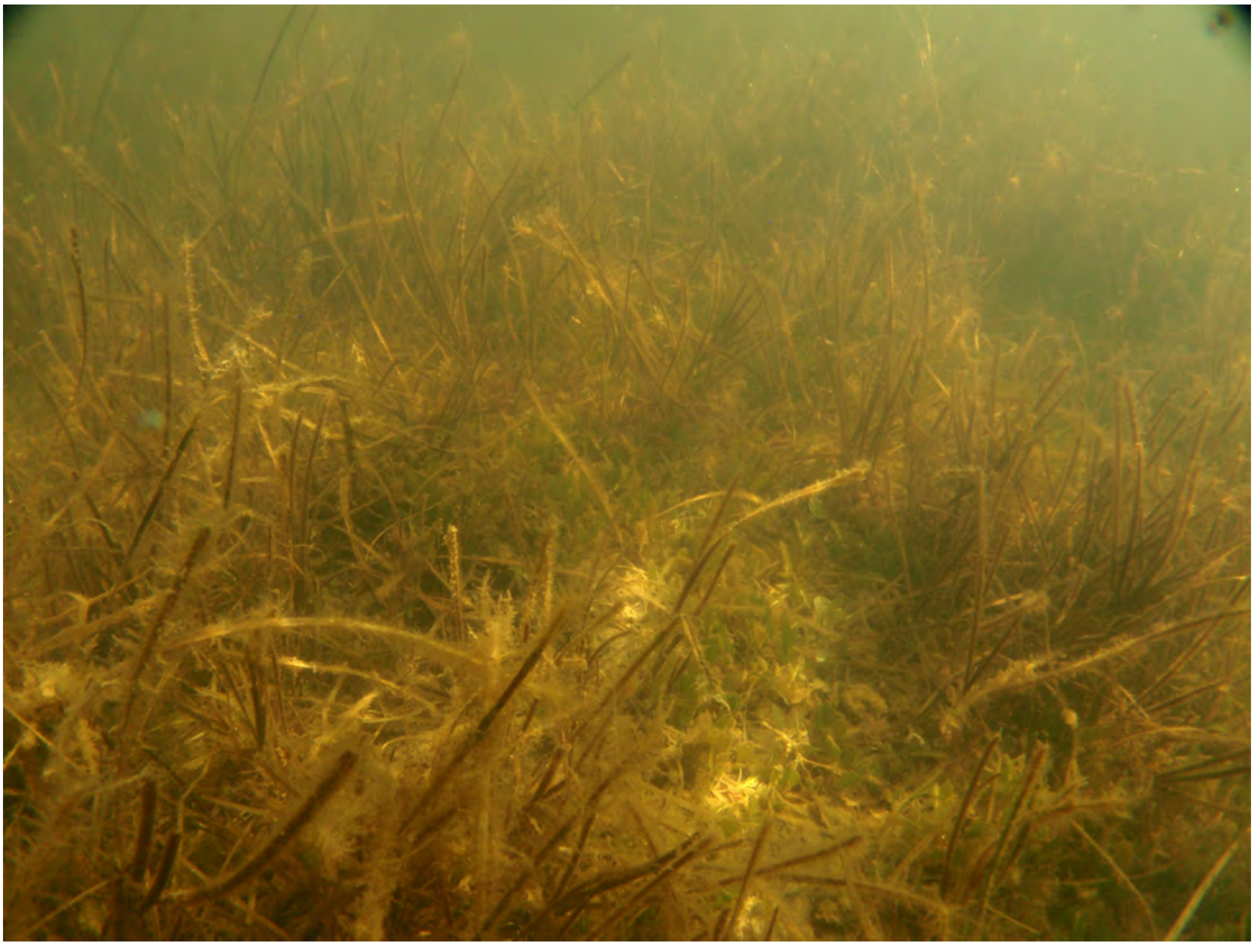
MARINE POLLUTION RESEARCH PTY LTD
Marine, Estuarine and Freshwater Ecology, Sediment and Water Quality Dynamics
A.B.N. 64 003 796 576
25 RICHARD ROAD SCOTLAND ISLAND NSW 2105
PO BOX 279 CHURCH POINT NSW 2105
TELEPHONE (02) 9997 6541 E-MAIL panink@iimetro.com.au

Project Officer – Reserves & Recreation
Northern Beaches Council
PO Box 882
MONA VALE NSW 1660 **31 January 2017**

AQUATIC ECOLOGY SURVEY FOR NARRABEEN LAGOON BOARDWALK



Underwater view of mixed *Halophila* and *Zostera* bed offshore from proposed Boardwalk alignment.

1. INTRODUCTION

The Narrabeen Lagoon Trail is a multi-use trail around the entire lagoon, which can be used by walkers, cyclists and people of all abilities (Figure 1). The section of the trail around the northern side of Narrabeen Lagoon Western Basin comprises an extensive gravel path plus boardwalk sections built through or around environmentally sensitive sections of the lagoon foreshore, and includes bridges spanning Middle and Deep Creeks.

Figure 1 Aerial view of Narrabeen Lagoon Trail showing location of section of track to be replaced with Boardwalk (source map: Council on-line Narrabeen Lagoon Trail Brochure).

A portion of the northern boardwalk between the Bilabong Reserve entry and the Deep Creek bridge is currently located immediately alongside Wakehurst Parkway (see Figures 1 to 4) and widening or relocating this section of the trail to afford a safe distance between the roadway and the trail users is limited by the narrow section of foreshore sensitive she-oak forest habitat along this part of the trail. In essence, for the trail to be made conforming and safe would require the removal of a continuous stand of she-oaks and associated foreshore habitat which is considered unacceptable from both environmental and ascetic points of view.

Northern Beaches Council Reserves & Recreation Branch are investigating the feasibility of providing an alternate solution for this part of the trail that would utilise a timber and metal mesh boardwalk section supported on piles and located over the in-shore shallows off the narrow section of foreshore.

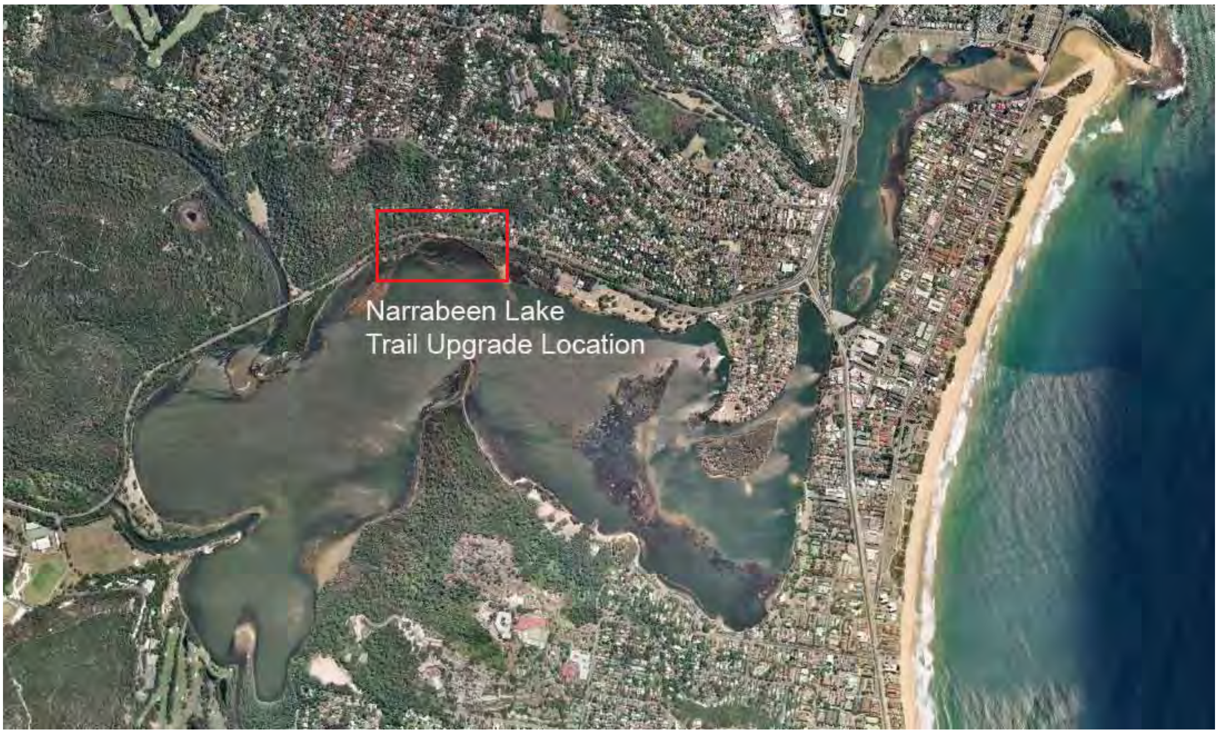


Figure 2 Aerial View of Narrabeen Lagoon showing study area – note proximity of Wakehurst Driveway to the lagoon edge in the study area.

Figure 3 Proximity of walkway to Wakehurst Parkway (looking west at Parkway Memorial).

Figure 4 View south to waters edge from walkway (from bench in Figure 3) showing the narrow foreshore dominated by swamp-oak forest habitat.

To this end Council commissioned Astute Surveying to provide a detailed survey plan of the study area that includes contours at 0.25m AHD intervals, the mapping of significant trees, the edge of the reed beds and patches of aquatic vegetation (see full survey plan attached to this report at **Appendix A**).

Marine Pollution Research Pty Ltd (MPR) was subsequently requested to prepare an aquatic ecological assessment report on the construction and use of the timber and mesh piled walkway section. The proposed location for the boardwalk section has been superimposed over a portion of the Astute Surveying plan and used to map the aquatic ecology features of the site (see Figure 10 below).

1.1 Background Information

Smith and Smith (205) mapped the native vegetation of the Warringah Local Government Area that included the following riparian and shallow tidal communities from the Narrabeen Lagoon northern foreshores:

- **Swamp Oak Forest** is listed as an endangered ecological community in NSW. The community is dominated by *Casuarina glauca* (Swamp Oak) and common understory species include *Baumea juncea*, *Entolasia marginata*, *Gahnia clarkei*, *Hypolepis muelleri*, *Phragmites australis* and *Viola hederacea*. There were two *Hibiscus diversifolius* specimens also noted.

- **Saltmarsh** is listed as an endangered ecological community in NSW. The rushland form is dominated by *Juncus kraussii* (Sea Rush) and *Phragmites australis* is common. Common herb species include *Leptinella longipes, Mimulus repens* and *Samolus repens,* the *grass, Paspalum vaginatum,* and the sedge *Cyperus laevigatus*.
- **Estuarine reedland** dominated by *Phragmites australis* (Common Reed) with other common species being *Baumea juncea, Juncus krausii* and *Samolus repens*.
- **Seagrass meadows** comprise submerged aquatic vegetation dominated by seagrass. The most common local species are *Zostera capricorni* (Eelgrass) and *Halophila ovalis(Paddle Weed)*. Another submerged angiosperm, *Ruppia polycarpa* also occurs in Narrabeen Lagoon.

NSW Fisheries mapped the estuarine vegetation of Narrabeen Lagoon from aerial photography (2005) and field surveys in 2008. Their mapping for the present study area indicated *Zostera* beds inshore along the lagoon edge with *Halophila* beds offshore ((Figure 5). Whilst the Map 38 inventory included "*Ruppia"* and "Mixed *Zostera, Halophila* plus *Ruppia*" mapping categories, neither were indicated for Narrabeen Lagoon.

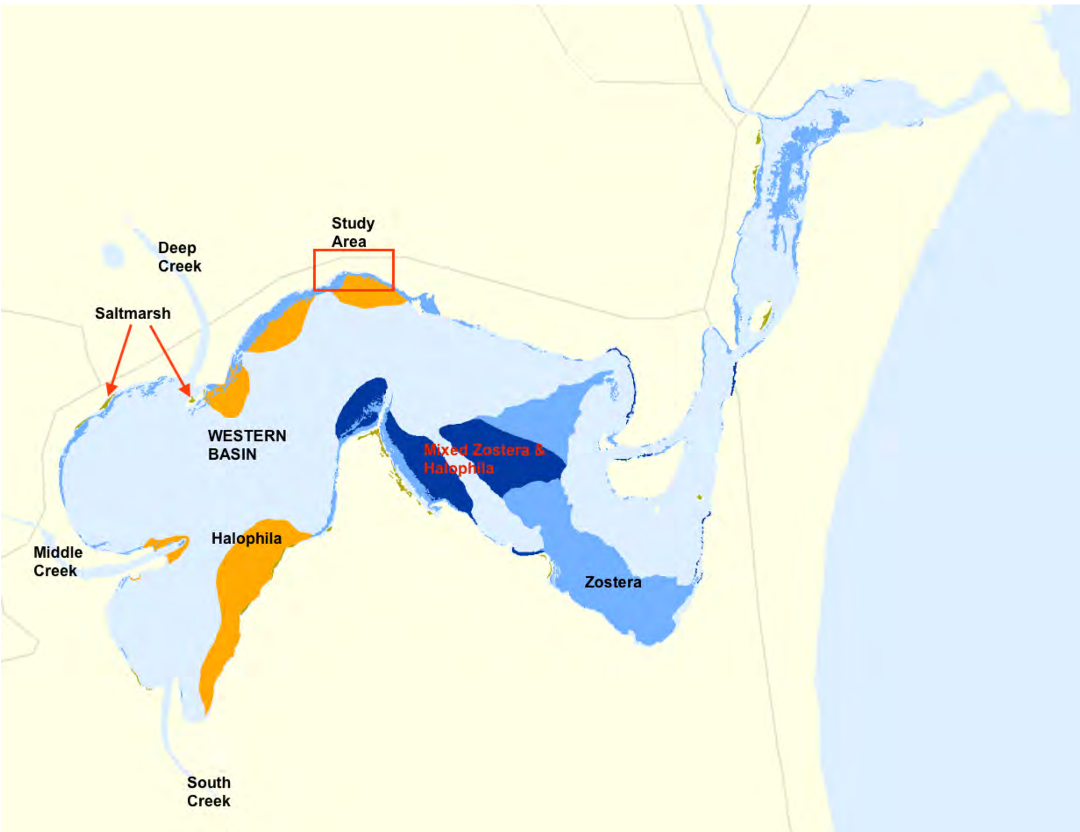


Figure 5 Portion of NSW Fisheries Estuarine Vegetation Map 38 based on 2008 field survey, showing estuarine vegetation in Narrabeen Lagoon.

Cardno Ecology Lab (CEL 2013) provided an updated summary plus validation study of seagrass mapping in Narrabeen Lagoon in relation to areas identified as potential dredging sites. They found that Area 24 (which encompasses the study area for this present study) supported 8822m^2 *Zostera* seagrass in the total study area of 17910m^2, i.e., 49.3% cover (see their Figure 9 produced in full in **Appendix B** to this report). Their mapping also indicated that the *Zostera* seagrass patches were located some 8m offshore in the present study area (see Figure 6 below).

Figure 6 Portion of Figure 9 from CEL (2013) showing *Zostera* seagrass distribution in Area 24 that encompasses the present study area. See **Appendix B** for the full CEL (2013) Figure 9.

Astute Surveying mapped the approximate outer edge of the shoreline reed beds and the marine vegetation patches in the study area on 23 September 2016. Their full survey plan is shown in **Appendix A**. Their survey indicated that the outer-edges of the reed beds were located around 0.36m AHD with marine vegetation patches offshore to around the -0.5m AHD contour. They also noted a swath of bare seabed running west to east between -0.2 and -0.3m AHD.

Comparing the CEL (2013) mapping against the Astute Surveying survey it would appear that the CEL (2013) inshore limit for seagrass growth is around the 0m AHD contour on the Astute Surveying plan.

2. FIELD SURVEY

2.1 Field Survey Methods

MPR staff made several combined snorkel and walkover surveys to map out the main inshore ecological habitats for the proposed boardwalk. A preliminary inspection of the location was made on 10th November 2016 in the company of Ms Stack from Council, and a preliminary swim-over was undertaken of 25th November 2016. This latter survey confirmed that there were scattered seagrass patches offshore from the study area foreshore with many of the patches smothered by algae (Figure 7). The survey also indicated that there was a very large seagrass wrack (accumulations of sloughed off seagrass blades and other organic debris) overlaying the inshore shallows and in most cases smothering the seabed (see also **Appendix C** Plates 1 to 4).

Figure 7 View south over the inshore shallows showing the algae smothered seagrass patches offshore.

Formal quantitative surveys to map the foreshore (riparian) and in-water vegetation and aquatic habitats were done over two survey days:

- The inshore water levels on 20 December 2016 were quite low and in-water surveys could not be undertaken without excessive disturbance of the in-shore wrack and sediments, making visual searches for live plants difficult, so the remainder of the day was taken with mapping the intertidal and riparian vegetation. The day was sunny and wind still.
- The second in-water survey day was delayed to the January spring-tide period with the in-water survey completed on 14 January 2017. The day was sunny and wind-still.

For both quantitative survey days a series of six plastic poles were set along the proposed centre-line of the boardwalk using gps coordinates supplied by Council and a two linked survey tapes (100m and 30m) were laid along the centre line to provide a longitudinal reference for point-intercept plant records:

- For the riparian and intertidal survey part of the investigation a description was made of the main plant assemblages through a 5m swath centred on the centre line (see Figures 8 and 9) in order to describe basic plant zonation and investigate whether there were any significant aquatic ecological plant assemblages such as saltmarsh present. The presence of saplings and trees was noted but not mapped, as they are already mapped on the Astute Surveying Survey plan (see attached).
- For the in-water survey component a snorkeler swam along the survey tape centre line recording seagrass plants and patches as they were encountered within a 2.5m swath centered on the centre-line. Owing to the proliferation of smothering wrack and algae throughout the survey area the diver had to remove the smothering wrack along the line to determine seagrass or other aquatic plant presence and as a consequence the transect swims were done three times, first along the centre line then along transects offset 2.5m either side.
- The five metre wide study area was selected to encompass the boardwalk footprint plus some leeway either side for potential construction or shading impacts.
- Following completion of the transect swims fifteen 100mm core samples for shoot density determinations were collected from random locations within the study area, selected prior to the survey. For each random site if there was no seagrass at that site the nearest seagrass patch (determined from the transect point intercept data) was located and sampled.

2.2 Field Survey Results

Table 1 provides the summary results of the combined point intercept riparian and intertidal zonation. Tables 2 to 4 provide the results of the shallow sub-tidal aquatic habitat zonation and seagrass distribution surveys and the overall location of seagrass habitats in relation to the proposed boardwalk is indicated in Figure 10 below. The results of the aquatic plant density determinations are shown in Table 5.

2.2.1 Riparian Vegetation

Figures 8 and 9 show views along the proposed boardwalk centre line at each end of the proposal. In terms of overall community zonation from the existing boardwalk to the fringing reed beds there is a loose transition from *swamp oak forest* through *saltmarsh* to fringing *reed swamp* communities at both ends of the proposal (Table 1).

Table 1 Vegetation communities and plants along the riparian footprints of the proposed boardwalk alignment

Transect West end & West to East Start	Finish	Community Type (Smith & Smith (2005)	Main Plants (see Astute Surveying Plan at Appendix A for location of trees)
0	4	*Swamp Oak Forest*	Bracken *Hypolepis muelleri*, pennywort *Hydrocotyle bonariensis*, spiny mat-rush *Lomandra longifolia*
4	16		Bracken, pennywort, snake vine *Stephania japonica var. discolor*, coastal morning glory *Ipomoea cairica*, low density of common reed *Phragmites australis*, several individuals of swamp hibiscus *Hibiscus diversifolius* and scattered native spinach *Tetragonia tetragonoides*.
16	21	Transition to *Saltmarsh*	Pennywort plus kikuyu grass *Pennisetum clandestinum* with scattered swamp she-oak *Casuarina glaucus* seedlings and saplings, native spinach, small patches of alligator weed *Alternanthera philoxeroides* and some morning glory.
21	27		Kikuyu plus scattered common reeds and bare twig rush *Baumea juncea*.
27	29	*Saltmarsh*	Native reed plus creeping brookweed *Samolus repens* and scattered native orache *Atriplex australasica*.
29	32	Reed swamp	All native reeds in boardwalk footprint.
Transect East end & East to West		**Community Type (Smith & Smith (2005)**	**Main Plants (see Astute Surveying Plan at Appendix A for location of trees)**
0	4	Transition to *Saltmarsh*	Kikuyu plus pennywort and some scattered native spinach.
4	8.3		Kikuyu plus pennywort, scattered swamp-oak saplings and evenly scattered bare twig rush
8.3	11.5		Bare twig rush plus scattered pennywort and scattered native reed
11.5	12.4		More native reed and less bare twig rush plus scattered pennywort
12.4	16.7	Saltmarsh	Native reed in shallow water
16.7	19.6		Mixed native reed and sea rush *Juncus kraussii* all in shallow water
19.6	21		Stand of bare twig rush in shallow water
21	23.2	Reed swamp	All native reeds in boardwalk footprint

Notwithstanding these defined community types, it is considered that all of the assemblages identified are common around the lagoon, and the loss of these swathes of ground vegetation would not be considered significant, nor would they represent a risk of survival of these community types (or of the individual species) in the near locality or around Narrabeen Lagoon.

Smith and Smith (2005) note that *Hibiscus diversifolius* is considered threatened in northern Sydney and two plants were noted at the western boardwalk proposal footprint. If necessary these specimens could be collected and relocated away from the boardwalk footprint.

Figure 8 View along survey centreline from western end of the proposed boardwalk looking ESE over the riparian vegetation – see Table 1 for zonation and main plant species.

Figure 9 View along survey centreline from eastern end of the proposed boardwalk looking WSW over the riparian vegetation towards the fringing reed bed. See Table 1 for zonation and main plant species.

2.2.2 Sub-tidal (seagrass) habitat survey results

Ass noted in Section 2.1, initial surveys indicated that there were scattered seagrass patches offshore from the study area foreshore with many of the patches smothered by algae. The inspection also indicated that there was a very large area of seagrass wrack (accumulations of sloughed off seagrass blades and other organic debris) overlaying the inshore shallows and in most cases smothering the seabed (see **Appendix C** Plates 1 to 4).

The results of the formal point-intercept transect surveys undertaken along the proposed boardwalk centre line (mid transect) and for the two transects set 2.5m either side of this line (north – inshore and south –offshore transects are detailed in Tables 2 to 4, and these results have been used to calculate areas of seagrass cover for the study area (Table 5) with the areas defined as three parallel swaths each 2.5m wide and total length from outer reed bed west to outer red bed east set at 120m. Results of shoot counts and shoot length are shown in Table 6. Results may be summarised as follows:

- The data on seabed structure confirm that for the most part the boardwalk footprint is located over essentially bare and firm sandy sediment overlaid with a combination of fine sulphurous black sediment that is the decay product of accumulated marine plant (seagrass blade and algae) debris which has accumulated in the small embayment.
- The entire study area seabed (120m long by 7.5m wide) is smothered in the wrack material with live plants either totally or partially smothered (see also Plates 5 to 8 in **Appendix C**).
- There were three marine plant species observed in the study area, two seagrass species – *Zostera capricorni* and *Halophila ovalis* and one aquatic plant *Ruppia magacarpa*. *Ruppia* was the most common species observed with 13.8% cover over the study area (20.5m^2). *Zostera* covered 9.8% of the study area (9.2m^2) and *Halophila* cover was too sparse to quantify.
- The plants were distributed asymmetrically; both *Ruppia* and *Zostera* cover were lowest at the western shallow end of transects where wrack accumulation was highest. *Ruppia* cover then increased to the east as overall wrack cover thinned a little.
- *Zostera* cover peaked in the deeper middle sections then decreased again in the eastern shallows.
- For the most part the *Zostera* shoots were long leafed, as is normal in sub-tidal waters. Average (± standard error of mean) shoot length was 489 ± 30 mm. There were three occurrences of short-form *Zostera* (average ± SE shoot length 65 ± 3mm) that is normally associated with intertidal waters; two occurred around the shallow western 26m end on the mid and south transects and one at the shallow eastern 100m end on the south transect.

- Shoot counts (per 100mm diameter core) were all very low and quite variable, with *Ruppia* counts ranging from 1 to 24 shoots per core and *Zostera* varying from 1 to 12 shoots per core. Notwithstanding there were discernable patterns in the distributions, with higher density *Ruppia* towards both shallow ends of transects. For *Zostera* the three highest densities were associated with the short-form shallow water *Zostera* (7, 10 & 12 shoots per core) with the remaining eight core densities between 1 and 5 shoots (mean ± SE 3 ± 0.5 shoots per core).
- A general snorkel swim over the remaining seagrass bed in deeper waters to the south of the study area indicated that the smothering wrack was more or less confined to the shallows and as wrack density decreased there was progressively more and denser seagrass cover including a proliferation of dense, tightly packed *Halophila* cover as the main seagrass component with patches of long-form *Zostera*, also more denser than the study area Zostera with smaller and isolated patches of *Ruppia*. The *Ruppia* patches had shoots reaching to the surface and, as noted for inshore waters, the surface *Ruppia* formed a suitable substratum for smothering algae, mainly *Ulva intestinalis*.

The overall distribution of seagrass in the study are conforms with the distributions indicated in the CEL (2010) and Astute Surveying (2016) surveys reviewed above, both of which indicate a broad shallow inshore area with no seagrass on the western side of the small embayment plus no seagrass for an 8 to 12m band in the shallows along the northern foreshore of the embayment.

The distribution of seagrass species within the study is different to that described in the CEL (2010) report (that notes only *Zostera* seagrass) or the NSW Fisheries 2008 mapping - that notes *Zostera* inshore and *Halophila* offshore. Notwithstanding, the described distribution is more generally in line with the NSW Fisheries survey results, as there was very little *Halophila* in the study area and *Halophila* was observed to be the dominant seagrass cover offshore from the study area. Further, the presence of *Ruppia*, whilst not mentioned in recent surveys of seagrass of Narrabeen Lagoon, is noted as a species that occurs in Narrabeen Lagoon (Smith and Smith 2005) and it may well be that the present distribution is associated with an extra large (and/or stable) accumulation of wrack decaying in this embayment, as *Ruppia grows on muddy sediments where siltation and nutrient enrichment have occurred* (West 2010).

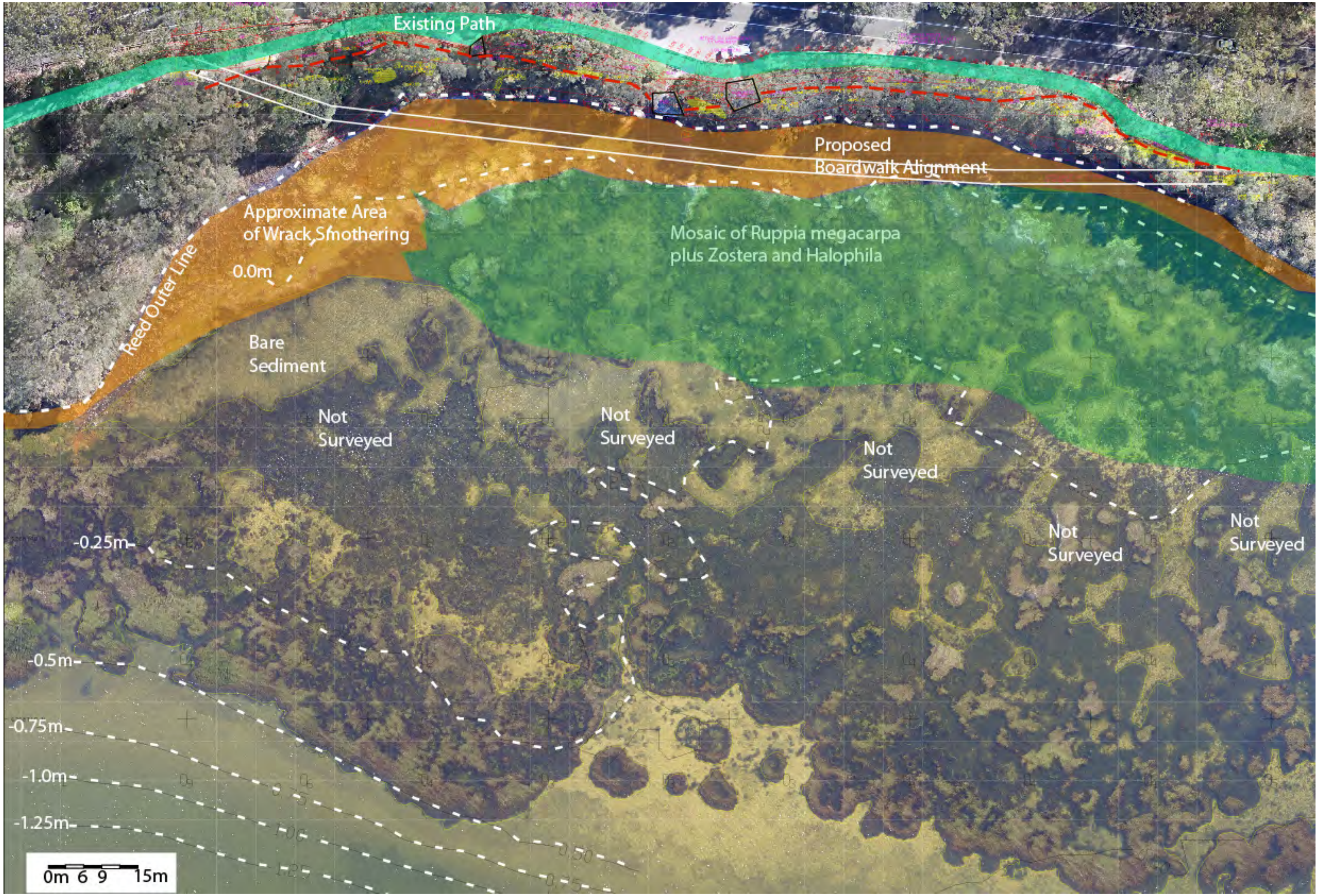


Figure 10 Aquatic Habitats in the vicinity of the boardwalk section proposed to replace the narrow section alongside Warringah Parkway. The red dashed line indicates the bottom of the slope and the riparian zone extends from there to the outer edge of the reed beds as indicated by the white dashed line. The remaining white dashed lines show depth contours (see Appendix A for complete survey).

Table 2 Sub tidal Boardwalk Transects - Point Intercept Data										Transect No:	Middle (mid line)
Patch Start	Patch Stop	SG Spp & Cover	Algae Cover & type)	Substratum & firmness	Depth Stop (m)	Time	Site depth	Gauge Depth	Shoot Density	Shoot form	Comments
0	5.2	dense wrack		firm silty sand		13:45	0.37				
5.2	26	dense wrack		firm silty sand	10	13:51	0.57				
26	26.6	sparse Z	none	firm silty sand	26	14:04	0.67	0.52	even med	short form	
26.6	31.8	dense wrack	none	firm silty sand							
31.8	33	even med Ruppia	none	more silty & softer	33	14:05	0.65		medium		Most *R megacarpa*
33	35	dense wrack		firm silty sand							
35	36.7	sparse Z	none	silt & rock	36	14:10	0.65		sparse	long form	well spaced shoots
36.7	38.6	med Ruppia	none	sand & silt overlay					medium		mixed with wrack
38.6	39.2	dense wrack	none	firm silty sand							
39.2	41.4	spZ & med R	smothered green	firm silty sand	41	14:18	0.66		mixed		Most *Ulva intestinalis*
41.4	47.4	dense wrack		firm silty sand							
47.4	49.5	medium R	smothered green	firm silty sand	47	14:22	0.67		medium		Mixed green algae
49.5	50.8	dense wrack	none	firm silty sand	50	14:23	0.65				
50.8	60.4	sp Z and patchy R	smothered green	firm silty sand	60	14:25	0.61		patchy		
60.4	61.5	dense wrack		firm silty sand							
61.5	62	sparse Z & R	less smothered	firm silty sand					sparse		
62	67.6	dense wrack		firm silty sand							
67.6	68.1	sparse Z	some green	firm silty sand	68		0.61		sparse		
68.1	70.6	dense wrack		firm silty sand							
70.6	71	sparse Z	some green	firm silty sand	71	14:30	0.6	0.5			
71	72.6	dense wrack		firm silty sand							
72.6	73	sparse Z & R	less smothered	sand & silt overlay					sparse	short form	
73	75	dense wrack		sand & silt overlay							
75	77	sparse Z & R	none	sand & silt overlay	77	14:35	0.6		sparse		
77	91.5	dense wrack	none	sand & silt overlay							
91.5	99.1	sparse R	smothered	sand & silt overlay	99	14:43	0.61		sparse		
99.1	120.8	dense wrack	none	sand & silt overlay	121	14:47	0.61				
110	120.8	dense wrack	none	sand & silt overlay		15:00		0.47			
						15:45		0.44			Tide gauging

Table 3 Sub-tidal Boardwalk Transects - Point Intercept Data Transect No: Outer (south)

Patch Start	Patch Stop	SG Spp & Cover	Algae Cover & type)	Substratum & firmness	Depth Stop (m)	Time	Site depth	Gauge Depth	Shoot Density	Shoot form	Comments
						15:45		0.44			Tide gauging
0	12.4	dense wrack	None	sand &silt overlay	10.1	16:00	0.51	0.42			
12.4	16.7	sp Ruppia & wrack	none	sand &silt overlay	16.7		0.55		variable	long	Uneven cover
16.7	20	sp Ruppia & wrack	Green filamentous	sand &silt overlay	20		0.56		very sparse	long	Algae likely *Ulva intestinalis*
20	29	dense wrack	None	sand &silt overlay		16:15	0.57				
29	29.5	Zostera	nil	sand &silt overlay					low	short	typical intertidal form
29.5	40	dense wrack	None	sand &silt overlay							
40	50	sparse R & sp Zost	low, green algae	sand &silt overlay	44	16:23	0.58				little or no Zostera epiphytes
50	56	med R & Z	None	also a lot rubble	56		0.57		medium	long leaf	
56	60	dense wrack		sand &silt overlay							
60	63	dense Z med R	low and green	sand &silt overlay	62.5		0.56		Dense	long leaf	Good dense Zostera patch
63	66	dense wrack		sand &silt overlay							
66	66.5	Zostera patch	None	sand &silt overlay	66.5		0.54			long	uneven, long form
66.5	70.5	dense wrack		sand &silt overlay							
70.5	71.6	desnse Zost	none	sand &silt overlay	71.6	16:30	0.52	0.4		long	good dense patch
71.6	75	wrack		sand &silt overlay							
75	78.5	med Zost	none	sand &silt overlay	77		0.53				
78.5	82.2	sparse Zost	none	sand &silt overlay							
82.2	85.7	med Z and R	none	sand &silt overlay	82.9		0.53				
85.7	90.7	Dense R, sparse Z	none	sand &silt overlay	90.7		0.54				
90.7	94.1	mixed sp Z&R		sand &silt overlay	94	16:40	0.54				
94.1	99.5	sparse R	none	sand &silt overlay			0.53				
99.5	100.5	patch short Zost	none	sand &silt overlay			0.5			short	typical intertidal form
100.5	130	dense wrack		sand &silt overlay	126	16:45	0.49	0.37			finish at outer reed edge

Table 4 Sub-tidal Boardwalk Transects - Point Intercept Data								Transect No:	Inner(north)
Patch Start	Patch Stop	SG Spp & Cover	Algae Cover & type)	Substratum & firmness	Depth Stop (m)	Time	Site depth	Gauge Depth	Comments
0	20	only. wrack	smothered	soft silt over firm sand	20	10:00		0.53	green and brown algae smothering
20	40	only. wrack	smothered	soft silt over firm sand	40	10:30		0.54	green and brown algae smothering
40	60	only. wrack	smothered	soft silt over firm sand	60	11:55		0.55	green and brown algae smothering
60	80	only. wrack	smothered	soft silt over firm sand	80	12:30		0.57	green and brown algae smothering
80	100	only. wrack	smothered	soft silt over firm sand	100	13:30		0.58	green and brown algae smothering
100	110	only. wrack	smothered	soft silt over firm sand	110	13:36		0.57	green and brown algae smothering

Table 5 Areas of seagrass along three transects									
Transect Distance (m)		South Transect (offshore)		Mid Transect (centre line)		Noreth Transect (inshore)		Total Distances for 3 transects	
Start	Stop	*Ruppia*	*Zostera*	*Ruppia*	*Zostera*	*Ruppia*	*Zostera*	*Ruppia*	*Zostera*
0	20	7.6	0	0	0	0	0	7.6	0
20	40	0	0.5	4.3	3.3	0	0	4.3	3.8
40	60	8	8	6.9	4.8	0	0	14.9	12.8
60	80	1	7.1	1.45	2.35	0	0	2.45	9.45
80	100	12.85	9.15	7.6	0	0	0	20.45	9.15
100	120	0	0	0	0	0	0	0	0
Vegetation Areas per Transect segment (20m long x 2.5m wide)								Total Study Area (900m^2)	
0	20	19	0	0	0	0	0	19.0	0.0
20	40	0	1.25	10.75	8.25	0	0	10.8	9.5
40	60	20	20	17.25	12	0	0	37.3	32.0
60	80	2.5	17.75	3.625	5.875	0	0	6.1	23.6
80	100	32.125	22.875	19	0	0	0	51.1	22.9
100	120	0	0	0	0	0	0	0.0	0.0
Totrals per transect		73.625	61.875	50.625	26.125	0	0	124.3	88.0
% Area cover per transect		24.5	20.6	16.9	8.7	0.0	0.0	13.8	9.8

Table 6 Shoot Density and Leaf Length Data

Random Site Coodinates		Shoot Density*		Max Shoot Lengths (mm)		
Distance	Zone	*Ruppia*	*Zostera*	*Ruppia*	*Zostera (long)*	*Zostera (short)*
26	mid		7			60
29	south		10			65
30	m	24		490		
40	s	5	5	510	320	
43	m	15	2	400	480	
47	m	3		450		
49	s	2	2	480	520	
50	m	1		470		
57	m	2	2	485	515	
66	m	1	4	480	600	
78	s		5		570	
82	s	4	3	490	455	
88	s	14	1	475	450	
96	m	3		490		
100	s		12			70
Count		11	11	11	8	3
Min		1	1	400	320	60
Median		3	4	480	497.5	65
Mean		6.7	4.8	475	489	65
Std Error of Mean		2.3	1.1	8.7	30.4	2.9
Max		24	12	510	600	70

Note *: Shoot density is number of shoots per 100mm diameter core

3 IMPACT ASSESSMENT & MANAGEMENT

The construction and use of the proposed boardwalk over the Narrabeen Lagoon shallows along the northern foreshore would require the placement of piles plus headstock beams to support the boardwalk. Generally, for a boardwalk up to 4m wide, paired piles at 3 to 5m intervals would be expected, with pile diameters a minimum of 300mm.

3.1 Construction Related Impact Management

Generally piling works and associated over water construction works are done from shore or from floating plant. For the present proposal the overwater works are sufficiently remote from shore to make construction from shore impractical. Further, the available on-land construction areas for housing large cranes and stockpiling materials for construction is severely limited.

The main constraint on floating plant methods is water depth, in that the seagrass beds offshore from the project footprint area are in shallow waters around -0.25m AHD. Inspection of neap and spring tides for the survey days indicates that the tidal ranges over the seabed were as follows; 0.6m to 1.05m depth range during neap tides, and 0.75m to 1.11m depth range during the spring tide. In order to avoid damage to seagrass beds the distance between the bottom of vessels under loaded and working conditions would need to be *at least* 200mm (but more probably 300 to 400 mm for all practical purposes) which means that under most tide conditions the loaded and working draft of vessels would have to be about 400mm to meet the minimum 200mm clearance at all tides. For larger working barges with a typical 600mm working draft and with a nominated clearance depth of say 300mm, the available tidal window at the site during the tidal periods described above would have been restricted to around 5 hours and less.

Another possibility is to use an "*overhand*" building process that advances the build out over the water from the shore using smaller plant on the walkway itself. This latter method has been used to build boardwalks through mature mangrove stands and alongside the Parramatta River (Colin Henstock of C W Henstock and Associates *pers. comm*.,). As this construction method is limited to the machinery that can be accommodated on the walkway itself, there is also a limit on the reach that the machinery would have and in the case of the Parramatta River boardwalk the piles were placed at 3m intervals as a consequence. The present boardwalk could also be built using a combination of the two methods.

The potential impacts associated with construction and use of the boardwalk are assessed as follows:

Direct loss of seabed habitat to pile placement:
Assuming a 120m span over water and using the 3m pile intervals, some 5.65m^2 of seabed habitat would be lost to piles:

- This loss of seabed habitat represents less than 1.2% of the total over-water span area of 480m^2 and is considered negligible.
- Further, given the low and asymmetric cover and density of seagrass through the study area (14% cover of *Ruppia* and 10% cover of *Zostera*, it is considered that there would be a negligible risk of direct loss of seagrass to direct piling activities.

Indirect loss of seabed habitat to smothering associated with piling activities:
Both pile driving methods (hammering and screwing piles into the seabed) disturb seabed sediments with the risk of creating turbid waters that can shade adjacent marine plant communities, inhibiting photosynthesis and in the extreme could result in displacement of sediments that smother adjacent marine plant:

- Given the observed fine silt layer on the seabed under the wrack in the study area turbidity can be expected from the piling activities but as the silts are very fine, turbidity would be diffuse and smothering of adjacent plants is unlikely.
- In regards to immediate *in-situ* impacts of turbidity from piling operations, the turbidity is unlikely to be any more inhibiting than the smothering wrack within the study area. For the offshore seagrass beds the turbidity from a piling turbidity plume is not likely to be any more persistent than natural stormwater turbidity following catchment storms and would certainly settle faster as the turbidity would be generated in saline waters which promotes resettlement of particulate matter more than freshwater environments.
- As a precaution, protection of the adjacent offshore seagrass beds could be enhanced by the use of silt curtains between the construction area and the offshore beds, noting however that setting a silt curtain within the seagrass bed would itself smother some seagrass. If on balance a silt curtain is required, the details of silt curtain deployment could be included in an Aquatic Construction Environmental Management Plan (CEMP), with the principle recommendation that the silt curtain be floating and limited in depth so as not to reach the bottom. This would minimise harm to seagrass on the bottom underneath the boom whilst containing and promoting settlement of the plume within the work area.

Indirect loss of seabed habitat arising from use of floating plant for the placement of piles and for building the boardwalk:
If floating plant is to be used there are four main areas of potential concern, (i) the risk of bottom scouring from propellers or propeller wash from vessels manoeuvring plant into place, (ii) plant bottoming out and crushing seagrass either when left in-situ through the tidal cycles or when one side of the barge is pushed down during work activities (iii) the loss of seagrass to barge anchoring gear via the setting of anchors or via scalping by the chains or wires used to keep the barge in place (or in the alternative damage to seagrass beds from use of spud piles that are attached to the barge and can be lowered into the seabed to allow the barge to pivot around the spud pile), and (iv) excessive shading of seagrass by barges left i*n-situ*:

- All construction personnel would need to be inducted in regards to the need for the protection of the seagrass beds and the seagrass beds would be defined as the seabed inshore of the –o.50m AHD contour line as indicated on the Astute Surveying survey drawing (see **Appendix A**). Inductions and the Survey Drawing would be included in the project CEMP.
- In order to minimise wash and to prevent bottom scouring, all masters of vessels will need to ensure that towing or pushing vessels not use excessive power to manoeuvre barges into place in the vicinity of the seagrass bed. They should work the tides and wind to minimise the potential for propulsion related damage to seagrass beds.
- Barges that need to be placed over seagrass beds should not be left *in-situ* if there is a risk of bottoming out over the tidal cycle. Even where there is no risk of bottoming out barges are not to be left in-situ over seagrass beds for periods longer than three days when waters are clear of stormwater turbidity. When there is stormwater turbidity the period could be extended to coincide with natural clearing rates but this would need to be determined and specified in an Aquatic CEMP.
- If mooring blocks or other anchoring gear to hold barges in place are to be used these must not be placed into the designated seagrass beds, and must be located so that associated mooring lines are unable to scrape the seagrass bed when slack of taut. In order to minimise the risk of mooring damage it may be preferable to set several temporary piles in deeper bare- sediment waters south of the -0.05m contour with mooring wires replaced with floating rope. Floating rope moorings would also be required for the mooring points north (inshore) and these would need to be attached to suitable mooring apparatus that would not impact inshore seagrass beds, reed beds or riparian vegetation habitats.
- If mooring is to be achieved by the use of spud piles attached to the work barge placed into known areas of little or no seagrass as indicated on the Astute Surveying plan the contractor proposing this method of work would need to prepare a comprehensive work plan indicating where the spud piles would be placed to minimise seagrass bed loss or damage and the planed spud locations would need to be confirmed free of seagrass immediately prior to commencement.
- In order to minimise vessel and mooring impacts the contractor would need to prepare a mooring and vessel manoeuvring management plan to be approved as part of the project CEMP.
- If the *overhand construction* method is to be used, the main construction related impacts relate to on-shore and over water spillages and materials handling. Spillages of materials and accidental spillages of fuels from plant can be minimised to insignificance by implementation of best construction practice to be specified in the CEMP including the direction that there will be no stockpiling of construction materials on the riparian or

seabed habitats and that there will be no refuelling or maintenance of machinery undertaken over edge or seabed habitats.

3.2 Operational Related Impact Management

The main direct impact of the boardwalk construction is the potential shading of riparian vegetation and seagrass under the boardwalk. Indirect impacts include changes to the water circulation patterns in the 'enclosed' embayment, loss of the structure to flood damage, disruption of wildlife use of the embayment (mainly by estuarine birds) and an increased possibility of litter reaching the waterways from users:

- The shading impacts of the structure have been quantified in this report and it is concluded that the constructed boardwalk would not result in a significant shading impact, as the main seagrass bed to be protected is located offshore from the boardwalk footprint. Notwithstanding, it is recommended that the boardwalk be constructed with a mesh platform to allow some sunlight penetration to the seabed to facilitate some continuing aquatic plant growth beneath the structure.
- Use of mesh construction is also probably preferable from the point of view of minimising flood damage, as raising floodwaters and wind waves would dissipate through the mesh rather than push up against a wooden deck.
- The deck could be damaged by large floating debris becoming lodged under the deck and being moved about by floodwaters and wind waves. This risk can be managed by the implementation of a regular inspection and maintenance regime.
- In regard to water circulation the embayment already acts to catch and concentrate wrack that floats across the lagoon under prevailing weather conditions and presumably the embayment is cleared of floating wrack under other favourable conditions from time to time. Accordingly, the placement of the boardwalk could alter the wind and current characteristics of the embayment to the extent that this cycling is altered. However, given that the boardwalk is located over the very shallow parts of the embayment inshore, it is considered that water and wind circulation patterns over the extant seagrass bed offshore from the boardwalk would not be altered to any degree and accordingly the wrack cycle would continue in a similar manner to the existing cycle.
- Litter from users of the boardwalk will either disperse into lagoon waters offshore from the boardwalk or be confined inshore and become enmeshed in the inshore wrack. The risk of increased little can be minimised by suitable signage at both ends of the boardwalk reminding users of the risks to wildlife of ingested litter plus implementation of suitable litter prevention methods and little collection methods either already in place for the lagoon walkway or under development.
- The embayment provides feeding and shelter habitat for black swans and a variety of ducks and the riparian shore provides additional riparian shelter for ducks. Given that

the boardwalk is located over the shallow wrack zone it is considered that swan and duck seagrass feeding habitats offshore would not be impacted.

- Notwithstanding, there is likely to be a greater level of disturbance of feeding birds using these habitats by virtue of the use of the boardwalk. The extent to which birds such as black swans would be disturbed hinges on the acclimatisation of these birds to human disturbance on the lagoon arising from other water activities such as kayaking and sailing. Overall it is considered that the potential disturbance of swans and ducks feeding offshore from the boardwalk would be insubstantial for the populations as a whole as there are alternative shallow water seagrass beds for grazing locally and around the lagoon that are exploited by these birds as they balance natural (tide, wind and wave) conditions and human disturbance to make their feeding and shelter choices.
- Use of the shallows and riparian shore by ducks with fledged chicks is unlikely to be altered to any significant degree, as the existing disturbance from people using the onshore track would be re-located an equal distance offshore.

4 SUMMARY AND CONCLUSIONS

The proposed replacement of a section of narrow Narrabeen Lagoon walkway immediately adjacent to Wakehurst Parkway between Deep Creek and Bilarong Reserve would result in the loss of a small amount of riparian vegetation that is common around the perimeter of Narrabeen Lagoon. It is concluded that the loss of the riparian plants to the boardwalk footprint would not result in any risk to the survival of riparian vegetation communities in the locality or around the lagoon. Any individual plants that are considered of local significance can be collected and relocated prior to construction. Further, the closure and rehabilitation of the section of walkway to be replaced will enhance the local riparian communities in the long term.

Whilst placing a section of the boardwalk over the inshore shallows of Narrabeen Lagoon would result in a minor loss of some *Zostera* seagrass and *Ruppia magacarpa* that is growing in amongst and/or smothered by accumulated and decaying wrack in the shallows of Narrabeen Lagoon, the proposed alignment of the boardwalk would avoid the main mixed *Halophila* and *Zostera* seagrass bed that is located seawards of the footprint. Use of mesh for the walkway platform would allow light penetration to the seabed further minimising the loss of seabed plant life to shading.

The placement and use of the boardwalk is not likely to alter the water and wrack circulation characteristics of the small embayment in any way that would put the seagrass beds in the embayment at risk, and there are unlikely to be any cumulative risk for aquatic birds (mainly black swans and ducks) that use the seagrass beds and riparian shallows of Narrabeen Lagoon for feeding and shelter.

As the proposal does not include dredging or reclamation and as it is considered that the potential seagrass loss is insignificant it is concluded that the project would most likely not require a permit under the Fisheries Management Act 1994 (FMA).

The potential impacts of construction of the walkway have been assessed, and it is concluded that the construction can be achieved with minimal risk to the adjacent riparian and aquatic habitats and communities provided suitable protection measures are implemented and specified in a project Construction Environmental Management Plan (CEMP) that includes the aquatic ecology management options specified in this report. In this way the project should be able to achieve the aims of aquatic ecological conservation of the Fisheries Management Act (1994) (as summarised in NSW Fisheries 2013) and the aims of aquatic ecological conservation of Pittwater 21.

5 REFERENCES

CEL (2013)

Seagrass mapping and validation in Narrabeen Lagoon. Letter report to Warringah Council 7 March 2013.

EPA (1992)

Coastal resource atlas for oil spills in Broken Bay, Pittwater and the Hawkesbury River. NSW EPA. March 1992.

NSW Fisheries (1999)

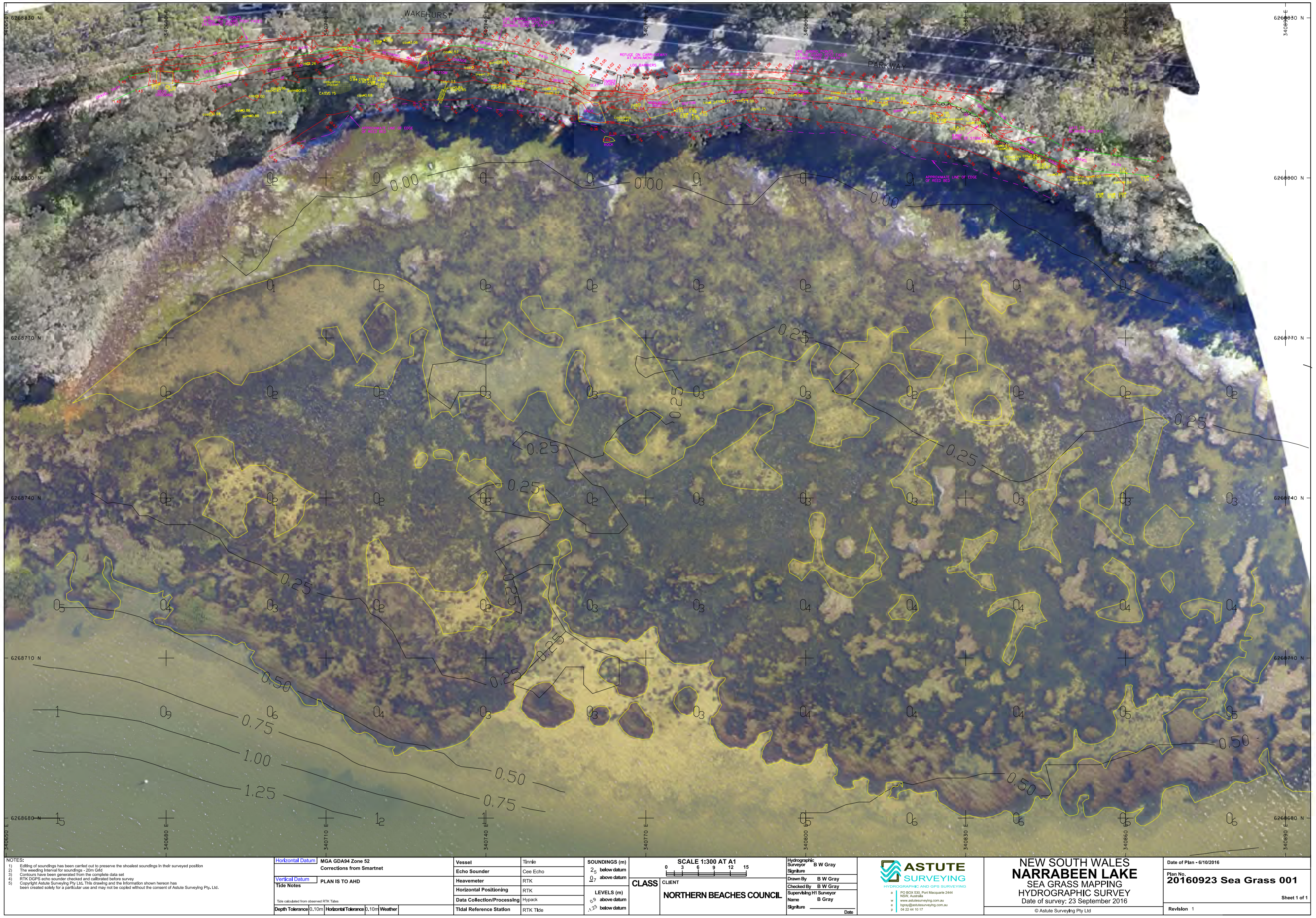
Policy and Guidelines. Aquatic Habitat Management and Fish Conservation (Eds A K Smith and D A Pollard) NSW Fisheries, Port Stephens Research Centre 86 pp.

West R J, Thorogood C, Walford T, Williams R J (1985)

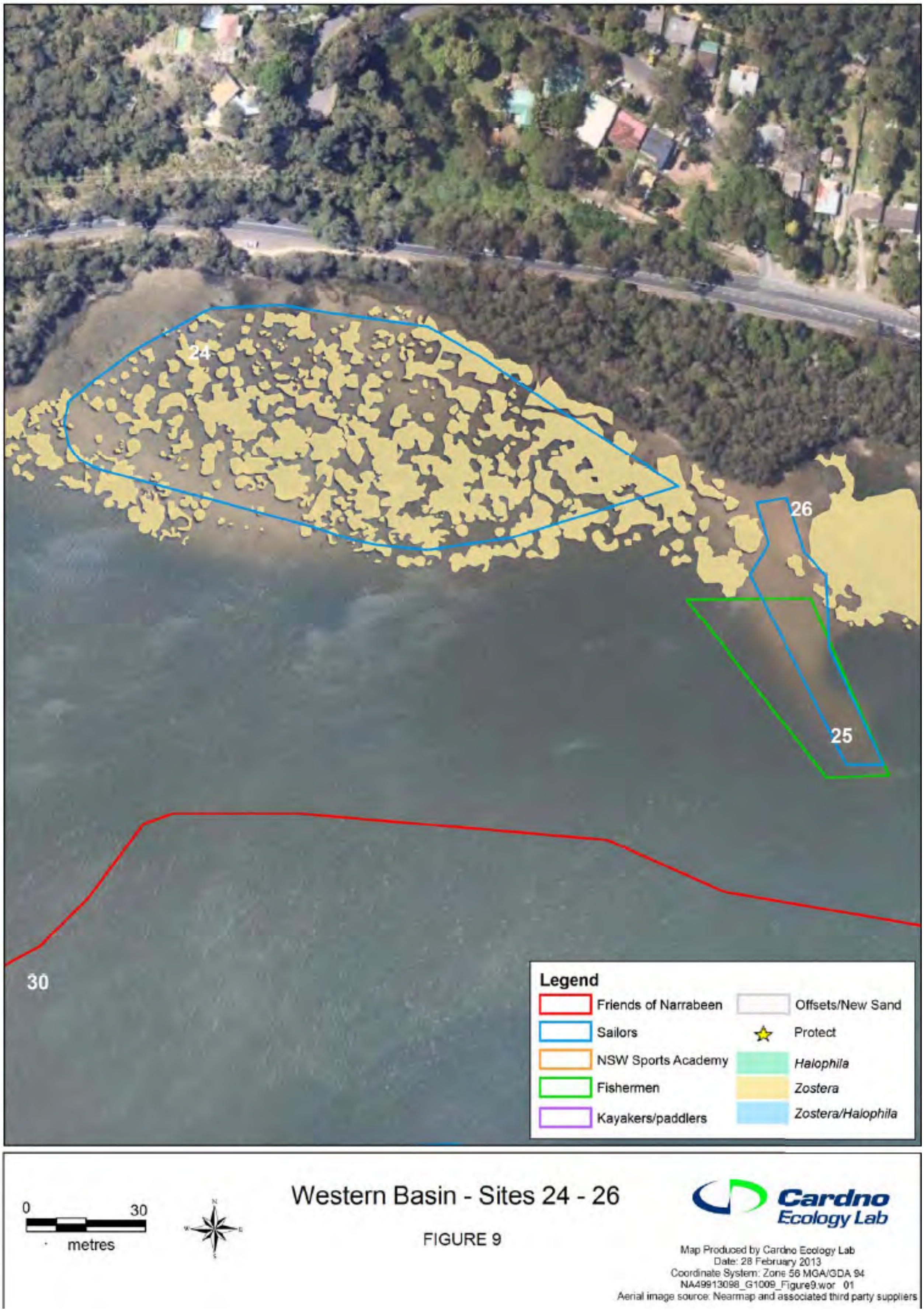
An estuarine inventory for New South Wales. Fisheries Bulletin No 2. Dept of Agriculture, NSW Sydney 165 pp.

West R J (2010)

The seagrasses of NSW estuaries and embayments. Wetlands (Australia) 26 (1): 34-44.



Appendix A Copy of the Astute Surveying Plan



Appendix B Copy of Figure 9 from CEL (2013)

APPENDIX C ADDITIONAL FIELD PHOTOGRAPHS

Plate 1 View of inner wrack habitat looking east from large rock adjacent Narrabeen Parkway parking bay.

Plate 2 View of inner wrack habitat looking west from large rock adjacent Narrabeen Parkway parking bay.

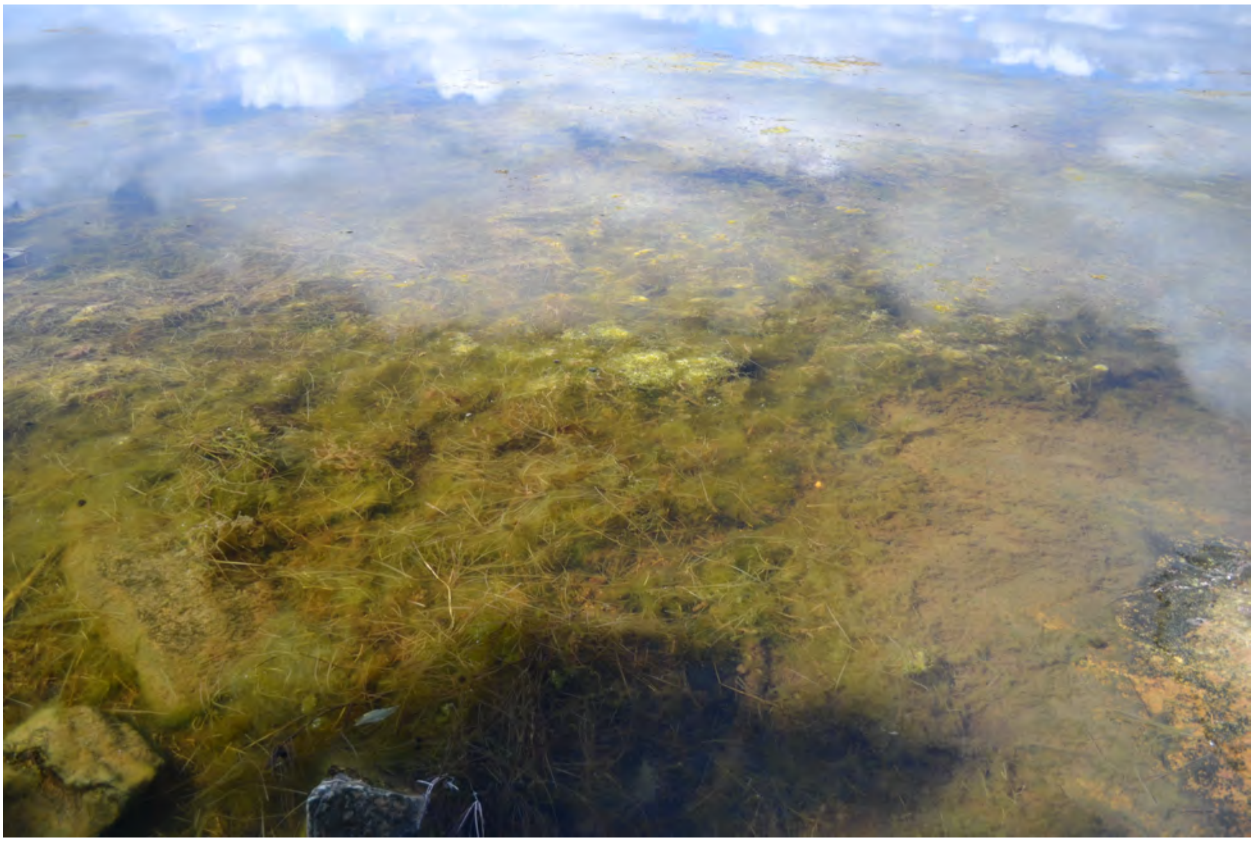


Plate 3 Close up view of inner wrack habitat looking south from large rock adjacent Narrabeen Parkway parking bay. Note green algae growing on the surface of the wrack accumulations.

Plate 4 Close up of wrack showing *Ulva* (formerly *Enteromorpha*) *intestinalis* green algae growing over the wrack accumulations.

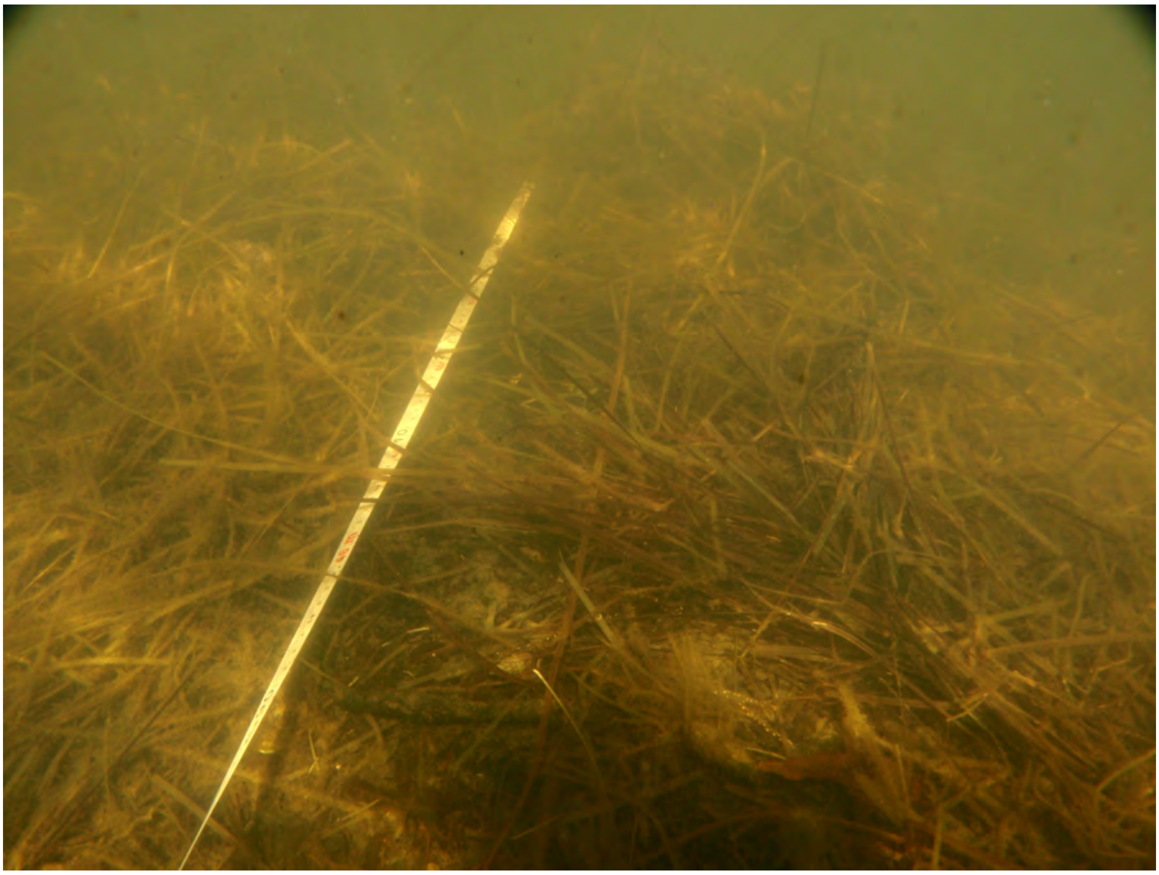


Plate 5 Transect tape laid over wrack deposits (inner shallow transect).

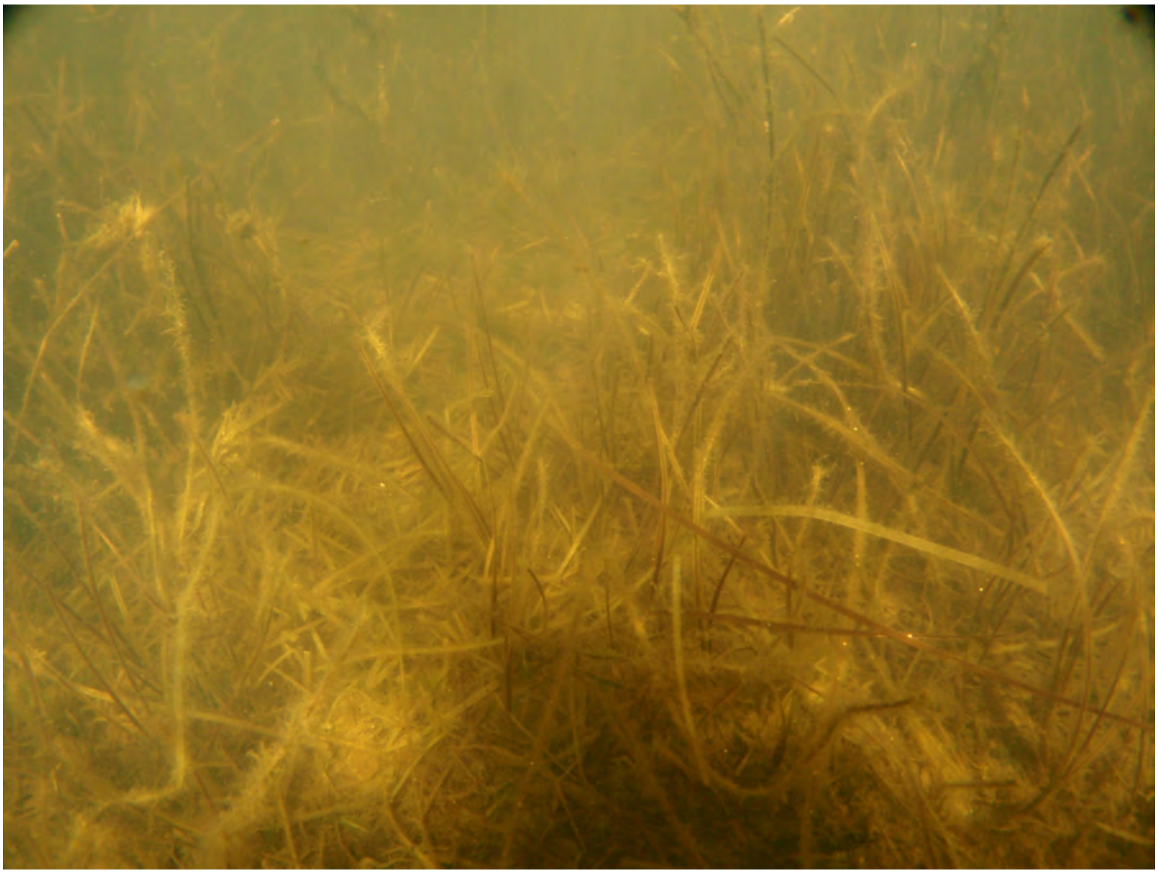


Plate 6 Sparse *Zostera* and *Ruppia* growth intermingled with seagrass wrack along boardwalk outer transect alignment.

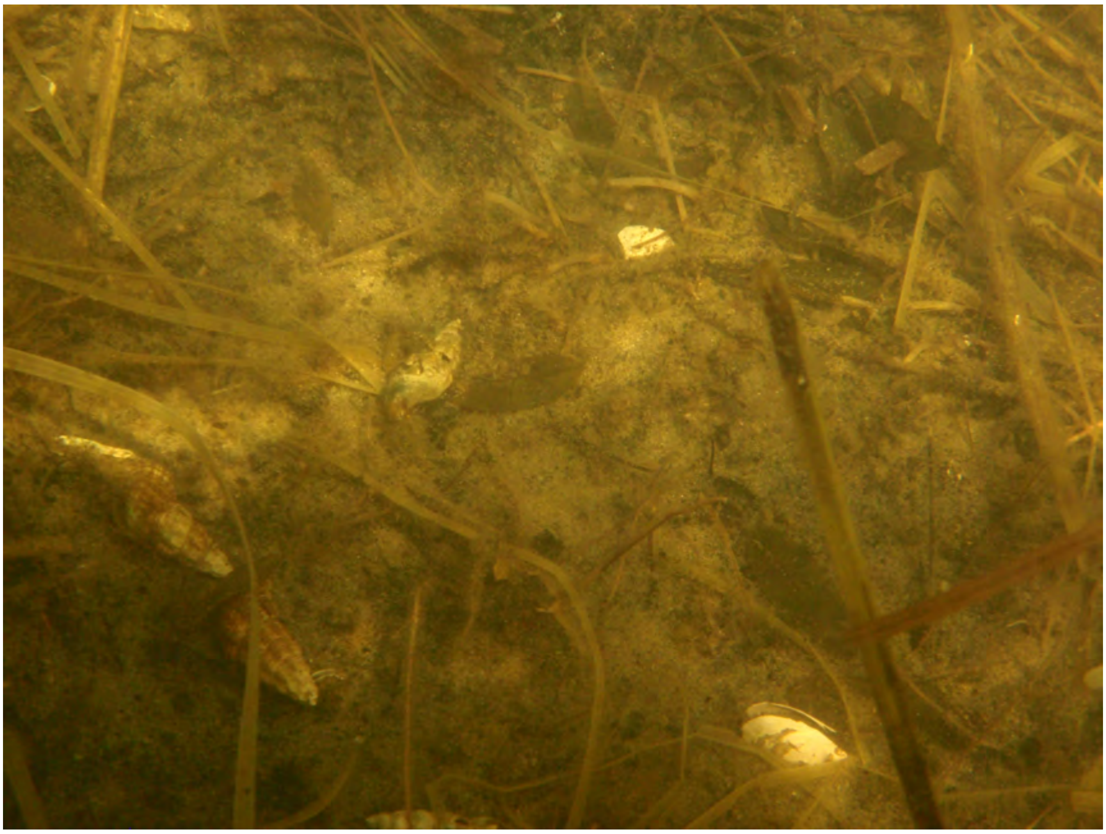


Plate 7 View of bare sandy habitat under wrack along boardwalk centreline

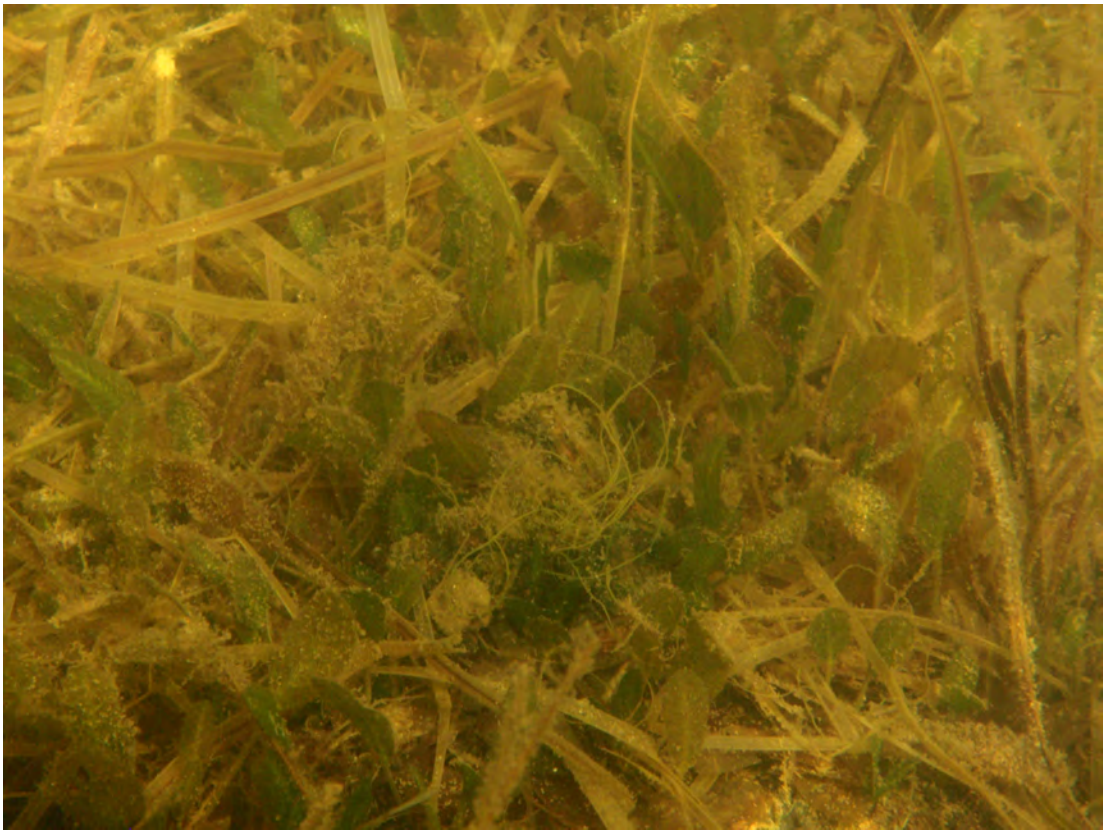


Plate 8 Small (less than 0.5m diameter patch of *Halophila* under wrack on outer transect line towards eastern end.

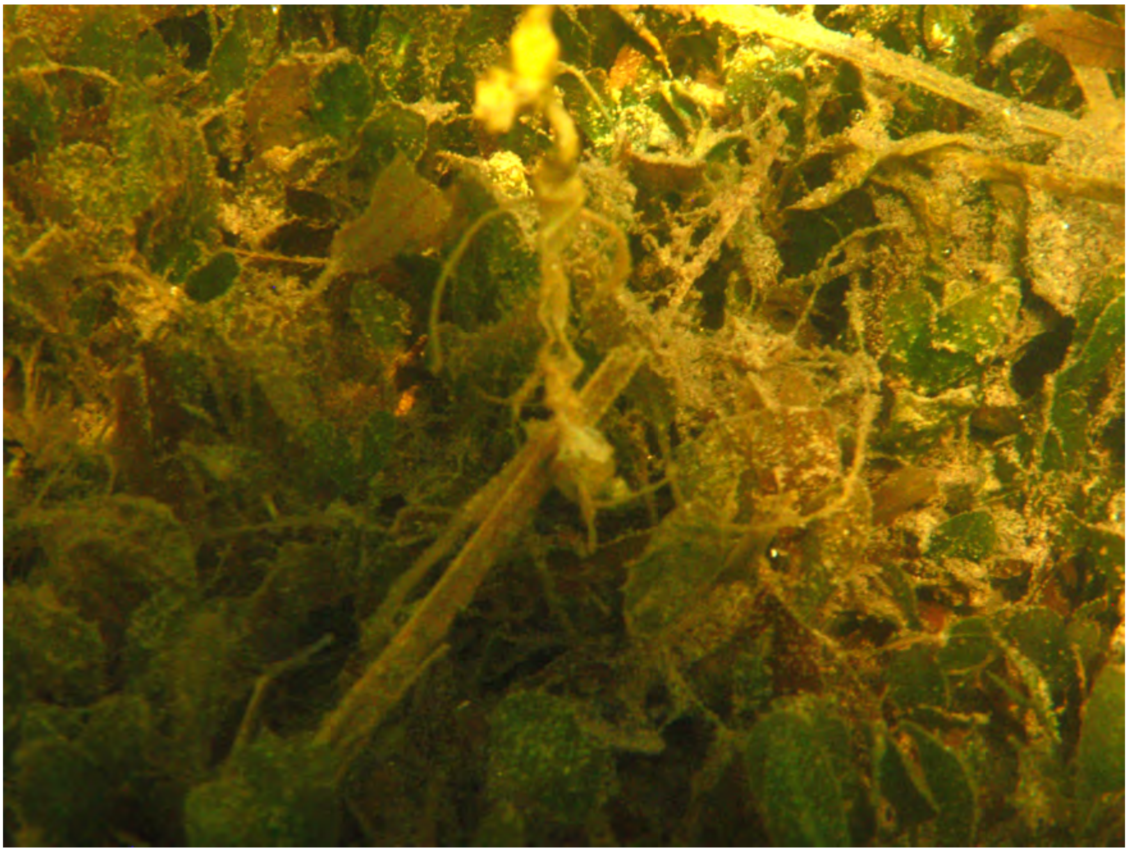


Plate 9 Contrast the sparse *Halophila* distribution in Plate 6 with the dense distribution offshore from the boardwalk study area.

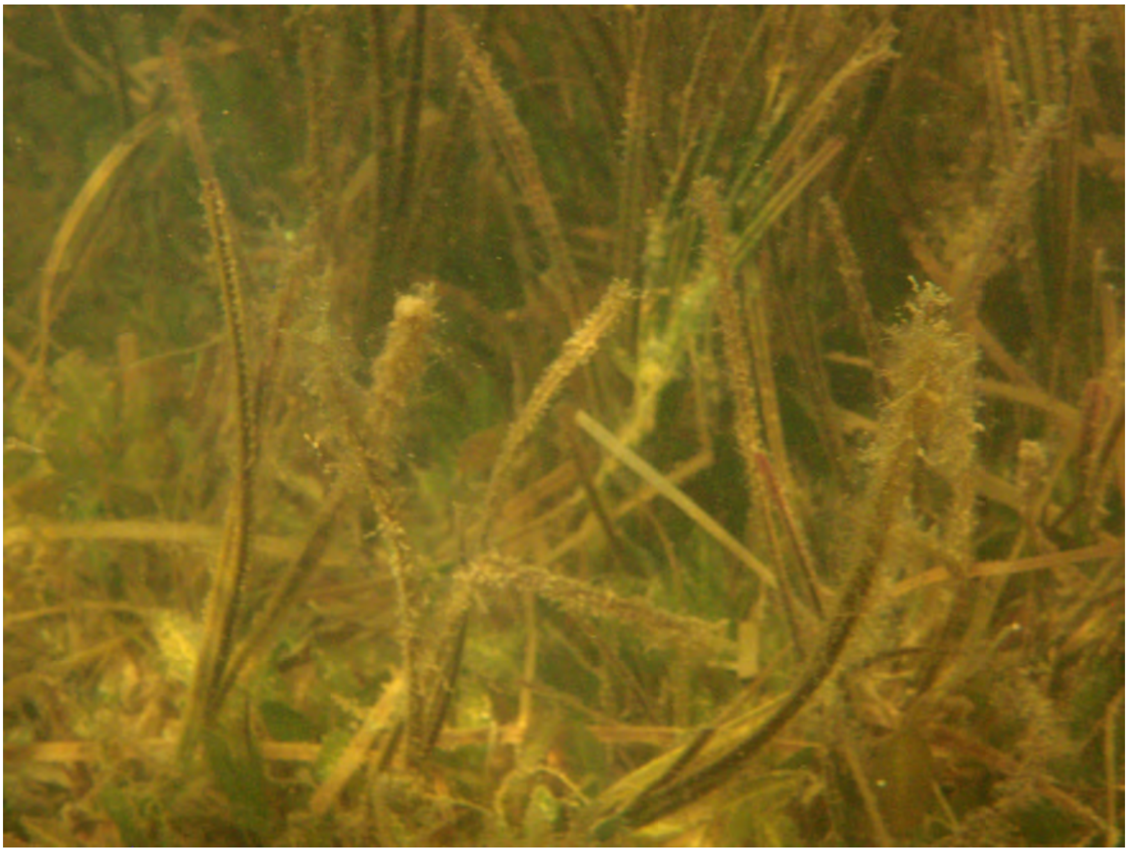


Plate 10 View of *Zostera* plus base *Halophila* distribution offshore from the boardwalk study area.

Plate 11 View from above the water of a *Ruppia* patch along the outer boardwalk transect.

Plate 12 View from the waster east along boardwalk centre line showing plastic poles set on the line to hold the transect tape in place for the survey.