along the northern portion of the site is generally attributed to southward meander progression of Yarrawarra Creek. This process will continue unless structural bank protection is provided.

2.11 Geomorphic Hazard Assessment.

Our assessment of geomorphic hazards at the site has been used to prepare a risk zonation plan to be prepared which shows those areas of the site most at risk of erosion. In particular;

- The eastern site boundary is highly exposed and thus may come under threat of wave attack.

- The south eastern boundary is moderately exposed and thus may come under threat of wave attack.

- The northern boundary is directly impacted by the tides, currents and flooding of the Yarrawarra Creek.

These geomorphic hazards pose a potential threat to the site, the property on the site and, potentially, the residents and visitors of the site. If these hazards are not dealt with there is potential for the following consequences;

- Minor to large scale erosion of the site boundaries,

- Increased sedimentation of the Arrawarra and Yarrawarra Creek,

- Bank failure of the northern and southern boundaries,

- Loss of riparian species,
- Coastal retreat of the site,
- Loss of land,
- Loss of property,
- Loss of life.

It is our view that there is a need for a revetment structure at the site in order to protect existing site boundaries from wave attack and fluvial erosion. The erosion that is currently occurring at the site indicates that the present sea wall structure is not fulfilling this role.

3 Impact Assessment of the Proposed Seawall.

3.1 Overview

An impact assessment of the proposed sea wall works has been conducted. This has been separated into various potentially impacted elements, and covers both short- (construction) and long-term impacts. Suitable mitigation measures are provided to ensure that any potential impacts are negligible.

3.2 Wave Climate

Sea wall structures have been, in some instances, associated with a number of impacts affecting wave climate (Short, 1999). This often comes about due to poor design leading to low energy absorptivity and high reflectivity. Such impacts are manifested in terms of, for example, increased wave reflection, refraction, increased wave runup and decreased energy dissipation. Table 3 summarises potential impacts of the proposed seawall on wave climate.

Table 3: Assessment of short and long-term impacts on local wave climate.

Impact	Short term	Long term	Comment / Mitigation Measures
Increased wave and energy reflection / refraction	na	Possible	Potential impacts are mitigated through the following design objectives: o Use a max wall grade of 1:1 o Use high porosity wall design (rock rubble) o Use semi-flexible wall design (rock rubble) o Use large, angular rocks at base to promote energy dissipation at wall
Increase wave runup and overtopping	na	Possible	Potential impacts are mitigated through the following design objectives: o Use a max wall grade of 1:1 o Use high porosity wall design (rock rubble) o Use semi-flexible wall design (rock rubble) o Use large, angular rocks at base to promote energy dissipation at wall

3.3 Tidal Currents

Sea walls can lead to a range of impacts on tidal behaviour. Primarily, decreased bank roughness and removal of bank vegetation can result in accentuation of tidal flow velocities around sea wall structures. In the case at this site, tidal ebb flow channels are already presently reinforced due to the near vertical and smooth existing wall surfaces.

Construction of the proposed wall would mitigate against some of the existing impacts. Table 4 summarises potential impacts of the proposed sea wall on tidal currents.

Table 4: Assessment short and long-term impacts on tidal currents.

Potential Impacts	Short-term	Long-term	Comment / Mitigation Measures
Reinforcement of tidal currents	na	Possible	Potential impacts are mitigated through the following design objectives: o Use a max wall grade of 1:1 o Use a high roughness wall to reduce near-shore ebb flow tidal current velocity o Use of irregular (non-linear) wall design to promote roughness and sedimentation

3.4 Groundwater

Impermeable or semi-permeable sea walls can result in elevated groundwater levels in retained land materials. This results in increased positive backfill / soil pore water pressures leading to increased wall degradation due to sediment losses where sediment barrier mechanisms (eg. geotextile layers) are imperfect. Table 5 summarises the potential impacts of the proposed sea wall on local groundwater levels.

Table 5: Assessment short and long-term impacts on groundwater levels.

Potential Impacts	Short Term	Long Term	Comment / Mitigation Measures
Increase groundwater levels and positive soil pore pressures.	na	Possible	Potential impacts are mitigated through the following design objectives: o Use a porous wall design o Use geotextile to prevent sediment loss o Implement drainage structures

3.5 Flooding

Sea walls can lead to a range of impacts on flood levels. Primarily, decreased bank roughness and removal of bank vegetation can result in increased flood levels and flow velocities around the wall. An assessment of the potential impacts of the proposed seawall on flooding has been carried out. The results are displayed in Table 6.

Table 6: Assessment short and long-term impacts on flood behaviour.

Potential Impacts	Short term	Long term	Comment / Mitigation Measures
Increased flow velocity	na	Possible	Potential impacts are mitigated through the following design objectives: o Use a max wall grade of 1:1 o Use a high roughness wall to reduce near-shore flow velocity o Use of irregular (non-linear) wall design to promote roughness and sedimentation

3.6 Water Quality

Sea walls and revetment structures have been associated with a range of water quality related impacts. These come about primarily through work associated with the construction phase and are manifested in terms of increased turbidity immediately adjacent to the wall, suspension of sediment and altered circulation patterns. We have undertaken an assessment of potential impacts of the development proposal on water quality in Table 7.

Table 7: Assessment short and long-term impacts on local water quality.

Potential Impacts	Short term	Long term	Comment / Mitigation Measures
Increased turbidity adjacent to wall	Possible	na	Sediments are generally coarse grained and turbidity effects are unlikely.
Re-suspension of bed sediments	Possible	Possible	Potential impacts are mitigated through the following design objectives: o Use a max wall grade of 1:1 o Use a high roughness wall to reduce near-shore flow velocity o Use of irregular (non-linear) wall design to promote roughness and sedimentation
Altered circulation patterns resulting in redistribution of aquatic food	Minor	na	There should be no significant changes to current circulation patters

3.7 Creek and Estuarine Morphology

Sea walls have been associated with a number of geomorphic impacts relating specifically to creek and estuarine morphology. These may arise through construction related impacts or changes to local wave and current climates, and are manifested in terms of, for example, increased erosion at the base of the wall (toe scour), soil loss behind the wall and, in extreme cases, a complete loss of the beach face. Table 8 summarises potential impacts of the development proposal on morphology.

Table 8: Assessment short and long-term impacts on morphology.

Potential Impacts	Short term	Long term	Comment / Mitigation Measures
Toe scour	na	Unlikely	The risk of toe scour is considerably reduced from the present given the selected design approach. Potential impacts are mitigated through the following design objectives: o Use a max wall grade of 1:1 o Use a high roughness wall to reduce near-shore flow velocity o Use of irregular (non-linear) wall design to promote roughness and sedimentation
Soil loss behind wall	na	Unlikely	See above.
Loss of beach face	na	na	No substantial existing beach exists adjacent to the proposed wall.
Acid Sulphate Soils (ASS) impacts	na	Possible	Prepare a suitable management plan for areas where ASS are likely to be disturbed by construction activities.
Creek bed erosion	na	na	In some instances, creek bed erosion (lowering) could occur under poor construction methodologies where creeks are considerably narrowed by a sea wall and flow is substantially constricted. This is not the case for this proposal. Creek bed erosion is not likely to occur as a consequence of the development proposal as channel dimensions remain unaltered.
Erosion on opposite bank	na	na	Where wave reflection or current deflection is significant, erosion on the opposite bank could occur under adverse conditions. At this site, this is unlikely given that such impacts are not presently manifest for the existing vertical gabion structure. Wave heights within the estuary are very low and travel distances are generally long (> 50 m) over very shallow water. Such conditions promote considerable wave and energy attenuation.
Change to bed sediment character	Minor	na	During construction, minor disturbances to bed sediments may occur through the placement of boulders. However, we understand that minimal excavation works will be undertaken during the construction process. On this basis, we do not see any significant impact on bed sediment character.
Habitat loss	na	na	We understand that no significant habitat is expected to be lost as a result of the proposed works. In fact, habitat will be created or enhanced where the existing sea wall is replaced by placed rock rip-rap, providing hollows and cervices for habitation.

3.8 Impact Summary

The proposed sea wall modifications and improvements will generally only result in some short term impacts during the construction phase. Table 9 summarises the potential impacts of the Arrawarra sea wall by chainage and the mitigative measures to prevent these impacts from occurring. The approach represents current best practice.

Table 9: Summary of potential sea wall impacts on site

Chainage (m)	Wall type/ Description	Reason for seawall	Key potential impacts	Mitigating measures
0-25	Rock over filter fabric	Scour protection from stormwater pipe.	na	na
25-120 and 130-180	Rock rubble wall over filter fabric.	Creek bank protection from erosion and undercutting, preservation of riparian species, prevention of toe scour.	Reinforcement of tidal flow along creek and increased flow velocity, increase positive pore pressure and groundwater level, creek bed erosion, erosion on opposite creek bank.	Design ensures impacts will not occur by implementing design objectives such as o A porous design with high roughness o Drainage structures o A max wall grade of 1:1
120-130	Large boulders at bottom of bank.	Prevent toe scour, provide bank support, and retain riparian species.	na	na
180-210	Current gabions retained, large boulders placed at toe, rubble wall increased in height.	Added protection from wave attack, protection from toe scour and erosion.	Wave reflection and refraction, increased toe scour due to decreased wave dissipation, positive pore pressure, increased wave run-up and overtopping.	Design ensures impacts will not occur by implementing design objectives such as o A porous design with high roughness o Drainage structures o A max wall grade of 1:1 o Extra toe protection by large boulders.
210-380	Current gabion seawall retained and maintained.	Protection from erosion caused by fluvial influences.	Toe scour, wave run up and overtopping without construction of a larger wall.	None required. However, wall replacement and redesign is recommended to protect site.
380-480	Retain riparian vegetation and place larger rocks at base of banks where required.	Added protection from toe scour and undercutting where required. Allows the retention of important riparian species.	Tree slumping and bank failure, toe scour and undercutting.	o Continued maintenance and monitoring ensures areas experiencing erosion are given added protection.

4 Management

Several items will require careful management during and after the works. These are summarised in the following sections.

4.1 Acid Sulphate Soils

Acid Sulphate Solis (AAS) typically occur in low lying areas such as estuaries, tidal flats, mangroves and saltmarsh habitats, and remain inert while waterlogged and undisturbed. However, if exposed to air, they react with oxygen forming sulphuric acid (DEH, 2006). Construction work in coastal environments, such as dredging for seawalls, could disturb these waterlogged environments facilitating this conversion and creating acid sulphate run-off.

The disturbance of potential acid sulphate soils should be avoided as a key management strategy. If avoidance is not possible there are a number of common remediation strategies identified by the CSIRO (2003). These involve first containing the leachate within the soil profile or with barriers which allows for the management of leachate movement or discharge and for neutralisation to begin. Neutralisation can then happen in a number of ways and commonly includes methods such as bioremediation, sea water re-flooding, fresh water dilution or chemical neutralisation with lime.

In general the problems of AAS are more severe in northern NSW and Queensland than other parts of the east Australian coast (DEH, 2006). For this reason, management plans need to be put into place in order to mitigate against the impacts of AAS. According to the CSIRO (2003) all disturbances to groundwater hydrology or surface drainage patterns in coastal areas below 5mAHD should be investigated, designed and managed to avoid potential adverse effects from ASS.

The likelihood of ASS occurrence at a site is a function of various geomorphic parameters (ASSMAC, 1998). Such parameters and their presence at the site are listed in Table 10.

Table 10: Geomorphic site features indicative of ASS and their presence or absence at the site.

Geomorphic Feature	Present on site?
Holocene sediments	Yes
Soil horizons less than 5 m AHD	Yes
Marine / estuarine sediments or tidal lakes	Yes
Coastal wetland; backwater swamps; waterlogged or scaled areas; interdune swales or coastal sand dunes	Yes
Dominant vegetation is mangroves, reeds, rushes and other swamp or marine tolerant species	Yes
Geologies containing sulphide bearing material	Unknown
Deep older (Pleistocene) estuarine sediments	Yes

Six (6) of the seven geomorphic features listed are present on site. This indicates a likelihood that ASS may be present in the lower elevations of the site.

Analysis of the presence of ASS material on site was conducted by Coffs Harbour Laboratory (2006). Sediments from four boreholes taken at varying depths were tested for ASS or potential ASS material. Results from the 5 samples are summarised below in Table 11.

Table 11: Results of SPOCUS testing of five soil samples from the site.

Sample ID	Bore Hole	Sample Depth (mAHD)	pH_{KCL}[1]	pH_{OX}[2]	TPA (mol H+/t)[4]	TSA (mol H+/t)[4]	S_{POS} (%S oxidisable)[5]
4216/1	BH1	1.9 to 1.45	5.4	6.4	9.7	9.7	<0.01
4216/2	BH1	0.3 to 0.0	4.2	5.9	32.4	18.3	<0.01
4216/3	BH2	0.8 to 0.25	4.7	5.4	11.9	6.5	0.02
4216/4	BH3	0.1to -0.4	5.0	7.0	26.5	23.3	0.02
4216/5	BH4	0.3 to -0.15	6.8	7.3	17.8	17.8	<0.01

Note: [1] Actual pH; [2] Post peroxide oxidation pH; [3] Titratable Peroxide Acidity; [4] Titratable Sulfidic Acidity; [5] Percentage peroxide oxidisable sulfur.

Using pH_{KCL} and post peroxide oxidation pH_{OX} criteria (ASSMAC, 1998, p12) all soils with a pH_{KCL} of <4.0 are considered actual ASS. Soils with

pH_{KCL} > 4.0 and pH_{OX} < 3.0 are classified as potential ASS. On the basis of this classification system no site samples are classified as potential or actual ASS, although samples from BH1 (3.0-3.3m) and BH2 were slightly acidic. According to the Action Criteria (ASSMAC, 2000. pg 27) a management plan is required if peroxide oxidisable sulphur (S_{POS}) is greater than 0.06 % or total potential acidity (TPA) is greater than 36 mol H+/tonne for sandy loams to light clays. Testing indicates that these levels are not exceeded and therefore a management plan is not required. However if excavation below 0mAHD is to be undertaken then we would recommend additional ASS testing to confirm the absence or presence of ASS materials.

4.2 Construction Requirements

During the construction of the Arrawarra Caravan Park sea wall, minimal impact should be experienced by the surrounding environment and habitats. Critical aspects of in-channel construction should be undertaken during a forecasted dry period with low ocean wave activity to avoid impacts associated with floods and high wave conditions and during times of the year where terrestrial and aquatic organisms' feeding, breeding and migration habits are disturbed the least (for example when local migratory birds are not using the estuary for feeding) (Landcom, 2004).

The majority of the construction, particularly on the northern and southern boundaries will be occurring within the riparian zone. The Soils and Construction Handbook (2004) states that construction works within this zone should maximise retention of any native species and minimise site disturbance. The current sea wall designs require that a number of native riparian trees be removed from the northern boundary between chainage 30 and 180. These trees have slumped to the base of the bank and are in danger of falling into the creek so their removal is necessary. Vegetation on the top of the bank, however, will be retained in order to maintain a dense riparian corridor. Suitable planting techniques in this area should also maintain a healthy corridor and minimise long term disturbance.

During construction, stockpiles should be kept away from the intertidal zone to avoid damage by floods and high tides, and pollution of the waterways. This way local habitats, as well as equipment, are not damaged.

When dredging and other creek bank work is undertaken, sediment retention basins or silt curtains can be used to intercept run-off and retain most sediment and other materials, thereby protecting the area from pollution and reduced water quality (Landcom, 2004). In the case of the proposed sea wall at Arrawarra, the impacts of sediment re-suspension and soil erosion during construction should be minimal and short-term. However, minimising sediment pollution to the receiving waterways is still an important construction requirement.

It is an important requirement during the entire construction period that the natural passage of the waterway is maintained at all times to allow for water exchange and passage for fish and other aquatic organisms. This allows for natural water flow and for organisms to escape the disturbance and return when required for feeding or shelter.

When building the sea wall and placing toe support, natural and endemic rock should be used to promote the natural functioning of the environment (Landcom, 2004). This will also encourage crevasses within the wall and the rock surfaces to become habitat for local crustaceans, fish and molluscs. It will also make the revetment appear more natural and aesthetically pleasing.

4.3 Maintenance

The recommended rock rubble design is relatively inexpensive and simple to maintain, if constantly monitored. The most common reason for seawall repair and maintenance is due to rock settling and movement associated with wave and tidal action or toe scour.

Maintenance or repair often only requires replacement of displaced or sunken rock rubble. Continued replacement and repair within the structure and at the toe should maintain the integrity of the wall and the coastline it is protecting.

4.4 Monitoring

Continued monitoring is essential not only to preserve the integrity of the seawall but also the surrounding environment. Structural monitoring of rock displacement, settling and warping ensures the continual maintenance of the seawall. Particular monitoring of the toe of the wall will not only prevent scour but also the failure and seaward collapse of the wall.

Environmental monitoring is also essential in order to ensure the revetment structure is not negatively impacting on the environment. Impacts associated with the change in wave climate, water quality, sedimentology and habitat impacts should be monitored not only during the construction period but also on a long term scale to ensure impacts do not arise in the future.

5 Conclusion

The Arrawarra Caravan Park is at considerable risk of ocean and riverine erosion under extreme events. Although the site has not been subject to recent severe or catastrophic erosive events, there is evidence of current erosion taking place. Due to the exposed location of the site to oceanic processes and its proximity to riverine influences, such events are possible and thus works should be carried out in order to mitigated against any potential loss of property or life. The proposed sea wall design is sympathetic to the local environment and any potential impacts such a structure may have on the local estuarine environment have been mitigated. A summary of advantages of the sea wall is provided below.

- Protect boundaries from wave attack and fluvial influences,
- Prevent toe scour, erosion and subsequent bank failure,
- Prevent coastal retreat,
- Provide habitat and shelter,
- Help retain riparian species and prevent them from slumping into the creek,
- Prevent the loss of land, property and life.

6 References

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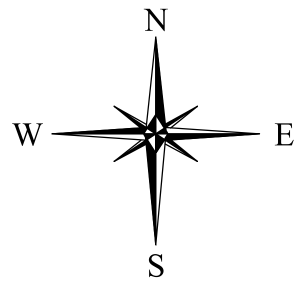
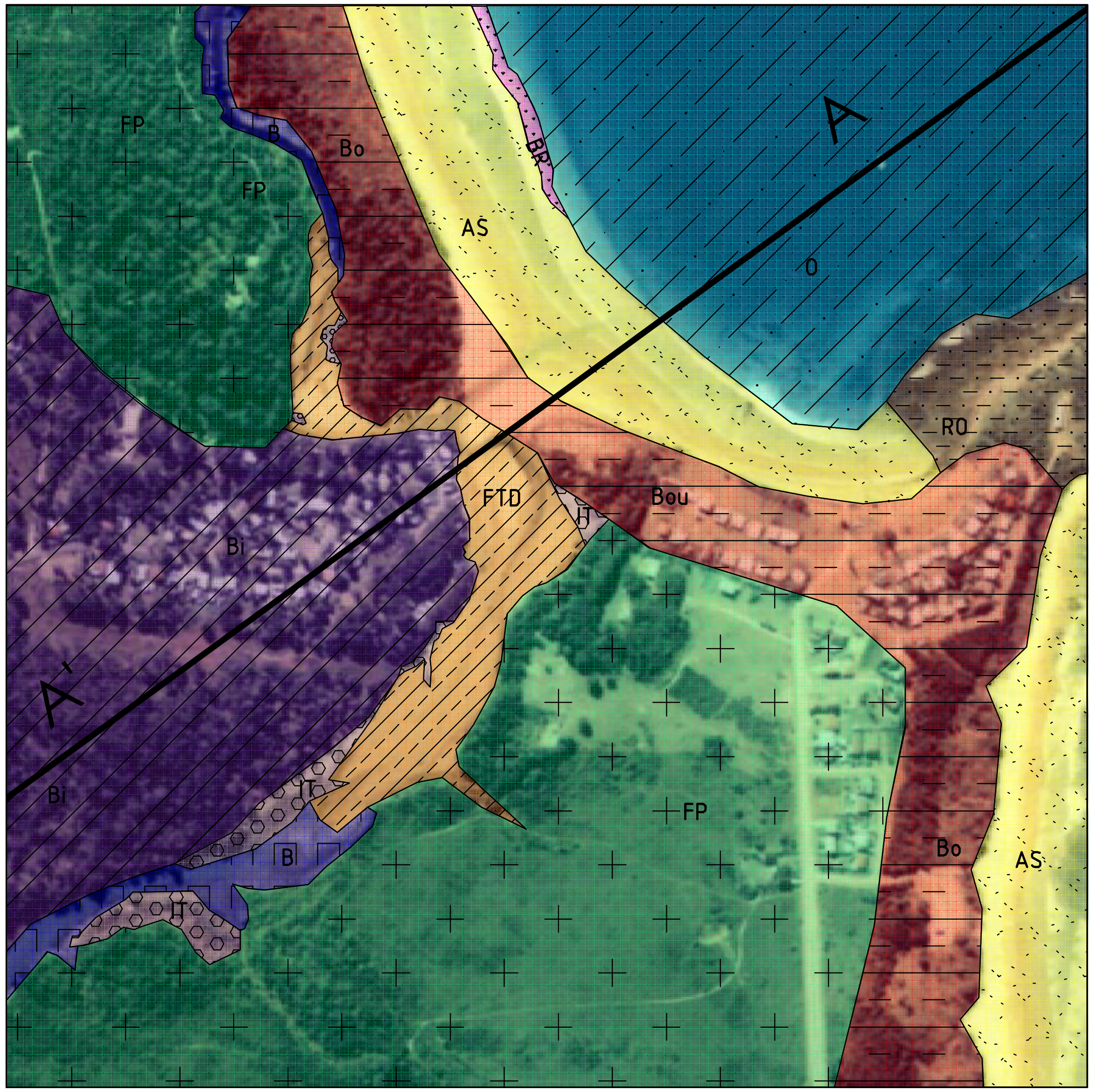
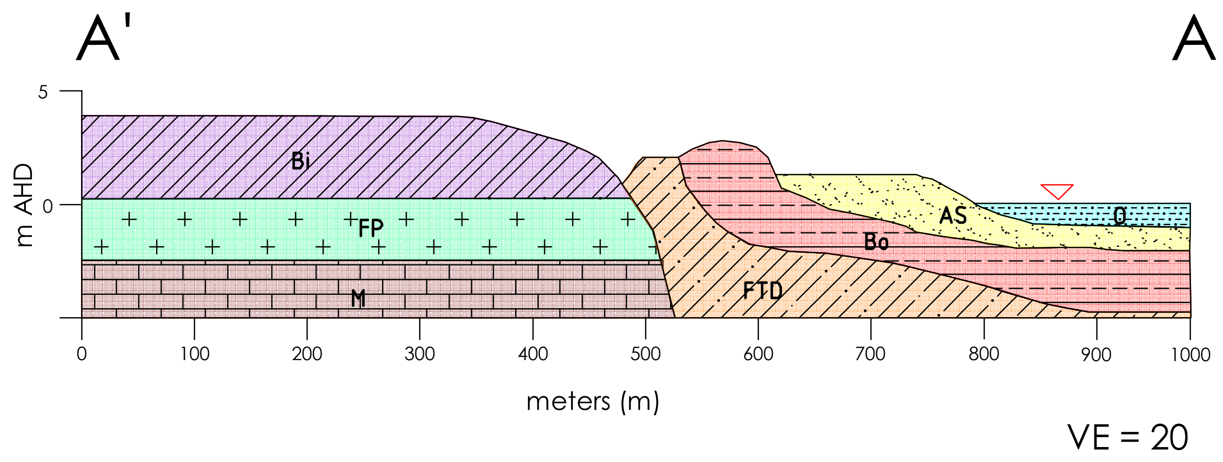
7 Attachment A – Geomorphic Map

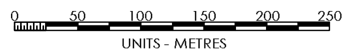






Key

- Site Boundary
- O Ocean
- FTD Flood Tide Delta
- BR Bar
- AS Active Shoreface
- Bo Outer Barrier
- B Basin
- FP Floodplain silts, swamp deposits
- RO Rocky Outcrop
- IT Intertidal Flats
- Bi Prograding Barrier
- M Estuarine Muds



Notes

Limitations:
-Based on 1994 Aerial and limited geotechnical information.

References:
- De Groot & Benson Pty Ltd, 2006. Geotechnical Investigation: Arrawarra Beach Caravan Park.
- Heap, A. D., Bryce S., and Ryan, D. A., (In Press).Quantifying the areas of geomorphic and sedimentary facies in Australian clastic coastal depositional environments:insights into the Holocene evolution of estuaries and deltas. Sedimentary Geology
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All measurements in mm unless otherwise specifiec.

TITLE
Geomorphic Map and Cross Section
Arrawarra Estuary

PROJECT MANAGER: Dr. Daniel M. Martens

DRAWING NUMBER: P0601565JD01_v1

DESIGNED: MLB	DATUM: AHD	SHEET 1
DRAWN: MLB	HORIZONTAL RATIO: 1:3000 @ A1 1:6000 @ A3	OF 1 SHEETS
REVIEWED: DMM	VERTICAL RATIO: 1:150 @ A1 1:300 @ A3	PAPER SIZE: A1 / A3

REV.	DESCRIPTION	DATE	ISSUED
1.0	Geomorphic study - Arrawarra Estuary	12.12.2006	DMM

8 Attachment B – Geomorphic Risk Map

Key

- High Risk - Wave Attack
- Moderate Risk - Wave Attack
- High Risk - Fluvial Erosion (bank undercutting).

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DESIGNED:	DATUM:	SHEET
MLB	AHD	1
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REVIEWED: DMM	VERTICAL RATIO: 1:6000 @ A4	PAPER SIZE: A4

REV.	DESCRIPTION	DATE	ISSUED
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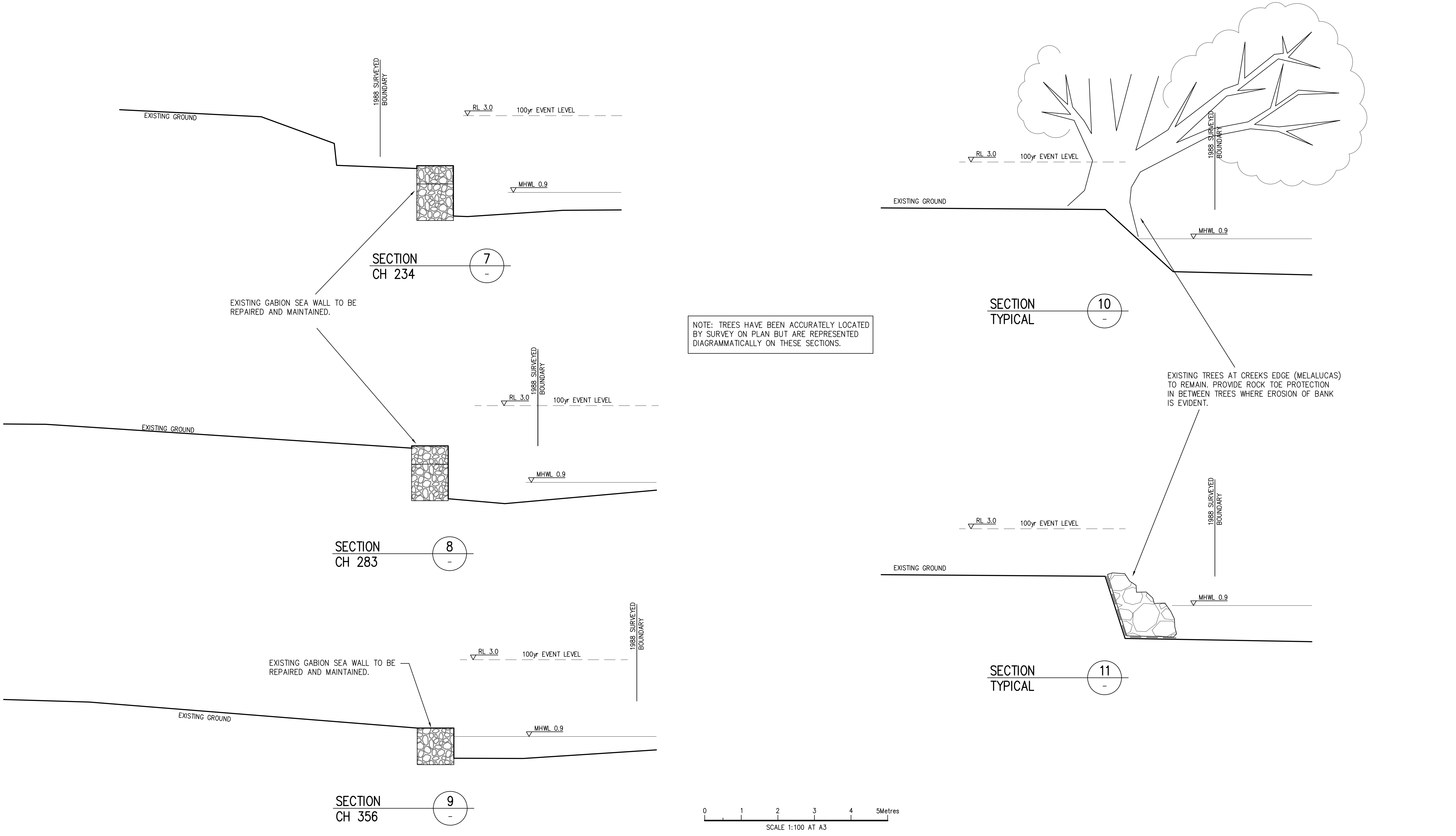
9 Attachment C – Site and Development Plan



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A	14.12.06	DA SUBMISSION	GJK	GJK

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CITY ENGINEER

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PROPOSED SEA WALL
ARRAWARRA BEACH CARAVAN PARK
ARRAWARRA

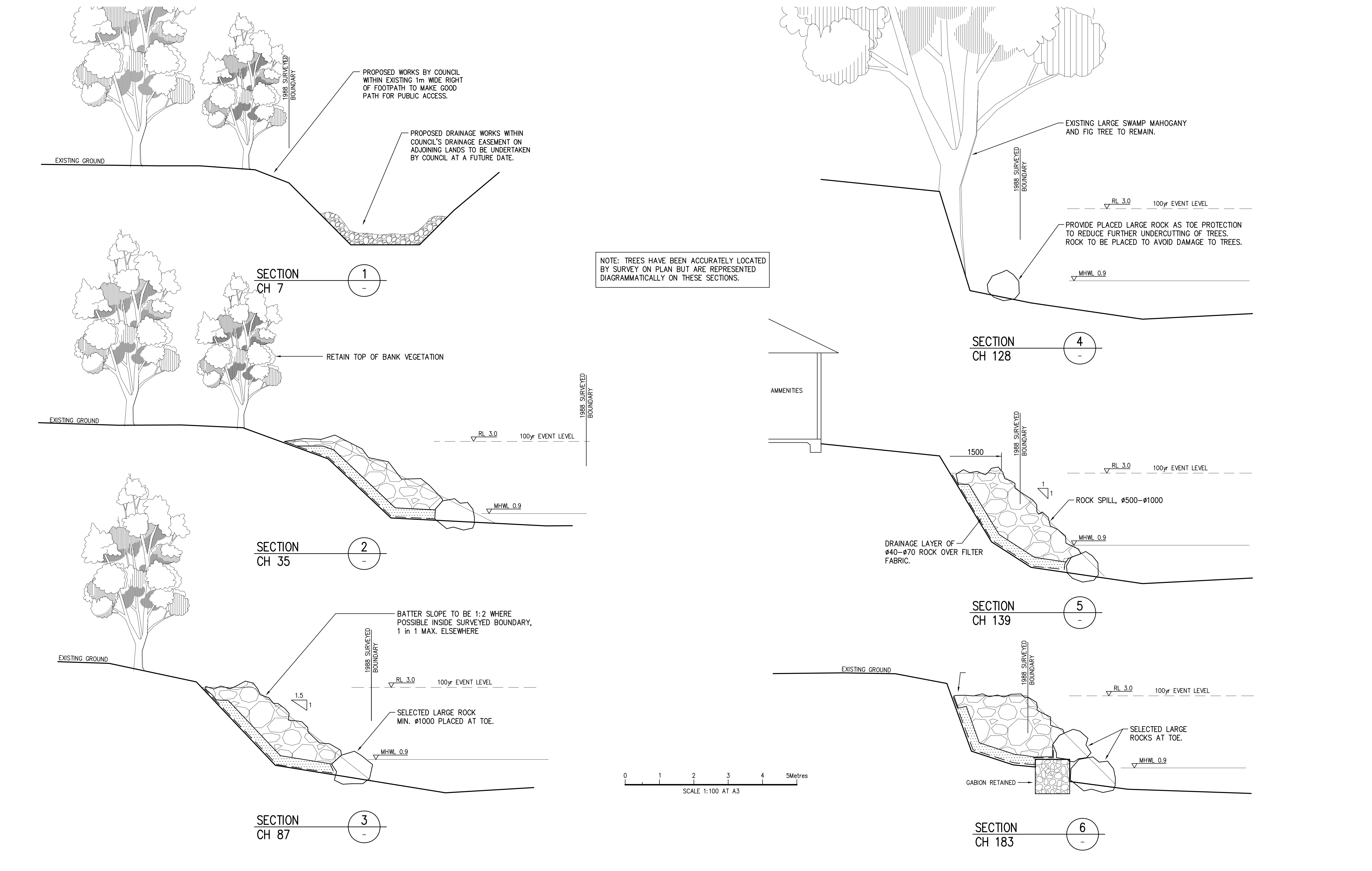
FOR *ASTORIA DEVELOPMENTS P/L*

STAGE 1 SEAWALL
NORTHERN BANK CH 234 – 460
TYPICAL CROSS SECTIONS

Drawing No. 00074–08

Amendment No. A

Council No.



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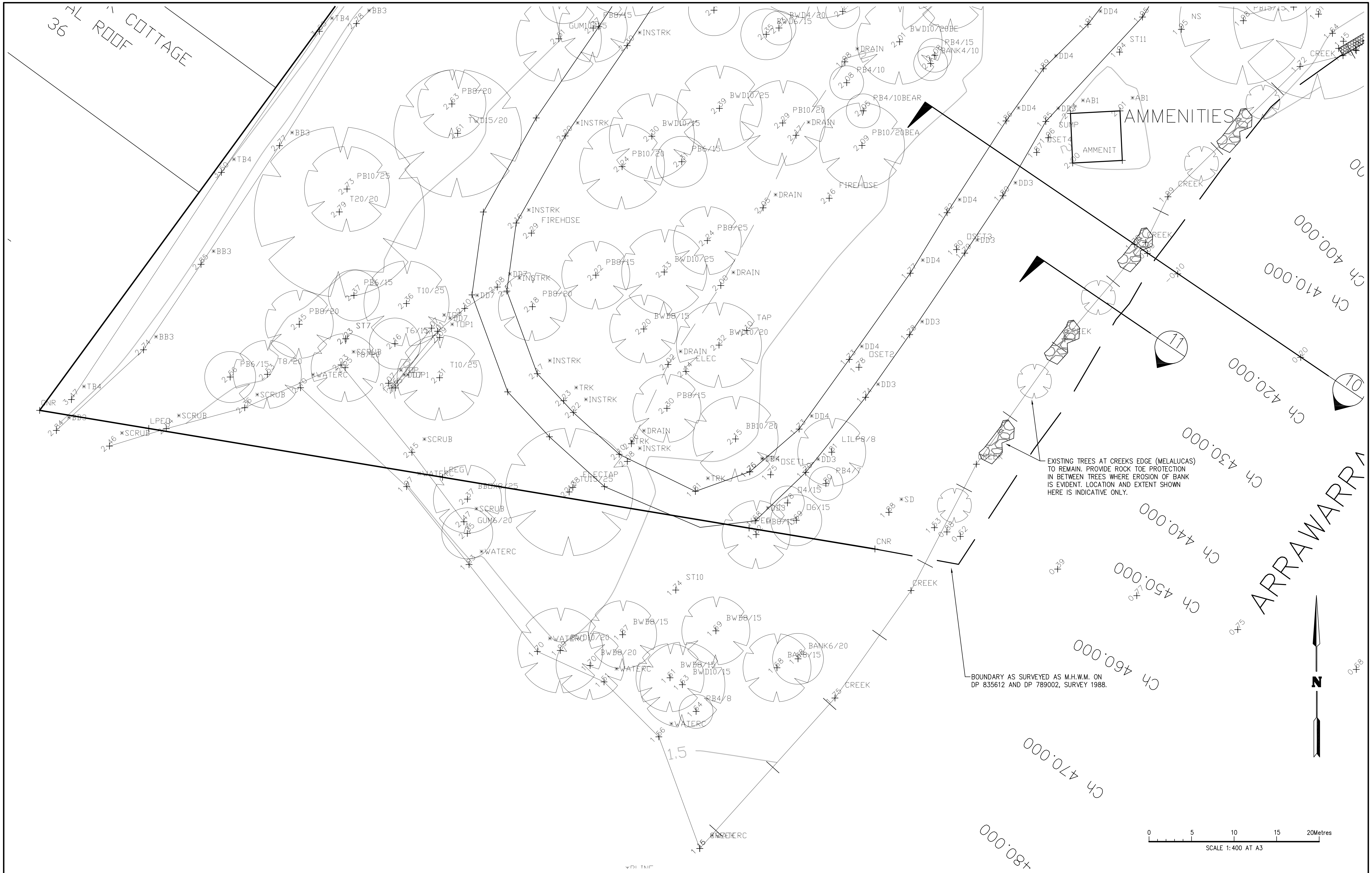
PROPOSED SEA WALL
ARRAWARRA BEACH CARAVAN PARK
ARRAWARRA

FOR *ASTORIA DEVELOPMENTS P/L*

STAGE 1 SEAWALL
NORTHERN BANK CH 0 – 210
TYPICAL CROSS SECTIONS

Drawing No. 00074-07
Amendment No. A
Council No.



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PROPOSED SEA WALL
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FOR ***ASTORIA DEVELOPMENTS P/L***

PLAN 4 OF 4

Drawing No. 00074-06

Amendment No. A

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PROPOSED SEA WALL
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FOR *ASTORIA DEVELOPMENTS P/L*

PLAN 3 OF 4

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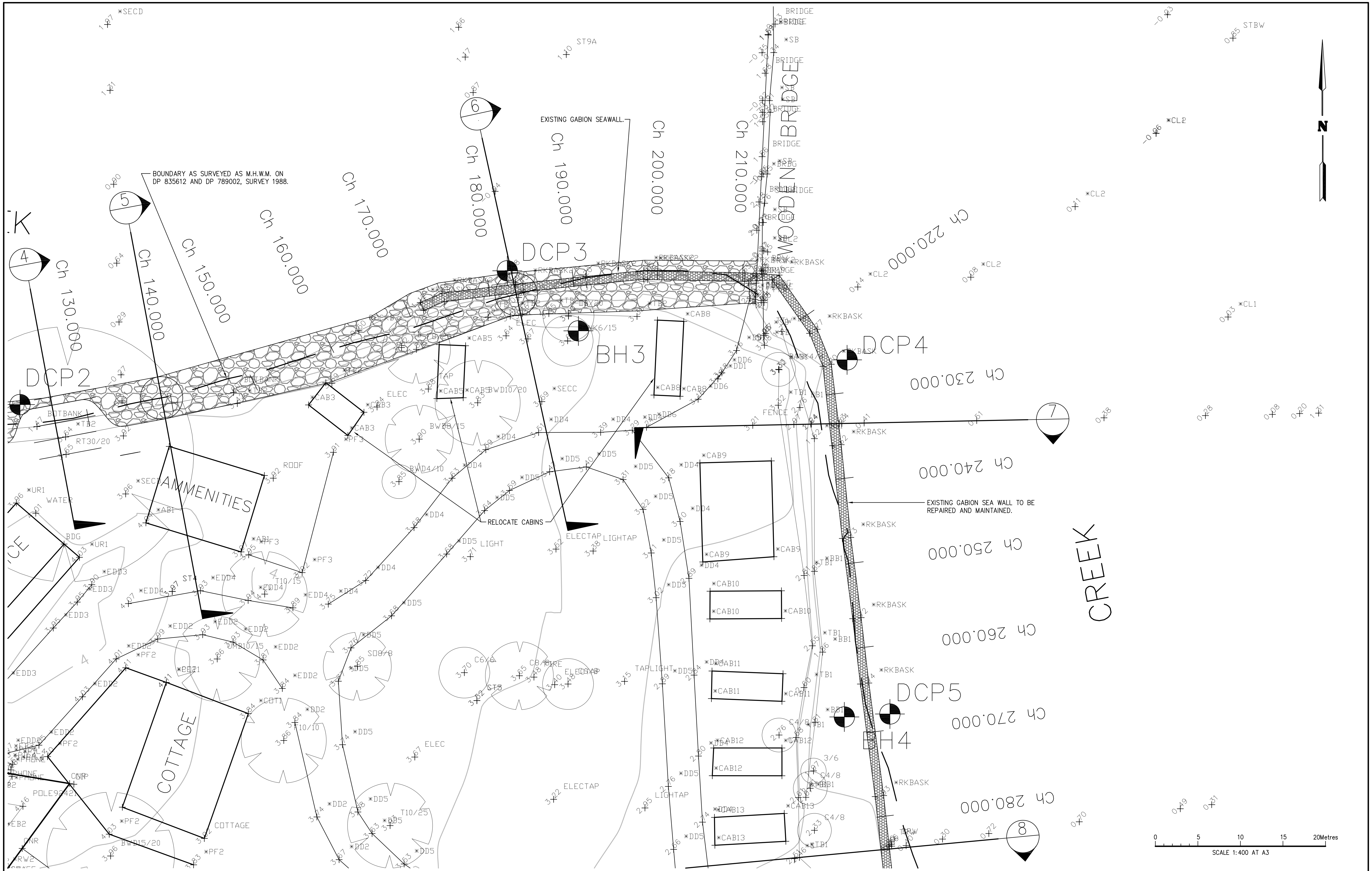

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PROPOSED SEA WALL
ARRAWARRA BEACH CARAVAN PARK
ARRAWARRA

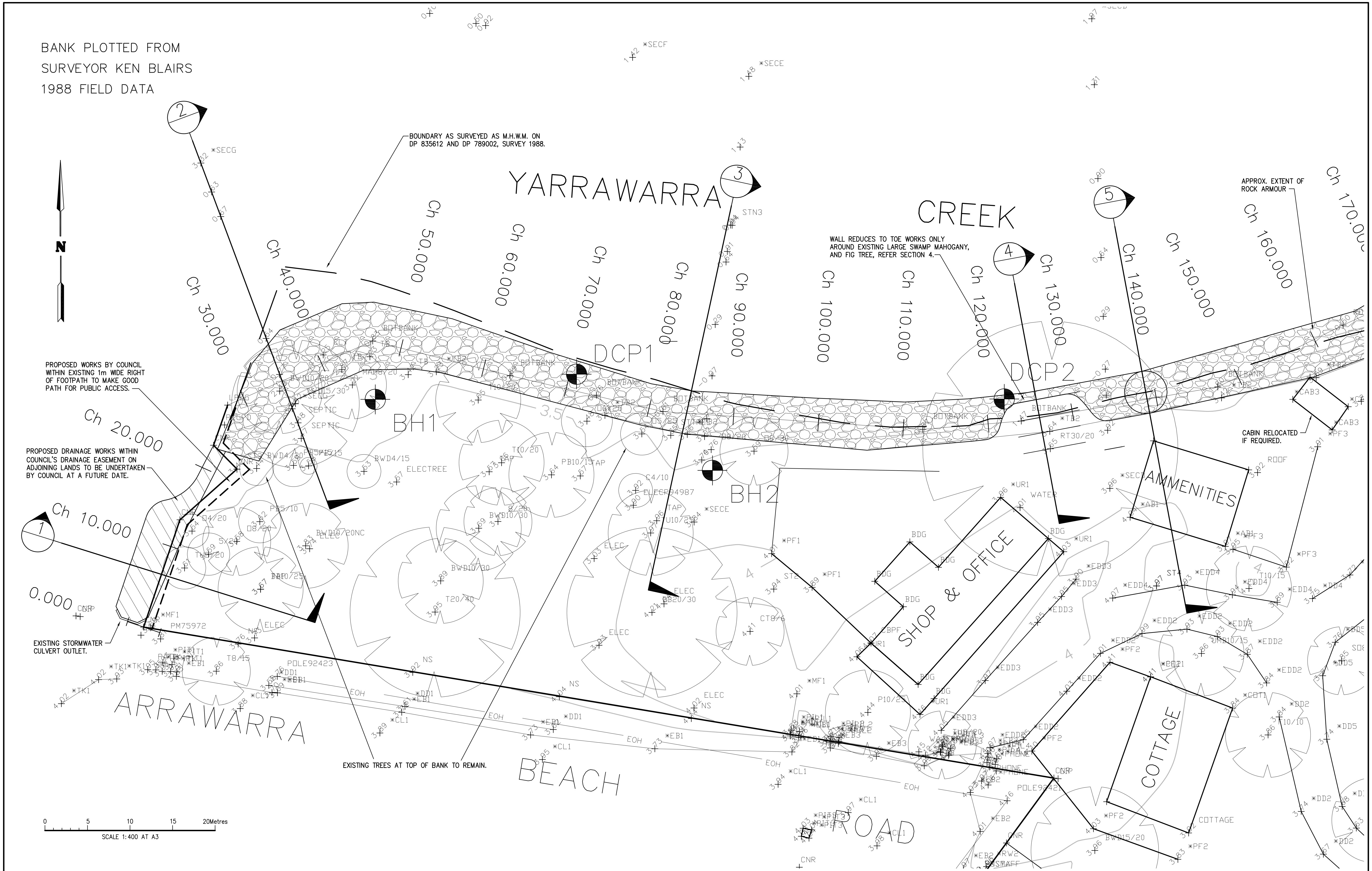
FOR ***ASTORIA DEVELOPMENTS P/L***

PLAN 2 OF 4

Drawing No. 00074-04

Amendment No. A

Council No.



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PROPOSED SEA WALL
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FOR *ASTORIA DEVELOPMENTS P/L*

PLAN 1 OF 4

Drawing No. 00074-03

Amendment No. A

Council No.

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CITY ENGINEER

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Checked xxx	Date xxx	No of Drawings

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PROPOSED SEA WALL
ARRAWARRA BEACH CARAVAN PARK
ARRAWARRA

FOR *ASTORIA DEVELOPMENTS P/L*

PLAN OVERVIEW

Drawing No. 00074-02

Amendment No. A

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CITY ENGINEER

DATE

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Surveyed		Datum	
Drawn xxx	Design xxx	Approved	
Checked xxx	Date xxx	No of Drawings	

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PROPOSED SEA WALL
ARRAWARRA BEACH CARAVAN PARK
ARRAWARRA

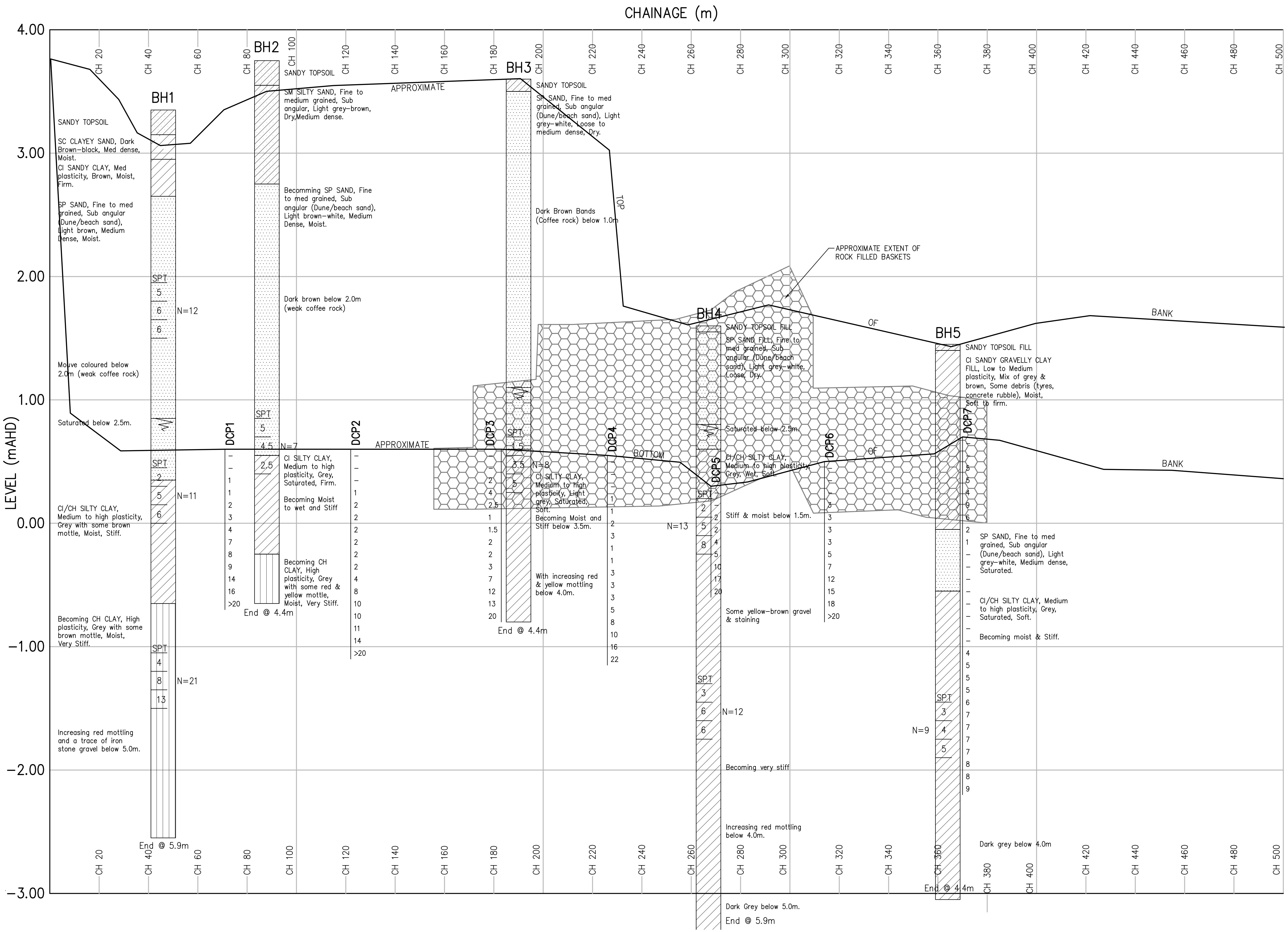
FOR *ASTORIA DEVELOPMENTS P/L*

SITE PLAN

Drawing No. 00074-01

Amendment No. A

Council No.



A	14.12.06	DA SUBMISSION	GJK	GJK	
REV.	DATE	REVISION	DR.BY	AP.BY	

APPROVED ON BEHALF OF COFFS HARBOUR CITY COUNCIL

CITY ENGINEER

DATE

Scale: AS SHOWN		Cad Disk No.: xxxx
Surveyed		Datum
Drawn: xxx	Design: xxx	Approved
Checked: xxx	Date: xxx	No of Drawings

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PROPOSED SEA WALL
ARRAWARRA BEACH CARAVAN PARK
ARRAWARRA

FOR *ASTORIA DEVELOPMENTS P/L*

BOREHOLE LOGS

Drawing No. 00074–09

Amendment No. A

Council No.

10 Attachment D – Plates

Plate Number	1
Chainage	0
Description	Storm water pipe and pit
Date	28/11/06
View Direction	North

Plate Number	2
Chainage	20
Description	Footpath at top of right bank of Yarrawarra Creek. Tree slumping indicating bank failure.
Date	28/11/06
View Direction	East

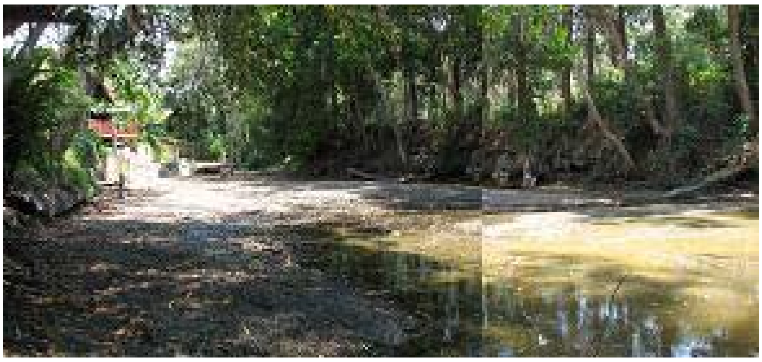

Plate Number	3
Chainage	30
Description	Western tributary joining with Yarrawarra Creek further east.
Date	28/11/06
View Direction	North West

Plate Number	4
Chainage	30-40
Description	Confluence of two additional tributaries with Yarrawarra Creek from north-west.
Date	28/11/06
View Direction	North East

Plate Number	5
Chainage	50-80
Description	Bank failure and tree slumping
Date	28/11/06
View Direction	South west

Plate Number	6
Chainage	90
Description	Bank undercutting and reworking of material by tidal flow
Date	28/11/06
View Direction	South

Plate Number	7
Chainage	100
Description	Root exposure and tree destabilisation indicates erosion.
Date	28/11/06
View Direction	south

Plate Number	8
Chainage	120 - 220
Description	Highly weathered coffee rock exposed along base of the bank.
Date	28/11/06
View Direction	south

CH 160 CH 150 CH 140

Plate Number	9
Chainage	140-160
Description	Figs and Melaluca's slumping. Underlying coffee rock supporting banks
Date	28/11/06
View Direction	South west

Plate Number	10
Chainage	160-170
Description	Slumping trees on top of underlying coffee rock.
Date	28/11/06
View Direction	South east

Plate Number	11
Chainage	175-210
Description	Start of rock gabion seawall. Erosion occurring behind wall
Date	28/11/06
View Direction	North East

Plate Number	12
Chainage	210-280
Description	Rock gabion sea wall on eastern boundary of site. Yarrawarra Creek running along wall.
Date	28/11/06
View Direction	West

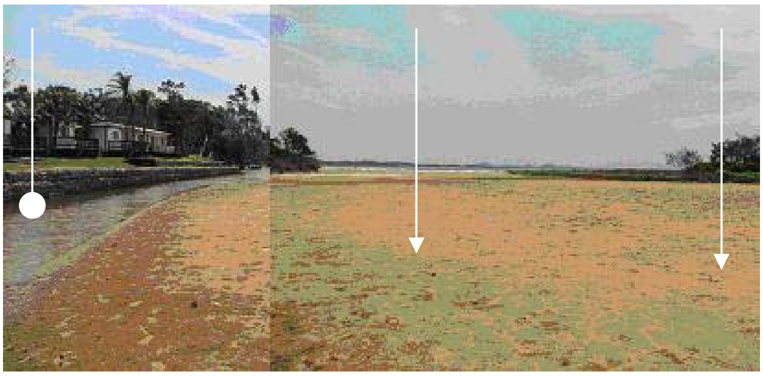

Plate Number	13
Chainage	330
Description	Flood tide delta with sand deposit blocking tidal flow to
Date	28/11/06
View Direction	North east

Plate Number	14
Chainage	340-360
Description	End of eastern seawall. Arrawarra Creek entrance
Date	28/11/06
View Direction	South West

CH 380 CH 360

Plate Number	15
Chainage	360-380
Description	Southern boundary of site. End of rock gabion wall at chainage 380
Date	28/11/06
View Direction	North East

Plate Number	16
Chainage	380-420
Description	Arrawarra Creek left bank. Rock gabions finish on north east end, then riparian vegetation only
Date	28/11/06
View Direction	North.

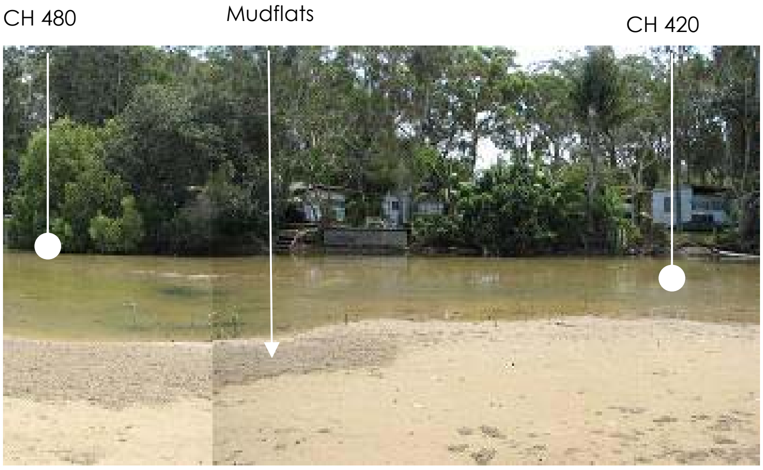

Plate Number	17
Chainage	420 - 480
Description	Arrawarra Creek left bank. End of Caravan Park site. Intertidal flat communities noted including
Date	28/11/06
View Direction	North west