6. Entrance Behaviour

6.1 Characteristics of ICOLLS

Intermittently closed and open lakes and lagoons (ICOLLs) are created in wave-dominated entrances when the wave action becomes so dominant that entrance closure occurs on an intermittent basis (Hanslow et al. 2000). ICOLLs go through a cyclical process of infilling and berm formation due to wave action and subsequent breaching and scour due to fluvial action.

Due to their intermittent closure ICOLLS are linked to specific management issues such as water quality problems, periodic flooding of areas below berm level, algal blooms and odour. Over three-quarters of the ICOLLs in NSW are artificially opened for reasons of poor water quality or flooding. The most common justification for the artificial opening of lagoon entrances is for flood mitigation (Lugg 1998). This is also the case for Killick Creek, which is part of the Macleay Flood Mitigation Scheme and is kept open as an ocean outlet. If the ocean outlet were not kept open flooding of adjacent areas would increase, dependent on the height of the entrance berm, the level of drainage in the hinterland, and entrance conditions at Ryans and Big Hill cuts.

The hydrology of the creek is determined by the frequency and duration of entrance opening. Lagoons with permanently open entrances, such as Killick Creek, tend to have relatively stable water levels, varying across the tidal range on a twelve-hour cycle (Lugg 1998). Salinity also tends to be stable, varying from saline during dry periods and near-fresh during floods.

Under natural conditions the frequency and duration of closure of estuarine entrances is influenced by a number of factors including the morphology of the entrance site, exposure of the entrance site to the processes of ‘longshore drift’, the size of the catchment, the tidal prism and prevailing climatic conditions (Lugg 1998). Killick Creek, like many other estuaries, has a stabilised entrance with a training wall. Together with periodic dredging programs this maintains a permanently open entrance channel. Regular artificial opening can degrade wetland and riparian vegetation, reduce fishery production in the long term and contribute to a decline in regional biodiversity (Hanslow et al. 2000).

ICOLLs have a natural breakout range and an artificial opening within this range is not likely to have significant environmental effects, and can be considered part of the natural variation of the system. Continued artificial opening of the entrance at a level within the natural range is likely to have significant impact since the frequency distribution will be altered (Lugg 1998). Continued artificial opening at a level outside the natural range is expected to have large impacts on the system, especially on ecological processes. Conceptual frequency distribution curves for natural and artificial breakouts are presented in Figure 6.1.

6.2 Historical Assessment of Entrance Characteristics

6.2.1 Wave Climate

The wave climate may be inferred from data from the Crowdy Head Waverider buoy operated by MHL which is located in 79 m of water about 10 km east of Crowdy Head (approximately 70 km south of Crescent Head). Long-term statistical analysis of this data is available from 10 October 1985 to date and includes deepwater wave direction from hindcasting from October 1985 to December 1996. A summary of wave height exceedance statistics for the period 10 October 1985 to 31 December 1999 is shown in Figure 6.2 and directional statistics are presented in Figure 6.3.

6.2.2 Storm History

Storms are generally defined as events in which the significant wave height (Hs) exceeds 3 m. Storm events recorded by the Crowdy Head Waverider buoy from 1985 to 1999 where Hs exceeded 5 m are listed in Table 6.1.

Table 6.1 Occurrence of Significant Waves H_s > 5 m at Crowdy Head for period 1985 to 1999

Storm Start Date	Storm End Date	Peak H_s (m)	Mean T_s (s)	Peak Direction
12-May-86	15-May-86	5.1	8.1	E
4-Aug-86	12-Aug-86	5.9	10.1	SE
12-Nov-87	13-Nov-87	5.9	9.6	S
8-Feb-88	11-Feb-88	6.5	10.6	S
9-Apr-88	12-Apr-88	5.0	9.9	SSE
24-Aug-88	25-Aug-88	5.0	9.6	SSE
23-Apr-89	30-Apr-89	5.3	9.0	E
20-Jun-89	25-Jun-89	5.8	10.2	ESE
26-Sep-89	29-Sep-89	5.8	10.0	SSE
7-Mar-90	10-Mar-90	6.3	10.4	SSE
28-May-90	30-May-90	6.7	9.2	SE
24-Aug-90	28-Aug-90	5.0	10.0	SSE
12-Oct-90	15-Oct-90	6.4	11.1	S
8-Jun-91	11-Jun-91	5.0	9.0	E
30-Nov-92	2-Dec-92	5.2	9.6	SE
12-Mar-94	15-Mar-94	5.3	11.0	S
7-Sep-94	9-Sep-94	5.0	11.2	S
2-Mar-95	5-Mar-95	7.4	9.9	ESE
6-Mar-95	8-Mar-95	6.3	10.4	E
5-Sep-95	8-Sep-95	5.1	10.8	S
25-Sep-95	28-Sep-95	5.4	10.0	SSE
19-Aug-96	20-Aug-96	5.8	9.9	S
9-May-97	12-May-97	6.3	10.1	SSE
4-Feb-99	5-Feb-99	5.3	9.8	E
22-Apr-99	25-Apr-99	6.5	11.2	ESE
13-Jul-99	17-Jul-99	6.8	10.5	ESE
9-Nov-99	12-Nov-99	5.0	11.0	SSE

As waves propagate from deep water onto the continental margin their speed and direction may be altered by the decreasing water depth. Waves approaching at an angle are refracted, or bent, such that their wave crests tend to align more parallel to the shore. The net longshore transport rate depends on the prevailing wave conditions. At Crescent Head the dominant angle of approach of waves (neglecting local wind waves) is from between east and south with waves from between north and east occurring less than 5% of the time. Net longshore transport is consequently strongly to the north.

6.3 Effect of Sea Level Rise on Entrance Conditions

Over the next 100 years the global mean temperature and sea level are expected to rise due to an increased 'greenhouse effect'. The greenhouse effect is a predicted global warming associated with the build-up of certain gases in the atmosphere. Greenhouse gases are essentially transparent to incoming short-wave solar radiation, but they absorb the longer wavelength infrared radiation (heat) emitted by the earth. Thus heat is trapped in the atmosphere and the global temperature is increased.

The most up-to-date estimates of temperature and sea level rise are those provided by the International Panel on Climate Change (IPCC). In the third assessment report of 2001 (Albritton et al. 2001), the IPCC predicts an increase of global-averaged surface temperature of 1.4 to 5.8°C over the period 1990 to 2100. The range is due largely to uncertainty in the amounts of greenhouse gases which nations will emit and the use of a variety of different climate models. The projected temperature increases are higher and display a wider range than those in the IPCC second assessment report of 1995 (Houghton et al. 1996). Since then a greater understanding of climate change has developed due to improved data analysis and modelling techniques.

Global warming is associated with sea level rise as a result of thermal expansion of the oceans and melting of glaciers and ice-sheets. Despite higher temperature change projections in the IPCC third assessment report, the sea level rise projections are slightly lower compared to earlier assessments. This is due to improved models which give a smaller contribution from glaciers and ice-sheets. The latest projected global mean sea level rise is 0.09 to 0.88 m between 1990 and 2100 (Albritton et al. 2001).

Increased sea level is expected to lead to general beach recession. Concerning ICOLLs, beach recession is expected to be accompanied by landward and upward translation of the entrance berm (Hanslow et al. 2000). This results in higher lagoon levels and a higher flood risk to shoreline development.

Besides sea level and temperature rise another possible effect of climatic change is a change in weather patterns through changes in wind and precipitation patterns. These changes may severely affect coastal areas, including foreshore alignment and stability, siltation, shoal formation and foreshore inundation levels. These potential changes need to be accommodated in planning foreshore development, facilities and services.

6.4 Berm Height and Flooding

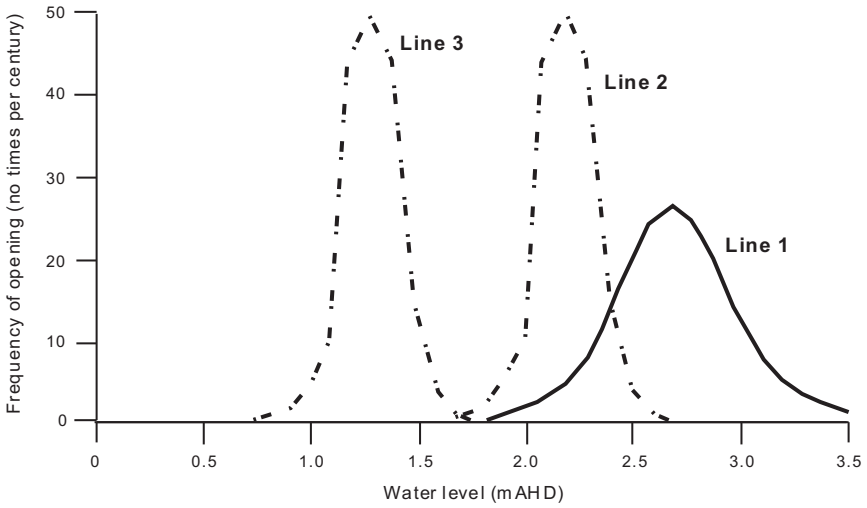
Berms are depositional features on beaches that develop as a result of wave runup and overwash. Berm development represents the final stage in an entrance closure. The formation of berms (shown in Figure 6.4) occurs when sediment is deposited near the limit of wave runup as the wave velocity decreases due to gravity, friction and percolation. If the wave height remains constant vertical growth of the berm continues until the berm height equals the maximum height of the wave runup. Higher waves produce higher berms but above the critical erosion-accretion threshold higher waves erode the beachface leading to rapid berm removal (Hanslow et al. 2000).

The hydraulics and water flows of the upper Belmore River, Connection Creek and Killick Creek, Ryans Cut and Big Hill drains is highly complex. The Killick Creek waterway is only a small fraction of this system. In the event that the Killick Creek entrance is permanently maintained in an open condition the flooding of the hinterland or upper Belmore area will continue to drain through Killick Creek alleviating flooding in these areas. The details of the water flows during such an event are not well understood and should be further investigated to assist with an assessment of the entrance management options.

6.5 Effects of Opening Strategies on Fringing Flora and Fauna

Clearly it is important to consider the impact of floodgates as well as the opening and closing of the creek mouth. For example, two commercially important prawns occurring in NSW (king prawns, *Penaeus plebejus* and school prawns, *Metapenaeus macleayi*) are known to migrate out of estuaries into the ocean to spawn. This migration occurs typically in late summer and autumn and there is compelling evidence that these migrations are triggered by flood events (Racek 1959, Ruello 1973, Glaister 1978). Glaister (1978) advised that changes to flood regimes within estuaries could affect the movement of prawns and potentially affect fisheries targeting these species. Second, sea mullet (*Mucil cephalus*) migrate from the upper reaches of estuaries to sea at two stages in their life cycle. The spawning migration of sea mullet typically occurs in autumn in NSW and appears due to the onset of westerly winds rather than flooding. Larval sea mullet are carried by currents back into estuaries, where they settle in suitable nursery habitat, often including shallow, brackish and freshwater backwaters and wetlands (TEL 1996). Third, Australian bass (*Macquaria novaemaculata*) normally reside in the freshwater upper reaches of estuaries along Australia's east coast. Bass migrate to the brackish reaches of estuaries in winter to spawn, typically in response to flooding. After spawning, the adults migrate back up the river and are followed by small juveniles migrating to upstream nursery habitats. There are several other, less well understood movements (SPCC 1981) such as the movements of yellowfin bream, luderick and sand whiting from estuarine habitats to rocky headlands and/or ocean beaches adjacent to estuaries to spawn; the reported movement of mulloway to spawn at the entrance to or the mouths of estuaries; and the reported movement of several freshwater fishes from the headwaters into brackish waters to spawn.

Physical changes to estuaries may affect these movements by affecting the cues triggering migration (e.g. by changing the hydrodynamic regime) or by imposing obstacles to movement (e.g. flood mitigation works). It is often difficult, however, to demonstrate unambiguously an effect due to these physical changes because of natural variability in populations and environmental conditions. Moreover, as is the case in the Macleay, such barriers may occur in different parts of an estuary and there is a need to distinguish which areas are being or have the potential to be affected. There is also a need to assess the relative impact of specific obstacles on the estuarine ecosystem (TEL 1996).



Line 1 - Natural breakout frequency curve. Upper and lower limits define natural breakout range

Line 2 - Artificial breakout frequency curve for a level set within the natural breakout range (in this case 2.2m)

Line 3 - Artificial breakout frequency curve for a level set below the natural breakout range (in this case 1.3m)

(Note: each of these lines represents exactly the same frequency of breakout i.e. 175 times per century)

Source: Lugg, A. 1998

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CONCEPTUAL FREQUENCY DISTRIBUTION CURVES FOR NATURAL AND ARTIFICIAL BREAKOUTS OF ICOLLS

MHL Report 1125
Figure 6.1
DRAWING 1125-06-01.CDR

NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES
MANLY HYDRAULICS LABORATORY

CROWDY HEAD
WAVE HEIGHT EXCEEDANCE STATISTICS
OCTOBER 1985 TO DECEMBER 1999

MHL1125 - 79

MHL Report 1125
Figure 6.2
DRAWING 1125SHEET.DGN

EXCEEDANCE STATISTICS FOR CRHDO

Public Works Department, NSW
Manly Hydraulics Laboratory
110B King Street
MANLY VALE NSW 2093

Nominated start/finish: 10-OCT-85 to 31-DEC-99
Data start/finish: 10-OCT-85 to 31-DEC-99

Creation date: 13-JAN-00
Maximum value: 7.35 recorded on 04-MAR-95
Minimum value: 0.42 recorded on 04 JUL 92

PERCENTAGE EXCEEDANCES FOR HSIG IN METRES

HSIG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	HSIG
0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.000	0.00
0.25	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.000	0.25
0.50	100.00	100.00	99.99	99.94	99.89	99.94	99.94	99.94	100.00	99.80	100.00	100.00	99.953	0.50
0.75	98.02	99.05	98.82	98.07	96.43	96.88	97.48	95.98	98.16	96.57	98.15	98.08	97.617	0.75
1.00	83.32	90.34	93.85	89.31	85.66	88.00	87.10	84.41	86.10	80.86	86.06	83.87	86.468	1.00
1.25	62.91	70.94	80.68	70.90	68.73	70.72	70.80	65.95	65.99	58.12	64.50	62.13	67.508	1.25
1.50	42.62	48.47	59.73	51.92	52.48	54.66	52.37	49.69	46.89	40.29	42.91	40.18	48.339	1.50
1.75	25.57	33.68	42.02	37.23	38.26	39.31	37.27	35.55	31.19	27.36	27.77	26.35	33.331	1.75
2.00	15.66	23.24	28.33	24.79	25.72	26.67	25.51	26.17	21.22	17.96	18.10	16.99	22.416	2.00
2.25	8.83	16.31	19.53	16.25	16.41	18.40	16.97	19.07	14.15	11.76	11.73	10.92	14.935	2.25
2.50	4.36	11.26	13.86	10.85	10.39	11.84	11.44	14.07	9.37	7.71	7.58	6.84	9.896	2.50
2.75	2.24	8.14	9.12	7.81	6.37	8.38	7.61	9.85	6.12	5.55	4.97	4.01	6.628	2.75
3.00	0.98	5.68	6.27	5.81	3.96	5.95	4.96	6.98	4.52	3.99	3.23	2.36	4.480	3.00
3.25	0.44	3.83	4.27	4.45	2.92	4.25	2.83	4.69	3.49	2.75	2.12	1.20	3.066	3.25
3.50	0.14	2.36	3.30	3.33	2.15	3.18	1.79	3.37	2.54	1.87	1.28	0.69	2.142	3.50
3.75	0.03	1.57	2.49	2.37	1.34	2.23	1.14	2.32	1.75	1.33	0.77	0.37	1.453	3.75
4.00	0.02	0.96	1.93	1.65	0.82	1.51	0.86	1.56	1.17	0.87	0.45	0.25	0.990	4.00
4.25	0.00	0.71	1.62	1.16	0.55	1.07	0.68	0.92	0.83	0.51	0.30	0.21	0.698	4.25
4.50	0.00	0.52	1.24	0.82	0.38	0.69	0.51	0.68	0.52	0.31	0.17	0.15	0.495	4.50
4.75	0.00	0.32	1.01	0.52	0.32	0.33	0.47	0.44	0.35	0.14	0.03	0.10	0.333	4.75
5.00	0.00	0.21	0.74	0.26	0.24	0.19	0.43	0.27	0.23	0.11	0.03	0.03	0.224	5.00
5.25	0.00	0.17	0.60	0.17	0.17	0.08	0.36	0.16	0.13	0.07	0.04	0.00	0.157	5.25
5.50	0.00	0.12	0.43	0.15	0.15	0.04	0.24	0.09	0.07	0.04	0.01	0.00	0.108	5.50
5.75	0.00	0.11	0.34	0.13	0.09	0.01	0.18	0.03	0.01	0.02	0.01	0.00	0.075	5.75
6.00	0.00	0.07	0.27	0.09	0.07	0.00	0.12	0.00	0.00	0.02	0.00	0.00	0.051	6.00
6.25	0.00	0.04	0.18	0.01	0.03	0.00	0.08	0.00	0.00	0.01	0.00	0.00	0.028	6.25
6.50	0.00	0.00	0.10	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.009	6.50
6.75	0.00	0.00	0.09	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.007	6.75
7.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.003	7.00
7.25	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.001	7.25

Number of data points used for statistical analysis:	8700	8022	8204	8762	9149	9043	9278	9298	8535	9091	10418	8898	108398
Percent capture based on Data start/finish:	83.53	82.74	78.76	86.92	87.84	89.71	89.07	89.27	84.67	83.13	96.46	85.70	86.78
Percent capture based on Nominated start/finish:	83.53	82.33	78.76	86.92	87.84	89.71	89.07	89.27	84.67	83.07	96.46	85.70	86.74
Average value:	1.49	1.67	1.80	1.69	1.66	1.71	1.68	1.68	1.61	1.52	1.55	1.51	1.63

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MANLY HYDRAULICS LABORATORY

CROWDY HEAD
DIRECTIONAL STATISTICS
OCTOBER 1985 TO DECEMBER 1999

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MHL Report 1125

Figure 6.3

DRAWING 1125DS3.CDR

OCCURRENCE STATISTICS FOR CRHDO

Public Works Department, NSW
Manly Hydraulics Laboratory
110B King Street
MANLY VALE NSW 2093

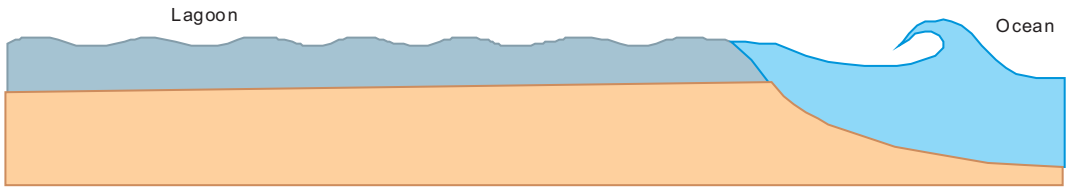
Nominated start/finish: 10-OCT-85 to 31-DEC-96
Data start/finish: 10-OCT-85 to 31-DEC-96

Creation date: 29-AUG-01

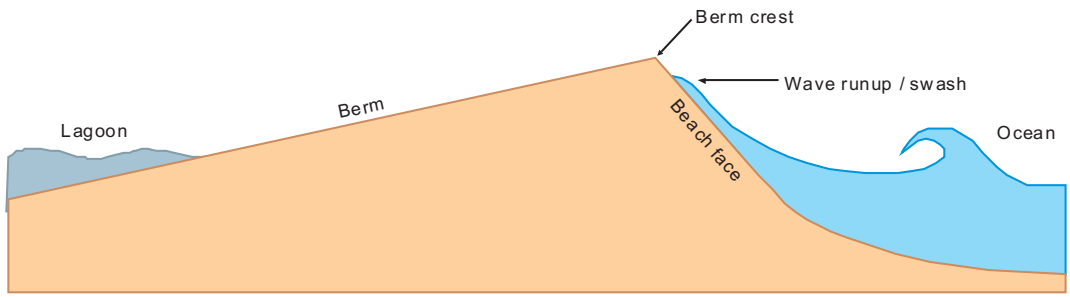
Wave direction origin:
Hindcast - 100 %

PERCENTAGE OCCURRENCE FOR WAVE_DIRECTION IN DEGREES FROM TRUE NORTH

DIRN	DEG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
N	348.75 - 11.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
NNE	11.25 - 33.74	1.17	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.58	0.52	0.256
NE	33.75 - 56.24	8.67	1.73	2.48	2.79	2.55	1.78	1.61	2.61	6.66	13.61	9.83	13.71	5.852
ENE	56.25 - 78.74	16.36	11.99	10.03	9.83	7.63	4.20	7.82	5.96	11.36	12.50	17.28	15.60	11.085
E	78.75 - 101.24	20.35	23.13	21.59	22.81	17.60	18.41	11.33	14.25	14.90	11.00	13.93	17.91	17.131
ESE	101.25 - 123.74	20.81	23.62	23.34	16.53	21.10	20.41	22.38	15.81	15.82	13.01	13.88	13.96	18.229
SE	123.75 - 146.24	17.81	23.62	21.56	21.99	27.75	26.57	27.65	31.89	20.99	22.33	23.00	17.40	23.541
SSE	146.25 - 168.74	8.03	10.74	12.86	15.38	14.04	15.38	14.65	15.80	17.45	14.71	11.26	9.98	13.289
S	168.75 - 191.24	6.78	5.18	8.15	10.66	8.69	13.25	14.56	12.68	12.83	12.84	10.24	10.92	10.619
SSW	191.25 - 213.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
SW	213.75 - 236.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
WSW	236.25 - 258.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
W	258.75 - 281.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
WNW	281.25 - 303.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
NW	303.75 - 326.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
NNW	326.25 - 348.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
Number of days used for statistical analysis:		287	270	269	281	297	302	298	297	270	294	354	332	3550
Percent capture based on Data start/finish:		84.30	85.30	78.85	85.03	87.15	91.38	87.46	87.10	81.70	89.97	98.19	89.12	86.44
Percent capture based on Nominated start/finish:		84.30	84.77	78.85	85.03	87.15	91.38	87.46	87.10	81.70	89.90	98.19	89.12	86.39
Average direction:		105.39	113.99	117.31	120.04	121.57	127.19	128.33	127.84	121.44	115.48	111.62	106.79	118.23



Open entrance conditions



Closed entrance conditions

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BERM FORMATION AS A RESULT OF WAVE RUNUP

MHL Report 1125
Figure 6.4
DRAWING 1125-06-04.CDR

7. Estuary Sediments

7.1 Introduction

A study undertaken by the University of New England in 1992 (UNE 1993) investigated the physio-chemical characteristics of the creek. In particular, information was collected on depth, volumes, tidal flux, water quality and sediment quality. It was found that sediments were mostly fine sands with varying amounts of silt and pebble depending on site. Areas where the creek deepens and widens (e.g. the junction with the flood cutting) had high organic content and high oxidisable sulfur content in sediments. Substantial quantities of organic matter accumulate in these depressions due to inadequate scouring. Sediments in depressions in the upper reaches of the estuary are characterised by an abundance of partly decomposed organic matter (black ooze) which forms the bulk of the reservoir of material with a high potential oxygen demand.

The black ooze is essentially organic-rich mud that is highly productive and generally anoxic. It is typically found in NSW coastal lakes such as Lake Ainsworth and Lake Curalo. The ooze contains considerable store of nutrients and may at times drive the nutrient balance of the system. While it is unpleasant to the human nose when exposed, it forms an important contribution to the nutrient budget and algal blooms.

A conceptual model of estuarine sedimentation in Killick Creek has been produced based on results of previous studies on similar systems and preliminary observations (Figure 7.1). Limited sediment sampling by DLWC conducted in 2001 qualitatively confirms the boundaries shown in Figure 7.1.

Major depositional environments within the study area include sandy fluvial deltas and estuarine mud basin deposits. The fluvial deltas occur in the entrance of the creek and are comprised of coarse-grained marine sands washed in by wave action and by wind erosion from the beach/dune. Mud basin sediments (organic rich muds and sandy muds) accumulate in the deeper sections of the estuary further away from the entrance and appear to be derived from both local (Killick catchment) and remote (Macleay River catchment) sources.

Surrounding soils are mostly sandy Pleistocene/Holocene deposits of marine sands. These sediments erode and result in some infilling of the system. Anecdotal evidence (from local residents) suggests the creek originally had some deep holes (>5 m deep) that have infilled since the 1950s. It is not possible after the event to confirm the veracity of these statements nor to quantify the rate of infill. A number of processes and activities could have led to accelerated infilling including clearing of dunes, realignment of the entrance, construction of roads and drainage channels etc.

7.2 Denitrification Efficiency

Denitrification efficiency refers to the biological 'self cleaning' ability of an estuarine ecosystem to convert bio-available nitrogen into unavailable nitrogen gas. Denitrification is an important process as it reduces the quantity of available nitrogen in the water column and thus restricts the development of harmful or excessive algal blooms. The process is carried out by groups of bacteria inhabiting the estuarine sediments.

The denitrification process has two steps and requires certain environmental conditions to proceed efficiently. The first step is 'nitrification' which involves the conversion of ammonium to nitrate and requires the presence of oxygen. The second step (denitrification) uses the nitrate in the breakdown of organic matter and produces nitrogen gas, requiring sufficient organic matter and nitrate. Denitrification efficiency can be impaired by chronic algal blooms as the breakdown of large amounts of algal material depletes oxygen in the water and sediments, stopping the process at the initial nitrification step.

Direct measurement of denitrification efficiency involves the collection and incubation of sediment cores and subsequent laboratory analysis using membrane inlet mass spectrometry. This procedure has not been undertaken in the Killick Creek estuary. The closest study performed was in the Brunswick estuary, where it was found that denitrification efficiency reduced towards the middle and upper sections of the estuary during the occurrence of large algal blooms (MHL 2000). The denitrification efficiency rates for most of the sites in the study were similar when compared with other shallow sub-tropical estuaries, although they were extremely high compared to efficiencies measured in other estuarine systems around the world.

It is recommended that measurements of denitrification efficiency be undertaken in Killick Creek at various temporal and spatial scales, as it has been suggested as a potentially useful health indicator in shallow sub-tropical estuaries where benthic microalgae and bioturbation are prevalent.

7.3 Littoral Transport

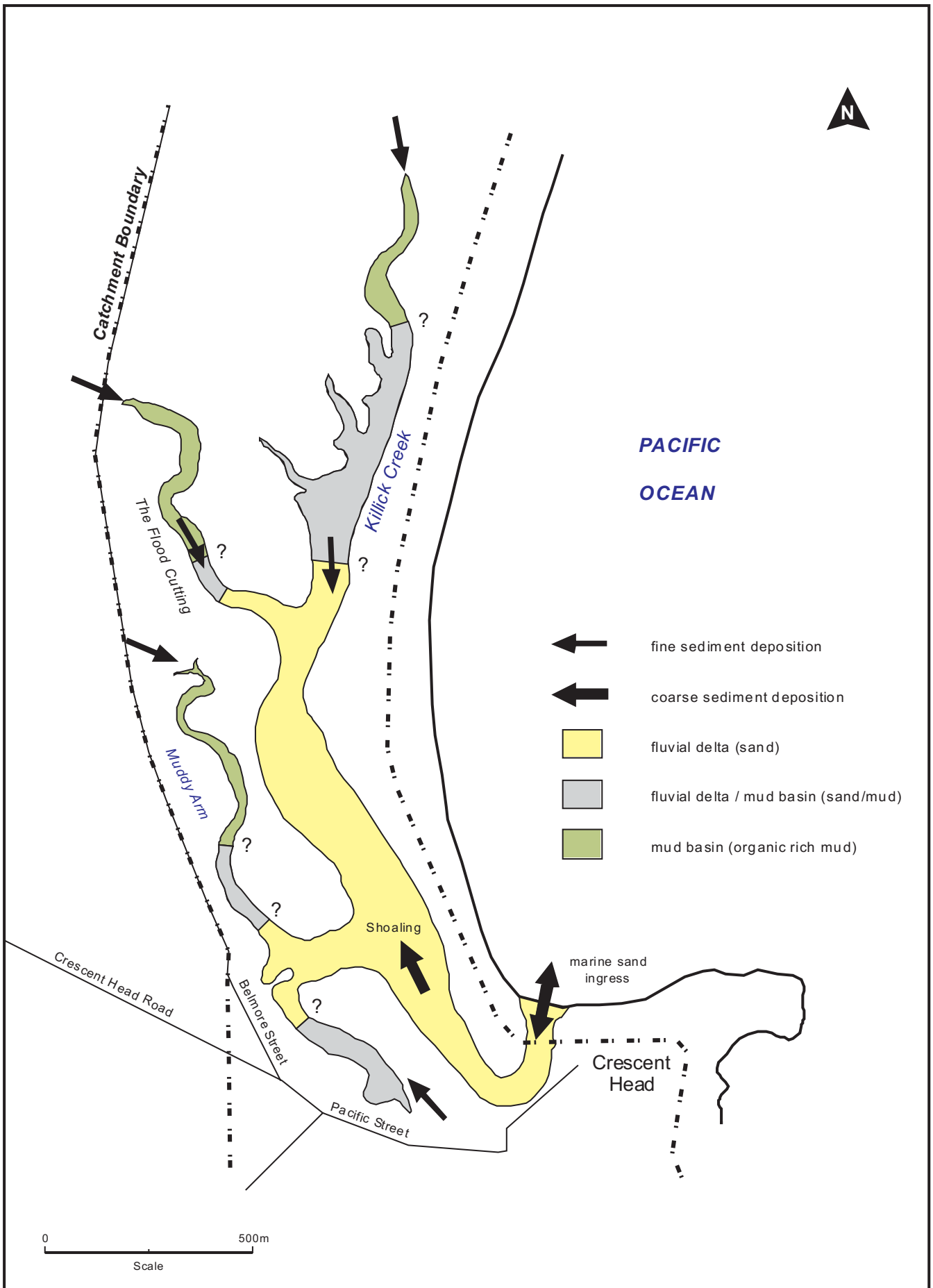
The entrance sediment dynamics are influenced by the littoral sediment transport along the beach, transport within the channel due to tidal and flood flow currents and aeolian sand drift along the aerial beach. The entrance channel is comprised of marine sands indicating a net ingress of marine sediments.

There are no known studies of littoral transport rates in the vicinity of Crescent Head and in particular near the Killick Creek entrance. In general there is a south to north littoral drift along the NSW coast. The magnitude of the drift increases towards the north but near Crescent Head it is thought that littoral transport rates are generally low. It would appear that a large sandy area exists off the entrance. The movement of this sand in response to storms and flood flows from the creek is not well understood. Certainly the local surfers report a seasonal migration of the sand bars but whether there is a net gain or loss of sand remains unknown. For the purpose of this study the important aspects include the movement of sand near the creek entrance and the potential for reshaping the entrance morphology.

Marine sediment transport along the beach is driven by the ocean waves, including long period ocean swell and locally generated wind waves, and the littoral currents due to wind and tides. The tidal currents along the beach (away from the entrance) are generally small and do not significantly affect the littoral transport. The combination of waves and wind-driven currents cause sediment movement both along and on/off the beach. The alongshore transport along the beach moves sediment towards the entrance resulting in a net movement into the entrance.

At times of entrance closure the alongshore sediment movement contributes to a gradual buildup of sand on the frontal dunes to the north of the entrance. This system presumably existed some time prior to the 1950s before the present entrance maintenance strategy.

Marine sediment movement into the estuary effectively causes a gradual shoaling or blocking of the entrance until a significant rainfall event or artificial means are used to open it. Within the estuary the shoaling and accretion patterns are a result of the sediment transport processes. Shoaling around the entrance to Muddy Arm has been noticed for some years and in recent times the mouth of Muddy Arm has been an area with a large shoal.



NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES
MANLY HYDRAULICS LABORATORY

SEDIMENT CHARACTERISTICS

MHL Report 1125

Figure 7.1

DRAWING 1112-07-01.CDR

8. Issues for Future Management

8.1 Key Issues Identified by Committee

The following issues were raised by the Killick Creek Working Party and the Coastal and Estuary Management Committee and were outlined in the brief.

- Water quality
- Salinity
  - Water quality of Scotts/Belmore/Kinchela drains and the impact on Killick Creek
  - Effect of Killick inundation of Belmore, Kinchela and Scotts drains and Belmore swamp area
  - Death of vegetation in freshwater swamp
  - 20 years saline incursion
  - Seawater inundation of local farmland.
- Stormwater
  - Effect of pollution on the health and recreational use of Killick Creek, tourism at Crescent Head and environs
  - Faecal coliform and contaminant (pesticides, insecticides and chemical residues) concentrations
  - Robust sample design
  - Runoff from the bowling green.
- Recreational use
  - Water quality within guidelines for swimming and recreational use now and in the future.
- Entrance management
  - Entrance shoaling, need for improved flushing
  - Entrance management scheme
  - Location and orientation of creek entrance
  - Berm heights – natural cycle of heights and widths
  - Protection of sand dune
  - Recreational access to ocean considers all groups
  - Communication by Council to local recreational groups.
- Ecology
  - Natural functions of Killick Creek
  - Extent of change to flora and fauna
  - Effect of flood mitigation on natural creek function
  - Wetland management
  - Fish stock depletion
  - Red weed access during north-east winds and king tides.

- Sediments
  - Black ooze in bottom sediments and effect on ecology (particularly in flood cutting)
  - Siltation of upper and lower sections of Killick Creek.
- Flood mitigation
- Floodgate management
  - Has flood mitigation become swamp drainage?
  - Explore ways of mimicking natural system functions
  - Maximise benefit for landholders and environment
  - Prevent scalding of pasture from saline incursion
  - Retain fresh water on wetland areas.
- Drains
  - Belmore Killick drain depth.

8.2 Key Issues Identified by Community

In addition, issues were discussed at the community meeting held in early April 2001. Issues identified as important to the community are listed below.

- Recreational access – to ocean for boats, swimmers and surfers
- Water quality of the creek – fish kills, red weed, high bacteria levels
- Water quality of surrounding areas – Scotts drain (acid, oxygen)
- Stormwater and runoff from residential areas
- Sediments – sand accretion, siltation of the creek
- Flushing
- Floodgate management
- Effect of past modifications
- Community consultation
- Rehabilitation of wetlands
- Acid sulphate soils
- Leachate from old rubbish tip.

Attendees at the meeting were asked to identify features of the estuary that they consider valuable. The most common response was the value of the estuary for future generations and as a recreational and natural amenity now. Protection of the foreshore, bushland and habitats were considered important as well as its drainage capacity for farmland in the Belmore Swamp areas.

The community was asked which of the valuable features were important to preserve and identified the natural habitats and features of the creek, access and recreational usage, water quality and water depth and a protected zone between development and the creek. Options for management of the creek were discussed.

8.3 Recommendations for Further Work

8.3.1 Community Values

The community wishes to preserve Killick Creek estuary as a healthy habitat for recreational and amenity purposes. This aspiration needs to be balanced by due consideration of the flood mitigation requirements of the Belmore Swamp/Connection Creek areas. An important aspect that has been affected by this flood mitigation system is water quality and its flow-on effects on the ecosystem. There are also natural inputs of algae from the ocean that can be trapped within the estuary, where their breakdown often leads to unsightly water colour and odour issues. It must be remembered that the Killick Creek system has been subject to a number of modifications that prevent it from being returned to a pre-European 'natural' condition.

8.3.2 Previous Recommendations

It is useful to review the recommendations put forward by the University of New England study (1993) in early 1993. They reported on the following changes suggested by Yates (1980) for improving water quality in Killick Creek:

- improve tidal exchange by increasing the cross-sectional area of the creek mouth
- periodic removal of accumulated organic matter from the lagoon
- relocation of the floodgates to improve tidal flushing.

All three options were considered unsuitable by Kempsey Shire Council. The first two options would only provide temporary improvement and require ongoing maintenance. Removal of the floodgates was considered unsuitable because saltwater penetration upstream may result in loss of pastoral land.

The UNE study itself identified three ways to reduce the frequency and intensity of dissolved oxygen depletion events in the Killick Creek estuary system; either the normal flushing rates need to be increased, or the rate of accumulation of oxidisable matter in the system needs to be reduced, or the availability of oxygen to the system needs to be increased (i.e. the Eh is raised). These mechanisms were translated into four management strategies, which could be used alone or in combination:

- the periodic opening of the floodgates during periods of 'normal' flow
- reduction of the volume of water in the deeper pools in the upper estuary by partly filling in the depressions with sand extracted from near the mouth of the creek
- construction of a tidally influenced artificial lake west of the junction between the flood cutting and Killick Creek and connected to the estuary by a canal to increase effective tidal inflow and flushing
- installation of a fountain either in the artificial lake or in the creek near the lake to aerate the less well-oxygenated estuary water.

It was considered unlikely that any of the above suggested management options would have a detrimental effect on the fauna of Killick Creek (UNE 1993).

8.3.3 Recommendations from this Study

In order to address the issues of concern identified by the community and to improve the understanding of the Killick Creek system a well-defined management plan must be initiated. At present there are a number of concerns for which the available information is not sufficient to make a reasonable assessment of the likely impacts of management decisions. Hence the plan will need to address those areas requiring further investigation to support the process of defining and assessing the merits of management options. It is recommended that such a plan for additional monitoring adopt the approach specified in the Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC 2000) to provide clear definition of management objectives and desired outcomes. To ensure that outcomes are meaningful the process recommended by ANZECC (2000) requires establishment of overall study objectives and a detailed study design, including preparation of a field sampling program and laboratory analysis protocol. Collected data should be quality controlled and retained in a robust database in a central location for access in future years when comparative assessments may be required.

Examples of studies that are required to enhance understanding and improve management of the Killick Creek system are listed below. Assessment of the prioritisation and need for these studies will be based on the strategies resulting from the Management Study. In addition, a strong association needs to be forged between the Coastal and Estuary Management Committee and the recently formed Mid North Coast Catchment Board, with its potential role in funding.

- *Flooding* - Since Killick Creek is formally connected to the Macleay Flood Mitigation Scheme via Killick drain and Connection Creek it has become part of a complex hydrodynamic system affecting its natural functioning. It is clear that the hydrodynamics of the estuary, including the operation of the floodgates, greatly influence the estuary ecosystem. It is also possible that closing the Killick drain to the flood mitigation scheme would lead to a more marine environment and less variable water quality in Killick Creek than at present. If this option is to be considered, then further studies should be undertaken to assess the effects of removing Killick Creek from the flood mitigation scheme on other parts of the scheme. One possibility suggested by the local residents is to improve the capacity of Ryans Cut and Big Hill Cut to essentially divert those waters presently discharging via Killick drain.

  It is recommended that a hydrological model study of these various cuts be carried out to assess the viability of diverting the flood waters that presently discharge through Killick Creek. These studies should be linked to the recommended studies into water quality and biota to gain a better understanding of the water quality processes and justification for possible modification to the flood mitigation scheme.

- *Land use practices* – Land use practices in the upper Belmore area have impacted drainage and water quality for a number of decades. As sea level rise and climate change are likely to increase the frequency of these impacts, through increased water levels and flooding, it is recommended that a study be conducted to assess future options for land management in the area including the important social effects on the local community and farmers. The inputs of stormwater from urban land use should also be investigated to assess their contribution to the system in terms of flow and water quality.

- *Entrance surveys* – Detailed surveying of the entrance at regular intervals and immediately after flood and storm events. This will provide greater understanding of entrance behaviour and relationships between water level and entrance condition. This may also include photographs taken from the surf club at hourly intervals over one day (ie. covering a tidal cycle) repeated on similar tides each three months. Alternatively, the approach could involve hydrological modelling and sand dune growth studies, including the sand dunes north of Crescent Head, to determine long-term changes in sediment and morphological characteristics.

- *Biota* – Detailed surveys of flora/fauna communities along the foreshores of the creek. Combined with good quality entrance survey information and water quality data the impact of the hydrological regime and catchment inflows on biota may be determined. Surveys should in particular consider the low-lying area of the catchment along and beyond the north arm of Killick Creek to determine the impact and extent of the estuarine system on biota in this area. An investigation into the role of red algae in water quality and odour issues should also be carried out.

- *Water quality* – Installation at a number of representative sites of continuous water quality monitoring devices capable of measuring chlorophyll-*a*, salinity, pH and flow. This will provide useful information regarding the dynamics of this high energy system and, in combination with the survey task described above, will enhance understanding of the effects of changing entrance conditions and floodgate operation on water levels and water quality. Examination of data from recent water quality monitoring in the upper Belmore and at the Killick Creek headworks will assist in assessing proposed monitoring requirements.

  Water quality processes that may be investigated through short-term specific studies include an assessment of denitrification efficiency of the sediments and investigation of nutrient inflows to the creek and internal cycling within the creek during normal, wet and dry conditions.

- *Data collection, analysis and storage* – As mentioned above it is imperative that all data collection programmes be coordinated under a management plan to ensure that meaningful data is collected which provides quality input towards management outcomes. Details of data collection should be established at the outset, including proposed data acquisition, processing, interpretation, dissemination, application, access and custodianship. Data should be stored in a database and a framework for detailed analysis should be derived to allow interpretation after a significant period of data collection. Any data collected should be integrated or linked to the water quality of the upper Belmore.

The recommendations from this study should be incorporated into the Mid North Coast Catchment Blueprint.

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Appendix A

Community Consultation

MANLY HYDRAULICS LABORATORY

110B King Street
Manly Vale NSW 2093

NSW DEPARTMENT
OF PUBLIC WORKS
AND SERVICES

Telephone 02 9949 0200
Facsimile 02 9948 6185

File No. LRE6-0107

26 February 2001

Mr S Sample
Organisation
Address line 1
Address line 2

Dear Mr Sample,

KILLICK ESTUARY PROCESS STUDY

As you may be aware Kempsey Shire Council has commissioned the Department of Public Works and Services' Manly Hydraulics Laboratory to carry out the Killick Creek Estuary Process Study. To assist in this project Manly Hydraulics Laboratory have engaged the services of subconsultants, The Ecology Lab Pty Ltd to assist with ecological issues.

Need for a Process Study

Killick Creek has substantial benefit for the local economy. It is also important visually and as a recreational facility for the local community and visitors to the area. The creek provides a safe swimming environment and attracts day picnickers and tourists. The adjacent Caravan Park and beach attract large numbers especially during the Easter, Christmas and school holidays. There is concern however, about the water quality in the creek.

In the preparation of planning measures for the future it is necessary to gain an understanding of the natural processes and their interactions with a range of activities that may affect this balance.

Project Process and Timing

The process study will take place in two stages. The first stage involves an intensive review of literature and information on the area and the identification of issues of importance to the community. Stage two involves investigation into processes operating in the creek and in similar systems, and production of a report including recommendations which will form a starting point for the development of a plan of management for the estuary.

We are currently at the beginning of stage one and seek your help to gather as much information on the system as possible.

What can you do to help?

If you have any information that may be of use in the study either:

- Make a written statement – written submissions can be made in relation to the project and should be sent to Manly Hydraulics Laboratory at the address below.
- Send information to Kempsey Shire Council – any information in relation to the project, photos, data collected etc. can be delivered to Kempsey Council at the address below.

Killick Creek Estuary Process Study
Manly Hydraulics Laboratory
110B King St
MANLY VALE NSW 2093

Killick Creek Estuary Process Study
Kempsey Shire Council
Civic Centre, Cnr Elbow & Tozer Sts
WEST KEMPSEY NSW 2440
Attn: Mr Tom Vermeulen

In order to progress the project please provide any written submissions or data that you may have by 20 April 2001.

If you require any submitted data (eg. photos) to be returned, please indicate in your submission and provide a return address.

We thank you very much for your assistance and look forward to reviewing the information shortly.

A community meeting will follow the receipt and synthesis of material relevant to Killick Creek. Information will be provided on the processes operating in the creek and a discussion will take place on the issues of importance to the community.

Regards,

David van Senden
Principal Engineer
Manly Hydraulics Laboratory

Table 1 Recipients of Letter

Name	Organisation	Address
Mr David Baker		58 Main St CRESCENT HEAD NSW 2440
Mr John Barnett	Macleay River Shellfish QAP Com	209 Inner Austral Eden Rd KEMPSEY NSW 2440
Ms Lee Blade	NSW Fisheries	PO Box 969 PORT MACQUARIE NSW 2444
Mr Roger Bull		PO Box 16 CRESCENT HEAD NSW 2440
Mr Colin Campbell	National Parks and Wildlife	PO Box 61 PORT MACQUARIE NSW 2444
P Coleing	Three Valleys National Parks Association	PO Box 27 STUARTS POINT NSW 2441
Mr Jai Cooper		6 High St CRESCENT HEAD NSW 2440
Mr Craig Copeland	NSW Fisheries, Habitat Management	PO Box 154 BALLINA NSW 2478
Mr Daniel Cross		38 Skyline Cres CRESCENT HEAD NSW 2440
Mr Lloyd Davis		1579 Right Bank Rd BELMORE RIVER NSW 2440
Mr Tony Emerton-Bell		2 Belmore St CRESCENT HEAD NSW 2440
Mr Max Enklaar	NSW Fisheries	PO Box 154 BALLINA NSW 2478
Mr Peter Ennis	MASSLAG	684 Left Bank Rd KINCHELA CREEK NSW 2440
Mr Bob Ford	Macleay River District Fisherman's Co-op	PO Box 88 SOUTH WEST ROCKS NSW 2431
Mr Jason Green		34 Delmer Close SOUTH WEST ROCKS NSW 2431
Mr Brian Hardy		C/- Post Office CRESCENT HEAD NSW 2440
Mr Scott Henderson	Department of Agriculture	PO Box 141 WEST KEMPSEY NSW 2440
Mr Tim Ingles		6 Third Ave STUARTS POINT NSW 2441
Mr John Jeayes	Crescent Head Residents & Ratepayers Association	56 Dulconghi St CRESCENT HEAD NSW 2440
Mr Geoff Johnson		48 Dulconghi St CRESCENT HEAD NSW 2440
Ms Jenny Kelly	Beach Holidays Caravan Park	PO Box 333 WEST KEMPSEY NSW 2440
Mr Howard Lee		501 Mooneba Rd MOONEBA NSW 2440
Ms M Lucas	Blue Water Fishing Club	C/- Crescent Head Country Club CRESCENT HEAD NSW 2440

Mr Allen Lyons	Trial Bay Fishing Club	14 James Carney Crescent WEST KEMPSEY NSW 2440
Councillor P Mainey	Kempsey Shire Council	PO Box 78 WEST KEMPSEY NSW 2440
Mr Tony Mayne	Macleay Valley Tourism Network	161-171 Phillip Dve SOUTH WEST ROCKS NSW 2431
Ms Maureen McCarthy		28 Korogora St CRESCENT HEAD NSW 2440
Mr Rod McDonagh	Waterways Authority	PO Box 156 SOUTH WEST ROCKS NSW 2431
Mr W McKay	Crescent Head Residents & Ratepayers Association	6 William Bailey Place CRESCENT HEAD NSW 2440
Mrs M Morris	Kempsey Shire Council	PO Box 78 WEST KEMPSEY NSW 2440
Mr Lewis Nicholl	Hat Head Dune Care	61 Straight St HAT HEAD NSW 2440
Ms Helen Ogston		4/11 Allman Place CRESCENT HEAD NSW 2440
Mr Terry Parkhouse	North Coast Environmental Council	442 Grassy Head Rd GRASSY HEAD NSW 2440
Councillor P Parkinson		Po Box 68 WEST KEMPSEY NSW 2440
Mr Malcolm Ptolemy		1557 Right Bank Rd BELMORE RIVER NSW 2440
Mr Kevin Pugh		8 Skyline Cres CRESCENT HEAD NSW 2440
Mr Greg Robinson	DLWC	PO Box 149 KEMPSEY NSW 2440
Mr John Schmidt	DLWC	PO Box 149 WEST KEMPSEY NSW 2440
Mr Derek Scoles		1141 Crescent Hill Rd CRESCENT HEAD NSW 2440
Secretary	State Pollution Control Commission	49 Victoria St GRAFTON NSW 2460
Ms P K Shaw		Dulconghi St CRESCENT HEAD NSW 2440
Mr Les Simons		6 View St CRESCENT HEAD NSW 2440
Mr G Steinmetz	C/- Crescent Head Real Estate	Main St CRESCENT HEAD NSW 2440
Mr Don Summerhayes		Site 269, Crescent Head Caravan Park CRESCENT HEAD NSW 2440
Mr Tim Trotter		3 Walker St CRESCENT HEAD NSW 2440
Mr Tom Vermeulen	Kempsey Shire Council	PO Box 78 WEST KEMPSEY NSW 2440
Mr Dave Walton	Killuke	Maria River Rd CRESCENT HEAD NSW 2440

Mr Stuart Watts		6 Allman Place CRESCENT HEAD NSW 2440
L Western		5 Belmore St CRESCENT HEAD NSW 2440
Ms Diana Woodward	Beranghi Coop. Ltd	Box 48, PO CRESCENT HEAD NSW 2440

Table 2 Parties Submissions Were Received From

Name	Address
Mr Tim Trotter	3 Walker St CRESCENT HEAD NSW 2440
Mr Kevin Pugh	8 Skyline Crescent CRESCENT HEAD NSW 2440
Mr Tim Ingles	Beranghi Cooperative PO Box 48 CRESCENT HEAD NSW 2440
Mr Ivan Sillitoe	MASSLAG PO Box 149 WEST KEMPSEY NSW 2440
Mr John Jeayes	Crescent Head Ratepayers Assoc. 56 Dulconghi Ave CRESCENT HEAD NSW 2440

Appendix B

UNE (1993) and Yates (1980)
Water Quality Data

Appendix B UNE (1993) and Yates (1980) water quality data

Yates (1980) data is in the lower part of the table with site numbers in italics.

Site No.	Location *	Water				Sediments			
		Salinity (ppt)	DO (mg/L)	pH	Water Eh (Volts)	Organic C (%)	SO_4 (mg/L)	Oxidisable S (mg/L)	Mean Eh (Volts)
1	Ocean entrance	40.0	5.95	8.1	0.20				0.20
incoming tide			7.36						
2	Killick Ck mainstream	40.0	6.00	8.1	0.19				0.17
3		40.0	5.90	8.0	0.21	0.26	1514	19	0.17
4a-north					0.21				-0.07
4b-main		39.0	5.50	8.0	0.15				0.11
5	Muddy Arm	38.0	7.30	8.3	0.19				0.14
6		38.0	5.85	8.3	0.18	0.34	502	697	-0.05
7		37.0	5.50	7.9	0.15				0.08
8	Killick Ck mainstream	36.0	7.15	8.1	0.15	0.37	52	509	-0.07
9		36.0	7.40	8.2	0.16				-0.09
10		35.0	6.70	8.2	0.10	0.87	1197	2797	-0.05
11	Flood cutting	35.0	6.60	8.2	0.13				-0.03
12		36.0	5.50	8.0	0.09				-0.09
13		36.0	4.56	5.0	0.11				-0.12
14		36.0	4.56	7.9	0.08				-0.07
15	Above flood gates	22.0	6.56	6.9	0.02				-0.27
16	Killick Ck mainstream	36.0	8.00	8.4	0.06				0.01
17		35.0	5.50	8.0	0.08				0.04
Ocean		35.0	7.8						
10	Killick Ck mainstream	30.0	7.8						
20		33.0	7.8						
30		33.0	6.0						
40		34.5	1.9						
50		35.5	0.2						
60		36.5	0.1						
25	Muddy Arm	34.0	7.4						
40	Flood cutting	34.5	1.9						
43		36.0	0.2						
45		36.5	0.1						
47	Above flood gates	0.0	7.0						
	* Higher site numbers are located further upstream								

Appendix C

Flora and Fauna Lists

Table C.1. List of fish recorded in Killick Creek by UNE and SCU (1993) and Richardson (1980).

Common Name	Scientific Name	UNE and SCU (1993)	Feb. 1978 Richardson (1980)	March 1978* Richardson (1980)	June 978 Richardson (1980)
Australian bass	*Macquaria novemaculeata*				X
Estuary perch	*Macquaria colonorum*		X	X	
Double-ended pipefish	*Sygnathoides biaculeatus*	X			
Yellow-finned leatherjacket	*Cantherines trachylepis*	X			
Three-bar porcupine fish	*Dicotylichthys punctulatus*	X			
Juvenile trumpeter	*Pelates quadrilineatus*	X			
Luderick	*Girella tricuspidata*	X	X	X	
Sand whiting	*Sillago ciliata*	X			
Dusky flathead	*Platycephalus fuscus*	X	X		
Mulloway (Jewfish)	*Argyrosomus hololepidontus*	X	X		
Bream	*Acanthropagrus australis*	X	X	X	
Silver biddy	*Gerres ovatus*	X	X	X	
Tailor	*Pomotomus saliatrix*	X	X		
Golden trevally	*Gnathanodon speciosus*	X	X		
Big-eye trevally	*Caranx sexfusciatus*			X	
Large-toothed flounder	*Pseudorhombus arsius*	X			
Southern herring	*Harengula abbreviata*	X	X	X	
Freshwater herring	*Potamalosa richmondia*		X	X	X
Ox-eye herring	*Megalops cyprinoides*		X		
Sand mullet	*Myxus elongatus*	X			
Sea mullet	*Mugil cephalus*	X	X	X	X
Flat-tail mullet	*Liza argentea*		X	X	
Freshwater mullet	*Trachystoma petardi*		X	X	
River garfish	*Hyporhamphus ardelio*	X			
Butterfish	*Scatophagus argus*	X		X	
Toado	*Spheroides hamiltoni*	X			
Weeping toado	*Spheroides pleurogramma*	X			
Diagonally banded toado	*Arothron aerostaticus*	X			
Bullrout	*Notesthes robusta*	X	X		X
Southern bullrout	*Centropogon marmoratus*	X			
Perchlet	*Velambassis jacksoniesis*		X	X	
Yellow perchlet	*Priopidichthys marianus*	X			
Bull shark	*Carcharhinus leucas*		X	X	
Mosquito fish	*Gambusia holbrooki*			X	
Short-finned eel	*Anguilla australis*			X	
Flathead gudgeon	*Philypnodon grandiceps*			X	
Goby (UID)		X			
Angelfish (UID)		X			

*Dead fish identified after fish kill.

Table C.2. List of birds, amphibians, mammals and reptiles observed within approximately 20 km of Killick Creek (NSW NPWS Wildlife Atlas) and their protected status under the TSC Act (1995). E1 = Endangered, V= Vulnerable, I = Introduced, P = Protected (NSW Wildlife Act, 1974), U = Unprotected. (nb: These data are only indicative and cannot be considered a comprehensive inventory, and may contain errors). Vulnerable and endangered species have been shaded.

		Scientific Name	Common Name	Legal Status	Count
Amphibia	Hylidae	*Litoria aurea*	Green and Golden Bell Frog	E1	17
		Litoria caerulea	Green Tree Frog	P	2
		Litoria chloris	Red-eyed Tree Frog	P	1
		Litoria dentata	Bleating Tree Frog	P	3
		Litoria fallax	Eastern Dwarf Tree Frog	P	12
		Litoria freycineti	Freycinet's Frog	P	2
		Litoria nasuta	Rocket Frog	P	6
		Litoria peronii	Peron's Tree Frog	P	8
		Litoria phyllochroa	Leaf Green Tree Frog	P	2
		Litoria tyleri		P	1
	Myobatrachidae	*Adelotus brevis*	Tusked Frog	P	8
		Crinia signifera	Common Eastern Froglet	P	13
		Crinia tinnula	Wallum Froglet	V	12
		Limnodynastes dumerilii	Eastern Banjo Frog	P	1
		Limnodynastes ornatus	Ornate Burrowing Frog	P	2
		Limnodynastes peronii	Brown-striped Frog	P	16
		Mixophyes fasciolatus	Great Barred Frog	P	8
		Mixophyes iteratus	Giant Barred Frog	E1	1
		Paracrinia haswelli	Haswell's Frog	P	3
		Pseudophryne bibronii	Brown Toadlet	P	5
		Pseudophryne coriacea	Red-backed Toadlet	P	19
		Uperoleia fusca		P	3
Aves	Accipitridae	*Accipiter cirrhocephalus*	Collared Sparrowhawk	P	3
		Accipiter fasciatus	Brown Goshawk	P	4
		Accipiter novaehollandiae	Grey Goshawk	P	5
		Aquila audax	Wedge-tailed Eagle	P	2
		Aviceda subcristata	Pacific Baza	P	6
		Circus approximans	Swamp Harrier	P	9
		Circus assimilis	Spotted Harrier	P	1
		Elanus axillaris	Black-shouldered Kite	P	2
		Haliaeetus leucogaster	White-bellied Sea-Eagle	P	13
		Haliastur indus	Brahminy Kite	P	9
		Haliastur sphenurus	Whistling Kite	P	10
		Hamirostra melanosternon	Black-breasted Buzzard	V	1
		Lophoictinia isura	Square-tailed Kite	V	14
		Pandion haliaetus	Osprey	V	23
	Aegothelidae	*Aegotheles cristatus*	Australian Owlet-nightjar	P	22
	Anatidae	*Anas castanea*	Chestnut Teal	P	5
		Anas gracilis	Grey Teal	P	7
		Anas platyrhynchos	Mallard	U	1
		Anas superciliosa	Pacific Black Duck	P	12
		Aythya australis	Hardhead	P	4
		Chenonetta jubata	Australian Wood Duck	P	6
		Cygnus atratus	Black Swan	P	5
		Tadorna radjah	Radjah Shelduck	P	1
	Apodidae	*Apus pacificus*	Fork-tailed Swift	P	1
		Hirundapus caudacutus	White-throated Needletail	P	6
	Ardeidae	*Ardea alba*	Great Egret	P	6
		Ardea ibis	Cattle Egret	P	5
		Ardea intermedia	Intermediate Egret	P	2
		Ardea pacifica	White-necked Heron	P	5
		Botaurus poiciloptilus	Australasian Bittern	V	1
		Butorides striatus	Striated Heron	P	2

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	Scientific Name	Common Name	Legal Status	Count
	Egretta novaehollandiae	White-faced Heron	P	10
	Egretta sacra	Eastern Reef Egret	P	3
	Ixobrychus flavicollis	Black Bittern	V	1
	Nycticorax caledonicus	Nankeen Night Heron	P	2
Artamidae	*Artamus cyanopterus*	Dusky Woodswallow	P	4
	Artamus leucorhynchus	White-breasted Woodswallow	P	5
	Artamus personatus	Masked Woodswallow	P	4
	Artamus superciliosus	White-browed Woodswallow	P	3
	Cracticus nigrogularis	Pied Butcherbird	P	6
	Cracticus torquatus	Grey Butcherbird	P	14
	Gymnorhina tibicen	Australian Magpie	P	14
	Strepera graculina	Pied Currawong	P	19
Cacatuidae	*Cacatua galerita*	Sulphur-crested Cockatoo	P	1
	Calyptorhynchus funereus	Yellow-tailed Black-Cockatoo	P	13
	Calyptorhynchus lathami	Glossy Black-Cockatoo	V	26
Campephagidae	*Coracina lineata*	Barred Cuckoo-shrike	V	1
	Coracina novaehollandiae	Black-faced Cuckoo-shrike	P	20
	Coracina papuensis	White-bellied Cuckoo-shrike	P	4
	Coracina tenuirostris	Cicadabird	P	10
	Lalage leucomela	Varied Triller	P	3
	Lalage sueurii	White-winged Triller	P	1
Caprimulgidae	*Eurostopodus mystacalis*	White-throated Nightjar	P	10
Centropodidae	*Centropus phasianinus*	Pheasant Coucal	P	2
Charadriidae	*Charadrius bicinctus*	Double-banded Plover	P	1
	Charadrius mongolus	Lesser Sand Plover	V	1
	Charadrius ruficapillus	Red-capped Plover	P	1
	Elseyornis melanops	Black-fronted Dotterel	P	2
	Pluvialis fulva	Pacific Golden Plover	P	1
	Vanellus miles	Masked Lapwing	P	12
	Vanellus tricolor	Banded Lapwing	P	2
Ciconiidae	*Ephippiorhynchus asiaticus*	Black-necked Stork	E1	15
Cinclosomatidae	*Psophodes olivaceus*	Eastern Whipbird	P	24
Climacteridae	*Climacteris erythrops*	Red-browed Treecreeper	P	7
	Climacteris picumnus	Brown Treecreeper	P	2
	Cormobates leucophaeus	White-throated Treecreeper	P	19
Columbidae	*Chalcophaps indica*	Emerald Dove	P	2
	Columba leucomela	White-headed Pigeon	P	7
	Columba livia	Rock Dove	U	2
	Geopelia humeralis	Bar-shouldered Dove	P	9
	Geopelia striata	Peaceful Dove	P	2
	Leucosarcia melanoleuca	Wonga Pigeon	P	16
	Lopholaimus antarcticus	Topknot Pigeon	P	7
	Macropygia amboinensis	Brown Cuckoo-Dove	P	10
	Ocyphaps lophotes	Crested Pigeon	P	7
	Phaps chalcoptera	Common Bronzewing	P	3
	Phaps elegans	Brush Bronzewing	P	4
	Ptilinopus magnificus	Wompoo Fruit-Dove	V	2
	Streptopelia chinensis	Spotted Turtle-Dove	U	6
Coraciidae	*Eurystomus orientalis*	Dollarbird	P	7
Corcoracidae	*Corcorax melanorhamphos*	White-winged Chough	P	1
Corvidae	*Corvus coronoides*	Australian Raven	P	8
	Corvus orru	Torresian Crow	P	4
	Corvus tasmanicus	Forest Raven	P	6
Cuculidae	*Cacomantis flabelliformis*	Fan-tailed Cuckoo	P	8

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	Scientific Name	Common Name	Legal Status	Count
	Cacomantis variolosus	Brush Cuckoo	P	4
	Chrysococcyx lucidus	Shining Bronze-Cuckoo	P	8
	Chrysococcyx minutillus	Little Bronze-Cuckoo	P	3
	Cuculus pallidus	Pallid Cuckoo	P	9
	Eudynamys scolopacea	Common Koel	P	9
	Scythrops novaehollandiae	Channel-billed Cuckoo	P	2
Dicaeidae	*Dicaeum hirundinaceum*	Mistletoebird	P	19
Dicruridae	*Dicrurus bracteatus*	Spangled Drongo	P	8
	Grallina cyanoleuca	Magpie-lark	P	12
	Monarcha melanopsis	Black-faced Monarch	P	9
	Monarcha trivirgatus	Spectacled Monarch	P	7
	Myiagra cyanoleuca	Satin Flycatcher	P	2
	Myiagra inquieta	Restless Flycatcher	P	2
	Myiagra rubecula	Leaden Flycatcher	P	14
	Rhipidura fuliginosa	Grey Fantail	P	34
	Rhipidura leucophrys	Willie Wagtail	P	13
	Rhipidura rufifrons	Rufous Fantail	P	9
Falconidae	*Falco berigora*	Brown Falcon	P	5
	Falco cenchroides	Nankeen Kestrel	P	3
	Falco longipennis	Australian Hobby	P	3
Haematopodidae	*Haematopus fuliginosus*	Sooty Oystercatcher	V	4
	Haematopus longirostris	Pied Oystercatcher	V	2
Halcyonidae	*Dacelo novaeguineae*	Laughing Kookaburra	P	26
	Todiramphus macleayii	Forest Kingfisher	P	10
	Todiramphus sanctus	Sacred Kingfisher	P	10
Hirundinidae	*Hirundo ariel*	Fairy Martin	P	3
	Hirundo neoxena	Welcome Swallow	P	15
	Hirundo nigricans	Tree Martin	P	4
Jacanidae	*Irediparra gallinacea*	Comb-crested Jacana	V	12
Laridae	*Larus novaehollandiae*	Silver Gull	P	7
	Sterna albifrons	Little Tern	E1	1
	Sterna bergii	Crested Tern	P	3
	Sterna hirundo	Common Tern	P	1
Maluridae	*Malurus cyaneus*	Superb Fairy-wren	P	21
	Malurus lamberti	Variegated Fairy-wren	P	13
	Malurus melanocephalus	Red-backed Fairy-wren	P	4
	Stipiturus malachurus	Southern Emu-wren	P	6
Megapodiidae	*Alectura lathami*	Australian Brush-turkey	P	2
Meliphagidae	*Acanthorhynchus tenuirostris*	Eastern Spinebill	P	20
	Anthochaera carunculata	Red Wattlebird	P	3
	Anthochaera chrysoptera	Little Wattlebird	P	19
	Grantiella picta	Painted Honeyeater	V	1
	Lichenostomus chrysops	Yellow-faced Honeyeater	P	24
	Lichmera indistincta	Brown Honeyeater	P	4
	Manorina melanocephala	Noisy Miner	P	8
	Manorina melanophrys	Bell Miner	P	2
	Meliphaga lewinii	Lewin's Honeyeater	P	22
	Melithreptus brevirostris	Brown-headed Honeyeater	P	1
	Melithreptus lunatus	White-naped Honeyeater	P	13
	Myzomela sanguinolenta	Scarlet Honeyeater	P	25
	Philemon citreogularis	Little Friarbird	P	1
	Philemon corniculatus	Noisy Friarbird	P	19
	Phylidonyris melanops	Tawny-crowned Honeyeater	P	2
	Phylidonyris nigra	White-cheeked Honeyeater	P	19

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	Scientific Name	Common Name	Legal Status	Count
	Phylidonyris novaehollandiae	New Holland Honeyeater	P	2
	Plectorhyncha lanceolata	Striped Honeyeater	P	5
	Xanthomyza phrygia	Regent Honeyeater	E1, Ea	1
Menuridae	*Menura novaehollandiae*	Superb Lyrebird	P	5
Meropidae	*Merops ornatus*	Rainbow Bee-eater	P	3
Motacillidae	*Anthus novaeseelandiae*	Richard's Pipit	P	4
Muscicapidae	*Zoothera dauma*	Unindentified Ground Thrush	P	1
Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella	P	8
Oriolidae	*Oriolus sagittatus*	Olive-backed Oriole	P	10
	Sphecotheres viridis	Figbird	P	12
Orthonychidae	*Orthonyx temminckii*	Logrunner	P	3
Pachycephalidae	*Colluricincla harmonica*	Grey Shrike-thrush	P	19
	Colluricincla megarhyncha	Little Shrike-thrush	P	1
	Falcunculus frontatus	Crested Shrike-tit	P	8
	Pachycephala olivacea	Olive Whistler	V	1
	Pachycephala pectoralis	Golden Whistler	P	13
	Pachycephala rufiventris	Rufous Whistler	P	17
Pardalotidae	*Acanthiza chrysorrhoa*	Yellow-rumped Thornbill	P	1
	Acanthiza lineata	Striated Thornbill	P	16
	Acanthiza nana	Yellow Thornbill	P	6
	Acanthiza pusilla	Brown Thornbill	P	27
	Acanthiza reguloides	Buff-rumped Thornbill	P	5
	Gerygone mouki	Brown Gerygone	P	10
	Gerygone olivacea	White-throated Gerygone	P	6
	Pardalotus punctatus	Spotted Pardalote	P	21
	Pardalotus striatus	Striated Pardalote	P	2
	Sericornis citreogularis	Yellow-throated Scrubwren	P	3
	Sericornis frontalis	White-browed Scrubwren	P	11
	Sericornis magnirostris	Large-billed Scrubwren	P	8
Passeridae	*Lonchura castaneothorax*	Chestnut-breasted Mannikin	P	3
	Lonchura punctulata	Nutmeg Mannikin	U	2
	Neochmia temporalis	Red-browed Finch	P	23
	Passer domesticus	House Sparrow	U	2
Pelecanidae	*Pelecanus conspicillatus*	Australian Pelican	P	4
Petroicidae	*Eopsaltria australis*	Eastern Yellow Robin	P	19
	Microeca fascinans	Jacky Winter	P	4
	Petroica multicolor	Scarlet Robin	P	1
	Petroica phoenicea	Flame Robin	P	2
	Petroica rosea	Rose Robin	P	3
	Tregellasia capito	Pale-yellow Robin	P	2
Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant	P	1
	Phalacrocorax melanoleucos	Little Pied Cormorant	P	7
	Phalacrocorax sulcirostris	Little Black Cormorant	P	5
	Phalacrocorax varius	Pied Cormorant	P	3
Phasianidae	*Coturnix pectoralis*	Stubble Quail	P	1
	Coturnix ypsilophora	Brown Quail	P	7
Pittidae	*Pitta versicolor*	Noisy Pitta	P	1
Podargidae	*Podargus ocellatus*	Marbled Frogmouth	V	1
	Podargus strigoides	Tawny Frogmouth	P	15
Podicipedidae	*Poliocephalus poliocephalus*	Hoary-headed Grebe	P	1
	Tachybaptus novaehollandiae	Australasian Grebe	P	4
Procellariidae	*Pterodroma cervicalis*	White-necked Petrel	P	2
	Puffinus pacificus	Wedge-tailed Shearwater	P	2
	Puffinus tenuirostris	Short-tailed Shearwater	P	1

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		Scientific Name	Common Name	Legal Status	Count
	Psittacidae	*Alisterus scapularis*	Australian King-Parrot	P	10
		Glossopsitta pusilla	Little Lorikeet	P	7
		Lathamus discolor	Swift Parrot	Ea	
		Platycercus elegans	Crimson Rosella	P	7
		Platycercus eximius	Eastern Rosella	P	6
		Psephotus haematonotus	Red-rumped Parrot	P	1
		Trichoglossus chlorolepidotus	Scaly-breasted Lorikeet	P	13
		Trichoglossus haematodus	Rainbow Lorikeet	P	18
	Ptilonorhynchidae	*Ailuroedus crassirostris*	Green Catbird	P	4
		Ptilonorhynchus violaceus	Satin Bowerbird	P	7
		Sericulus chrysocephalus	Regent Bowerbird	P	2
	Rallidae	*Fulica atra*	Eurasian Coot	P	2
		Gallinula tenebrosa	Dusky Moorhen	P	6
		Gallirallus philippensis	Buff-banded Rail	P	3
		Porphyrio porphyrio	Purple Swamphen	P	5
		Porzana fluminea	Australian Spotted Crake	P	1
		Porzana pusilla	Baillon's Crake	P	2
	Rostratulidae	*Rostratula benghalensis*	Painted Snipe	V	1
	Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	P	1
		Calidris acuminata	Sharp-tailed Sandpiper	P	1
		Gallinago hardwickii	Latham's Snipe	P	2
		Heteroscelus brevipes	Grey-tailed Tattler	P	1
		Limosa lapponica	Bar-tailed Godwit	P	1
		Numenius madagascariensis	Eastern Curlew	P	2
		Numenius phaeopus	Whimbrel	P	1
		Tringa nebularia	Common Greenshank	P	2
		Tringa stagnatilis	Marsh Sandpiper	P	1
	Spheniscidae	*Eudyptula minor*	Little Penguin	P	2
	Strigidae	*Ninox novaeseelandiae*	Southern Boobook	P	12
		Ninox strenua	Powerful Owl	V	9
	Sturnidae	*Sturnus vulgaris*	Common Starling	U	1
	Sulidae	*Morus serrator*	Australasian Gannet	P	3
	Sylviidae	*Acrocephalus stentoreus*	Clamorous Reed-Warbler	P	3
		Cinclorhamphus cruralis	Brown Songlark	P	2
		Cisticola exilis	Golden-headed Cisticola	P	2
		Megalurus gramineus	Little Grassbird	P	1
		Megalurus timoriensis	Tawny Grassbird	P	4
	Threskiornithidae	*Platalea flavipes*	Yellow-billed Spoonbill	P	1
		Platalea regia	Royal Spoonbill	P	4
		Plegadis falcinellus	Glossy Ibis	P	1
		Threskiornis molucca	Australian White Ibis	P	4
		Threskiornis spinicollis	Straw-necked Ibis	P	5
	Turnicidae	*Turnix varia*	Painted Button-quail	P	8
	Tytonidae	*Tyto alba*	Barn Owl	P	4
		Tyto capensis	Grass Owl	V	1
		Tyto novaehollandiae	Masked Owl	V	4
		Tyto tenebricosa	Sooty Owl	V	7
	Zosteropidae	*Zosterops lateralis*	Silvereye	P	17
Mammalia	Balaenopteridae	*Megaptera novaeangliae*	Humpback Whale	V	1
	Burramyidae	*Acrobates pygmaeus*	Feathertail Glider	P	1
	Canidae	*Canis familiaris*	Dingo and Dog (feral)	U	2
		Vulpes vulpes	Fox	U	8
	Dasyuridae	*Antechinus sp.*	Unidentified Antechinus	P	2

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	Scientific Name	Common Name	Legal Status	Count
	Antechinus stuartii	Brown Antechinus	P	15
	Dasyurus maculatus	Spotted-tailed Quoll	V	5
	Phascogale tapoatafa	Brush-tailed Phascogale	V	8
	Sminthopsis murina	Common Dunnart	P	1
Delphinidae	*Dolphin sp.*	Unidentified Dolphin	P	2
	Grampus griseus	Risso's Dolphin	P	1
	Peponocephala electra	Melon-headed Whale	P	2
	Stenella attenuata	Spotted Dolphin	P	1
	Stenella coeruleoalba	Striped Dolphin	P	1
	Tursiops truncatus	Bottlenose Dolphin	P	1
Equidae	*Equus caballus*	Horse (feral)	U	1
Felidae	*Felis catus*	Cat (feral)	U	4
Leporidae	*Lepus capensis*	Brown Hare	U	1
	Oryctolagus cuniculus	Rabbit	U	5
Macropodidae	*Macropus giganteus*	Eastern Grey Kangaroo	P	21
	Macropus rufogriseus	Red-necked Wallaby	P	14
	Thylogale thetis	Red-necked Pademelon	P	6
	Wallabia bicolor	Swamp Wallaby	P	24
Molossidae	*Mormopterus sp 1*	undescribed mastiff-bat	P	1
	Nyctinomus australis	White-striped Mastiff-bat	P	1
Muridae	*Hydromys chrysogaster*	Water-rat	P	1
	Melomys burtoni	Grassland Melomys	P	1
	Melomys cervinipes	Fawn-footed Melomys	P	1
	Mus musculus	House Mouse	U	19
	Pseudomys gracilicaudatus	Eastern Chestnut Mouse	V	43
	Rattus fuscipes	Bush Rat	P	21
	Rattus lutreolus	Swamp Rat	P	16
	Rattus rattus	Black Rat	U	13
	Rattus sp.	rat	P	9
Ornithorhynchidae	*Ornithorhynchus anatinus*	Platypus	P	2
Otariidae	*Arctocephalus pusillus*	Australian Fur-seal	P	1
Peramelidae	*Isoodon macrourus*	Northern Brown Bandicoot	P	3
	Perameles nasuta	Long-nosed Bandicoot	P	2
Petauridae	*Petauroides volans*	Greater Glider	P	2
	Petaurus australis	Yellow-bellied Glider	V	2
	Petaurus breviceps	Sugar Glider	P	19
	Petaurus norfolcensis	Squirrel Glider	V	6
	Pseudocheirus peregrinus	Common Ringtail Possum	P	7
Phalangeridae	*Trichosurus caninus*	Mountain Brushtail Possum	P	5
	Trichosurus sp.	brushtail possum	P	9
	Trichosurus vulpecula	Common Brushtail Possum	P	13
Phascolarctidae	*Phascolarctos cinereus*	Koala	V	105
Physeteridae	*Kogia breviceps*	Pygmy Sperm Whale	P	1
	Physeter macrocephalus	Sperm Whale	V	1
Pteropodidae	*Pteropus poliocephalus*	Grey-headed Flying-fox	P	11
	Pteropus scapulatus	Little Red Flying-fox	P	2
	Syconycteris australis	Common Blossom-bat	V	7
Rhinolophidae	*Rhinolophus megaphyllus*	Eastern Horseshoe-bat	P	4
Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked Echidna	P	4
Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat	P	3
	Chalinolobus morio	Chocolate Wattled Bat	P	1
	Kerivoula papuensis	Golden-tipped Bat	V	1
	Miniopterus australis	Little Bent-wing Bat	V	16
	Miniopterus schreibersii	Common Bent-wing Bat	V	1

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		Scientific Name	Common Name	Legal Status	Count
		Myotis adversus	Large-footed Myotis	V	1
		Nyctophilus geoffroyi	Lesser Long-eared Bat	P	2
		Nyctophilus gouldi	Gould's Long-eared Bat	P	6
		Nyctophilus sp.	long-eared bat	P	1
		Scotorepens orion	Eastern Broad-nosed Bat	P	3
		Scotorepens sp 1	undescribed broad-nosed bat	P	1
		Vespadelus pumilus	Eastern Forest Bat	P	12
		Vespadelus sp.	Unidentified Eptesicus	P	1
		Vespadelus vulturnus	Little Forest Bat	P	3
Reptilia	Agamidae	*Amphibolurus muricatus*	Jacky Lizard	P	5
		Physignathus lesueurii	Eastern Water Dragon	P	7
		Pogona barbata	Bearded Dragon	P	2
	Boidae	*Morelia spilota*	Carpet or Diamond Python	P	1
	Cheloniidae	*Caretta caretta*	Loggerhead Turtle	V	2
	Elapidae	*Cacophis krefftii*	Krefft's Dwarf Snake	P	1
		Cacophis squamulosus	Golden Crowned Snake	P	1
		Hemiaspis signata	Black-bellied Swamp Snake	P	1
		Pseudechis porphyriacus	Red-bellied Black Snake	P	4
		Pseudonaja textilis	Eastern Brown Snake	P	3
		Rhinoplocephalus nigrescens	Eastern Small-eyed Snake	P	5
		Vermicella annulata	Bandy Bandy	P	1
	Pygopodidae	*Lialis burtonis*	Burton's Legless Lizard	P	3
	Scincidae	*Calyptotis ruficauda*		P	12
		Calyptotis scutirostrum		P	1
		Ctenotus robustus	Striped Skink	P	8
		Ctenotus taeniolatus	Copper-tailed Skink	P	4
		Egernia major	Land Mullet	P	2
		Egernia mcpheei		P	1
		Eulamprus murrayi		P	1
		Eulamprus quoyii	Eastern Water Skink	P	2
		Eulamprus tenuismartini	Barred-sided Skink	P	1
		Lampropholis amicula		P	3
		Lampropholis delicata	Grass Skink	P	19
		Lampropholis guichenoti	Garden Skink	P	1
		Saiphos equalis	Three-toed Skink	P	3
		Saproscincus challengeri		P	1
		Tiliqua scincoides	Eastern Blue-tongued Lizard	P	2
	Typhlopidae	*Ramphotyphlops proximus*		P	1
	Varanidae	*Varanus gouldii*	Gould's Goanna	P	1

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	Scientific Name	Common Name	Legal Status	Count
Acanthaceae	*Brunoniella australis*	Blue Trumpet	U	9
	Brunoniella pumilio	Dwarf Blue Trumpet	U	2
	Brunoniella spp.		U	1
	Pseuderanthemum variabile	Pastel Flower	U	22
Adiantaceae	*Adiantum aethiopicum*	Common Maidenhair	P13	6
	Adiantum hispidulum	Rough Maidenhair	P13	1
	Cheilanthes austrotenuifolia	Rock Fern	U	3
	Cheilanthes sieberi ssp sieberi		U	4
Aizoaceae	*Carpobrotus glaucescens*		U	1
Anthericaceae	*Caesia parviflora*	Pale Grass-lily	U	1
	Laxmannia gracilis		U	2
	Thysanotus tuberosus	Common Fringe-lily	U	2
	Thysanotus tuberosus ssp tuberosus		U	7
	Tricoryne elatior	Yellow Autumn-lily	U	7
	Tricoryne simplex		U	1
Apiaceae	*Centella asiatica*	Pennywort	U	6
	Hydrocotyle bonariensis		U	1
	Hydrocotyle geraniifolia	Forest Pennywort	U	1
	Hydrocotyle laxiflora	Stinking Pennywort	U	1
	Hydrocotyle peduncularis		U	10
	Xanthosia pilosa		U	1
Apocynaceae	*Parsonsia dorrigoensis*	Milky Silkpod	V	1
	Parsonsia straminea	Common Silkpod	U	12
	Tabernaemontana pandacaqui	Banana Bush	U	6
Araceae	*Gymnostachys anceps*	Settler's Flax	U	4
Araliaceae	*Polyscias elegans*	Celery Wood	U	1
	Polyscias sambucifolia	Elderberry Panax	U	6
	Polyscias sambucifolia ssp A		U	18
Arecaceae	*Archontophoenix cunninghamiana*	Bangalow Palm	P13	1
Asclepiadaceae	*Gomphocarpus physocarpus*	Balloon Cotton Bush	U	1
	Marsdenia rostrata	Common Milk Vine		
Aspleniaceae	*Asplenium attenuatum*	Simple Spleenwort	U	1
	Asplenium australasicum forma australasicum	Bird's Nest Fern	P13	1
	Asplenium nidus		P13	1
Asteliaceae	*Cordyline stricta*	Narrow-leaved Palm Lily	U	9
Asteraceae	*Baccharis halimifolia*	Groundsel Bush	U	1
	Bidens pilosa	Cobbler's Pegs	U	4
	Centratherum punctatum ssp australianum		U	1
	Chrysanthemoides monilifera		U	1
	Chrysanthemoides monilifera ssp rotundata	Bitou Bush	U	3
	Cirsium vulgare	Spear Thistle	U	2
	Conyza albida	Tall Fleabane	U	3
	Conyza bonariensis	Flaxleaf Fleabane	U	1
	Crassocephalum crepidioides	Thickhead	U	2
	Gamochaeta americana		U	2
	Hypochaeris glabra	Smooth Catsear	U	1
	Hypochaeris radicata	Catsear	U	6
	Lagenifera gracilis	Slender Lagenophora	U	2
	Minuria leptophylla		U	1
	Ozothamnus diosmifolius	White Dogwood	U	16
	Picris hieracioides	Hawkweed Picris	U	1
	Senecio amygdalifolius		U	1
	Senecio madagascariensis	Fireweed	U	2
	Sigesbeckia orientalis ssp orientalis	Indian Weed	U	1
	Sonchus oleraceus	Common Sowthistle	U	1
	Taraxacum officinale	Dandelion	U	2
	Vernonia cinerea		U	3
	Vernonia cinerea var cinerea		U	16
Avicenniaceae	*Avicennia marina subsp australasica*	Grey Mangrove	U	1
Bignoniaceae	*Pandorea pandorana*	Wonga Wonga Vine	U	8
Blandfordiaceae	*Blandfordia grandiflora*		P13	1
Blechnaceae	*Blechnum cartilagineum*	Gristle Fern	U	8
	Blechnum indicum	Swamp Water Fern	U	5
	Blechnum minus	Soft Water Fern	U	2
	Doodia aspera		U	7

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	Scientific Name	Common Name	Legal Status	Count
	Doodia caudata		U	1
Casuarinaceae	*Allocasuarina defungens*		E1	12
	Allocasuarina littoralis	Black Sheoak	U	29
	Allocasuarina torulosa	Forest Oak	U	17
	Casuarina glauca	Swamp Oak	U	3
Celastraceae	*Maytenus silvestris*	Narrow-leaved Orangebark	U	1
Commelinaceae	*Commelina cyanea*		U	6
	Murdannia graminea		U	1
Convolvulaceae	*Calystegia marginata*		U	1
	Convolvulus erubescens		U	1
	Convolvulus remotus		U	6
	Cuscuta australis	Australian Dodder	U	1
	Dichondra sp.A		U	1
	Polymeria calycina		U	4
Cunoniaceae	*Schizomeria ovata*	Crabapple	U	1
Cyperaceae	*Baumea articulata*	Jointed Twig-rush	U	1
	Baumea spp.		U	1
	Carex appressa		U	1
	Carex breviculmis		U	1
	Carex declinata		U	1
	Caustis recurvata		P13	1
	Chorizandra cymbaria		U	4
	Cyperus enervis		U	1
	Cyperus eragrostis	Umbrella Sedge	U	1
	Cyperus imbecillis		U	1
	Cyperus laevigatus		U	1
	Cyperus laevis		U	3
	Cyperus polystachyos		U	1
	Cyperus spp.		U	1
	Cyperus tetraphyllus		U	1
	Gahnia aspera		U	2
	Gahnia clarkei		U	13
	Gahnia radula		U	1
	Gahnia sieberiana		U	4
	Isolepis nodosa	Knobby Club-rush	U	1
	Lepidosperma laterale		U	33
	Ptilothrix deusta		U	17
	Rhynchospora brownii		U	1
	Schoenus apogon	Fluke Bogrush	U	5
	Schoenus brevifolius		U	3
Davalliaceae	*Davallia solida var pyxidata*	Hare's Foot Fern	U	1
	Nephrolepis cordifolia	Fishbone Fern	U	1
Dennstaedtiaceae	*Pteridium esculentum*	Bracken	U	33
Dicksoniaceae	*Calochlaena dubia*	Common Ground Fern	U	
Dilleniaceae	*Hibbertia acicularis*		U	1
	Hibbertia aspera		U	7
	Hibbertia diffusa		U	1
	Hibbertia empetrifolia		U	4
	Hibbertia empetrifolia subsp empetrifolia		U	13
	Hibbertia linearis		U	3
	Hibbertia obtusifolia		U	7
	Hibbertia riparia		U	1
	Hibbertia scandens	Climbing Guinea Flower	U	10
	Hibbertia serpyllifolia		U	3
	Hibbertia vestita		U	11
Dioscoreaceae	*Dioscorea transversa*	Native Yam	U	4
Droseraceae	*Drosera auriculata*		U	3
	Drosera peltata		U	2
	Drosera spatulata		U	2
Dryopteridaceae	*Lastreopsis acuminata*	Shiny Shield Fern	U	1
	Lastreopsis decomposita	Trim Shield Fern	U	3
	Lastreopsis spp.		U	1
Elaeocarpaceae	*Elaeocarpus reticulatus*	Blueberry Ash	U	5
Epacridaceae	*Epacris microphylla*		U	2
	Epacris pulchella		U	11

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	Scientific Name	Common Name	Legal Status	Count
	Leucopogon ericoides		U	10
	Leucopogon lanceolatus		U	1
	Leucopogon leptospermoides		U	2
	Leucopogon margarodes		U	2
	Melichrus procumbens	Jam Tarts	U	2
	Monotoca elliptica		U	5
	Monotoca scoparia		U	2
	Pentachondra pumila	Carpet Heath	U	1
	Trochocarpa laurina	Tree Heath	U	5
Euphorbiaceae	*Breynia oblongifolia*	Coffee Bush	U	17
	Glochidion ferdinandi	Cheese Tree	U	7
	Glochidion ferdinandi var ferdinandi	Cheese Tree	U	12
	Phyllanthus hirtellus		U	4
	Phyllanthus tenellus		U	1
	Phyllanthus virgatus		U	1
	Poranthera microphylla		U	7
	Ricinocarpos pinifolius	Wedding Bush	U	1
Eupomatiaceae	*Eupomatia laurina*	Bolwarra	U	1
Fabaceae (Caesalpinioideae)	*Senna septemtrionalis*		U	1
Fabaceae (Faboideae)	*Aotus subglauca*		U	3
	Bossiaea obcordata		U	3
	Bossiaea rhombifolia ssp rhombifolia		U	9
	Chorizema parviflorum	Eastern Flame Pea	U	4
	Daviesia acicularis		U	2
	Daviesia genistifolia	Broom Bitter Pea	U	2
	Daviesia ulicifolia	Gorse Bitter Pea	U	7
	Daviesia umbellulata		U	4
	Derris involuta		U	1
	Desmodium brachypodum	Large Tick-trefoil	U	1
	Desmodium nemorosum		U	2
	Desmodium rhytidophyllum		U	13
	Desmodium varians	Slender Tick-trefoil	U	10
	Dillwynia retorta		U	23
	Glycine canescens	Silky Glycine	U	1
	Glycine clandestina		U	25
	Glycine microphylla		U	1
	Glycine tabacina		U	2
	Gompholobium latifolium	Golden Glory Pea	U	2
	Gompholobium pinnatum	Pinnate Wedge Pea	U	21
	Hardenbergia violacea	False Sarsaparilla	U	25
	Hovea linearis		U	3
	Jacksonia scoparia	Dogwood	U	9
	Kennedia rubicunda	Red Kennedy Pea	U	9
	Mirbelia rubiifolia		U	3
	Oxylobium robustum	Tree Shaggy Pea	U	2
	Phyllota phylicoides	Heath Phyllota	U	1
	Pultenaea capitellata		U	2
	Pultenaea myrtoides		U	24
	Pultenaea paleacea		U	1
	Pultenaea retusa		U	23
	Pultenaea villosa		U	9
	Sphaerolobium vimineum		U	1
Fabaceae (Mimosoideae)	*Acacia binervata*	Two-veined Hickory	U	2
	Acacia binervia	Coast Myall	U	7
	Acacia concurrens	Curracabah	U	4
	Acacia falcata		U	3
	Acacia floribunda	White Sally	U	22
	Acacia implexa	Hickory Wattle	U	1
	Acacia irrorata	Green Wattle	U	5
	Acacia longifolia	Sydney Golden Wattle	U	5
	Acacia longissima		U	3
	Acacia maidenii	Maiden's Wattle	U	3
	Acacia myrtifolia	Red-stemmed Wattle	U	13
	Acacia terminalis	Sunshine Wattle	U	13
	Acacia ulicifolia	Prickly Moses	U	9

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	Scientific Name	Common Name	Legal Status	Count
Frankeniaceae	*Frankenia foliosa*		U	18
Gentianaceae	*Centaurium spicatum*	Spike Centaury	U	1
Geraniaceae	*Geranium solanderi var solanderi*		U	2
Goodeniaceae	*Dampiera stricta*		U	17
	Goodenia bellidifolia		U	3
	Goodenia hederacea		U	1
	Goodenia hederacea ssp hederacea		U	2
	Goodenia heterophylla ssp eglandulosa		U	6
	Goodenia ovata		U	1
	Goodenia paniculata		U	3
	Goodenia stelligera		U	1
	Velleia spathulata		U	2
Haloragaceae	*Gonocarpus chinensis ssp verrucosus*		U	3
	Gonocarpus humilis		U	1
	Gonocarpus micranthus		U	1
	Gonocarpus micranthus ssp ramosissimus		U	9
	Gonocarpus salsoloides		U	1
	Gonocarpus tetragynus		U	15
	Gonocarpus teucrioides		U	3
Hydrocharitaceae	*Ottelia ovalifolia subsp ovalifolia*	Swamp Lily	U	1
Iridaceae	*Patersonia fragilis*		U	1
	Patersonia glabrata		U	9
	Patersonia sericea		U	6
Juncaceae	*Juncus continuus*		U	2
	Juncus kraussii spp. *australiensis*	Sea Rush	U	1
	Juncus usitatus		U	1
Lamiaceae	*Plectranthus parviflorus*		U	3
Lauraceae	*Cassytha filiformis*		U	5
	Cassytha glabella		U	1
	Cassytha pubescens		U	21
	Cinnamomum camphora	Camphor Laurel	U	5
	Cryptocarya meissneriana	Thick-leaved Laurel	U	1
	Cryptocarya microneura	Murrogun	U	4
	Endiandra discolor	Rose Walnut	U	1
	Endiandra muelleri	Green-leaved Rose Walnut	U	1
	Litsea reticulata	Bolly Gum	U	1
Lindsaeaceae	*Lindsaea dimorpha*		U	1
	Lindsaea linearis	Screw Fern	U	7
	Lindsaea microphylla	Lacy Wedge Fern	U	7
Lobeliaceae	*Lobelia alata*	Angled Lobelia	U	3
	Pratia purpurascens	Whiteroot	U	15
Loganiaceae	*Logania albiflora*		U	1
	Logania pusilla		U	5
	Mitrasacme alsinoides		U	1
Lomandraceae	*Lomandra filiformis*	Wattle Matt-rush	U	16
	Lomandra filiformis ssp filiformis		U	3
	Lomandra glauca	Pale Mat-rush	U	2
	Lomandra hystrix		U	3
	Lomandra laxa		U	1
	Lomandra longifolia	Spiny-headed Mat-rush	U	31
	Lomandra multiflora ssp multiflora		U	6
	Lomandra spicata		U	1
Loranthaceae	*Amyema congener ssp congener*		U	5
	Amyema pendulum		U	2
	Dendrophthoe vitellina		U	1
Luzuriagaceae	*Eustrephus latifolius*	Wombat Berry	U	14
	Geitonoplesium cymosum	Scrambling Lily	U	6
Lycopodiaceae	*Lycopodiella cernua*	Scrambling Clubmoss	U	3
	Lycopodiella lateralis		U	1
	Lycopodium spp.		U	2
Malvaceae	*Abutilon oxycarpum*	Flannel Weed	U	1
	Hibiscus heterophyllus ssp heterophyllus	Native Rosella	U	1
	Sida rhombifolia	Paddy's Lucerne	U	2
Meliaceae	*Dysoxylum fraserianum*	Rosewood	U	1
	Melia azedarach	White Cedar	U	2

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	Scientific Name	Common Name	Legal Status	Count
	Synoum glandulosum	Scentless Rosewood	U	2
	Synoum glandulosum subsp glandulosum	Scentless Rosewood	U	3
Menispermaceae	*Sarcopetalum harveyanum*	Pearl Vine	U	2
	Stephania japonica		U	4
Monimiaceae	*Wilkiea huegeliana*	Veiny Wilkiea	U	2
Moraceae	*Ficus coronata*	Creek Sandpaper Fig	U	5
	Ficus fraseri	Sandpaper Fig	U	1
	Maclura cochinchinensis	Cockspur Thorn	U	2
Myrsinaceae	*Embelia australiana*		U	1
	Rapanea howittiana	Brush Muttonwood	U	3
	Rapanea variabilis	Muttonwood	U	5
Myrtaceae	*Acmena smithii*	Lilly Pilly	U	6
	Archirhodomyrtus beckleri	Rose Myrtle	U	3
	Babingtonia pluriflora		U	5
	Baeckea linifolia		U	1
	Baeckea ramosissima	Rosy Baeckea	U	4
	Baeckea sp. *aff. virgata*		U	5
	Callistemon flavovirens	Green Bottlebrush	U	1
	Callistemon pachyphyllus	Wallum Bottlebrush	U	1
	Callistemon salignus	Willow Bottlebrush	U	13
	Corymbia gummifera	Red Bloodwood	U	34
	Corymbia intermedia	Pink Bloodwood	U	17
	Darwinia leptantha		U	1
	Eucalyptus acmenoides	White Mahogany	U	7
	Eucalyptus agglomerata	Blue-leaved Stringybark	U	3
	Eucalyptus biturbinata		U	2
	Eucalyptus carnea	Thick-leaved Mahogany	U	13
	Eucalyptus eugenioides	Thin-leaved Stringybark	U	14
	Eucalyptus globoidea	White Stringybark	U	14
	Eucalyptus grandis	Flooded Gum	U	3
	Eucalyptus laevopinea	Silver-top Stringybark	U	1
	Eucalyptus maculata	Spotted Gum	U	9
	Eucalyptus microcorys	Tallowwood	U	27
	Eucalyptus pilularis	Blackbutt	U	21
	Eucalyptus placita	A Grey Ironbark	U	1
	Eucalyptus planchoniana	Bastard Tallowwood	U	8
	Eucalyptus propinqua	Small-fruited Grey Gum	U	12
	Eucalyptus resinifera	Red Mahogany	U	13
	Eucalyptus resinifera ssp hemilampra		U	1
	Eucalyptus resinifera ssp resinifera		U	3
	Eucalyptus robusta	Swamp Mahogany	U	10
	Eucalyptus saligna	Sydney Blue Gum	U	1
	Eucalyptus seeana	Narrow-leaved Red Gum	U	2
	Eucalyptus siderophloia	Grey Ironbark	U	24
	Eucalyptus signata	Scribbly Gum	U	30
	Eucalyptus tereticornis	Forest Red Gum	U	4
	Eucalyptus umbra		U	4
	Kunzea capitata		U	1
	Leptospermum juniperinum		U	4
	Leptospermum liversidgei		U	4
	Leptospermum polygalifolium		U	19
	Leptospermum trinervium		U	5
	Lophostemon confertus	Brush Box	U	10
	Melaleuca linariifolia		U	10
	Melaleuca nodosa		U	5
	Melaleuca quinquenervia	Paperbark	U	11
	Melaleuca sieberi		U	6
	Melaleuca styphelioides	Prickly-leaved Tea Tree	U	12
	Rhodamnia rubescens	Scrub Turpentine	U	3
	Rhodomyrtus psidioides	Native Guava	U	1
	Syncarpia glomulifera	Turpentine	U	21
	Syzygium australe	Brush Cherry	U	1
	Syzygium spp.		U	2
	Tristaniopsis laurina	Kanuka	U	1
Oleaceae	*Ligustrum sinense*	Small-leaved Privet	U	1

Table C.3. List of plants observed within approximately 20 km of Killick Creek (NSW NPWS Wildlife Atlas) and their protected status under the TSC Act. E1 = Endangered, V= Vulnerable, I = Introduced, P13 = Protected Plants (NSW Wildlife Act, 1974) U = Unprotected. (nb: These data are only indicative and cannot be considered a comprehensive inventory, and may contain errors). Vulnerable and endangered species have been shaded.

	Scientific Name	Common Name	Legal Status	Count
	Notelaea longifolia	Large Mock-olive	U	4
	Notelaea ovata		U	24
Orchidaceae	*Acianthus* spp.		U	1
	Caladenia carnea	Pink Fingers	U	1
	Calochilus paludosus	Red Beard Orchid	U	1
	Cryptostylis erecta	Tartan Tongue Orchid	U	5
	Cryptostylis spp.		U	2
	Cryptostylis subulata	Large Tongue Orchid	U	10
	Cymbidium suave	Snake Orchid	P13	1
	Dipodium punctatum		P13	3
	Dipodium spp.		U	1
	Gastrodia sesamoides	Cinnamon Bells	U	1
	Genoplesium spp.		U	1
	Plectorrhiza tridentata	Tangle Orchid	U	2
Oxalidaceae	*Oxalis chnoodes*		U	1
	Oxalis corniculata	Creeping Oxalis	U	2
	Oxalis exilis		U	7
Passifloraceae	*Passiflora edulis*	Common Passionfruit	U	1
	Passiflora subpeltata	White Passionflower	U	1
Philydraceae	*Philydrum lanuginosum*	Frogsmouth	U	2
Phormiaceae	*Dianella caerulea*		U	35
	Dianella caerulea var producta		U	2
	Dianella revoluta		U	3
	Thelionema caespitosum		U	1
Phytolaccaceae	*Phytolacca octandra*	Inkweed	U	2
Pittosporaceae	*Billardiera scandens*	Appleberry	U	21
	Billardiera scandens var scandens		U	2
	Citriobatus pauciflorus	Orange Thorn	U	3
	Pittosporum revolutum		U	3
	Pittosporum undulatum	Pittosporum	U	2
Plantaginaceae	*Plantago debilis*		U	1
Poaceae	*Andropogon virginicus*	Whisky Grass	U	11
	Aristida vagans	Threeawn Speargrass	U	5
	Austrostipa pubescens		U	4
	Axonopus affinis	Narrow-leaved Carpet Grass	U	1
	Capillipedium spicigerum	Scented-top Grass	U	1
	Chloris truncata	Windmill Grass	U	1
	Cymbopogon refractus	Barbed Wire Grass	U	4
	Deyeuxia parviseta		U	1
	Dichelachne crinita	Longhair Plumegrass	U	1
	Dichelachne inaequiglumis		U	1
	Dichelachne micrantha	Shorthair Plumegrass	U	10
	Digitaria parviflora	Small-flowered Finger Grass	U	21
	Echinopogon caespitosus		U	4
	Echinopogon caespitosus var cunninghamii		U	1
	Entolasia marginata	Bordered Panic	U	8
	Entolasia stricta	Wiry Panic	U	43
	Eragrostis benthamii		U	4
	Eragrostis brownii	Brown's Lovegrass	U	7
	Imperata cylindrica var major	Blady Grass	U	36
	Ischaemum australe		U	2
	Joycea pallida	Silvertop Wallaby Grass	U	1
	Oplismenus aemulus		U	7
	Oplismenus imbecillis		U	13
	Ottochloa gracillima		U	4
	Panicum simile	Two-colour Panic	U	16
	Paspalidium distans		U	2
	Paspalum dilatatum	Paspalum	U	1
	Paspalum orbiculare	Ditch Millet	U	4
	Paspalum urvillei	Vasey Grass	U	1
	Pennisetum clandestinum	Kikuyu Grass	U	1
	Poa labillardieri var labillardieri	Tussock	U	1
	Poa sieberiana		U	11
	Poa spp.		U	1
	Sacciolepis indica	Indian Cupscale Grass	U	1

Table C.3. List of plants observed within approximately 20 km of Killick Creek (NSW NPWS Wildlife Atlas) and their protected status under the TSC Act. E1 = Endangered, V= Vulnerable, I = Introduced, P13 = Protected Plants (NSW Wildlife Act, 1974) U = Unprotected. (nb: These data are only indicative and cannot be considered a comprehensive inventory, and may contain errors). Vulnerable and endangered species have been shaded.

	Scientific Name	Common Name	Legal Status	Count
	Stenotaphrum secundatum	Buffalo Grass	U	1
	Themeda australis	Kangaroo Grass	U	31
	Themeda triandra		U	4
Polygalaceae	*Comesperma defoliatum*		U	2
	Comesperma ericinum		U	1
	Comesperma volubile		U	2
	Polygala japonica		U	2
Polypodiaceae	*Platycerium bifurcatum ssp bifurcatum*	Elkhorn	P13	1
	Platycerium superbum	Staghorn	P13	1
	Pyrrosia confluens	Horseshoe Felt Fern	U	1
	Pyrrosia rupestris	Rock Felt Fern	U	1
Proteaceae	*Banksia aemula*		U	2
	Banksia ericifolia		U	2
	Banksia integrifolia		U	8
	Banksia oblongifolia		U	10
	Banksia spinulosa var collina		U	6
	Hakea salicifolia	Willow-leaved Hakea	U	1
	Lomatia myricoides	River Lomatia	U	1
	Lomatia silaifolia	Crinkle Bush	P13	17
	Persoonia conjuncta		U	2
	Persoonia cornifolia		U	5
	Persoonia levis	Broad-leaved Geebung	U	22
	Persoonia linearis	Narrow-leaved Geebung	U	4
	Persoonia sericea		U	3
	Persoonia spp.		U	2
	Persoonia stradbrokensis		U	29
	Petrophile canescens		U	2
	Petrophile pulchella		U	1
Pteridaceae	*Pteris tremula*	Tender Brake	U	1
Ranunculaceae	*Clematis aristata*		U	2
Restionaceae	*Baloskion pallens*		U	1
	Baloskion tetraphyllum		U	3
	Empodisma minus		U	2
	Hypolaena fastigiata		U	1
	Leptocarpus tenax		U	1
	Lepyrodia muelleri		U	3
	Sporadanthus interruptus		U	1
Rhamnaceae	*Alphitonia excelsa*	Red Ash	U	5
Ripogonaceae	*Ripogonum album*	White Supplejack	U	2
Rosaceae	*Rubus parvifolius*	Native Raspberry	U	2
	Rubus rosifolius	Rose-leaf Bramble	U	3
Rubiaceae	*Canthium coprosmoides*	Coast Canthium	U	1
	Durringtonia paludosa		U	4
	Morinda jasminoides		U	5
	Pomax umbellata		U	9
Rutaceae	*Acronychia oblongifolia*	Common Acronychia	U	4
	Boronia pinnata		P13	3
	Boronia polygalifolia		P13	1
	Citrus x taitensis	Rough Lemon	U	1
	Nematolepis squamea subsp squamea	Satinwood	U	1
	Zieria laevigata		U	1
	Zieria laxiflora		U	1
	Zieria smithii	Sandfly Zieria	U	1
Santalaceae	*Exocarpos cupressiformis*	Native Cherry	U	6
	Exocarpos strictus	Dwarf Cherry	U	1
	Thesium australe		V	5
Sapindaceae	*Cupaniopsis anacardioides*	Tuckeroo	U	2
	Dodonaea triquetra		U	2
	Guioa semiglauca		U	3
	Mischocarpus pyriformis ssp pyriformis	Yellow Pear-fruit	U	1
Schizaeaceae	*Schizaea bifida*	Forked Comb Fern	U	8
Scrophulariaceae	*Veronica plebeia*	Trailing Speedwell	U	2
Selaginellaceae	*Selaginella uliginosa*		U	3
Smilacaceae	*Smilax australis*	Sarsaparilla	U	7
	Smilax glyciphylla	Sweet Sarsparilla	U	7

Table C.3. List of plants observed within approximately 20 km of Killick Creek (NSW NPWS Wildlife Atlas) and their protected status under the TSC Act. E1 = Endangered, V= Vulnerable, I = Introduced, P13 = Protected Plants (NSW Wildlife Act, 1974) U = Unprotected. (nb: These data are only indicative and cannot be considered a comprehensive inventory, and may contain errors). Vulnerable and endangered species have been shaded.

	Scientific Name	Common Name	Legal Status	Count
Solanaceae	*Solanum densevestitum*		U	3
	Solanum mauritianum	Wild Tobacco Bush	U	2
Sterculiaceae	*Brachychiton populneus*	Kurrajong	U	1
Stylidiaceae	*Stylidium graminifolium*	Grass Triggerplant	U	7
Surianaceae	*Guilfoylia monostylis*		U	1
Symplocaceae	*Symplocos thwaitesii*	Buff Hazelwood	U	1
Thymelaeaceae	*Pimelea ligustrina*		U	2
	Pimelea linifolia		U	7
	Pimelea linifolia ssp linifolia		U	22
Verbenaceae	*Clerodendrum tomentosum*		U	2
	Lantana camara	Lantana	U	9
Violaceae	*Hybanthus enneaspermus*		U	2
	Hybanthus monopetalus	Slender Violet-bush	U	1
	Hybanthus stellarioides		U	8
	Hybanthus vernonii ssp scaber		U	1
	Viola betonicifolia		U	3
	Viola hederacea	Ivy-leaved Violet	U	11
	Viola spp.		U	1
Vitaceae	*Cissus antarctica*	Water Vine	U	2
	Cissus hypoglauca	Giant Water Vine	U	3
Winteraceae	*Tasmannia insipida*	Brush Pepperwood	U	1
Xanthorrhoeaceae	*Xanthorrhoea johnsonii*		U	3
	Xanthorrhoea latifolia		U	3
	Xanthorrhoea latifolia ssp latifolia		U	20
	Xanthorrhoea macronema		U	5
	Xanthorrhoea resinifera		U	1
Xyridaceae	*Xyris gracilis*		U	1
	Xyris gracilis ssp gracilis		U	1
Zingiberaceae	*Alpinia caerulea*	Native Ginger	U	1

Table C.4. List of fish, birds, amphibians, mammals, reptiles and plants likely to occur within the vicinity of Killick Creek protected under the EPBC Act (1999). The list includes species classed as threatened ecological communities, threatened species, marine protected species and migratory species.

	Scientific Name	Common Name	Legal Status
Threatened Species			
Amphibia	*Litoria aurea*	Green and Golden Bell Frog	Vulnerable
	Mixophyes iteratus	Southern Barred Frog	Endangered
Aves	*Diomedea amsterdamensis*	Amsterdam Albatross	Endangered
	Diomedea antipodensis	Antipodean Albatross	Vulnerable
	Diomedea dabbenena	Tristan Albatross	Endangered
	Diomedea exulans	Wandering Albatross	Vulnerable
	Diomedea gibsoni	Gibson's Albatross	Vulnerable
	Lathamus discolor	Swift Parrot	Endangered
	Macronectes giganteus	Southern Giant-Petrel	Endangered
	Macronectes halli	Northern Giant-Petrel	Vulnerable
	Pterodroma leucoptera leucoptera	Gould's Petrel	Endangered
	Pterodroma neglecta neglecta	Kermadec Petrel (western)	Vulnerable
	Thalassarche bulleri	Buller's Albatross	Vulnerable
	Thalassarche cauta	Shy Albatross	Vulnerable
	Thalassarche impavida	Campbell Albatross	Vulnerable
	Thalassarche steadi	White-capped Albatross	Vulnerable
	Xanthomyza phrygia	Regent Honeyeater	Endangered
Chondrichthyes	*Carcharias taurus*	Grey Nurse Shark	Vulnerable
	Carcharodon carcharias	Great White Shark	Vulnerable
Mammalia	*Balaenoptera borealis*	Sei Whale	Vulnerable
	Balaenoptera musculus	Blue Whale	Endangered
	Balaenoptera physalus	Fin Whale	Vulnerable
	Chalinolobus dwyeri	Large-eared Pied Bat, Large Pied Bat	Vulnerable
	Dasyurus maculatus maculatus	Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll (	Vulnerable
	Eubalaena australis	Southern Right Whale	Endangered
	Megaptera novaeangliae	Humpback Whale	Vulnerable
	Petrogale penicillata	Brush-tailed Rock-wallaby	Vulnerable
	Potorous tridactylus tridactylus	Long-nosed Potoroo (SE mainland)	Vulnerable
Plant	*Cryptostylis hunteriana*	Leafless Tongue-orchid	Vulnerable
	Cynanchum elegans	White-flowered Wax Plant	Endangered
	Thesium australe	Austral Toadflax, Toadflax	Vulnerable
Reptilia	*Chelonia mydas*	Green Turtle	Vulnerable
	Dermochelys coriacea	Leathery Turtle, Luth	Vulnerable
Marine birds covered by migratory provisions of the EPBC Act, 1999			
Aves	Diomedea amsterdamensis	Amsterdam Albatross	
	Diomedea antipodensis	Antipodean Albatross	
	Diomedea dabbenena	Tristan Albatross	
	Diomedea exulans	Wandering Albatross	
	Diomedea gibsoni	Gibson's Albatross	
	Macronectes giganteus	Southern Giant-Petrel	
	Macronectes halli	Northern Giant-Petrel	
	Pterodroma leucoptera leucoptera	Gould's Petrel	
	Thalassarche bulleri	Buller's Albatross	
	Thalassarche cauta	Shy Albatross	
	Thalassarche impavida	Campbell Albatross	
	Thalassarche melanophris	Black-browed Albatross	
	Thalassarche steadi	White-capped Albatross	

Table C.4. List of fish, birds, amphibians, mammals, reptiles and plants likely to occur within the vicinity of Killick Creek protected under the EPBC Act (1999). The list includes species classed as threatened ecological communities, threatened species, marine protected species and migratory species.

	Scientific Name	Common Name	Legal Status
Marine species covered by migratory provisions of the EPBC Act, 1999			
Chondrichthyes	Rhincodon typus	Whale Shark	
Mammalia	Balaenoptera musculus	Blue Whale	
	Eubalaena australis	Southern Right Whale	
	Megaptera novaeangliae	Humpback Whale	
Reptilia	Chelonia mydas	Green Turtle	
	Dermochelys coriacea	Leathery Turtle, Luth	
Terrestrial species covered by migratory provisions of the EPBC Act, 1999			
Aves	Haliaeetus leucogaster	White-bellied Sea-Eagle	
	Hirundapus caudacutus	White-throated Needletail	
	Monarcha melanopsis	Black-faced Monarch	
	Monarcha trivirgatus	Spectacled Monarch	
	Myiagra cyanoleuca	Satin Flycatcher	
	Rhipidura rufifrons	Rufous Fantail	
	Xanthomyza phrygia	Regent Honeyeater	
Wetland species covered by migratory provisions of the EPBC Act, 1999			
Aves	Gallinago hardwickii	Latham's Snipe, Japanese Snipe	
Aves	Rostratula benghalensis	Painted Snipe	
Species covered by marine provisions of the EPBC Act, 1999			
Aves	Catharacta skua	Great Skua	Listed
	Diomedea amsterdamensis	Amsterdam Albatross	Listed
	Diomedea antipodensis	Antipodean Albatross	Listed
	Diomedea dabbenena	Tristan Albatross	Listed
	Diomedea exulans	Wandering Albatross	Listed
	Diomedea gibsoni	Gibson's Albatross	Listed
	Gallinago hardwickii	Latham's Snipe, Japanese Snipe	Listed
	Haliaeetus leucogaster	White-bellied Sea-Eagle	Listed
	Hirundapus caudacutus	White-throated Needletail	Listed
	Lathamus discolor	Swift Parrot	*
	Macronectes giganteus	Southern Giant-Petrel	Listed
	Macronectes halli	Northern Giant-Petrel	Listed
	Monarcha melanopsis	Black-faced Monarch	Listed
	Monarcha trivirgatus	Spectacled Monarch	Listed
	Myiagra cyanoleuca	Satin Flycatcher	Listed
	Rhipidura rufifrons	Rufous Fantail	Listed
	Rostratula benghalensis	Painted Snipe	Listed
	Thalassarche bulleri	Buller's Albatross	Listed
	Thalassarche cauta	Shy Albatross	Listed
	Thalassarche chlororhynchos	Yellow-nosed Albatross, Atlantic Yellow-nosed Al	Listed
	Thalassarche impavida	Campbell Albatross	Listed
	Thalassarche melanophris	Black-browed Albatross	Listed
	Thalassarche steadi	White-capped Albatross	Listed
Osteichthyes	Acentronura tentaculata	Pipehorse	Listed
	Festucalex cinctus	Girdled Pipefish	Listed
	Filicampus tigris	Tiger Pipefish	Listed
	Heraldia nocturna	-	Listed
	Hippichthys heptagonus	Reticulated Freshwater Pipefish	Listed
	Hippichthys penicillus	Steep-nosed Pipefish	Listed
	Hippocampus whitei	Crowned Seahorse	Listed
	Histiogamphelus briggsii	Briggs' Pipefish	Listed
	Lissocampus runa	Javelin Pipefish	Listed
	Maroubra perserrata	Sawtooth Pipefish	Listed
	Solegnathus dunckeri	Duncker's Pipehorse	Listed
	Solegnathus spinosissimus	Spiny Pipehorse	Listed
	Solenostomus cyanopterus	Blue-finned Ghost Pipefish	Listed

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	Scientific Name	Common Name	Legal Status
	Solenostomus paradoxus	Harlequin Ghost Pipefish	Listed
	Stigmatopora nigra	Black Pipefish	Listed
	Syngnathoides biaculeatus	Alligator Pipefish	Listed
	Trachyrhamphus bicoarctatus	Short-tailed Pipefish	Listed
	Urocampus carinirostris	Hairy Pipefish	Listed
	Vanacampus margaritifer	Mother-of-pearl Pipefish	Listed
Reptilia	Chelonia mydas	Green Turtle	Listed
	Dermochelys coriacea	Leathery Turtle, Luth	Listed
	Hydrophis elegans	Elegant Seasnake	Listed
	Pelamis platurus	Yellow-bellied Sea Snake	Listed

Appendix D

Glossary of Terms

Appendix D Glossary of Terms

accretion	Deposition of sediment in the channel and on the banks of the estuary resulting in the growth of bars and other depositional features.
acid sulfate soil	Estuarine sediments in which metal sulfides (mainly pyrite) accumulate, and the subsequent dehydration of these sediments by evapotranspiration and/or disturbance which enables the oxidation of pyrite/sulfides to produce sulfuric acid.
algal bloom	The excessive growth of phytoplankton, generally caused by high nutrient levels. Can result in deoxygenation of the water mass, leading to the death of aquatic flora and fauna.
anoxic	A lack of oxygen in the water.
Australian Height Datum (AHD)	A common national plane of level corresponding approximately to mean sea level.
bathymetry	The measurement of depths of water; also information derived from such measurements.
benthos, benthic organisms	Organisms living in or on the bed of a waterbody.
catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
dissolved oxygen	Atmospheric oxygen that dissolves in water. The solubility of oxygen in water depends upon temperature and salinity.
ebb tide	The outflow of coastal waters from bays and estuaries caused by the falling tide.
estuarine processes	Those processes that affect the physical, chemical and biological behaviour of an estuary, e.g. predation, water movement, sediment movement, water quality, etc.
estuary	An enclosed or semi-enclosed body of water having an open or intermittently open connection to coastal waters in which water levels vary in a periodic fashion in response to ocean tides.
estuary management process	A sequence of activities starting with the formation of an Estuary Management Committee and culminating in the implementation of an Estuary Management Plan that will foster the balanced and sustainable use of estuaries.

flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream or river.
flood mitigation works	Structures that are designed to manage floodwaters (e.g. levees, retarding basins).
floodplain	The portion of a river valley, adjacent to the river channel, which is covered with water when the river overflows during floods.
flood tide	The inflow of coastal waters into bays and estuaries caused by the rising tide.
habitat	The places in which an organism lives and grows. Many estuarine organisms require different habitats at different stages of their life cycles.
hydraulic regime	The variation of estuarine discharges in response to seasonal freshwater inflows and diurnal tides.
levee	A man-made embankment or wall built to exclude floodwaters, or a natural embankment adjacent to a waterway built by the deposition of silt from floodwaters.
littoral drift processes	Wave, current and wind processes that facilitate the transport of sediments along a shoreline.
management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, problems, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
mangroves	An intertidal plant community dominated by trees.
neap tides	Tides with the smallest range in a monthly cycle. Neap tides occur when the sun and moon lie at right angles relative to the earth (the gravitational effects of the moon and sun act in opposition on the ocean).
nutrients	Substances containing or conveying nourishment. Common nutrients are phosphorus and nitrogen.
phase lag	Difference in time of the occurrence between high (or low water) and maximum flood (or ebb) velocity at some point in an estuary.
recruitment	The addition of new members to an existing population, such as the settling of planktonic fish and crustacean larvae into seagrass beds.

riparian vegetation	Vegetation growing along banks of rivers, including the brackish upstream reaches of an estuary.
salinity	The total mass of dissolved salts per unit mass of water. Seawater has a salinity of about 35 g/kg or 35 parts per thousand .
salt wedge	The wedge-shaped body of saltwater that underlies freshwater in poorly-mixed estuaries.
sediment load	The quantity of sediment moved past a particular cross-section in a specified time.
shoaling	The influence of the seabed on wave behaviour. Such effects only become significant in water depths of 60m or less. Manifested as a reduction in wave speed, a shortening in wave length and an increase in wave height.
shoals	Shallow areas in an estuary created by the deposition and build-up of sediments.
spring tides	Tides with the greatest range in a monthly cycle, which occur when the sun, moon and earth are in alignment (the gravitational effects of the moon and sun act in concert on the ocean) .
tidal exchange	The proportion of the tidal prism that is flushed away and replaced with 'fresh' coastal water each tide cycle.
tidal excursion	The distance travelled by a water particle from low water slack to high water slack and vice versa.
tidal lag	The delay between the state of the tide at the estuary mouth (e.g. high water slack) and the same state of tide at an upstream location.
tidal limit	The most upstream location where a tidal rise and fall of water levels is discernible. The location of the tidal limit changes with freshwater inflows and tidal range.
tidal planes	A series of water levels that define standard tides, e.g. 'Mean High Water Spring' (MHWS) refers to the average high water level of spring tides.
tidal prism	The total volume of water moving past a fixed point on an estuary during each flood tide or ebb tide.
tidal propagation	The movement of the tidal wave into and out of an estuary.
tidal range	The difference between successive high water and low water levels. Tidal range is maximum during spring tides and minimum during neap tides.

tides	The regular rise and fall of sea level in response to the gravitational attraction of the sun, moon and planets. Tides along the New South Wales coastline are semi-diurnal in nature, i.e. they have a period of about 12.5 hours.
topography	The relief features or surface configuration of an area.
water quality	The suitability of the water for various purposes, as measured by the concentration or level of a wide variety of contaminants.

Appendix E

Definition of Tidal Planes

Appendix E Definition of Tidal Planes

For a detailed discussion on tides and tidal analysis see the National Tidal Facility website, www.ntf.flinders.edu.au, or the Manly Hydraulics Laboratory website, www.mhl.nsw.gov.au.

HHW(SS) – Higher High Water (Spring Solstices)

The highest of the high waters (or single high water) of any specified tidal day due to the declination effects of the moon and sun.

MHWS – Mean High Water Springs

The height of the MHWS is the average, throughout a year when the average maximum declination of the moon is 23.5°, of the heights of two successive high waters during those periods of 24 hours (approximately once a fortnight) when the range of the tide is greatest.

MHW – Mean High Water

The average of all the high water heights observed over the National Tidal Datum Epoch. For stations with shorter series, simultaneous observational comparisons are made with a control tide station in order to derive the equivalent datum.

MHWN – Mean High Water Neaps

The height of the MHWN is the average, throughout a year when the average maximum declination of the moon is 23.5°, of the heights of two successive high waters during those periods of 24 hours (approximately once a fortnight) when the range of the tide is least.

MSL – Mean Sea Level

The average level of the sea surface over a long period, preferably 18.6 years or more, or the average level which would exist in the absence of tides.

MLWN - Mean Low Water Neaps

The height of the MHWN is the average, throughout a year when the average maximum declination of the moon is 23.5°, of the heights of two successive low waters during those periods of 24 hours (approximately once a fortnight) when the range of the tide is least.

MLW – Mean Low Water

The average of all the low water heights observed over the National Tidal Datum Epoch. For stations with shorter series, simultaneous observational comparisons are made with a control tide station in order to derive the equivalent datum.

MLWS – Mean Low Water Springs

The height of the MHWN is the average, throughout a year when the average maximum declination of the moon is 23.5°, of the heights of two successive low waters during those periods of 24 hours (approximately once a fortnight) when the range of the tide is greatest.

ISLW – Indian Spring Low Water

The lowest level to which a tide will fall under exceptional, predictable, astronomical conditions. It seldom occurs. Meteorological and oceanographical influences, which cannot be predicted, can cause the tide to fall even lower.

MSR – Mean Spring Range
The difference obtained by subtracting the MLWS plane level from the MHWS plane level.

MNR – Mean Neap Range
The difference obtained by subtracting the MLWN plane level from the MHWN plane level.