7 FORESHORE EROSION AND STRUCTURES ASSESSMENT

SMEC has assessed the severity of foreshore erosion and condition of existing foreshore structures through a series of field visits in late 2009. This section of the report presents summaries of erosion and foreshore erosion protection and stormwater structures on a site by site basis, assigning gradings of light, moderate or severe to the foreshore erosion, and condition assessments for seawalls as good, fair or poor.

Management responses for each particular site are suggested.

Locations of foreshore erosion and foreshore structure assessments are mapped and described in Appendix 2. Particular sites for management actions are prioritised based on a catchment wide basis, and on an LGA basis. Priorities for particular management actions at particular sites were based on a combination of cost and environmental benefit.

7.1 Introduction

Some erosion occurs with various degrees of severity in various locations all along the Georges River foreshore. In general, most erosion occurs in the areas of the river underlain by Wianamatta Shales in the upper reaches while the lower reaches are located in sandstone or are highly urbanised and protected by seawalls. The study team visited the site over several days by land and boat to assess the severity of erosion and the seawall conditions along the Georges River foreshore.

Foreshore erosion along the Georges River is generally due to factors such as boat waves, tidal undercutting, floods and stormwater runoff. Erosion was rated as being light, moderate or high/severe.

Many seawalls have been constructed along the Georges River. Most of them are located in the lower reaches and all around Chipping Norton foreshore. Seawall conditions were rated as followed:

- Good: the seawall is quite new or intact; it is properly engineered and does not need any maintenance or only minor maintenance.
- Fair: the seawall is in relatively good condition but would need maintenance or upgrades
- Poor: Dumped materials, collapsed seawall or seawall in need of major maintenance and upgrades

Locations of foreshore erosion are provided in Table A in Appendix 2. The seawall assessment is documented in Table B in Appendix 2. The numbered locations are indicated on the maps 1 to 45. The recommendation options refer to the option presented in Section 7.3. Key management options per council and for the Georges River are described in Section 7.4. Stormwater, GPTs and WSUD are described in Section 7.5 and in Table C in Appendix 2.

The prioritisation was undertaken using a “cost x environmental gain” methodology. This means that the lower the cost and the higher the environmental benefit, the higher the priority.

7.2 Site Summaries

7.2.1 Liverpool Weir to Moore Lake

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 1 of Appendix 2.

7.2.1.1 Foreshore Erosion

The main channel of the Georges River between Liverpool Weir and Moore Lake is not protected by seawall – except the area surrounding the Liverpool Weir – and is subject to erosion (Figure 7.1). The foreshore along the railway is highly-to-severely eroded as well as the north-western part of McMillan Park foreshore. Some light undercutting occurs on the foreshore opposite the park and moderate erosion occurs opposite the railway (location reference E1 to E6).

Figure 7.1 – Severe erosion between Liverpool Weir and Moore Lake

Recommendations

Suggested management options for the erosion management are given in Table 7.1 below.

Table 7.1 – Erosion management option between Liverpool and Moore Lake

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E1.Along the railway between Liverpool Weir and Liverpool Hospital	Liverpool	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E2.Opposite the railway between Liverpool Weir and Liverpool Hospital	Liverpool	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E3.Along the carpark east of the railway	Liverpool	Medium	Stabilisation of the bank toe with small seawall (Option E2)
E4.Directly east of the carpark	Liverpool	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E5.Along McMillan Park	Liverpool	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E6.Opposite McMillan	Liverpool	Medium/High	Stabilisation of the bank toe with

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
Park			small seawall (Option E2) Vegetation planting (Option E3)

7.2.1.2 Seawall Assessment

A part of Liverpool Weir is settling on its eastern half. There are only a few seawalls along the foreshore upstream of Chipping Norton. A small gabion seawall supported by sheet piles is located along the northern bank between McMillan Park and Gandangara Island (Figure 7.2). This seawall looks to be in relatively good condition but has been covered with invasive plants (location reference S1-2).

Figure 7.2 – Gabions seawall between McMillan Park and Gandangara Island

Recommendations

Suggested management options for the seawall management are given in Table 7.2 below.

Table 7.2 – Seawall management option between Liverpool and Moore Lake

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S1.Liverpool Weir	Liverpool	Medium	Fix the settling part of the weir on its eastern half Creation of more habitat in front of weir (Option S2)
S2.Along northern bank between McMillan Park and Gandangara Island	Liverpool	Medium/High	Sheet piles can be replaced by environmentally friendly rock seawall to allow vegetation growing in the gap of rocks (Option S5) Creation of more habitat in front of sheet piles seawall (Option S2)

7.2.2 Moore Lake

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 2 of Appendix 2.

7.2.2.1 Foreshore Erosion

Moore Lake foreshore is in good condition and mostly well vegetated. Some light tidal undercutting occurs along the northern side of the lake and some moderate erosion occurs along the south-eastern side of Bulba Dibeen Island (Figure 7.3). The bank located directly east of Moore Lake entrance along Georges River main channel is moderately eroding (location reference E7 to E10).

Figure 7.3 – Moderate undercutting at Bulba Dibeen Island

Recommendations

Suggested management options for the erosion management are given in Table 7.3 below.

Table 7.3 – Erosion management option at Moore Lake

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E7.Northern bank of Lake Moore	Liverpool	Medium	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Stabilisation of the bank toe with small seawall (Option E2)
E8.South-eastern side of Bulba Dibeen Island	Liverpool	Medium	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Stabilisation of the bank with small

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
			rocks (Option E8) Stabilisation of the bank toe with small seawall (Option E2)
E9.North of Bridges Road Wharf	Liverpool	High	Vegetation planting where gaps in vegetation along bank (Option E3)
E10.Directly east of Lake Moore entrance along the Georges River	Liverpool	Low/Medium	Stabilisation by further vegetation planting(Option E3) No action

7.2.2.2 Seawall Assessment

Some rock protections have been built to protect the bridge crossing Lake Moore entrance (location reference S3).

Recommendations

Suggested management options for the seawall management are given in Table 7.4 below.

Table 7.4 – Seawall management option at Moore Lake

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S3.Bridge crossing Lake Moore entrance	Liverpool	N/A	No specific action required

7.2.3 Moore Lake to Governor Macquarie Bridge

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 3 of Appendix 2.

7.2.3.1 Foreshore Erosion

Ngamba Island located in the Georges River east of Lake Moore entrance and upstream of the River bend is subject to light tidal undercutting. The Georges River embankments surrounding this island suffer from light to moderate erosion. The area downstream of this island but upstream of the private dwellings located along the river on the eastern bank within the bend is subject to high erosion (Figure 7.4). Many of the private dwellings have their own seawall and some undercutting is noticeable between the private seawalls (location reference E11 to E16). Between the bend of the river and the Cabramatta Creek entrance, some erosion is visible on both side of the river (location reference E17 to E20).

Figure 7.4 – Erosion east of Chauvel Park

Recommendations

Suggested management options for the erosion management are given in Table 7.5 below.

Table 7.5 – Erosion management option between Moore Lake and Governor Macquarie Bridge

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E11.Ngamba Island	Liverpool	Low	Stabilisation of the bank toe with small seawall (Option E2) Sand nourishment (Option E9)
E12.Northern bank opposite Ngamba Island	Liverpool	Medium	Stabilisation of the bank toe with small seawall (Option E2) Sand nourishment (Option E9)
E13.Western end of Chauvel Park	Liverpool	Medium/High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Stabilisation of the bank toe with small seawall (Option E2)
E14.Opposite Chauvel Park	Liverpool	Medium/High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Stabilisation of the bank toe with small seawall (Option E2)
E15.Along Chauvel Park and downstream to the river bend	Liverpool	Medium/High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Stabilisation of the bank toe with small seawall (Option E2)
E16.Outside of the river bend	Liverpool	Medium/High	Stabilisation of the bank toe with small seawall (Option E2) Vegetation planting (Option E3)
E17.East of the pipe	Liverpool	Medium	Levelling of the bank to reach a stable slope

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
crossing the River between the river bend and Governor Macquarie Bridge			(Option E1) Construction of a seawall opposite the pipe foundation (Option E4)
E18.Eastern bank directly downstream the pipe crossing the river	Liverpool	Low	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Stabilisation of the bank toe with small seawall (Option E2)
E19.Western bank between the river bend and Governor Macquarie Bridge	Liverpool	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E20.Eastern bank between the river bend and Governor Macquarie Bridge	Liverpool	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)

7.2.3.2 Seawall Assessment

A couple of multi-layer gabion seawalls have been constructed along the private properties in the bend of the River upstream of Governor Macquarie Drive. Some dumped rocks have been used under the pipe crossing the River between the bend and Governor Macquarie Bridge (location reference S4).

Recommendations

Suggested management options for the seawall management are given in Table 7.6 below.

Table 7.6 – Seawall management option between Moore Lake and Governor Macquarie Bridge

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S4.Eastern bank at the level of the pipe crossing the River upstream of Governor Macquarie Bridge	Liverpool	Medium	Replace dumped materials by seawall built to engineered standard and allowing vegetation to grow in the gaps of rocks (Option S1)

7.2.4 Governor Macquarie Bridge to Chipping Norton Lake

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 4 of Appendix 2.

7.2.4.1 Foreshore Erosion

Between the bend of the river and the Cabramatta Creek entrance, some severe erosion is visible on both side of the river (Figure 7.5). Some stormwater drains have been destroyed by the strong erosion in this area. Some areas show old severe erosion which has been stabilised and covered with vegetation (location reference E19-23 and E25-26).

Figure 7.5 – Erosion along Warwick Farm

Recommendations

Suggested management options for the erosion management are given in Table 7.7 below.

Table 7.7– Erosion management option between Governor Macquarie Bridge and Chipping Norton Lake

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E21.Directly north of Governor Macquarie Bridge, both banks	Bankstown	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E22.Southern end of South Park	Liverpool	Medium	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Stabilisation of the bank toe with small seawall (Option E2) Sand nourishment (Option E9)
E23.Along South Park	Liverpool	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E25.Southern end of the Warwick Farm	Liverpool	N/A	No particular response needed due to natural recovery
E26.Along Warwick Farm up to Cabramatta Creek entrance	Liverpool	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)

7.2.4.2 Seawall Assessment

Some dumped rocks have been used on the western embankment under the bridge itself. The eastern embankment under the bridge has been stabilised using seawalls but these seawalls are subject to settling (Figure 7.6). Gabion protection has been placed on a stormwater drain along South Park (location reference S5-6).

Figure 7.6 – Protections under the eastern (left) and western (right) side of Governor Macquarie Bridge

Recommendations

Suggested management options for the seawall management are given in Table 7.8 below.

Table 7.8– Seawall management option between Governor Macquarie Bridge and Chipping Norton Lake

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S5.Governor Macquarie Bridge Western Bank	Liverpool	Medium	Replace dumped materials by seawall built to engineered standard and allowing vegetation to grow in the gaps of rocks (Option S1)
S6.Governor Macquarie Bridge Eastern Bank	Liverpool	Low	Replace settling part of seawall by a rocks seawall (Option S1)

7.2.5 Cabramatta Creek

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 5 of Appendix 2.

7.2.5.1 Foreshore Erosion

Westlake Point is eroding moderately (Location reference E24). Generally, Cabramatta Creek is well vegetated and some minor tidal undercutting appears where there are gaps in the vegetation. Some high erosion is visible on the western bank in the most downstream bend of the River and under Hume Highway Bridge (Figure 7.7). The bank located between the two small seawalls along Hoy and Cherrybrook Parks west of Cabramatta River mouth suffer from severe erosion (location reference E27-30 and E38).

Figure 7.7 – Erosion under Hume Highway Bridge

Recommendations

Suggested management options for the erosion management are given in Table 7.9 below.

Table 7.9– Erosion management option at Cabramatta Creek

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E24.Westlake Point	Liverpool	Medium/High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Construction of a seawall around Westlake Point (Option E2 or E6) Use of small rocks as protection (Option E8)
E27.Western bank of Cabramatta Creek directly upstream the entrance	Liverpool	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Construction of a seawall on the second side of the creek entrance (Option E7)
E28.Stormwater drain near the intersection of Cherrybrook Road and Silverwater Crescent along Cabramatta Creek	Liverpool	High	Upgrade the stormwater outlet direction to lower erosion Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E29.Under Liverpool Road Bridge at Cabramatta Creek	Liverpool	Low	Rock protection under the bridge (Option E4)
E30.Rest of Cabramatta Creek	Liverpool/Fairfield	N/A	No particular response needed
E38.East of Cabramatta Creek Entrance	Fairfield	Medium/High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Joining the different scattered seawall to create one unique seawall to avoid edge effect (Option E10)

7.2.5.2 Seawall Assessment

A good condition rock seawall protects the eastern side of Cabramatta Creek entrance which might be responsible for the high erosion of the western side and of the foreshore directly east of the seawall (location reference S7). Some scattered small seawalls have been constructed along Cherrybrook and Hoy Parks, increasing erosion around them (location reference S8).

Recommendations

Suggested management options for the seawall management are given in Table 7.10 below.

Table 7.10 – Seawall management option at Cabramatta Creek

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S7.Cabramatta Creek Mouth Eastern Bank	Fairfield	N/A	No specific action required
S8.Hoy Park	Fairfield	Low	Prolongation of seawall to avoid edge effect (Option S3)

7.2.6 Chipping Norton Lake

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 6 and 7 of Appendix 2.

7.2.6.1 Foreshore Erosion

Most of Chipping Norton Lake foreshore is protected by seawalls. Some light undercutting is also noticeable along Silver Crescent. Crescent and Bass Island located along the northern embankment of the Lake are well vegetated but some undercutting is visible where there are some gaps in the vegetation. The same phenomenon is observable on the northern end of Wildlife (or Bulba-Gong) Island (Figure 7.8) and on the bank opposite the southern end of the island. Some light undercutting is visible along Angle Park despite some dumped rocks and on both side of Grand Flaneur Beach where some trees are falling into the water on the western side (location reference E31 to E42).

Figure 7.8 – Undercutting at Wildlife Island

Recommendations

Suggested management options for the erosion management are given in Table 7.11 below.

Table 7.11– Erosion management option at Chipping Norton

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E31.Western side of Angle Park	Liverpool	Medium	Replenishment of the eroded part and vegetation planting (Option E9) Levelling to reach a new equilibrium profile and vegetation planting (Option E1)
E32.Northern side of Angle Park	Liverpool	N/A	No particular response needed
E33.Western side of Grand Flaneur Beach	Liverpool	Medium	Replenishment of the eroded part and vegetation planting (Option E9) Levelling to reach a new equilibrium profile and vegetation planting (Option E1)
E34.Eastern Side of Grand Flaneur Beach	Liverpool	Medium	Replenishment of the eroded part and vegetation planting (Option E9) Levelling to reach a new equilibrium profile and vegetation planting (Option E1)
E35.Bass Island	Liverpool	Low	Stabilisation of the bank by deposition of small rocks like around Daruk Island (Option E8) Stabilisation by further vegetation planting (Option E3) Replenishment with sand (Option E9)
E36.Crescent Island	Liverpool	Low	Stabilisation of the bank by deposition of small rocks like around Daruk Island (Option E8) Stabilisation by further vegetation planting (Option E3) Replenishment with sand (Option E9)
E37.Wildlife Island	Liverpool	Low/Medium	Replenishment with sand (Option E9) Stabilisation by further vegetation planting (Option E3)
E38.East of Cabramatta Creek Entrance	Fairfield	Medium/High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Joining the different scattered seawall to create one unique seawall to avoid edge effect (Option E10)
E39.Along Silver Crescent	Fairfield	High	Construction of a seawall along the different parks and carparks (Option E5 or E6) Stabilisation by vegetation planting (Option E3)
E40.East of Howards boat ramp	Fairfield	Medium	Construction of a seawall along the carpark (Option E5 or E6) Stabilisation by vegetation planting (Option

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
			E3)
E41.Strong Park	Fairfield	Medium/High	Construction of a seawall along the park (Option E5 or E6) Stabilisation by vegetation planting (Option E3)
E42.Between Strong and Howard Park	Fairfield	Medium/High	Extend Howard Park seawall (Option E10) Stabilisation by vegetation planting (Option E3)

7.2.6.2 Seawall Assessment

Chipping Norton Lake has mostly been surrounded by seawalls. Fair condition seawalls surround Ascot Point (Figure 7.9). Some small rocks – same size as gabion filling rocks – have been placed all along Long Point and Daruk Island. A poor condition seawall was observed along the southern end of Wildlife Island while a fair condition seawall protects the eastern embankment along the channel separating Wildlife Island from the Chipping Norton Foreshore (location reference S9 to S15).

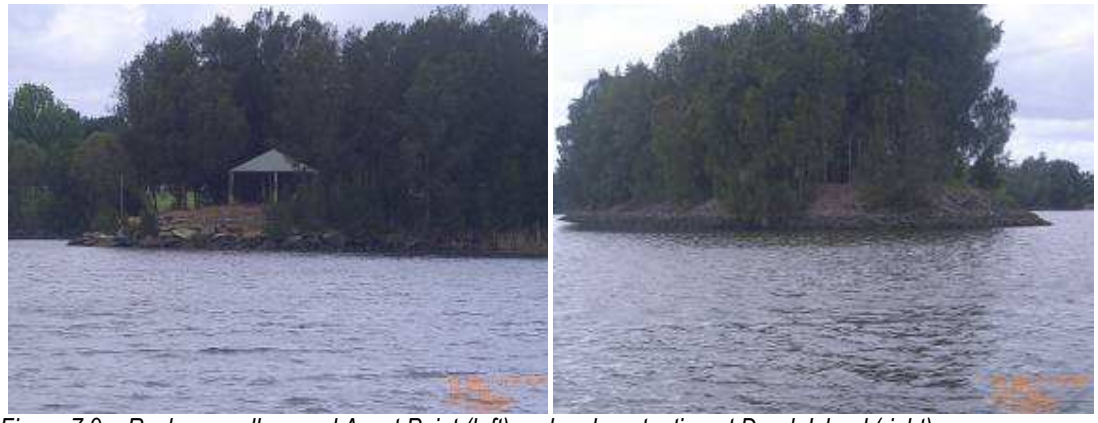

Figure 7.9 – Rock seawall around Ascot Point (left) and rock protection at Daruk Island (right)

Recommendations

Suggested management options for the seawall management are given in Table 7.12 below.

Table 7.12– Seawall management options at Chipping Norton

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S9.Ascot Point	Liverpool	N/A	No specific action required
S10.Grand Flaneur Beach	Liverpool	N/A	No specific action required
S11.Howard Boat Ramp	Fairfield	N/A	No specific action required
S12.Daruk Island	Liverpool	N/A	No specific action required
S13.Long Point	Liverpool	N/A	No specific action required
S14.Between Eora Beach and Strong Park Wharf	Fairfield	Medium/High	Upgrade of seawall to engineered standard and environmentally friendly condition using rocks (Option S1)
S15.Wildlife Island Southern Bank	Liverpool	Medium	Rock seawall can be extended to avoid edge effect along Wildlife Island (Option S3)

7.2.7 Chipping Norton Lake to Floyd Bay

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 8 of Appendix 2.

7.2.7.1 Foreshore Erosion

The channel separating Chipping Norton Lake from Floyd Bay is subject to high erosion where there is no seawall. A stormwater drain has been eroded (Figure 7.10). Erosion weakens along the western bank in direction of Floyd Bay. Some undercutting is visible along the southern bank of Floyd Bay. Some light undercutting is noticeable on the eastern side of Floyd Bay northern bank (location reference E43 to E46).

Figure 7.10 – Erosion directly south of Long Point

Recommendations

Suggested management options for the erosion management are given in Table 7.13 below.

Table 7.13– Erosion management option between Chipping Norton and Floyd Bay

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E43.South of Long Point opposite Howard Park	Liverpool	Medium/High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Southwards prolongation of Long Point seawall (Option E10)
E44.Between the eroded part south of Long Point and Black Muscat Park	Liverpool	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E45.Along Black Muscat Park	Liverpool	Medium	Construction of a seawall along the park where embankment is low (Option E5-E6) Stabilisation of the toe by small seawall where higher embankment (Option E2) Replenishment with sand of eroded part (Option E9) Stabilisation by vegetation planting (Option E3)
E46.East of Shearer Park Wharf	Fairfield	Medium	Construction of a seawall along the park where embankment is low (Option E5-E6) Replenishment with sand of eroded part (Option E9) Stabilisation by vegetation planting (Option E3)

7.2.7.2 Seawall Assessment

Howard Park has been surrounded by good quality and environmentally friendly seawalls all along its foreshore up to the Dowling Beach Boat Ramp (Figure 7.11) while a poor condition rock wall protects Shearer Park (location reference S16-17).

Figure 7.11 – Rock seawall at Howard Park

Recommendations

Suggested management options for the seawall management are given in Table 7.14 below.

Table 7.14– Seawall management option between Chipping Norton and Floyd Bay

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S13.Long Point	Liverpool	N/A	No specific action required
S16.Howard Park and Dowling Beach Boat Ramp	Fairfield	N/A	No specific action required
S17.Western End of Shearer Park	Fairfield	Medium/High	Environmentally friendly seawall along Dowling beach can be extended in front of Shearer Park (Option S5)

7.2.8 Floyd Bay to Dhurawal Bay

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 9 of Appendix 2.

7.2.8.1 Foreshore Erosion

High erosion has been observed along Coot Island southern embankment where there is no seawall (Figure 7.12). High erosion is visible on the eastern side of Dhurawal Bay certainly due to the edge effect created by the private seawalls directly south of this eroded area. The eastern bank of the Prospect Creek mouth is subject to moderate-to-high erosion (location reference E47 and E57-58).

Figure 7.12 – Severe erosion behind vegetation, south of Beatty Reserve

Recommendations

Suggested management options for the erosion management are given in Table 7.15 below.

Table 7.15– Erosion management option between Floyd Bay and Dhurawal Bay

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E47.Coot Island	Fairfield	Medium/High	Extension of the rock protection along the island (Option E10) Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Small rocks protection like on Daruk Island (Option E8)
E57.Eastern bank of Prospect Creek mouth	Bankstown	High	Replenishment with sand (Option E9) Stabilisation by vegetation planting (Option E3) Construction of a seawall to stabilize Prospect Creek mouth like at Cabramatta Creek (Option E7)
E58.South of Beatty Reserve	Bankstown	High	Replenishment with sand (Option E9) Levelling of the bank to reach a stable slope and vegetation planting (Option E1)

7.2.8.2 Seawall Assessment

The western tip of Coot Island is covered by rocks while some dumped rocks have been used to protect the small bridge linking the island to Hollywood Park as well as the southern side of Hollywood Park. A good quality seawall was noticeable in the middle of Lawrence Beach and a good condition groyne protects the Beach at its eastern end (location reference S18-20 and S22).

Recommendations

Suggested management options for the seawall management are given in Table 7.16 below.

Table 7.16– Seawall management option between Floyd Bay and Dhurawal Bay

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S18.Western End of Coot Island	Fairfield	N/A	No specific action required
S19.Coot Island footbridge	Fairfield	N/A	No specific action required
S20.Southern bank of Hollywood Park	Fairfield	Low	Dumped rocks can be replaced by engineered rock seawall (Option S1)
S22.Lawrence Beach	Liverpool	N/A	No specific action required

7.2.9 Prospect Creek

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figures 9 to 11 of Appendix 2.

7.2.9.1 Foreshore Erosion

Along Prospect Creek, some moderate erosion is noticeable along Liverpool Golf Course southern embankment and on both side of the creek along the northern embankment of the Club while some light undercutting appears on the foreshore opposite the eastern side (Figure 7.13). Some undercutting has also been observed downstream of the private houses located along Knight Street. Some moderate erosion occurs in the gaps of vegetation between Day Street end and Liverpool Road Bridge (location reference E48 to E56).

Figure 7.13 – Undercutting along Prospect Creek

Recommendations

Suggested management options for the erosion management are given in Table 7.17 below.

Table 7.17– Erosion management option at Prospect Creek

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E48.Inside of the most downstream bend of Prospect Creek	Bankstown	Low/Medium	Replenishment with sand (Option E9) Stabilisation by vegetation planting (Option E3)
E49.Outside of the most downstream bend of Prospect Creek	Fairfield	Low/Medium	Replenishment with sand (Option E9) Stabilisation by vegetation planting (Option E3)
E50.Southern end of Liverpool Golf Course	Fairfield	Low/Medium	Replenishment with sand (Option E9) Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E51.Opposite south-eastern bank of Liverpool Golf Course	Bankstown	Low	Replenishment with sand (Option E9) Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E52.North-eastern bank of Liverpool Golf Course	Fairfield	Low/Medium	Replenishment with sand (Option E9) Stabilisation by vegetation planting (Option E3)

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E53.Opposite north-eastern bank of Liverpool Golf Course	Bankstown	Low/Medium	Replenishment with sand (Option E9) Stabilisation by vegetation planting (Option E3)
E54.Directly downstream the dwelling along Knight Street, northern bank	Bankstown	Low	Replenishment with sand (Option E9) Stabilisation by vegetation planting (Option E3)
E55.Directly downstream the dwelling along Knight Street, southern bank	Fairfield	Low	Replenishment with sand (Option E9) Stabilisation by vegetation planting (Option E3)
E56.Eastern bank between Day Street and Hume Highway Bridge	Bankstown	Low/Medium	Replenishment with sand (Option E9) Stabilisation by vegetation planting (Option E3)

7.2.9.2 Seawall Assessment

Along Prospect Creek, within the most downstream bend of the creek the remnant of a timber retaining wall was observed along the north-eastern side of Hollywood Park while some dumped concrete plate have been dumped directly upstream of the poor condition timber wall (Figure 7.14). A poor condition brick wall surrounding a small boat ramp is noticeable on the eastern side of Beatty Reserve. Some seawalls of various qualities were visible along the private properties along Knight Street (location reference S21 and S24).

Figure 7.14 – Remnant of a timber retaining wall (left) and dumped concrete plate (right) at Hollywood Park

Recommendations

Suggested management options for the seawall management are given in Table 7.18 below.

Table 7.18– Seawall management option at Prospect Creek

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S21.Most downstream bend of Prospect Creek along Hollywood Park	Fairfield	High	Timber retaining wall can be removed and replaced by vegetation (Option S4)
S24.Eastern bank of Prospect Creek mouth	Bankstown	High	Old abandoned structures can be replaced by vegetation (Option S4)

7.2.10 Dhurawal Bay to Georges River Golf Club

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 12 of Appendix 2.

7.2.10.1 Foreshore Erosion

Light erosion is noticeable south of Heron Park and at the northern end of Georges River Golf Course where there are gaps in the vegetation (location reference E59-61).

Recommendations

Suggested management options for the erosion management are given in Table 7.19 below.

Table 7.19 – Erosion management option between Dhurawal Bay and Georges River Golf Club

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E59.South-eastern end of Heron Park	Liverpool	Low	Replenishment with sand (Option E9) Stabilisation by vegetation planting (Option E3)
E60.Opposite the south-eastern end of Heron Park	Bankstown	Low	Replenishment with sand (Option E9) Stabilisation by vegetation planting (Option E3) Northward extension of the seawall (Option E10)
E61.Along Georges River Golf Course	Bankstown	Medium	Vegetation planting (Option E3)

7.2.10.2 Seawall Assessment

The same wide range of seawall condition was observed along the private houses located between Dhurawal Bay and Georges River Golf Course. The area located under the footbridge directly south of Heron Park is covered with rocks. The northern end of the Golf course is protected by a good quality and environmentally friendly seawall (Figure 7.15) and opposite this seawall a small gabion seawall was visible (location reference S23, S25 and S26).

Figure 7.15 – Rock seawall at the northern end of Georges River Golf Course

Recommendations

Suggested management options for the seawall management are given in Table 7.20 below.

Table 7.20 – Seawall management option between Dhurawal Bay and Georges River Golf Club

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S23.Natural entrance under footbridge directly south of Heron Park	Liverpool	N/A	No specific action required
S25.Northern End of Georges River Golf Course	Bankstown	N/A	No specific action required
S26.Bank opposite the northern end of the Georges River Golf Course	Liverpool	Medium	Seawall can be removed and replaced by vegetation (Option S4)

7.2.11 Georges River Golf Club to Davy Robinson Drive

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 13 of Appendix 2.

7.2.11.1 Foreshore Erosion

Some localised erosion is visible on both sides along the bend of the River directly upstream of Newbridge Road Bridge (Figure 7.16) as well as the western embankment under the bridge (location reference E62-63).

Figure 7.16 – Erosion north of Newbridge Road Bridge, eastern bank

Localised high erosion is noticeable on the southern bank directly downstream of the private properties along Auld Avenue certainly as a result of the edge effect of the old brick stormwater device. The erosion destroyed a stormwater drain at this location. Some light to moderate erosion occurs between the different private seawalls around the Beveridge Park and the wharf at the end of Davy Robinson Drive (location reference E64 to E67).

Figure 7.17 – Localised severe erosion opposite Hind Park

Recommendations

Suggested management options for the erosion management are given in Table 7.21 below.

Table 7.21 – Erosion management option between Georges River Golf Club and Davy Robinson Drive

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E62.Inside of the bend around Newbridge Road	Liverpool	Low/Medium	Construction of a rock protection under the bridge (Option E4)

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
Bridge			
E63.Outside of the bend around Newbridge Road Bridge	Bankstown	Medium/High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Northward extension of the rock protection of the bridge (Option E10)
E64.Opposite Hind Park	Bankstown	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E65.Directly upstream of Beveridge Park	Liverpool	Medium	Construction of a seawall along the undercut area (Option E2 or E6) Stabilisation by vegetation planting (Option E3)
E66.Opposite Beveridge Park	Bankstown	Low/Medium	Construction of a seawall along the park (Option E2 or E6) Stabilisation by vegetation planting (Option E3)
E67.End of Davy Robinson Drive	Liverpool	High	Join the different protection to avoid edge effect between the different protections (Option E10) Stabilisation by further vegetation planting (Option E3)

7.2.11.2 Seawall Assessment

The bank along the northern end of Rickard Street is protected by an old poor condition concrete seawall covered with invasive plants. The tip located on the western side of the Newbridge Road Bridge is mostly surrounded by a poor condition seawall and dumped rocks (Figure 7.18) with only a good condition small seawall along Hind Park (Figure 7.19). The seawall under the bridge on the eastern side of the bridge is in good condition. Some damaged brick wall and brick stormwater drains were observed opposite Hind Park. Beveridge Park located behind a good condition gabion seawall (location reference S27 to S31).

Figure 7.18 – Dumped material south-west of Newbridge Road Bridge

Figure 7.19 – Good condition seawall along Hind Park

Recommendations

Suggested management options for the seawall management are given in Table 7.22 below.

Table 7.22 – Seawall management option between Georges River Golf Club and Davy Robinson Drive

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S27.Along northern end of Rickard Street	Liverpool	High	Seawall can be removed and replaced by vegetation (Option S4) Seawall can be replaced by environmentally friendly seawall (boulder seawall) (Option S5)
S28.Tip on the western side of Newbridge Road Bridge	Liverpool	High	Dumped material can be replaced by rock seawall allowing vegetation to grow between rocks (Option S1)

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S29.Eastern side of Newbridge Road Bridge	Bankstown	N/A	No specific action required
S30.Hind Park	Liverpool	N/A	No specific action required
S31.Beveridge Park	Liverpool	Low/Medium	Gabion seawall can be replaced by a step seawall or boulder seawall (Option S5)

7.2.12 Davy Robinson Drive to New Brighton Golf Course

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figures 14 and 15 of Appendix 2.

7.2.12.1 Foreshore Erosion

The northern embankment along Gordon Parker Reserve is subject to light undercutting in the areas unprotected by vegetation due to high motor boat waves (Figure 7.20). This zone of light erosion where there is neither seawall nor vegetation stretches until the recycling plant, Vale Of Ah Reserve embankment and the foreshore along New Brighton Golf Course (location reference E68 to E72).

Figure 7.20 – Undercutting along Gordon Parker Reserve

Recommendations

Suggested management options for the erosion management are given in Table 7.23 below.

Table 7.23 – Erosion management option between Davy Robinson Drive and New Brighton Golf Course

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E68.Opposite the southern end of the recycling station	Bankstown	Low	Stabilisation by vegetation planting (Option E3)
E69.Southern extremity of the recycling station	Liverpool	Medium	Extend dumping/protection to the south (Option E10) Stabilisation by vegetation planting (Option E3)
E70.Inside of the bend south of the recycling station	Liverpool	Medium	Stabilisation by vegetation planting (Option E3)
E71.Outside the bend south of the recycling station	Bankstown	Low	Stabilisation by vegetation planting (Option E3)
E72.Northern end of New Brighton Golf Course	Liverpool	Low	Stabilisation by vegetation planting (Option E3)

7.2.12.2 Seawall Assessment

The wharf and boat ramp located at the end of Davy Robinson Drive is in poor to fair condition with the small seawall along the pier and boat ramp suffering from settling. From the boat ramp downstream to the southern end of the recycling plant (Figure 7.21), the western embankment of the river is covered with dumped rocks and diverse material such as bricks, concrete blocks, etc. (location reference S32).

Figure 7.21 – Dumped materials along the recycling plant

Recommendations

Suggested management options for the seawall management are given in Table 7.24 below.

Table 7.24 – Seawall management option between Davy Robinson Drive and New Brighton Golf Course

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S32.Between Davy Robinson Drive and the southern end of the recycling station	Liverpool	Medium/High	Replace dumped materials by rock seawalls to allow seedlings to grow between the rocks (Option S1) Replace existing protection by boulder seawall without cement to create new habitats (Option S5)

7.2.13 New Brighton Golf Course to Williams Creek entrance

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figures 16-17 of Appendix 2.

7.2.13.1 Foreshore Erosion

High erosion is visible downstream of the M5 bridge until Williams Creek mouth on the eastern embankment (Figure 7.22). From the building located opposite Williams Creek mouth downstream along Webster Street erosion reduces and there is only light undercutting remaining (location reference E73-74 and E76).

Figure 7.22 – Erosion opposite Williams Creek Entrance

Recommendations

Suggested management options for the erosion management are given in Table 7.25 below.

Table 7.25 – Erosion management option between New Brighton Golf Course and Williams Creek Entrance

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E73.Along the carpark north of the M5 bridge	Bankstown	Medium/High	Stabilisation by vegetation planting (Option E3)
E74.Between the M5 bridge and Williams Creek mouth, eastern bank	Bankstown	Medium	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Construction of a rock protection under the bridge (Option E4)
E76.Along Webster Street, downstream Williams Creek mouth	Bankstown	Low	Stabilisation by vegetation planting (Option E3)

7.2.13.2 Seawall Assessment

Several localised dumped materials were also noticed along New Brighton Golf Course foreshore (location reference S33). Along the area opposite Williams Creek entrance (Figure 7.23), the seawalls are in very poor condition with sometimes only some remnants of previous structures remaining (location reference S34).

Figure 7.23 – Eroded seawall opposite Williams Creek

Recommendations

Suggested management options for the seawall management are given in Table 7.26 below.

Table 7.26 – Seawall management option between New Brighton Golf Course and Williams Creek Entrance

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S33.New Brighton Golf Course	Liverpool	Medium/High	Replace dumped materials by native vegetation (Option S4) Replace dumped materials by rocks seawall allowing seedling to grow in the gap between

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
			the rocks (Option S1)
S34.Inside of Georges River bend along opposite Williams Creek mouth	Bankstown	Medium/High	Replace dumped materials by rocks seawall allowing seedling to grow in the gap between the rocks (Option S1) Replace dumped materials by native vegetation (Option S4)

7.2.14 Williams, Deadmans and Mill Creek

Results of the assessment of the foreshore erosion and seawalls at these locations are summarised below and in Figures 18 (Williams Creek), 21 (Deadmans Creek) and 23 (Mill Creek) of Appendix 2.

7.2.14.1 Foreshore Erosion

Williams, Deadmans and Mill Creeks are in similar condition. Mostly well vegetated and well protected, the foreshore along these creeks looks relatively pristine. Some tidal undercutting is visible where there are gaps in the vegetation (Figure 7.24). However, these creeks are generally in very good condition as they are located in sandstone areas which are less erodible. Some small occasional natural entrances bring sediments within these creeks (location reference E75, E80 and E84).

Figure 7.24 – Tidal undercutting where there is no vegetation at Mill Creek

Recommendations

Suggested management options for the erosion management are given in Table 7.27 below.

Table 7.27 – Erosion management option at Williams, Deadmans and Mill Creeks

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E75.Williams Creek	Liverpool	Low	No particular response needed as very natural

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E80.Deadmans Creek	Liverpool/Sutherland Shire	Low	No particular response needed as very natural
E84.Mill Creek	Sutherland Shire	Low	No particular response needed as very natural

7.2.14.2 Seawall Assessment

No seawall is present as the creeks are natural.

7.2.15 Kelso Park to East Hills and Pleasure Point

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figures 19-20 of Appendix 2.

7.2.15.1 Foreshore Erosion

Some light erosion stretches until the railway bridge and Monash Reserve. Between Monash Reserve and Deadmans Creek, some erosion occurs between the private seawalls due to edge effect (location reference E77-79).

Recommendations

Suggested management options for the erosion management are given in Table 7.28 below.

Table 7.28 – Erosion management option between Kelso Park and Pleasure Point

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E77.Along East Hills Park	Bankstown	Medium	Stabilisation by vegetation planting (Option E3) Construction of a low seawall along the park (Option E6)
E78.Along the western part of Pleasure Point	Liverpool	Medium	Stabilisation by vegetation planting (Option E3)
E79.East of Pleasure Point	Liverpool	Low	Stabilisation by vegetation planting (Option E3) Extend seawall along the military entrance (Option E10)

7.2.15.2 Seawall Assessment

Opposite East Hills Park, some scattered dumped rocks are visible where there is no vegetation (Figure 7.25). Along the bend of the river adjacent to Pleasure Point, the south-western embankment is protected by poor condition seawalls while the seawalls on the

north-eastern side are in relatively good condition. The private seawalls on this side of the river extend until Deadmans Creek mouth (location reference S35 to S38).

Figure 7.25 – Dumped rocks in gap of vegetation opposite East Hills Park

Recommendations

Suggested management options for the seawall management are given in Table 7.29 below.

Table 7.29 – Seawall management option between Kelso Park and Pleasure Point

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S35.South of the Kelso Park	Bankstown	N/A	No specific action required
S36.Opposite East Hills Park	Liverpool	High	Replace dumped materials by native vegetation (Option S4)
S37.Directly upstream of Monash Reserve natural entrance	Bankstown	Medium/High	Seawall can be replaced by boulder seawall to create more habitats (Option S5)
S38.Inside of the bend along Pleasure Point	Liverpool	Medium	Replace seawall by boulder seawall to create more habitats (Option S5) Creation of more habitats by adding rocks in front of the seawall (Option S2)

7.2.16 Pleasure Point to Sandy Point

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 21 of Appendix 2.

7.2.16.1 Foreshore Erosion

A small groyne located opposite Deadmans Creek entrance is accumulating sand on the upstream side and eroding on the downstream side. Deadmans Creek is relatively pristine and well vegetated with some erosion visible where there are gaps in vegetations. Some localised erosion provoked seawall collapsing (location reference E80-81).

Recommendations

Suggested management options for the erosion management are given in Table 7.30 below.

Table 7.30 – Erosion management option between Pleasure Point and Sandy Point

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E80.Deadmans Creek	Liverpool/Sutherland Shire	N/A	No particular response needed as very natural
E81.Sandy Point	Liverpool	High	Complete/Fix the seawall and building in a proper way to avoid any undermining (Option E10)

7.2.16.2 Seawall Assessment

The small military entrance directly upstream of Deadmans Creek entrance was built with sheet pile (Figure 7.26) and a good seawall is located between the military entrance and the military boat ramp (location reference S39).

Figure 7.26 – Sheet pile protection at the military entrance upstream of Deadmans Creek mouth

Seawalls at the tip of Sandy Point are in good condition while the ones opposite the Lambeth Reserve groyne (Figure 7.27) are in poor to fair condition. The groyne is in good condition and is accreting on the upstream side while eroding on the downstream side (location reference S40 to S42).

Figure 7.27– Lambeth Reserve groyne

Recommendations

Suggested management options for the seawall management are given in Table 7.31 below.

Table 7.31 – Seawall management option between Pleasure Point and Sandy Point

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S39.Military boat ramp directly upstream Deadmans Creek mouth	Liverpool	High	Rusty sheet pile seawall can be replaced by vertical seawall including object to increase surface and habitats (Option S7)
S40.Lambeth Reserve	Bankstown	High	Groyne can be removed and replaced by vegetation (Option S4)
S41.Opposite Lambeth Reserve	Sutherland Shire	Medium	Some rocks can be placed in front of the existing seawall to increase habitats (Option S2) Objects can be placed along or in front of the seawall to increase colonisation by various species (Option S7)
S42.Sandy Point	Sutherland Shire	High	Fix eroded seawall Some rocks can be placed in front of the existing seawall to increase habitats (Option S2) Objects can be placed along or in front of the seawall to increase colonisation by various species (Option S7)

7.2.17 Sandy Point to Picnic Point

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 22 of Appendix 2.

7.2.17.1 Foreshore Erosion

The tip of Sandy Point was subject to moderate erosion while some light undercutting was observed on both sides of the river along Picnic Point in some localised unprotected areas (location reference E82-83).

Recommendations

Suggested management options for the erosion management are given in Table 7.32 below.

Table 7.32 – Erosion management option between Sandy Point and Picnic Point

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E82.Opposite southern half of Sandy Point	Bankstown	Medium	Stabilisation by further vegetation planting(Option E3) Extend Picnic Point small seawall (Option E2 and E10)
E83.Western Bank between Sandy Point and Picnic Point	Liverpool	Medium	Stabilisation by further vegetation planting(Option E3)

7.2.17.2 Seawall Assessment

Between Sandy and Picnic Point, the western bank is protected by a fair condition seawall while some scattered good condition seawalls are protecting the walkway along the eastern bank in some area. Picnic Point is well protected by good condition seawalls. Some maintenance is needed in a localised area along the eastern side of Picnic Point (Figures 7.28 and 7.29) and the seawall is currently being upgraded in this area (location reference S43-S44).

Figure 7.28 – Seawall maintenance along Picnic Point

The foreshore located between Little Salt Pan Creek entrance and Yeramba Lagoon entrance is mostly protected by fair to good condition seawalls with a couple of pocket beaches which formed within the seawall bends (location reference S45).

Figure 7.29 – Seawall needing light maintenance east of Picnic Point

Recommendations

Suggested management options for the seawall management are given in Table 7.33 below.

Table 7.33 – Seawall management option between Sandy Point and Picnic Point

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S43.Between Sandy and Picnic Point	Sutherland Shire	Medium/High	Seawall can be removed and replaced by vegetation (Option S4)
S44.Western and Southern side of Picnic Point	Bankstown	Medium	Scattered seawall at the northern end can be removed and replaced by vegetation (Option S4) Some rocks can be placed in front of the existing vertical seawalls to increase habitats (Option S2) Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7)
S45.Eastern side of Picnic Point and Yeramba Lagoon entrance	Bankstown	Medium/High	Maintain eroded area of the seawall along the eastern foreshore of Picnic Point Some rocks can be placed in front of the existing vertical seawalls to increase habitats (Option S2) Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7) Low vertical seawall can be replaced by boulder seawall to allow the creation of new habitat (Option S5)

7.2.18 Anvil Rock to Mill Creek Entrance

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 23 of Appendix 2.

7.2.18.1 Foreshore Erosion

No erosion issues.

7.2.18.2 Seawall Assessment

The foreshore from Yeramba Lagoon entrance downstream up to Anvil Rock is protected by low-height seawalls in poor to fair condition (Figures 7.30 and 7.31). Along this foreshore, parts of the seawall have failed and need significant maintenance. Seawalls from Anvil Rock to the Little Salt Pan Creek entrance are in relatively good condition with only some rare locations where the top of the seawall needs maintenance (location reference S46-47).

Figure 7.30 – Seawall needing light maintenance east of Anvil Rock

Figure 7.31 – Pocket beach along the seawall west of Georges River National Park carpark

Recommendations

Suggested management options for the Seawall management are given in Table 7.34 below.

Table 7.34 – Seawall management option between Anvil Rock and Mill Creek Entrance

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S46.Cattle Duffers Flat up to Anvil Rock	Bankstown	Medium/High	Highly eroded seawalls can be removed and replaced by vegetation (Option S4) Seawall can be replaced by boulder seawall to increase habitats (Option S5) Low vertical seawall can be faced by vegetation (Option S6) Some rocks can be placed in front of the existing vertical seawalls to increase habitats

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
			(Option S2)
S47.Between Anvil Rock and the Little Salt Pan Creek entrance	Bankstown	Medium/High	Replace existing seawall by boulder seawall without cement to increase habitats (Option S5) Vertical seawall can be faced by vegetation (Option S6) Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7)

7.2.19 Mill Creek to Little Salt Pan Creek and Alfords Point Road Bridge

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 24-26 of Appendix 2.

7.2.19.1 Foreshore Erosion

Some undercutting occurs along the foreshore opposite to Little Salt Pan Creek entrance (Figure 7.32) and directly eastward to the entrance (location reference E85 to E87).

Figure 7.32 – Light undercutting opposite Little Salt Pan Creek

Recommendations

Suggested management options for the erosion management are given in Table 7.35 below.

Table 7.35 – Erosion management option between Mill Creek and Alfords Point Rod Bridge

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E85.Western side of Henry Lawson Drive Bridge at Little Salt Pan Creek entrance	Bankstown	Low	Rock protection on both side of the bridge to avoid further erosion (Option E4)
E86.Beach on the opposite side of Little Salt Pan Creek entrance from the carpark at the end of River Road	Bankstown	Low	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Sand replenishment along the back of the dune (Option E9)
E87.Bank opposite the south-western end of the Georges River National Park	Sutherland Shire	N/A	No particular response needed as very natural

7.2.19.2 Seawall Assessment

Alfords Point Road Bridge is protected by good condition seawall on both side of the river (location reference S48-49).

Recommendations

Suggested management options for the seawall management are given in Table 7.36 below.

Table 7.36 – Seawall management option between Mill Creek and Alfords Point Rod Bridge

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S48.Northern Side of Alfords Point Road Bridge	Bankstown	N/A	No specific action required
S49.Southern Side of Alfords Point Road Bridge	Sutherland Shire	N/A	No specific action required

7.2.20 Lugarno

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 27 of Appendix 2.

7.2.20.1 Foreshore Erosion

Downstream of Little Salt Pan Creek, most areas are either private properties or public land protected behind seawalls or natural areas protected by sandstones. Erosion can only occur in some localised zones along the Georges River or along the beaches of Botany Bay.

Moderate erosion is visible at Illawong (opposite Lugarno) along Old Ferry Road carpark where a small seawall is generating some edge effect (location reference E88).

Recommendations

Suggested management options for the erosion management are given in Table 7.37 below.

Table 7.37 – Erosion management option at Lugarno

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E88.Along Old Ferry Road carpark, east of Little Moon Bay	Sutherland Shire	Medium/High	Extend seawall (Option E10) Removal of seawall, levelling of the bank to an equilibrium profile and vegetation planting (Option E1)

7.2.20.2 Seawall Assessment

A small seawall in fair condition located along Old Ferry Road, east of Little Moon Bay (Figure 7.33), is generating some erosion on both side and should either be extended or removed (location reference S50).

Figure 7.33 – Small rock seawall at Illawong opposite Lugarno

Recommendations

Suggested management options for the seawall management are given in Table 7.38 below.

Table 7.38 – Seawall management option at Lugarno

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S50.Along Old Ferry Rd east of Little Moon Bay	Sutherland Shire	High	Seawall can be removed or extended (Option S3)

7.2.21 Jewfish Bay

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 28 of Appendix 2.

7.2.21.1 Foreshore Erosion

No erosion issues.

7.2.21.2 Seawall Assessment

Jewfish Bay swimming area is protected by a vertical sandstone seawall (Figure 7.34) in fair condition (location reference S51).

Figure 7.34 – Seawall at Jewfish Bay Swimming Area

Recommendations

Suggested management options for the seawall management are given in Table 7.39 below.

Table 7.39 – Seawall management option at Jewfish Bay

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S51.Jewfish Bay swimming area	Hurstville	Medium/High	Fix seawall where needed (Option S9) Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7)

7.2.22 South of Como Bridge

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 29 of Appendix 2.

7.2.22.1 Foreshore Erosion

No erosion issues.

7.2.22.2 Seawall Assessment

The southern end of Como Bridge is protected by various types of seawalls. Scylla Reserve and Como Pleasure Gardens are surrounded by vertical sandstone seawalls (location reference S52-55).

Recommendations

Suggested management options for the seawall management are given in Table 7.40 below.

Table 7.40 – Seawall management option south of Como Bridge

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S52.Western side of the southern end of Como Bridge	Sutherland Shire	N/A	No specific action required
S53.Eastern side of the southern end of Como Bridge	Sutherland Shire	Medium/High	Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7)
S54.Como Pleasure Gardens	Sutherland Shire	N/A	No specific action required
S55.Scylla Bay Reserve	Sutherland Shire	Medium/High	Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7) Some rocks can be placed in front of the existing vertical seawalls to increase habitats (Option S2)

7.2.23 Oatley Bay

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 30 of Appendix 2.

7.2.23.1 Foreshore Erosion

At Moore Reserve Boat Ramp, some erosion is visible on the foreshore between the boat ramp and a big stormwater overflow west of the ramp. Along Poulton Park (Figure 7.35), some severe erosion is noticeable, certainly due to two overflow pipe or the runoff water from the road (location reference E89-90).

Recommendations

Suggested management options for the erosion management are given in Table 7.41 below.

Table 7.41 – Erosion management option at Oatley Bay

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E89.Moore Reserve Boat Ramp	Kogarah	Medium	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Stabilisation of seawall toe with small seawall (Option E2)
E90.Southern end of Poulton Park	Kogarah	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)

Figure 7.35 – Erosion at the southern end of Poulton Park

7.2.23.2 Seawall Assessment

Oatley Pleasure Ground is also protected by a vertical sandstone seawall along its eastern half and by rock along the western half while a concrete boat ramp is located at the southern end Moore Reserve Boat Ramp (Figure 7.36) is surrounded by a low concrete seawall and some rocks were dumped in front of the overflow outlet west of the boat ramp (location reference S56-57).

Recommendations

Suggested management options for the seawall management are given in Table 7.42 below.

Table 7.42 – Seawall management option at Oatley Bay

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S56.Oatley Pleasure Ground	Kogarah	High	Boat ramp should be fixed and seawalls can be fixed and faced by objects to allow the creation of more habitats (Option S9 and S7)
S57.Moore Reserve Boat Ramp	Kogarah	Medium	Boat ramp should be fixed and seawalls can be upgraded to allow the creation of more habitats (Option S7)

Figure 7.36 – Seawall at Moore Reserve Boat Ramp

7.2.24 Connells Bay

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 31 of Appendix 2.

7.2.24.1 Foreshore Erosion

A small beach along Connells Point Reserve (Figure 7.37) needs significant maintenance with erosion reaching the pile of a lamp post. Overflow from a GPT created a gully on the western side of the beach while some erosion is visible around an overflow pipe on the eastern side (location reference E91).

Figure 7.37 – Erosion at Connells Point Reserve

Recommendations

Suggested management options for the erosion management are given in Table 7.43 below.

Table 7.43 – Erosion management option at Connells Bay

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E91.Connells Point Reserve	Kogarah	High	Construction of an environmentally friendly seawall along the beach (Option E5 or E6) Sand replenishment using the sand from the extensive shallow facing the park (Option E9) Sizing of the GPT to avoid overflows

7.2.24.2 Seawall Assessment

Donnelly Park (Figure 7.38) is protected all along by a fair condition vertical sandstone seawall (location reference S58). Some parts of the seawall need maintenance and some leakage is visible through the bottom of the seawall on the eastern side.

Figure 7.38 – Seawall at Donnelly Park

Recommendations

Suggested management options for the erosion management are given in Table 7.44 below.

Table 7.44 – Seawall management option at Connells Bay

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S58.Donnelly Park	Kogarah	Medium/High	Top of the seawall needs maintenance as well as the eastern end as some water is leaking from the bottom of the seawall (Option S9) Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7)

7.2.25 Kyle Bay

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 32 of Appendix 2.

7.2.25.1 Foreshore Erosion

No erosion issues.

7.2.25.2 Seawall Assessment

Some rocks have been dumped along the beach located at the northern end of Kyle Bay and fair condition rock protection covers two overflow pipes (location reference S59).

Recommendations

Suggested management options for the seawall management are given in Table 7.45 below.

Table 7.45 – Seawall management option at Kyle Bay

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S59.Kyle Bay	Kogarah	N/A	No particular action required

7.2.26 Shipwrights Bay

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 33 of Appendix 2.

7.2.26.1 Foreshore Erosion

Dover Park seawall is subject to overtopping and erosion is visible behind the seawall. At Dover Park West (Figure 7.39), severe erosion is noted along the whole height of the bank as a result of toe scouring by tides or scour around the overflow pipe and the few big rocks present along the bank (location reference E92 to E93).

Figure 7.39 – Erosion at Dover Park West

Recommendations

Suggested management options for the erosion management are given in Table 7.46 below.

Table 7.46 – Erosion management option around Shipwrights Bay

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E92.Dover Park	Kogarah	High	Replacement of the seawall by an environmentally friendly seawall
E93.Dover Park West	Kogarah	High	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)

7.2.26.2 Seawall Assessment

A relatively low vertical seawall is located along the north-eastern side of Shipwrights Bay. The rock seawall along Dover Park at Kogarah Bay (Figure 7.40) is in poor condition and has been overtopped by waves; some erosion is noticeable behind the seawall (location reference S60 and S63).

Figure 7.40 – Eroded seawall at Dover Park

Recommendations

Suggested management options for the seawall management are given in Table 7.47 below.

Table 7.47 – Seawall management option around Shipwrights Bay

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S60.Shipwright Bay	Kogarah	High	Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7)
S63.Dover Park Kogarah Bay	Kogarah	High	Seawall can be replaced by an environmentally friendly step seawall like at Claydon Reserve (Option S5)

7.2.27 Shag Point and Tom Ugly's Bridge

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 34 of Appendix 2.

7.2.27.1 Foreshore Erosion

No erosion issues.

7.2.27.2 Seawall Assessment

Shag Point, south-east of Tom Ugly's Bridge and the northern end of the bridge are protected by fair condition vertical sandstone seawalls (location reference S61-62).

Recommendations

Suggested management options for the seawall management are given in Table 7.48 below.

Table 7.48 – Seawall management option at Shag Point and Tom Ugly's Bridge

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S61.Around tip at northern end of Tom Ugly's Bridge	Kogarah	Medium	Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7)
S62.Shag Point, north of Gwawler Bay	Sutherland Shire	N/A	No specific action required

7.2.28 North-Western Side of Woolooware Bay

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 35 of Appendix 2.

7.2.28.1 Foreshore Erosion

Some erosion occurs along the north-western side of Woolooware Bay along a small seawall due to the edge effect generated by this seawall and wave attack by wind generated waves (Figure 7.41). However, the beach is underlain by coffee rock and the erosion of the park would therefore be limited (location reference E94).

Figure 7.41 – Erosion due to edge effect of a small seawall along the north-western side of Woolooware Bay

Recommendations

Suggested management options for the erosion management are given in Table 7.49 below.

Table 7.49 – Erosion management option along the north-western side of Wooloowarre Bay

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E94.North-western end of Woolooware Bay	Sutherland Shire	High	Sand replenishment (Option E9) Creation of a small boulder or step seawall (Option E6 or E5)

7.2.28.2 Seawall Assessment

Both ends of Captain Cook Bridge are protected by fair condition seawalls. A low seawall is present around a GPT located in a small park on the north-western side of Woolooware Bay location reference S69 and S71).

Recommendations

Suggested management options for the seawall management are given in Table 7.50 below.

Table 7.50 – Seawall management option along the north-western side of Wooloowarre Bay

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S69.Southern end of Captain Cooks Bridge	Sutherland Shire	Medium	Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7)
S71.North-western end of Woolooware Bay	Sutherland Shire	High	Seawall can be extended along the whole park (Option S3) Seawall can be replaced by boulder seawall to increase habitats (Option S5) Seawall can be faced by vegetation (Option S6)

7.2.29 Kogarah Bay

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figures 36-37 of Appendix 2.

7.2.29.1 Foreshore Erosion

No erosion issues within the bay.

7.2.29.2 Seawall Assessment

Within Kogarah Bay, Carss Park is protected along its whole length by vertical sandstone seawalls. Along the northern half, the seawall is a bit higher than the ground level to avoid overtopping. Claydon Reserve is protected by a two-step rock seawall in perfect condition and is environmentally friendly with saltmarsh vegetation between the two steps (Figure 7.42). A good vertical sandstone seawall is noticeable along Bonney Street Wharf and Anderson Park. (location reference S64 to S67).

Figure 7.42 – Good condition seawall at Claydon Reserve, Kogarah Bay

Recommendations

Suggested management options for the seawall management are given in Table 7.51 below.

Table 7.51 – Seawall management option at Kogarah Bay

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S64.Carss Park	Kogarah	Medium/High	Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7) Some rocks can be placed in front of the existing vertical seawalls to increase habitats (Option S2)
S65.Claydon Reserve	Kogarah	N/A	No specific action required
S66.Bonney Street Wharf	Kogarah	Medium	Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7) Some rocks can be placed in front of the existing vertical seawalls to increase habitats (Option S2)
S67.Anderson Park	Kogarah	Medium	Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7)

7.2.30 North of Captain Cook Bridge

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 38 of Appendix 2.

7.2.30.1 Foreshore Erosion

No erosion issues.

7.2.30.2 Seawall Assessment

An old sandstone seawall is visible at the end of Harris Street east of St Georges Motor Boat Club (location reference 68). East of Captain Cook Bridge, a fair condition rock seawall has been fully covered with sand and vegetation (Figure 7.43) illustrating that there is no erosion along Riverside Drive (location reference S70 and S72).

Figure 7.43 – Seawall covered by sand and vegetation east of Captain Cook Bridge

Recommendations

Suggested management options for the seawall management are given in Table 7.52 below.

Table 7.52 – Seawall management option north of Captain Cook Bridge

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S68.End of Harris Street near St Georges Motor Boat Club	Kogarah	Low	Replace old existing seawall by rocks seawall allowing seedling to grow in the gap between the rocks (Option S1)
S70.Northern end of Captain Cooks Bridge	Kogarah / Rockdale	Medium	Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7)
S72.Along Riverside Drive	Rockdale	N/A	No specific action required

7.2.31 Sandringham Bay

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 39 of Appendix 2.

7.2.31.1 Foreshore Erosion

A seawall along Sandringham Bay located under a line of trees is generating some edge effect at its southern end (Figure 7.44). At the northern end of the bay, west of the Sailing Club, the beach is eroding due to wave action in this zone and the presence of a vertical concrete seawall at the back of the beach (location reference E95 to E96).

Figure 7.44 – Erosion at the northern end of Sandringham Bay

Recommendations

Suggested management options for the erosion management are given in Table 7.53 below.

Table 7.53 – Erosion management option in Sandringham Bay

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E95.Eastern side of Sandringham Bay	Rockdale	Medium	Southward extension of the seawall (Option E10) Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E96.Peter Depena Reserve	Rockdale	Low	Levelling of the slope to reach an equilibrium profile (Option E1) Replenishment of the beach (Option E9) No action option

7.2.31.2 Seawall Assessment

Along Sandringham Bay, the western side of the bay is mostly protected by seawalls with a good vertical seawall along the northern half and a short fair condition rock seawall under the trees at the southern end generating edge effect on the dune directly south of the seawall (Figure 7.45). At the northern side of the bay, the entrance of a GPT was observed and protected by good condition large rocks. A timber groyne is located directly east of the entrance at the level of the Sailing Club (Figure 7.45). This groyne maintains the sand in this zone (location reference S73-S74).

Figure 7.45 –Timber groyne (left) and rock seawall (right) at Sandringham Bay

Recommendations

Suggested management options for the seawall management are given in Table 7.54 below.

Table 7.54 – Seawall management option in Sandringham Bay

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S73.Eastern Side of Sandringham Bay	Rockdale	Medium	Northern seawall can be upgraded to engineered standard with geotextile Some rocks can be placed in front of the existing southern vertical seawalls to increase habitats (Option S2)
S74.Peter Depena Reserve	Rockdale	N/A	No specific action required

7.2.32 Lady Robinsons Beach

Results of the assessment of the foreshore erosion and seawalls at this location are summarised below and in Figure 40-45 of Appendix 2.

7.2.32.1 Foreshore Erosion

Lady Robinsons Beach is impacted by wave action with some areas more severely impacted. The southernmost groyne is overtopped by wave on its landward end. The area between the two southernmost groynes is devoid of sand. At the level of the two first northern groynes, some strong erosion (Figure 7.46) is visible on the northern side of each groyne due to the impact of the groyne (location reference E97 to E99). The wave climate appeared to be higher at the southern end of the beach, in accordance with Figure 4.8 (page 48).

Figure 7.46 – Erosion generated by the northernmost groyne along Lady Robinsons Beach

Recommendations

Suggested management options for the erosion management are given in Table 7.55 below.

Table 7.55 – Erosion management option at Lady Robinsons Beach

Location	LGA	Priority Rating	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E97.Southern end of Lady Robinsons Beach	Rockdale	Low	Landward extension of the last groyne Replenishment of the beach between the 2 southernmost groynes (Option E9) No action option
E98.Lady Robinsons Beach centre	Rockdale	Low	Replenishment of the northern side of the groyne (Option E9) Construction of a new groyne further north
E99.Northern end of Lady Robinsons Beach	Rockdale	Low	Replenishment of the beach (Option E9) No action option

7.2.32.2 Seawall Assessment

Along Lady Robinsons Beach, ten good condition groynes have been built along the southern half at regular interval. At the southern end of the beach, an old rock seawall covered with water is noticeable between the two last groynes and the southernmost groyne is overtopped by water on its landward side (Figure 7.47). A good vertical sandstone seawall is noticeable at the back of the beach from the third northern groyne southward. Another fair condition rock seawall is present along the most exposed area of the beach located between the fourth and the fifth groyne from the north (location reference S75 to S78).

Figure 7.47– Rock seawall in the middle of Lady Robinsons Beach (left) and seawall covered by water at the southern end of the beach (right)

Recommendations

Suggested management options for the seawall management are given in Table 7.56 below.

Table 7.56 – Seawall management option at Lady Robinsons Beach

Location	LGA	Priority Rating	Management Options (Options provided refer to Seawall Options of Section 7.3.2 of the report)
S75.From the third northern groyne southward	Rockdale	N/A	No specific action required
S76.Between the fourth and fifth groynes (from the north)	Rockdale	Low	Seawall can be properly engineered with geotextile
S77.Between the two southernmost groynes of Lady Robinsons Beach	Rockdale	Low/Medium	Vertical seawall can be faced by more rocks to create additional habitats (Option S2)
S78.Lady Robinsons Beach Groynes	Rockdale	Low	Southernmost groyne can be extended landward (Option S3) Additional groynes can be built north of the groyne field

7.3 Response to Erosion and Seawall Management

Erosion and seawall management should take into account the environment and therefore follow the guideline given in Figure 7.48.

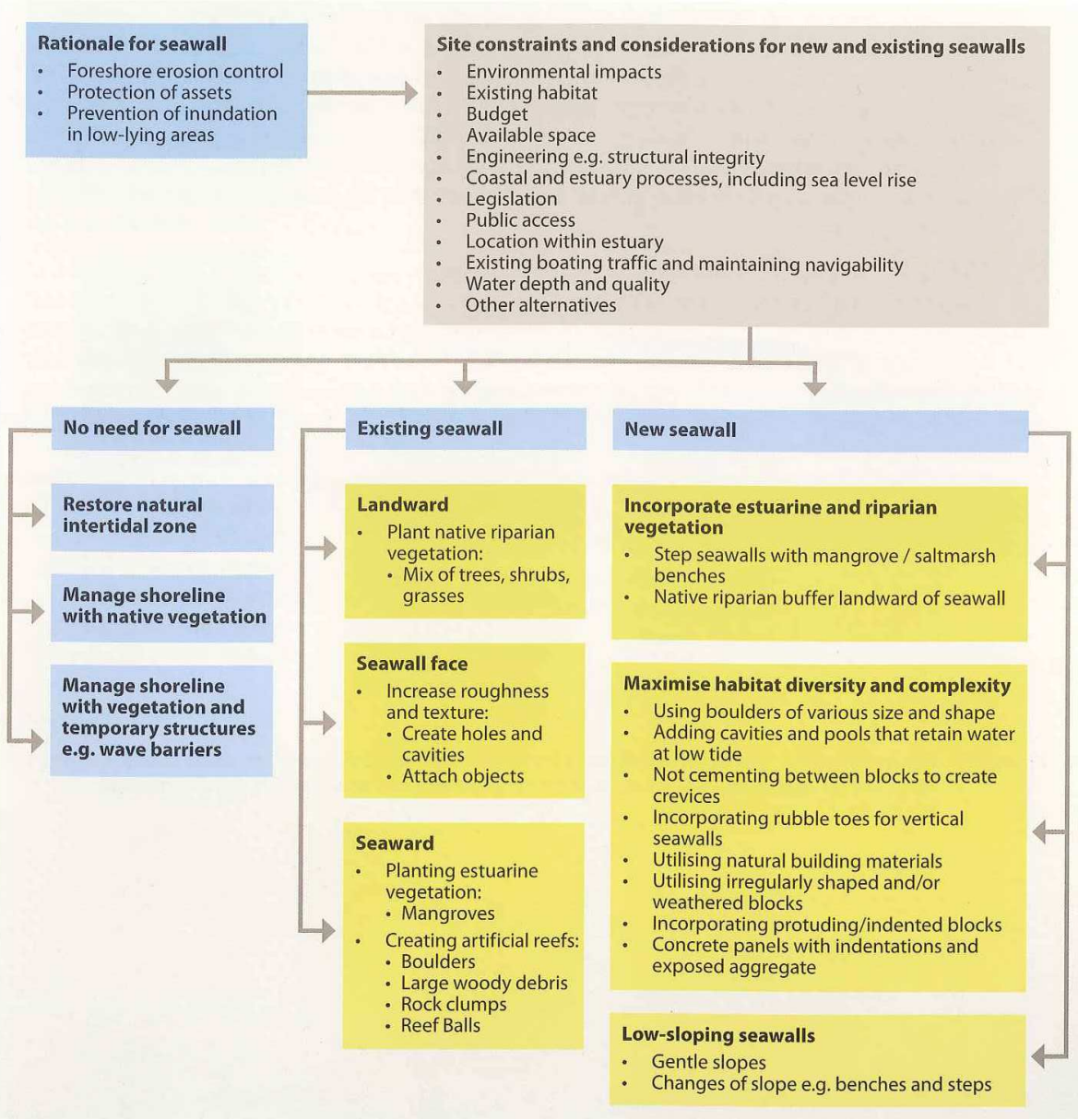

Figure 7.48 –Summary guide for building new seawalls or modifying existing seawalls (DECCW, 2009)

7.3.1 Erosion Management

Response to erosion issues depends on the severity of the erosion, the height of the embankment and the land use directly behind the eroded area.

Erosion Management Option E1

In areas of very severe erosion such as the area downstream of Liverpool Weir where the bank is very high and steep, the bank should be levelled to reach a stable slope – to an angle depending on the type of sediment and soils present along the slope – and vegetation should be planted to stabilise this new equilibrium slope. This management option is illustrated in Figures 7.49 and 7.50.

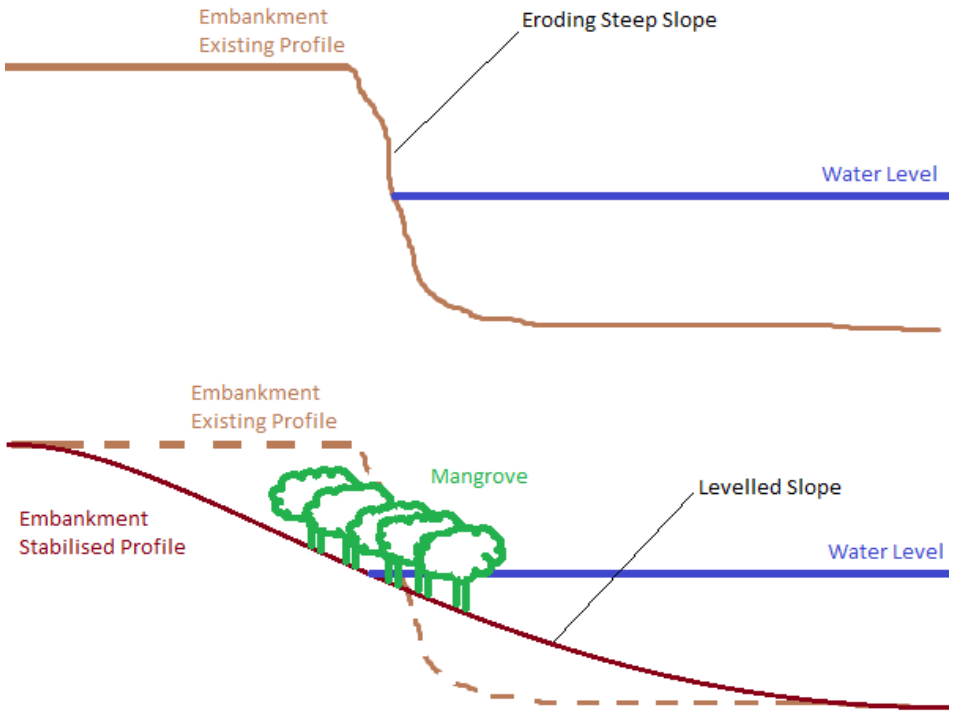

Figure 7.49 – Levelling of the dune and vegetation planting

Figure 7.50 – Severe erosion on steep and height bank at South Park (left) and possible solution from the DECCW, 2009 (right)*

**This solution is possible where the water is not too deep, otherwise battering the bank back and placing erosion protection on the slope would be preferred. Where the water is deep and battering back the bank is not possible due to the presence of a building or other structure, a boulder revetment could be another option.*

Erosion Management Option E2

In areas of light erosion at the toe of a steep slope, the erosion can be stopped by setting some rock seawall at the bottom of the bank where mangrove seedlings can grow amongst the gaps between the rocks (Figure 7.51).

*7.51 – Undercutting at Strong Park (left) and possible solution** from the DECCW, 2009 (right)*

***Once again, this solution would be possible where the water is not too deep. In this case, a replenishment of the toe of the bank would be a better solution.*

Erosion Management Option E3

In areas where erosion occurs in gaps of vegetation, some native vegetation can be planted to close the gaps and avoid further erosion (Figure 7.52).

Figure 7.52 – Erosion between gap of vegetation at Moore Lake

Erosion Management Option E4

In areas located under bridges or along concrete structures in the river, some seawalls should be built to prevent the bank from eroding due to the turbulences generated by the obstacle structure (Figure 7.53).

Figure 7.53 – Erosion under seawall at Governor Macquarie Bridge (left) and possible bridge abutment scour protection e.g. Newbridge Road Bridge (right)

Erosion Management Option E5

In areas of moderate erosion in low height embankment e.g. Westlake Point or along parks, some step seawalls with mangrove or saltmarsh benches or some seawalls with a riparian vegetation buffer growing between the rock could be an efficient solution (Figure 7.54).


Figure 7.54 – Moderate erosion along low bank at Dover Park (left) and possible solution e.g. Claydon Reserve at Kogarah bay (right)*

**Dover Park being more exposed and subject to higher wave climate, saltmarsh could be replace by mangroves*

Erosion Management Option E6

In areas of moderate erosion in low height embankment, the creation of boulders seawalls of various sizes and shapes placed without cement is another option (Figure 7.55).

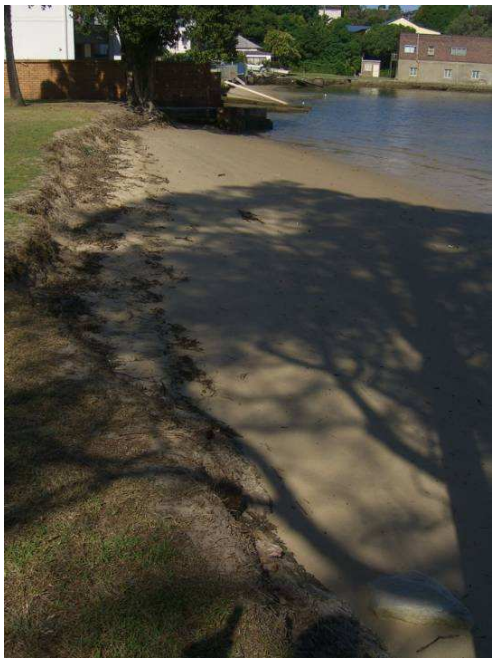


*Figure 7.55 – Moderate erosion along low bank at Connells Point Reserve (left) and possible solution** from the DECCW, 2009 (right)*

***The right picture illustrates the possible type of seawall to use against this type of erosion. However, for Connells Point Reserve a single layer of large block would be efficient enough, given the low height of the bank*

Erosion Management Option E7

The entrance of a creek where one side has been stabilised by rocks, like at Cabramatta Creek entrance, should be stabilised on the second side to avoid further erosion. This stabilisation could be undertaken by constructing step seawalls or seawalls made of various sizes and boulders without cement between the rocks to provide some habitat in the crevices (Figure 7.56).

Figure 7.56 – Comparison between western side (left) and eastern side (right) of Cabramatta Creek entrance

Erosion Management Option E8

The different islands located within Chipping Norton Lake could be protected using the same method as on Daruk Island, i.e. a layer of small rocks of around 20-30 cm of diameter all along the island (Figure 7.57).

Figure 7.57 – Erosion along Wildlife Island (left) and possible solution e.g. along Daruk Island (right)

Erosion Management Option E9

Another solution could be the replenishment by sand of the areas where undercutting occurred in order to less disturb the vegetation when placing some rocks. Some additional native vegetation could be planted. Replenishment with sand was mostly suggested for places where levelling of the bank would generate too much damage to the local vegetation (e.g. trees directly at the edge of the bank) and where options such as construction of a small seawall at the bottom of the slope would be overkill. For areas located in shale-based sediments such as Prospect Creek, sand was proposed instead of the natural fine sediments found on site, due to the high erodibility of such fine sediments, which would affect the water quality and turbidity of the creek or river channel.

Erosion Management Option E10

Where short seawalls have been constructed in a disjointed fashion or have an edge effect generating erosion around the seawall, the seawalls should respectively be unified or extended to avoid further edge effects. In areas where these scattered seawalls are placed between some vegetated areas, these seawalls can be removed and replaced by native vegetation.

7.3.2 Seawall Management

Where seawalls already exist along the Georges River, they can be upgraded and improved in an environmental way.

Seawall Management Option S1

In areas where various building material have been dumped, these materials could be replaced by rock seawalls allowing mangrove seedlings to establish amongst the gaps between the rocks (Figure 7.58). This will improve the visual aspect and the level of protection against erosion.

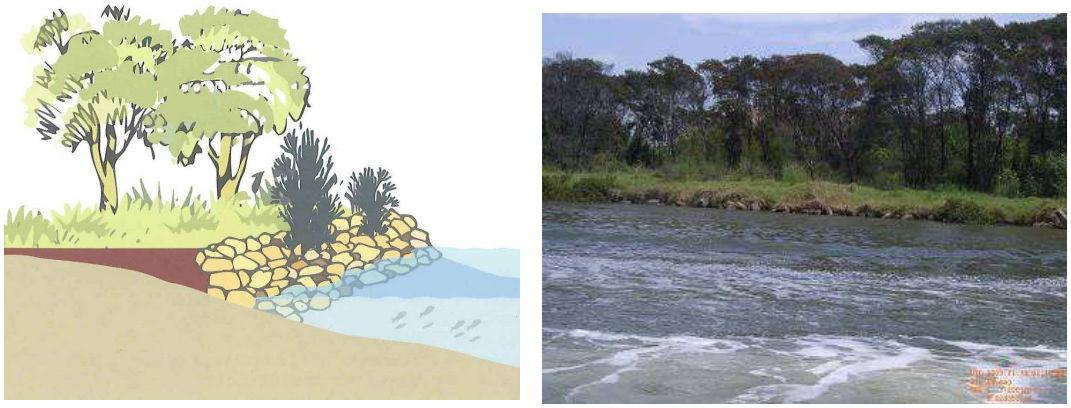

Figure 7.58 – Dumped materials along Benedict Recycling plant (right) and possible solution from DECCW, 2009 (left)

Seawall Management Option S2

In front of steep seawalls such as concrete or brick walls, some boulders or other objects should be placed to created more habitat for marine organisms (Figure 7.59).

Figure 7.59 – Vertical seawall along Carss Park (left) and possible improvement from DECCW, 2009 (right)

Seawall Management Option S3

Seawalls surrounded by erosion (such as at Illawong, Figure 7.60) should either be extended or dismantled to stop edge effects.

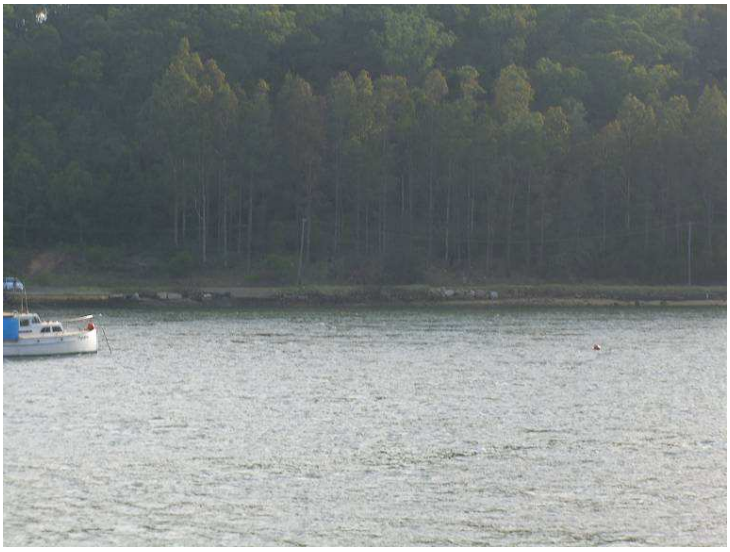

Figure 7.60 – Old seawall provoking edge effect at Illawong opposite Lugarno

Seawall Management Option S4

Some abandoned structure such as the brick wall located on the eastern bank of Prospect Creek mouth (Figure 7.61) could be removed and replaced by native vegetation.

Figure 7.61 – Abandoned brick wall, east of Prospect Creek Mouth

Seawall Management Option S5

Remnants of old seawalls could be removed (e.g.in front of Williams Creek mouth) and replaced by native vegetation or a new rock seawall allowing seedlings to establish between the rocks (Figure 7.62).

Figure 7.62 – Remnant of seawalls opposite Williams Creek (left) and possible solution from DECCW, 2009 (right)

Seawall Management Option S6

Low concrete seawalls which are overtopped could be faced by native vegetation, which would reduce the overtopping and allow the growth of native vegetation (Figure 7.63).

Figure 7.63 – Vertical seawall along Carss Park (left) and possible improvement from DECCW, 2009 (right)

Seawall Management Option S7

Old sheet pile or vertical seawalls can be replaced by vertical seawall including objects to increase surface for colonisation and usable habitat (Figure 7.64).

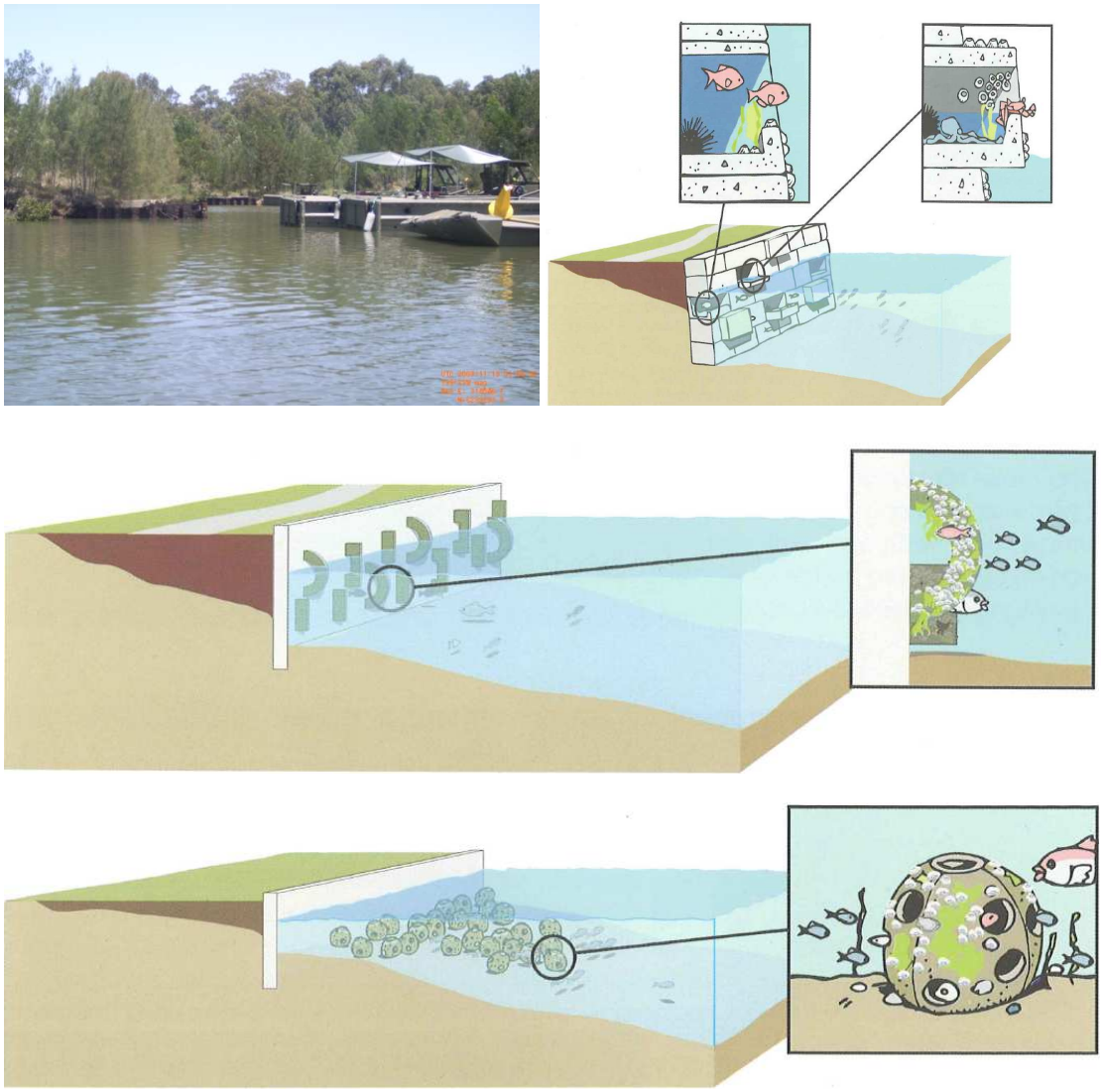

Figure 7.64 – Rusty sheet pile seawall at the military entrance upstream of Deadmans Creek mouth and possible actions to increase habitats (DECCW, 2009)

Seawall Management Option S8

In areas located underneath bridges, old seawalls such as the one in Figure 7.65 can be improved to an engineered standard and underlain with geotextile for better protection. These seawalls can be optimised to welcome new habitats at the seawall toe (e.g. boulder seawall without cement).

Figure 7.65 – Example of poor condition protection located under Governor Macquarie Bridge

Seawall Management Option S9

Seawalls needing minimal maintenance can be repaired instead of being replaced.

7.4 Key Management Actions

The highest priority management actions are those which provide the greatest environmental benefit at minimum cost. The prioritisation methodology is shown in Table 7.57. The prioritisation was subjective and the cost used for the priority ranking is relative to the benefits of the work (difficulty of work, cost-efficiency) and is not the exact cost of the work. Cost relative to result, erosion severity, seawall condition and priority ranking are shown in the Table A and B of Appendix 2.

Five specific locations for management responses have been chosen for each local government area as being the highest priority, with ten overall locations for management options chosen as being the highest priority for the entire study area.

Key management actions relating to erosion and seawall remediation are presented in Tables 7.58 to 7.65 below. These management actions have been prioritised for each local government area, and for the Georges River estuary as a whole.

Table 7.57 – Matrix of the prioritisation for erosion and seawall management

Severity / Degree of degradation		Cost (relative to results)			
		Descriptions of cost	Short distance of seawall / erosion OR site easily improved	Moderate distance of seawall / erosion OR medium site improvement difficulty	Long distance of seawall / erosion OR site difficult to improve
	Descriptions of degrees of degradation	Ranking Cost / Ranking for Erosion / Seawall	Low	Medium	High
	Seawall in reasonable condition OR only light / minor erosion	Light / Good	Medium/High*	Low	Low
	Seawall needs maintenance OR moderate erosion	Moderate / Fair	High	Medium	Low
	Seawall collapsed OR severe erosion	Severe / Poor	High	High	Medium/Low**

*High priority in this case occurs in area where environmental benefits are significant for as low cost
**Low priority in this case occurs in area where environmental benefits are unsignificant for a significant cost

Table 7.58 – Key Management Actions for Bankstown LGA

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E64.Opposite Hind Park	Bankstown	Severe	High	Erosion along the whole height of the bank Exposed roots and fallen trees	Stormwater runoff Edge effect from the old stormwater drain adjacent to the area Gap in vegetation	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E57.Eastern bank of Prospect Creek mouth	Bankstown	Severe	High	Erosion creating a small pocket beach	Tidal erosion Movement of Prospect Creek entrance	Replenishment with sand (Option E9) Stabilisation by vegetation planting (Option E3) Construction of a seawall to stabilize Prospect Creek mouth like at Cabramatta Creek (Option E7)
E58.South of Beatty Reserve	Bankstown	Severe	High	Erosion along the whole height of the bank Exposed roots and fallen trees	Edge effect from the Private seawalls of the properties located between Beatty Reserve and Georges River Golf Course Tidal erosion Steep embankment with possible collapsing after toe scour	Replenishment with sand (Option E9) Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
S24.Eastern bank of Prospect Creek mouth	Bankstown	Poor	High	10m vertical brick wall surrounding boat ramp	Cracked wall, tree growing in the middle of the misused boat ramp	Old abandoned structures can be replaced by vegetation (Option S4)

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
S40.Lambeth Reserve	Bankstown	Fair	High	30m long rock groyne at Lambeth Reserve	Eroding on the downstream side while accreting on the upstream side	Groyne can be removed and replaced by vegetation (Option S4)

Table 7.59 – Key Management Actions for Fairfield LGA

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E39.Along Silver Crescent	Fairfield	Light	High	Undercutting and exposed roots	Tidal erosion Wind wave generated within Chipping Norton Lake Edge effect from Howards boat ramp	Construction of a seawall along the different parks and carparks (Option E5 or E6) Stabilisation by vegetation planting (Option E3)
E38.East of Cabramatta Creek Entrance	Fairfield	Severe	Medium/High	Erosion along the whole height of the bank Exposed roots and fallen trees	Edge effect from the several scattered short seawall constructed along Hoy and Cherrybrook Parks Tidal erosion Wind wave generated within Chipping Norton Lake Steep embankment with possible collapsing after toe scour	Levelling of the bank to reach a stable slope and vegetation planting (Option E1) Joining the different scattered seawall to create one unique seawall to avoid edge effect (Option E10)

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E42.Between Strong and Howard Park	Fairfield	Severe	Medium/High	Severe undercutting	Tidal erosion Wind wave generated within Chipping Norton Lake Edge effect of the seawall along Howard Park	Extend Howard Park seawall (Option E10) Stabilisation by vegetation planting (Option E3)
S21.Most downstream bend of Prospect Creek along Hollywood Park	Fairfield	Poor	High	Remnant of old 10-15m long timber retaining wall	Ineffective Almost totally destroyed	Timber retaining wall can be removed and replaced by vegetation (Option S4)
S17.Western End of Shearer Park	Fairfield	Poor	Medium/High	Small layer of small rocks along around 80m of the foreshore	Protection against undercutting Some vegetation growing through the rocks	Environmentally friendly seawall along Dowling beach can be extended in front of Shearer Park (Option S5)

Table 7.60 – Key Management Actions for Hurstville LGA

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
S51.Jewfish Bay swimming area	Hurstville	Fair	Medium/High	Vertical sandstone seawall all along the area	Needing minor maintenance with a couple of blocks out of the wall to fix	Fix seawall where needed (Option S9) Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7)

Table 7.61 – Key Management Actions for Kogarah LGA

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E90.Southern end of Poulton Park	Kogarah	Severe	High	Severe erosion at the location of two stormwater outlets	Proximity to the stormwater outlets Water runoff from the road Tidal erosion	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E91.Connells Point Reserve	Kogarah	Moderate	High	Erosion behind small beach Pile of light in water GPT creating a gully at the level of the beach on the western side	Wave action Stormwater outlet proximity Spills from GPT	Construction of an environmentally friendly seawall along the beach (Option E5 or E6)

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
				An overflow pipe surrounded by erosion on the eastern side of the beach		Sand replenishment using the sand from the extensive shallow facing the park (Option E9) Sizing of the GPT to avoid overflows
S56.Oatley Pleasure Ground	Kogarah	Poor/Fair	High	Vertical sandstone seawall on the eastern half, rocks on the western half and small concrete boat ramp at the southern end	Boat ramp need maintenance. Other structure enough for the protection of the area	Boat ramp should be fixed and seawalls can be fixed and faced by objects to allows the creation of more habitats (Option S9 and S7)
S60.Shipwright Bay	Kogarah	Fair	High	Vertical sandstone seawall	Relatively low seawall	Objects can be placed along or in front of the vertical seawalls to increase colonisation by various species (Option S7)
S63.Dover Park	Kogarah	Poor	High	Low rock seawall between the boat ramps	Erosion visible behind the seawall Buffer behind seawall	Seawall can be replaced by an environmentally friendly step seawall like at Claydon Reserve (Option S5)

Table 7.62 – Key Management Actions for Liverpool LGA

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E1.Along the railway between Liverpool Weir and Liverpool Hospital	Liverpool	Severe	High	Erosion along the whole height of the bank Reduced accessibility by land	Storm water runoff Tidal erosion (exacerbated by changes in tidal characteristics due to the Lakes construction) Steep embankment with possible collapsing after toe scour	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E4.Directly east of the carpark	Liverpool	Severe	High	Erosion along the whole height of the bank	Storm water runoff Tidal erosion (exacerbated by changes in tidal characteristics due to the Lakes construction) Steep embankment with possible collapsing after toe scour	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E21.Directly north of Governor Macquarie Bridge, both bank	Liverpool	Severe	High	Erosion along the whole height of the bank Exposed roots and fallen trees	Stormwater runoff Tidal erosion (exacerbated by changes in tidal characteristics due to the Lakes construction) Steep embankment with possible collapsing after toe scour	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
S28.Tip on the western side of Newbridge Road Bridge	Liverpool	Poor	High	Low small rocks seawall north of the bridge Dumped rocks and concrete blocks along the foreshore under the bridge	Low seawall north of the bridge facing reeds Ineffective as only a few blocks are dumped	Dumped material can be replaced by rock seawall allowing vegetation to grow between rocks (Option S1)

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
				and directly south of the bridge	Poor visual quality	
S36.Opposite East Hills Park	Liverpool	Poor	High	Scattered dumped materials where there is no vegetation	Slow erosion in area devoid of vegetation Very bad visual aspect	Replace dumped materials by native vegetation (Option S4)

Table 7.63 – Key Management Actions for Rockdale LGA

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E98.Lady Robinsons Beach centre	Rockdale	Severe	Low	Severe erosion on the northern side of the two northernmost groyne Beach north of the northernmost groyne totally eroded and covered with water at high tide	Wave action Groyne impact	Replenishment of the northern side of the groyne (Option E9) Construction of a new groyne further north
E95.Eastern side of Sandringham Bay	Rockdale	Moderate	Medium	Erosion south of the rock seawall along the line of tree	Edge effect of the seawall Wave action	Southward extension of the seawall (Option E10) Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
S76.Between the fourth and fifth groynes (from the north)	Rockdale	Fair/Good	Low	At this place, the vertical seawall is replace by a large rocks and concrete blocks seawall	Not engineered but efficient Most exposed area of the beach	Seawall can be properly engineered with geotextile

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
S77.Between the two southernmost groynes of Lady Robinsons Beach	Rockdale	Poor	Low/Medium	Old rock seawall totally covered with water	No real effect except provided habitat along the vertical concrete seawall formed by the walkway	Vertical seawall can be faced by more rocks to create additional habitats (Option S2)
S73.Eastern Side of Sandringham Bay	Rockdale	Fair Good	Medium	Short rock seawall located under the trees Vertical sandstone seawall continuing the rock seawall northward up to the beach	Generates erosion at the southern end, not engineer but efficient May be responsible for the erosion of the beach at its northern end	Northern seawall can be upgraded to engineered standard with geotextile Some rocks can be placed in front of the existing southern vertical seawalls to increase habitats (Option S2)

Table 7.64 – Key Management Actions for Sutherland LGA

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E94.North-western end of Woolooware Bay	Sutherland Shire	Light	High	Erosion all along the park where no seawall or vegetation	Beach underlain by coffee rocks limiting erosion	Sand replenishment (Option E9) Creation of a small boulder or step seawall (Option E6 or E5)
E88.Along Old Ferry Road carpark, east of Little Moon Bay	Sutherland Shire	Moderate	Medium/High	Localised erosion on both side of a small rock	Edge effect of a very short rock seawall	Extent seawall (Option E10) Removal of seawall, levelling of the bank to an equilibrium

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
						profile and vegetation planting (Option E1)
S42.Sandy Point	Sutherland Shire	Fair	High	Various kind of vertical seawalls all along Sandy Point	One localized highly eroded area close to a boat ramp at the tip of Sandy Point	Fix eroded seawall Some rocks can be placed in front of the existing seawall to increase habitats (Option S2) Objects can be placed along or in front of the seawall to increase colonisation by various species (Option S7)
S50.Along Old Ferry Rd east of Little Moon Bay	Sutherland Shire	Fair	High	Short rock seawall close to boat ramp	Generates edge effect on both side	Seawall can be removed or extended (Option S3)
S71.North-western end of Woolooware Bay	Sutherland Shire	Fair	High	Low rock seawall surrounding a GPT along the northern half of the park	Seawall subject to overtopping	Seawall can be extended along the whole park (Option S3) Seawall can be replaced by boulder seawall to increase habitats (Option S5) Seawall can be faced by vegetation (Option S6)

Table 7.65 – Key Management Actions for overall study area

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
E1.Along the railway between Liverpool Weir and Liverpool Hospital	Liverpool	Severe	High	Erosion along the whole height of the bank Reduced accessibility by land	Storm water runoff Tidal erosion (exacerbated by changes in tidal characteristics due to the Lakes construction) Steep embankment with possible collapsing after toe scour	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E4.Directly east of the carpark	Liverpool	Severe	High	Erosion along the whole height of the bank	Storm water runoff Tidal erosion (exacerbated by changes in tidal characteristics due to the Lakes construction) Steep embankment with possible collapsing after toe scour	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
S28.Tip on the western side of Newbridge Road Bridge	Liverpool	Poor	High	Low small rocks seawall north of the bridge Dumped rocks and concrete blocks along the foreshore under the bridge and directly south of the bridge	Low seawall north of the bridge facing reeds Ineffective as only a few blocks are dumped Poor visual quality	Dumped material can be replaced by rock seawall allowing vegetation to grow between rocks (Option S1)
S24.Eastern bank of Prospect Creek mouth	Bankstown	Poor	High	10m vertical brick wall surrounding boat ramp	Cracked wall, tree growing in the middle of the misused boat ramp	Old abandoned structures can be replaced by vegetation (Option S4)
S40.Lambeth Reserve	Bankstown	Fair	High	30m long rock groyne at Lambeth Reserve	Eroding on the downstream side while accreting on the upstream side	Groyne can be removed and replaced by vegetation (Option S4)
E21.Directly north of Governor Macquarie	Liverpool	Severe	High	Erosion along the whole height of the bank	Stormwater runoff Tidal erosion (exacerbated by changes	Levelling of the bank to reach a stable slope and vegetation

Location	LGA	Severity	Priority Rating	Details / Comments	Possible Causes	Possible Management Response (Options provided refer to Erosion Options of Section 7.3.1 of the report)
Bridge, both bank				Exposed roots and fallen trees	in tidal characteristics due to the Lakes construction) Steep embankment with possible collapsing after toe scour	planting (Option E1)
E91.Connells Point Reserve	Kogarah	Moderate	High	Erosion behind small beach Pile of light in water GPT creating a gully at the level of the beach on the western side An overflow pipe surrounded by erosion on the eastern side of the beach	Wave action Stormwater outlet proximity Spills from GPT	Construction of an environmentally friendly seawall along the beach (Option E5 or E6) Sand replenishment using the sand from the extensive shallow facing the park (Option E9) Sizing of the GPT to avoid overflows
S36.Opposite East Hills Park	Liverpool	Poor	High	Scattered dumped materials where there is no vegetation	Slow erosion in area devoid of vegetation Very bad visual aspect	Replace dumped materials by native vegetation (Option S4)
E58.South of Beatty Reserve	Bankstown	Severe	High	Erosion along the whole height of the bank Exposed roots and fallen trees	Edge effect from the Private seawalls of the properties located between Beatty Reserve and Georges River Golf Course Tidal erosion Steep embankment with possible collapsing after toe scour	Replenishment with sand (Option E9) Levelling of the bank to reach a stable slope and vegetation planting (Option E1)
E90.Southern end of Poulton Park	Kogarah	Severe	High	Severe erosion at the location of two stormwater outlets	Proximity to the stormwater outlets Water runoff from the road Tidal erosion	Levelling of the bank to reach a stable slope and vegetation planting (Option E1)

7.5 Stormwater Outlets and GPTs assessment

The stormwater outlets and GPTs were assessed during the site visit both by boat and by land-based inspections. However, these assets are often hidden by vegetation and not easily accessible. Hence, these devices have been mostly assessed using desktop work and study of maps from diverse reports and GIS data from the various Councils in the study area. GPT data were not able to be obtained from all Councils.

Table C of Appendix 2 shows the list of the assets observed during the site visit. Figures 46 to 51 of Appendix 2 illustrate the sewer networks from the various Council areas and the observed assets during the fieldwork.

Condition of the assets was rated as followed:

- Good: Asset is quite new or intact; do not need any maintenance or only minor maintenance.
- Fair: Asset is in relatively good condition but would need maintenance or upgrades
- Poor: Asset collapsed or needs major maintenance and upgrades

7.5.1 GPTs in the Georges River Catchment

Various types of GPT are present within Georges River catchment, depending on the different councils:

- A common GPT within Kogarah Council is made of floating plastic tubes across channels or creeks, forming a constriction generating a funnel effect where a metal grid stops the gross pollutants (Figure 7.66). The Kogarah Council's GPTs that have been observed were in good condition and working efficiently.

Figure 7.66 – Kogarah Council GPT at Kogarah Bay

- Another GPT/stormwater overflow outlet was observed at Connells Point Reserve, Kogarah (Figure 7.67). This infrastructure appears to be under-capacity and overflow from the structure appears to have created a gully along the reserve.

Figure 7.67 – GPT/Stormwater overflow outlet at Connells Point Reserve

- A GPT was observed near the northern end of Salt Pan Creek (Figure 7.68). This GPT comprises of a trash rack crossing the whole channel trapping the gross pollutants. The GPT was full of gross pollutants during the site visit whereas the channel was almost dry.

- A last type of GPT was observed along Woolooware Bay (Figure 7.69). This GPTs is also comprised of a trash rack crossing the channel in front of a stormwater outlet.

Figures 6.16 and 6.17 (Section 6.3.7) show the location of the stormwater overflows and the major sewage system in the Mid-Georges River and the Lower Georges River respectively.

Figure 7.68 – GPT located at the north-eastern end of Salt Pan Creek

Figure 7.69 – GPT at the north-east of Woolooware Bay

7.5.2 Water Sensitive Urban Design (WSUD)

Water Sensitive Urban Design (WSUD) has the main goal of ensuring that urban development and urban landscapes are carefully designed, constructed and maintained so as to minimise the impacts on the urban water cycle including potable water, wastewater and stormwater.

The key objectives of WSUD are:

- Reducing potable water demand through water efficient appliances, rainwater and greywater reuse.
- Minimising wastewater generation and treatment of wastewater to a standard suitable for effluent reuse opportunities and/or release to receiving waters.
- Protect and restore aquatic ecosystems and habitats
- Treating urban stormwater to meet water quality objectives for reuse and/or discharge to surface waters.
- Preserving the natural hydrological regime of catchments.
- Protect the scenic, landscape and recreational values of waterways
- Reducing minor flood risks in urban areas

WSUD is likely to be one of the key solutions to improving water quality within the Georges River/Botany Bay catchment and minimising ecological impacts on Botany Bay and its waterways. WSUD is particularly essential in the treatment of stormwater and it consists of seeing stormwater as a valuable resource rather than as a nuisance.

Many different devices and management practices can be classified as WSUD, including:

- GPTs (see Section 7.4.1)
- Sand filters
- Street retrofits
- Street trees
- Rainwater tanks
- Permeable paving
- Greenroofs

- Buffer Strips & vegetated swales
- Bioretention system
- Constructed wetlands, saltmarsh and lakes
- Public art
- Signage and community education

Several examples of WSUD which have been undertaken within the Georges River catchment are shown in Figure 7.70 to 7.74 (pictures from WSUD website http://www.wsud.org/picture-library/).

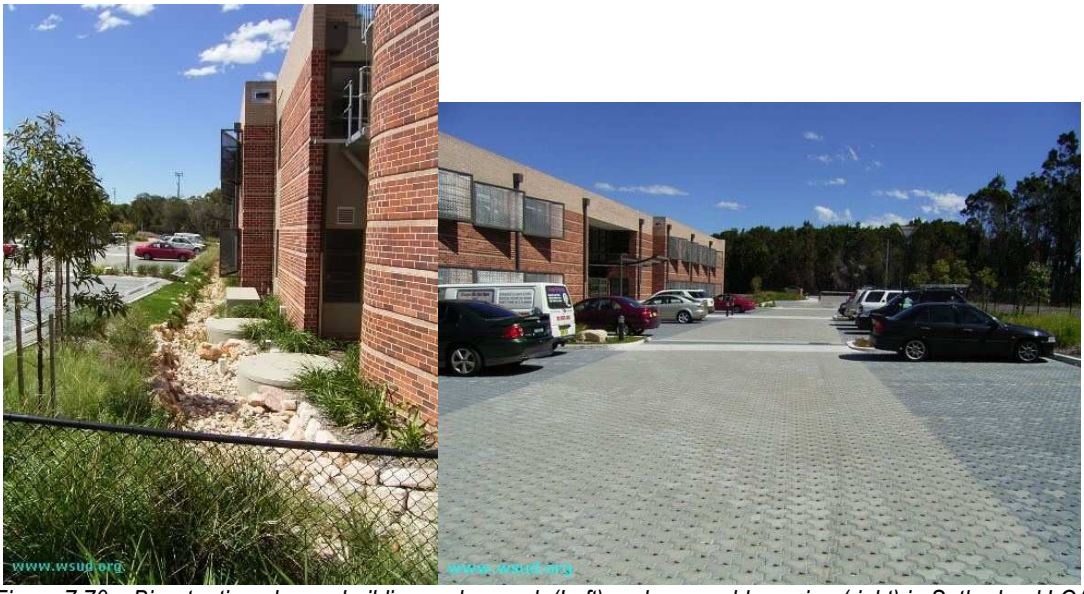

Figure 7.70 – Bioretention along a building and carpark (Left) and permeable paving (right) in Sutherland LGA

Figure 7.71 – Installation of a rainwater tank (left) and constructed wetlands (right) within Rockdale LGA

Figure 7.72 – Grassed Swale (left) and constructed wetland (right) in Fairfield LGA

Figure 7.73 – Public art (left) and street tree (right) within Kogarah LGA

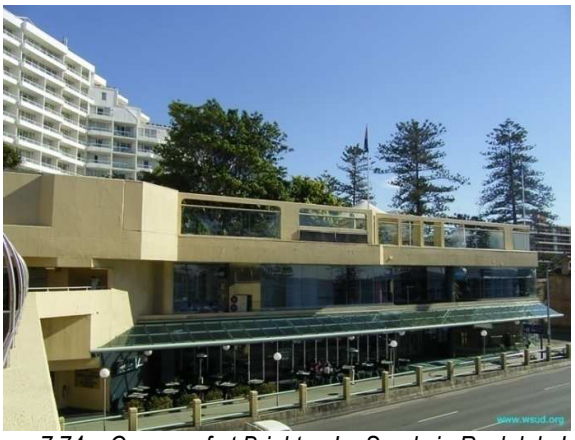

Figure 7.74 – Greenroof at Brighton Le Sands in Rockdale LGA

8 ECOLOGY

This chapter describes the terrestrial and aquatic ecosystems of the Georges River Estuary and their interactions. The study area includes the estuarine environments of Botany Bay, up the Georges River to Liverpool Weir and also the riparian edge environments of the river up to 50m landward from the high water mark, which is influenced by and contains habitat for, the flora and fauna associated with the river.

This section has been split into the following constituents:

- Flora, which includes both:
  - Estuarine vegetation; and
  - Riparian vegetation.
- Fauna

The aim of the ecology component of this study is to document the ecological processes of the estuary to better manage and prioritise management actions for foreshore assets in the study area.

This has been achieved by documenting the location, type, condition, identifying threats and issues and prioritised management actions for each of the aforementioned constituents. Management actions have been recommended that will allow councils to address threats and issues identified. This includes conservation, rehabilitation and possible reinstatement of vegetation communities.

8.1 Methodology

8.1.1 Estuarine Vegetation

The vegetation communities mapped by the Sydney Metropolitan CMA (DECCW 2009a) were utilised for this study as this mapping project provided the most current coverage of the study area and included terrestrial, riparian and estuarine vegetation. This layer contains digital mapping of the vegetation communities of the Sydney Metropolitan Catchment Management Authority area and were derived from Aerial Photographic Interpretation with communities defined using survey and statistical analysis. The layer includes the boundaries of vegetation communities and lists attributes including vegetation community, understorey, disturbance type & severity as described in DECCW (2009a).

Specific methodology for seagrass, mangrove and saltmarsh condition assessments are outlined in the ‘condition’ sections in 8.2.1-8.2.3 below.

8.1.2 Historical Estuarine Vegetation Assessment

Trends in seagrass, saltmarsh and mangrove distribution were investigated by using historical data provided by I&I (I&I NSW 2009). This data set was developed as part of a project to assess the distribution and abundance of seagrass, mangrove and saltmarsh communities in the Sydney regions. The suite of data sets produced includes layers for Botany Bay for the 1940s/1950s, 1970s, 1980s and 2000s. Vegetation boundaries were identified using aerial photos (contact prints) from the following years: 1951, 1971 and 1986. Digital orthorectified aerials were also used for 2005.

To carry out an assessment of the past temporal change of estuarine vegetation (seagrass, mangroves and saltmarsh) and to provide insight into succession of these communities,

SMEC's modelling staff utilised the Land Change Modeller (LCM) GIS package (Clark Labs , 2009). LCM is a suite of tools used to analyse and explain land cover change over time. Historical estuarine vegetation data (DECCW, 2009) based on aerial photograph (contact print) interpretation and vegetation mapping from 1951, 1971, 1986 and 2005 was imported into LCM to analyse and map both the loss and gain of these vegetation types and the change in average area of each vegetation community over this period.

It is assumed that the same methods for the identification and classification of the different communities within the mapping were used by DECC (2009a), and as such the location and distribution of these communities can be compared over time. It should be noted that historical data for estuarine vegetation was only available for seagrass, mangroves (including mangroves with a saltmarsh understorey) and saltmarsh and not for swamp oak forest or estuarine reedland. Therefore the results were not able to provide insight into Saltmarsh/Swamp Oak/Estuarine Reedland succession in the study area.

8.1.3 Riparian Vegetation

Sydney Metropolitan CMA mapping (DECCW 2009a) was utilised to determine riparian vegetation distribution in the study area. The condition of riparian vegetation within the study area was investigated by analysis of disturbance mapping (DECCW 2009a) and field investigation. Condition assessment methodology is further described in Section 8.2.2.

8.1.4 Fauna

Information on fauna has been collected from the desktop component of this study, the data compilation study (Appendix 1). The DECCW Atlas database (2010) and of the DEWHA Protected Matters Search Tool (2010) were used to find species listed as threatened and protected species under the *Threatened Species Conservation Act 1995* (TSC Act) and *Environment protection and Biodiversity Conservation Act 1999* (EPBC Act) (as per the) in the study area.

8.2 Estuarine Vegetation

Estuarine vegetation is the vegetation associated with an estuary that is affected by tides or ocean salinity. Five forms of estuarine vegetation occur within the Georges River Estuary, These include:

- Seagrass;
- Mangroves;
- Saltmarsh;
- Swamp Oak Forest; and
- Estuarine Reedland

The distribution and abundance of each of these vegetation types is influenced by tidal, sedimentation and anthropogenic processes and impacts. A Biodiversity Study of the Georges River Catchment (Williams, 2004) identified four main geomorphic zones in the estuary adopted from Roy *et al* (2001), which relate to the distribution of estuarine vegetation within the study area. The zones were determined using a combination of water depth, bottom sediment and geomorphic setting. Marine tidal delta, central mud basin, fluvial delta and riverine channel (Refer to Figure 8.0, Appendix 3).

The following section details the composition, distribution, abundance and threats to each of the estuarine vegetation communities that occur within the Georges River Estuary study area.

8.2.1 Seagrass

Description

Seagrasses are a specialised aquatic flowering plant that forms meadows in brackish and marine waters (Keith 2004). At low tide seagrasses may be seen floating on the water surface and can be completely exposed during exceptionally low tides. Seagrasses form a simple community with usually just one species in a meadow, however many species of algae as epiphytes on the leaves may also be present (Price, 2007). Salinity, turbidity and water depth influence the distribution of seagrass meadows and of different species within the meadows (Keith, 2004).

The Georges River study area supports two main species of Seagrass, *Zostera capricorni* (Eel grass) and *Posidonia australis* (State Pollution Control Commision , 1978). *Z. capricorni* occurs in estuaries and sheltered coastal waters from exposure at low tide to a depth of 4-5 metres, while *P. australis* is found in sheltered waters on sandy substrate from 2-10m depth (Robinson, 2003). The Georges River also supports *Halophilia* species (*Halophila ovalis* and *Halophilia deciepiens*). Both these species occur in sheltered coastal waters with *Halophila ovalis* occuring to a depth of 10 metres and *Halophilia deciepiens* to a depth of 20 metres (Robinson 2003).

Distribution

Local distributions of seagrass meadows are dynamic, shifting in response to shifting estuarine sediments, extreme tides, storms and intense wave action (Keith, 2004). *P. australis* prefers the lower reaches of river systems where there are large tidal exchanges (West et al. 1985). This species was once common in Botany Bay however the original cover has reduced as a result of exposure to wave action due to dredging activities in the Bay (Watford & Williams 1998). The distribution of *P. australis* in the study area is now confined to Botany Bay, around Towra Point (State Pollution Control Commission 1978 in Williams 2004). In the study area, *Z. capricornia* occurs from Botany Bay along the Georges River with the most upstream presence recorded near Newbridge Rd in Moorebank (DECCW, 2009)(Abbott, L. & D'Unienville pers. obs.). Other studies of the estuary have recorded small patches of Zostera further upstream than this (DECCW, 2009) (Williams, 2004). *Halophila ovalis* and *Halophilia deciepiens* species are restricted to Botany Bay and occur in mixed beds with Zostera and Posidonia (Creese *et al.* 2009).

The total area of seagrass in the study area is 374.4 ha (Table 8.1) with the largest meadows occurring in Botany Bay around Towra Point, Woolooware Bay and in North Botany Bay near Lady Robinson Beach (Figure 8.1c, Appendix 3). The location and size of these meadows is a result of sediment transport in Botany Bay where ocean swell has moved sand northward along Lady Robinson Beach and westward along Towra Point (refer to Section 3.2 and Figure 3.1). The movement of sand in the bay has created substantial sand banks which provide suitable depth for seagrass growth.

Several smaller areas of seagrass occur in Gwawley Bay; Kogarah Bay; and at the mouth of the Woronora River and Salt Pan Creek (Figures 8.1b and 8.1c, Appendix 3). Sutherland Shire, Rockdale and Kogarah LGA's have the largest seagrass meadows respectively (Table 8.1).

Seagrass is also present at the mouth of other creeks in the catchment: Mill, Deadman and Williams Creeks (Figures 8.1a and 8.1b, Appendix 3). The distribution of seagrass at the mouth of creeks is primarily due to deposition patterns of eroded sediment, which form alluvial pans within the estuary, providing suitable conditions for seagrass growth. Though this deposition provides favourable depth and substrate for seagrass to establish, it can also influence tidal flushing of the tributaries which effects water quality.

Based on existing estuarine vegetation mapping (DECCW, 2009) and field observations, the presence of seagrass beds doesn't appear to be affiliated with any one estuary zone. Seagrass are present in all four zones of the estuary, however the size of the meadow is higher in the Marine Tidal Delta zone where the substrate comprises of >90% sand and the depth is from 0-10m (Williams, 2004).

Table 8.1 – Seagrass areas per LGA in the study area (I&I NSW 2009)

LGA	Area (ha) of seagrass (number of patches)
Bankstown	1.48 (19)
City of Kogarah	20.89 (58)
Hurstville	0.24 (3)
Liverpool	0.40(20)
Rockdale	13.91 (76)
Sutherland Shire	261.85(430)
Unincorporated (North Botany Bay)[1]	75.69(654)
Total	**374.40 (1260)**

Condition

Detailed condition assessments of seagrass are labour intensive requiring examination of differences in leaf length, leaf and rhizome biomass, occurrence of leaf damage, density of epiphytes and occurrence of flowering. As such, the current study did not undertake formal condition assessments. However, a rapid condition assessment following the *Wetland Assessment Techniques Manual* (Price, 2007) was undertaken within four seagrass meadows along the river. These were located at the mouth of Saltpan Creek, Great Moon Bay, the mouth of the Woronora River and in Kyle Bay. The assessments were undertaken on the 13th and 27th of November and 3rd of December 2009.

The assessment technique undertaken (Price, 2007) aimed to rapidly assess the health of a wetland and the environmental components in the system, including estuarine vegetation condition. Several indices were recorded such as 'cover' of the seagrass (i.e. how dense the meadow is) and the amount of epiphyte cover on the seagrass blades. High epiphyte cover can be an indication of eutrophication and can lead to death of a meadow due to the epiphyte cover limiting the ability of seagrass to photosynthesise (Price 2009). These

[1] Refer to Appendix 7 for limitations to the data

condition indicies can determine anthropogenic effects on seagrass such as boat propellers and sedimentation and toxic runoff.

Results of seagrass cover (Figure 8.1) show that the Salt Pan Creek meadow (89%), had the greatest cover, followed by the meadow at the mouth of Woronora River, then Kyle Bay and Great Moon Bay. The greatest density of epiphyte cover was also recorded at the meadow at Salt Pan Creek (46%) followed by the meadow at the mouth of Woronora River, then Great Moon Bay and Kyle Bay (Figure 8.1).

The results do not necessarily reflect the physical impacts observed during the survey. The meadow at Salt Pan Creek was shown to have the highest per cent cover of the sites assessed. However, this site had been affected by boat propellers with large prominent cuts observed through this large and relatively good condition meadow.

This was impacting on the condition of the meadow, however was not able to be conveyed within the rapid assessment parameters.

Other limitations of this assessment are associated with choice of the sites and weather. Due to the sampling replicates required for the assessment, only meadows large enough to sample 10x1m^2 quadrats were chosen. There were also weather restrictions during sampling with overcast and raining weather and the change in tides limiting sight of the seagrass beds and hindering accurate cover and depth measurements.

The results of the assessment are basic and preliminary, providing only an indication of the condition of a few of the seagrass meadows in the estuary. The assessment would need to be replicated both at these sites and at other sites throughout the catchment to conclude any associated distribution and 'catchment health' trends.

It is recommended that a more thorough seagrass condition assessment be undertaken in the future. This is likely to be undertaken as part of the next step in the estuary management process. The assessment should ascertain differences in spatial distribution and condition of meadows throughout the catchment. The assessment should also aim to detect attributes of seagrass that will help differentiate between natural and anthropogenic (both physical e.g. boat propellers and other anthropogenic e.g. water quality) disturbance and impacts. The results from the assessment should be used as a baseline for monitoring the distribution and health of seagrass meadows into the future as part of the Estuary Management Plan.

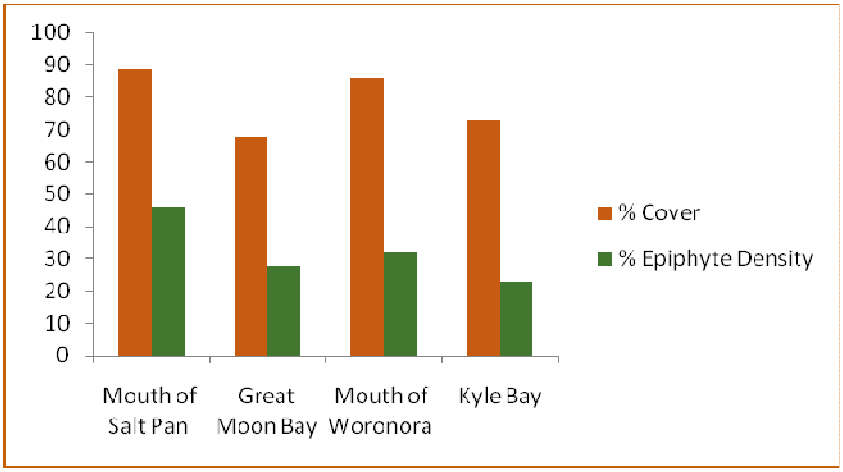

Figure 8.1 – Conditions of Seagrass Meadows of the Georges River

Values

Seagrass meadows contribute significantly to the primary productivity of coastal waters and thus hold high ecological and economic values in the following areas:

- They function as fish 'nurseries', providing suitable habitat and refuge from predators for the young of many species of fish as well as for some crustaceans;
- They provide abundant food for molluscs and other herbivorous animals that feed on or among the leaves (Keough and Jenkins 1995 *in* Keith 2004);
- Seagrass beds are important nursery areas for many commercially harvested species and hence economic significance being valuable to the fishing industry (Larkum *et al* 1989 *in* Keith 2004); and
- They also have an important role binding marine sediments with their thick mat of rhizomes and roots (Keith 2004).

Marine vegetation including seagrass is also protected from harm by the *Fisheries Management Act 1994 (FM Act)*. *Posidonia* seagrass in the Georges River is currently being considered for listing as an Endangered Population under the FM Act. A permit to destroy or harm marine vegetation (Division 4 section 205 and 205B of the *FM Act*) is required from I&I NSW for any development that may impact marine vegetation.

Threats

A number of natural and human activities pose threats to the distribution and health of Seagrass communities (DECCW 2009). Threats can be categorised under 'direct' e.g. damage from boat propellers, or 'indirect' e.g. increased erosion upstream leading to increased turbidity of the water and reducing light availability for the plants.

Direct damage to seagrass beds can arise from boating, dredging, foreshore development (moorings, jetties and marinas) and scouring from stormwater outlets. Evidence of this can be seen throughout the whole estuary, particularly where water recreation activities occur and in areas of concentrated foreshore urbanisation.

Figure 8.4f shows a number of areas where seagrass is currently distributed and where mooring zones occur. This includes the mouth of Salt Pan Creek, Kogarah Bay, Gwawley Bay and Sandringham Bay. Not all areas zoned for mooring have mooring locations currently designated to them. The allocation of mooring areas within these zones is the responsibility of NSW Maritime. Damage to seagrass was observed during site inspections for example along the eastern side of Kyle Bay.

The most pressing indirect threat to seagrasses is water quality degradation primarily from nutrients levels (both high and low) and increased turbidity (sedimentation). Loss of water quality arising from sedimentation clouds water and restricts sunlight reaching plant beds. High turbidity over extended periods also limits the depth at which seagrasses can survive (Price, 2007). Nutrient enriched water dispersed from storm water and sewage runoff can result in prolific growth of epiphytic algae growth on the seagrass fronds. Both these processes cause stress to plants by reducing the capacity of plants to photosynthesise and can lead to death of whole meadows.

Natural threats such as severe storms, floods and extreme low tides can alter hydrology and sea levels and also directly uproot seagrass. Though there is little that can be done to control natural storm events seagrasses are more likely to recover from storm damage if there is less pressure from anthropogenic threats. Global warming is considered to threaten

seagrass distribution and condition in the future by contributing to more frequent and severe weather events which will cause damage to the species by increased turbidity and damage by smothering them or uprooting them. Sea level rise may also impact on seagrass as the increase in water depth may impact on the amount of substrate at suitable depths to support this species.

One contributing factor to global warming is an increase in atmospheric CO_2. This also contributes to a decrease in ocean pH (or ocean acidification) caused by the uptake of anthropogenic carbon dioxide from the atmosphere (Caldeira & Wickett 2003). Findings by Palacios & Zimmerman (2007) suggest that as CO_2 content of the surface ocean rises, so too will the productivity of seagrass meadows.

The full extent the impacts of these potential threats may have on the environment is not known and is the subject of current scientific debate. With this aside, it can be safely said that sea level rise is likely to impact on the distribution of seagrass within the estuary in the future in both negative and positive ways. If storm events are indeed more frequent and sever there is likely to be more direct damage to seagrass by uprooting and less time to recover from the events and suitable habitat for seagrass may be restricted through changes in water from changed bathemetry depth. However, of all marine species, seagrass is the most likely to benefit from ocean acidification. An increased in eelgrass density could increase sediment retention, which could lead to increased water clarity and an expansion in the depth distribution of eelgrasses to deeper waters (Palacios & Zimmerman 2007).

Management

Table 8.2 identifies management actions to ameliorate the current threats to seagrass within the study area. Priority management areas are identified in Appendix 3.

Table 8.2 – Threats and suggested management actions for Seagrass

Threat	Suggested Management Actions
Water quality	▪ Stabilisation of banks to minimize erosion and sedimentation ▪ Control of pollution from point and diffuse sources such as sewage outlets, stormwater, runoff from golf courses ▪ Signage and educational pamphlets to educate and discourage people dumping rubbish (including lawn clippings) ▪ Installation of GPTs and adequate maintenance of GPTs
Boat moorings	▪ As the boat moves during mooring the dragging chain tears up seagrass from the substrate. (http://www.seagrassmooring.com.au). ▪ Identify moorings located within existing seagrass beds. ▪ Relocation of these moorings outside seagrass beds. ▪ Removal of existing traditional dump weight and chain moorings in these areas and replace with seagrass friendly moorings (http://www.Seagrassmooring.com.au). These moorings raise the chain off the seafloor stopping the chain dragging as the boat moves during mooring. Without this, movement of the chain tears up seagrass from the substrate. ▪ Results and recommendations from current trials of seagrass-

Threat	Suggested Management Actions
	friendly moorings at Manly, Pittwater and Port Stephens should be incorporated into the management of moorings in the Georges River. ▪ The Department of Industries and Investment is undertaking an inventory of seagrasses in NSW this will assist in identifying appropriate mooring areas and help to determine where anchoring will not damage seagrasses. Results of this inventory should be used to update Maritimes mooring zones in the study area.
Development (marinas, jetties)	▪ Council approval for new marinas and jetties should prioritise areas that will not impact seagrass. ▪ Expansion of current Marinas and jetties should not be considered if the surrounding area is seagrass habitat or if direct impacts will be made on existing meadows ▪ Stricter fines and enforcement is needed to crack down on illegal jetty building by residents ▪ Need to obtain 'permit to destroy' from I&I for any removal or detrimental impact to seagrass
Boat propellers	▪ Increased signage and education ▪ Identify options to manage boating impacts, such as propeller damage to seagrass. Although less boating may occur in shallow areas, it is these areas that are most susceptible to propeller scarring impacts.
Dredging	▪ If dredging is proposed the effects on seagrass (from tidal, sediment and current changes) should be seriously considered and a feasibly study undertaken. The study should include a risk assessment to weigh up the possible effects of dredging on seagrass and the fauna habitat it provides.
Altered hydrology and sea level rise	▪ It is likely that seagrass will persist in areas identified in Figures 8.5a to c due to existing benthic sediment locations. These areas are likely to promote future colinisation should sea level changes be experienced and should therefore be prioritised for management of seagrass in the Georges River. ▪ These areas should be continually monitored in the future for distribution, condition and diversity

8.2.2 Mangroves

Description

Mangroves are found in the intertidal sedimentary areas of estuaries typically growing between saltmarsh and seagrass beds (Keith 2004). Mangrove pneumatophores provide both habitat, and protect shorelines from erosion (in combination with the Mangrove tree or shrub itself). Mangrove root systems are efficient at dissipating wave energy (Massel *et al*

1999). Likewise, they slow down tidal water enough that its sediment is deposited as the tide comes in and is not re-suspended when the tide leaves, except for fine particles (Mazda et al 1997).

Thirty six species of Mangrove occur in Australia however only two types exist in Sydney: the Grey Mangrove (*Avicennia marina var. australasica)* and the River Mangrove (*Aegiceras corniculatum).* These are both present throughout the Georges River with the Grey Mangrove, the more salt tolerant of the two, being found on the downstream foreshores. Behind this and upstream in the areas of brackish water, the River Mangrove is commonly found. Within the Mangrove margins are rushland and Saltmarsh species such as Sea Rush (*Juncus kraussii*), Native Reed (*Phragmites australis)* and Glasswort (*Sarcocornia quinqueflora*). Saltmarsh species can also occur as an understorey to mangroves along the inland perimeter of their distribution.

Distribution

Mangroves are found throughout the Georges River estuary in intertidal flats extending from Botany Bay to Liverpool Weir (refer to figures 8.1a-c, Appendix 3). A total of 471ha of mangroves have been mapped in the study area (Table 8.3). Sutherland LGA has the largest area of mangroves with 376ha. Bankstown and Hurstville have similar areas with 46ha and 40ha respectively whilst Liverpool and Kogarah LGA's have much smaller areas with 6.5ha and 1.6ha (Table 8.3). Rockdale LGA has no mangroves recorded in the study area.

Generally the mangroves upstream of the Georges River National Park are thin, often patchy stands (Figure 8.1a, Appendix 3) as they are restricted by the tidal limit of the tributaries or by landuse that has hindered the inland spread of this species. Mangroves are also known as pioneer colonisers in areas of sedimentary deposition in shallow intertidal waters and so opportunistically colonise these small fringe areas.

Table 8.3 – Area of Mangroves in the study area for each LGA (DECCW 2009a)

LGA	Area in study area (ha) (number of patches)
Bankstown	46.17 (95)
City of Kogarah	1.66(32)
Hurstville	40.07 (57)
Liverpool	6.56 (71)
Rockdale	0.00 (0)
Sutherland Shire	376.12 (1745)
Total	**470.57 (2000)**

Further downstream, substantial stands occur primarily within the bays of the estuary where suitable sediment and topography exist for tidal inundation. These areas include Towra

Point, Little Salt Pan Creek and Salt Pan Creek (Figures 8.1b and 8.1c). These large stands of mangroves occur as a result of two different processes in the estuary. The stands at Towra Point have been protected from clearing for a number of years due to its Ramsar listing and it being a National Park. Therefore, the mangroves have been allowed to migrate landward and seaward depending on the natural movement of sediment. Little Salt Pan and Salt Pan Creek, however, are areas that have been subject to considerable development since the 1930's.

The construction of major engineering works (South Western Motorway, East Hills Railway Bridge, Sydney Water Sewer Aqueduct and Henry Lawson Drive Bridge) over Little Salt Pan Creek and Salt Pan Creek have led to a constriction of the main channel width, which may have altered the natural estuarine and sedimentary processes within the estuary (Patterson Britton, 2001). This also led to additional mudflat and tidal areas being available for Mangrove colonisation.

Another example of this is seen further downstream of Salt Pan Creek where similar filling of the river was completed for the construction of the East Hills Railway Bridge and Henry Lawson Drive. However, as with the projects mentioned above, the channel was not returned to the pre-construction condition. As a result of this the creek is extremely narrow at these two points restricting tidal flushing and sediments and nutrients are infilling the creek on the upstream side of the structure, leading to favourable habitat for Mangrove colonisation.

Condition

Condition assessment was undertaken for five mangrove areas along the Georges River on the 13th and 27th of November and 3rd of December 2009. Methods used were following the *Wetland Assessment Techniques Manual for Australian Wetlands* (Price, 2007). The assessment recorded diameter at breast height (DBH) of all mangroves with a DBH >2.5cm in a 10x10 metre quadrat. It also looked at total number of trees and average height as well as condition of the leaves (foliage health) and foliage cover. Due to time constraints the required four quadrats per site was not achieved to calculate the Mangrove condition index for each site during the current study.

The general condition of mangroves was assessed during site visits of the study area. The health of the trees was scored as 'high', 'medium' or 'low' according to Saenger (2002) in Price *et al.* (2008). Generally, mangroves appeared to fall under the 'High' classification reflecting healthy trees. Characteristics recorded that reflect condition of the stand indicating 'healthy' trees (Saenger *et al*. 2002 in price *et al*. 2008) include:

- A large number of leaves per branch;
- Foliage along the entire length of the branch;
- Normal leaf size with little deformation (twisting or curling);
- Consistent foliage colour (no chlorosis or necrosis); and
- Good foliage cover.

Stands that are well established and appear to be healthy include: Salt Pan Creek; Little Salt Pan Creek; Lime Kiln Bay; Gungah Bay and Woolooware Bay. However several areas along the river showed some indication of low health. These include: Quabray Bay at Towra Point and the Mangrove islands near Ovens Reach. Details of field observations on Mangrove condition for representative areas throughout the study area are included in Table 8.4 below.

Table 8.4 – Mangrove condition observations

Location	Field Observations
Salt Pan Creek	▪ 'High' tree condition score ▪ Extensive stands, particularly at the upper most estuarine limit of the Creek ▪ Some areas where mangroves have been illegally cut to provide water access, views for residence and construction of illegal pontoons (refer to Figure 8.2, photos 1 and 3, Appendix 3) ▪ Large amounts of rubbish have been washed into the Mangrove areas with the tide ▪ Eastern side has a number of invasive plants along the landward edge of the Mangrove stands
Gungah Bay	▪ 'High' tree condition score ▪ Well established extensive stand ▪ Large stormwater drain releasing water at the landward side of the stand. ▪ Some rubbish observed throughout
Lime Kiln Bay	▪ 'High' tree condition score Continuity of the stands has been impacted by several areas where illegal removal of mangroves has occured (Refer to Figure 8.2, photo 4, Appendix 3) ▪ Several areas where mangroves are re-establishing along the foreshore
Great Moon Bay	▪ Some black spot observed ▪ Mature trees form a distinct stand along the river front, tree size and DBH appear to quickly decrease as trees extend landward and into Saltmarsh ▪ Landward expansion of juvenile mangroves into saltmarsh area ▪ Some undercutting of tree roots in trees lining the Georges River
Towra Point/Weeny Bay/Quibray Bay	▪ Most areas appear to exhibit 'high' condition of trees ▪ Dieback observed along foreshore between Weeny and Quibray Bays ▪ Several areas where mangroves have not grown back after oyster depots were abandoned ▪ The protection of mangroves along the foreshore of this area is evident as they appear more established and mature than many other stands in the study area.

It is recommended that more thorough and detailed assessments of mangrove condition be undertaken for Mangrove stands throughout the Georges River as part of the next step in the estuary management process.

The assessments should form the basis for a mangrove health monitoring program to determine impacts on mangroves over time within the Management Plan for the estuary.

Values

Mangrove forests play an important role in estuarine and marine ecology, providing habitat for many fauna species. Mullet, prawns, molluscs and crabs eat mangrove detritus broken down by bacteria and fungi. Mangrove forests are nursery grounds, feeding areas and shelter sites for fish such as the flat-tail mullet and silver biddy, and support many bird species. Mangrove forests are also often used by migratory shorebirds as roost sites, and sometimes as foraging sites (Keith, 2004).

Mangroves are also an important nursery area for many fish, however few animals use mangroves as their only habitat. Most species that utilise these species move in and out of the mangroves seasonally, at different stages of their lifecycle or with the tides (Chapman & Underwood 1995 (Keith, 2004). Many visit to feed on the copious decaying plant matter on the forest floor and the fleshy succulent leaves. For some vertebrates, in particular a number of birds and nectar-feeding bats, the abundant nectar provided by the Mangrove flowers is an important seasonal food source. Hollows in mangroves also provide habitat for a number of reptiles such as the Eastern Water Skink (*Eulamprus quoyii*).

Mangrove forests are important for bank stabilisation and water quality along foreshore areas of the Georges River estuary. Mangroves filter pollutants from run-off as the fine anoxic sediments deposited under mangroves act as sinks for a variety of heavy metals. Subsequently, where mangroves are cleared and the underlying sediment disturbed this may cause trace metal contamination in seawater and aquatic biota (Maunsell Australia Pty Ltd, 2008).

Mangroves also provide protection from erosion caused by wave action and screening along developed shorelines. Clearing of mangroves is regulated by the *Fisheries Management Act*, 1994 and a permit to destroy or harm such marine vegetation is required from I&I NSW.

Threats

Mangroves occurred extensively throughout the estuaries of Sydney prior to European settlement (Keith 2004). The value of their timber was soon exploited as their ash was used to provide a source of sodium that was used in glass manufacture. Over the last century threats to mangroves have shifted from removal for industries to removal for land reclamation, and whilst the species are known to be an aggressive recoloniser, opportunities for re-establishment in Sydney are constrained by built environments (e.g. seawalls) and steep sandstone banks (Keith, 2004).

A number of other threats to mangrove distribution and health are:

- Water quality (pollution from sewage outlets, stormwater, runoff from golf courses and oil spills);
- Bank erosion;
- Construction of seawalls and erosion control devices that limit the expansion and establishment of Mangrove areas;
- Die-back caused by moth larvae; and
- Increase in tidal amplitudes from sea level rise.

A study by Gilman *et. al.* (2008) concluded that based on available evidence relative sea-level rise may be the greatest threat to mangroves. Rising sea-level will have the greatest impact on mangroves experiencing net lowering in sediment elevation, where there is limited area for landward migration (Gilman *et.al.* 2008).

Management

This study has identified the need to protect mangroves along the foreshore of the study area to stabilise banks, improve water quality and provide valuable habitat. It is important that future planning for the estuary and foreshore of the Georges River includes monitoring of changes to vegetation communities, particularly increased distribution of mangrove communities above and below the high water mark, and the impact of this change on the other vegetation communities within the estuary.

Management actions to protect and preserve mangroves in the Georges River estuary are listed in Table 8.5.

Table 8.5 – Threats and suggested management for mangroves

Threat	Suggested Management Actions
Bank erosion	▪ Installation of Mangrove and aquatic fauna friendly seawalls.
Water quality	▪ Control of pollution from point sources such as sewage outlets, stormwater and runoff from golf courses ▪ Monitoring of water quality throughout the river, including turbidity and nutrient levels
Land reclamation (foreshore development)	▪ Zoning of foreshore areas as reserves/recreation ▪ Incorporate sea level rise results by prioritising protection of foreshore areas that are vital for future inland migration of estuarine vegetation ▪ Clean up of decommissioned oyster leases including contamination assessment, complete removal of structures where appropriate and rehabilitation and revegetation of the sites.
Vandalism	▪ Investigation into impacts of pruning Grey Mangroves ▪ Monitoring and enforcing fines on residents who undertake illegal pruning/killing of native vegetation to allow water views from their residence
Rubbish	▪ Signage and educational pamphlets to educate and discourage people dumping rubbish (including lawn clippings) ▪ Installation of GPTs and adequate ongoing maintenance ▪ Continued rubbish removal
Sea level rise	▪ Areas identified in Figures 8.5 a to c should be prioritised for management of mangroves. This figure highlights locations that are to be above the forecast areas of inundation. Therefore, they are possible areas for landward migration of estuarine vegetation. ▪ These areas should be continually monitored for temporal changes in distribution, diversity and condition

Threat	Suggested Management Actions
	▪ Install Mangrove friendly seawalls to promote Mangrove growth

8.2.3 Coastal Saltmarsh

Description

Saltmarsh is a salt-tolerant plant community that lives between high and low tide. Saltmarshes are complex mosaics of closed sedge lands, grasslands and open herbfields, and occasionally have emergent shrubs (Keith, 2004). These are the most diverse of the saline wetland classes, and they show considerable diversity both within patches and between communities across their range (Keith, 2004).

The saltmarsh areas of the Georges River contain a diverse range of flora species. These include: *Sarcocornia quinqueflora ssp. quinqueflora* (Samphire/Glasswort); *Suaeda australia* (Austral seablite); *Paspalum vaginatum* (Saltwater Couch); *Cotula coronopifolia* (Water Buttons); *Samolus repens* (Creeping Brookweed); and *Juncus kraussii* (Sea Rush). Chenopod species (e.g. *Sarcocornia quinqueflora*) dominate areas more frequently inundated by the tides, while Sea Rush (*Juncus kraussii*) occupies the more elevated terrestrial margin (DECCW, 2009). One juncus species, *Juncus acutus*, is a prolific invasive plant throughout the area and once established, appears to outcompete all other saltmarsh species (Abbott, L. pers.obs. 13 & 27 November 2009).

The presence, absence and distribution of species of saltmarsh is dependent on salinity. It is also dependant on the topography of an area, the level of tidal influence, evaporation and freshwater accumulation, however this will vary between Saltmarsh areas. Some of the areas are flooded regularly, while at slightly higher elevations flooding is rare. After rain freshwater accumulates and adds extra water to the marsh, leaving pools of standing water when the tide recedes. Small depressions in the marsh will usually be characterized by the absence of flora. This is due to the accumulation of intensely saline deposits from the evaporation of tidal waters preventing the growth of any plants at all (Keith 2004).

A number of significant saltmarsh species occur along the Georges River. These are:

- *Wilsonia backhousei* (Narrow-leaved Wilsonia) - This prostrate herb is listed as vulnerable under the TSC Act;
- *Gahnia filum* - A sedge of regional significance in western Sydney; and
- *Selliera radicans* - A sensitive saltmarsh species with limited occurrence in the area. A creeping herb preferring brackish, less tidal places in the upper estuary, such as saltmarshes bordering rivers and swamps and occasionally in River-flat Forest.

Distribution

Saltmarshes are restricted to estuarine mudflats that are exposed to intermittent tidal inundation and to small soaks on exposed headlands that receive abundant salt spray from onshore winds. In estuaries, they generally occur between the average high tide water mark of spring tides and the high water mark of neap tides. The upper limit to the distribution of saltmarsh in general is the highest astronomical tide. Saltmarsh is limited in its distribution, being mostly found at the Marine Tidal Delta (Towra Point) and along the Fluvial Delta. Saltmarsh communities often grow in neglected lands, and are often used for dumping and reclamation, or infilled for development.

Although widely distributed, saltmarshes are restricted in both the size of their patches and their total area (West *et al.* in (Keith, 2004). Towra Point Nature Reserve is a good example of a saltmarsh community in the Sydney region and the largest area of saltmarsh in the study area (Figure 8.1c, Appendix 3). This location is protected under the NSW National Park reserve system and is also listed as a Wetland of International Importance under the Ramsar Convention for migratory bird habitat.

Significant saltmarsh plant species within the study area are distributed in the following locations:

- *Wilsonia backhousei*- The best stand in the Georges River is located on Salt Pan Creek (Robinson, 1994; R. Williams, pers.comm), and it has also been recorded in Little Saltpan Creek;
- *Gahnia filum*- In Bankstown, it is found near the edge of saltmarsh in Salt Pan Creek and in low numbers in Lambeth Reserve; and
- *Selliera radicans*- Occurs at Deepwater Park, and has also been found nearby on the southern side of the Georges River along the foreshore between Mill Creek and Williams Creek.

Within the Georges River study area, saltmarsh occurs from Towra Point throughout the Georges in discrete patches to Williams Creek (Figures 8.1a-c, Appendix 3). A total of 144.65 ha of saltmarsh (not including other vegetation types that have a saltmarsh understorey) is present in the study are (Table 8.6). Sutherland Shire Council has the largest area with 139.5 ha, due to the large area located in Towra Point. Bankstown and Liverpool councils have the next highest area of Saltmarsh respectively (Table 8.6). Of the total amount of saltmarsh that occurs in all LGA's, 85% occurs in the study area and 93% occurs in parks/reserves or National Parks. This highlights the importance of future management options for this community in the study areas, particularly with regard to management of existing parks/reserves and National Parks to ensure the health and abundance of this community is appropriately managed into the future.

Results of the saltmarsh mapping (Table 8.6) show that 54% of Liverpool's saltmarsh community occurs in the study area, but none of it is protected in a park, reserve or national park. A large portion of the saltmarsh present in Bankstown, Hurstville and Sutherland Shire LGA's occurs in parks, reserves or National Parks (Table 8.6). In the study area the remaining 36 ha of the saltmarsh community exists on land that is not zoned as a park, reserve or National Park.

Table 8.6 – Area of saltmarsh in the study area per LGA and amount of this that occurs in parks, reserves or National Parks (DECCW 2009a)

LGA	Area of saltmarsh community in the whole LGA (ha) (no. of patches recorded)	Area of saltmarsh community in the study area (ha) (no. of patches recorded)	% of saltmarsh community in the LGA that occurs in the study area	Area in parks, reserves or National Parks (ha)	% of the community in parks, reserves or National Park
Bankstown	3.64 (28)	2.43 (23)	66.96	2.36	97.01%
City of Kogarah	0.09 (3)	0.01 (2)	9.45	0.00	0.00%

LGA	Area of saltmarsh community in the whole LGA (ha) (no. of patches recorded)	Area of saltmarsh community in the study area (ha) (no. of patches recorded)	% of saltmarsh community in the LGA that occurs in the study area	Area in parks, reserves or National Parks (ha)	% of the community in parks, reserves or National Park
Hurstville	1.01 (3)	1.01 (3)	100.00	0.82	80.84%
Liverpool	3.12 (9)	1.67 (7)	53.56	0.00	0.00%
Rockdale	1.40(10)	0.00 (0)	0.00	0.00	0.00%
Sutherland Shire	161.83 (300)	139.52 (211)	86.21	131.91	94.54%
Total	**171.09 (353)**	**144.65 (246)**	**84.44**	**135.00**	**93.32%**

Condition

Saltmarsh species were recorded at twelve sites in the study area, refer to Table 8.7. The assessments were undertaken on the 13th and 27th of November and 3rd and 17th of December 2009. The most abundant species recorded were Austral Seablite (*Suaeda australis*) and *Sarcocornia quinqueflora subsp. quinqueflora* (samphire or beaded glasswort). *Sarcocornia quinqueflora subsp. quinqueflora* occurs in dense colonies and is one of the dominant plant species in Saltmarsh in the Sydney region. Both glasswort and seablite are known to dominate Saltmarsh areas in the Sydney region. However, of the two species glasswort is the most salt tolerant (Morrisey 1995 *in* (Keith, 2004)) with Seablite occurring on the higher ground towards the upper reach of the tides.

Several sites have been regenerated and have been a focus of council flora and foreshore management (Table 8.7). This is the case at several sites along Salt Pan Creek, managed by Bankstown Council. Other sites are not currently managed but appear to be in good condition with fewer anthropological pressures observed than other sites. These sites include Deadmans Creek and Towra Point Nature Reserve.

The saltmarsh areas surveyed had few invasive plants due to most common invasive plants being intolerant of high concentrations of salt. One invasive plant species that was observed at several sites was *Juncus acutus*. This species was present at Beauty Point and Mid Salt Pan Creek where the current control and removal of this species was evident.

Table 8.7 – Species list and characteristics of saltmarsh sites in the study area.

Location	Species recorded	Characteristics of the site
Deadmans Creek: Holsworthy Military Reserve (Figure 8.3a photo 1 , Appendix 3)	▪ Sporobolus virginicus (Sand Couch, Saltwater Couch, Nioaka) [or Paspalum vaginatum (Saltwater Couch); or Zoysia macrantha (Prickly Couch)] ▪ Goodenia ovate (Hop Goodenia)	▪ Good condition ▪ Few invasive plants ▪ Part of Holsworthy Military Reserve ▪ Evidence of heavy fauna use (wallaby paths

Location	Species recorded	Characteristics of the site
	▪ Apium prostratum var. prostratum (Sea Celery) ▪ Melaleuca ericifolia (Swamp Paperbark) ▪ Juncus kraussii subsp. australiensis (sea rush)	throughout the vegetation)
Georges River National Park (Figure 8.3a photo 2, Appendix 3)	▪ Paspalum vaginatum (Saltwater Couch) ▪ Phragmites australia ▪ Sarcocornia quinqueflora subsp. quinqueflora (Samphire/Glasswort)	▪ Past disturbance from 4wd vehicles ▪ Some sections of this area have been replanted
Mill Creek: Georges River National Park (Figure 8.3a photo 3, Appendix 3)	▪ Ozothamnus diosmifolius (Rice flower) ▪ Goodenia ovate (Hop Goodenia) ▪ Phragmites Australia ▪ Suaeda australia	▪ Relatively undisturbed ▪ Some invasive plants present
Beauty Point (Figure 8.3b photos 1 &2, Appendix 3)	▪ Suaeda australia (Austral Seablite) ▪ Sarcocornia quinqueflora subsp. quinqueflora (Samphire/Glasswort) ▪ Juncus acutus	▪ Past disturbance from 4wd vehicles ▪ Removal of Juncus acutus has been undertaken however large areas are still dominated by this species ▪ Parts of the area has been replanted with several Saltmarsh species and other flora species endemic to the area
Upper Salt Pan Creek Reserve (Figure 8.3b photo 4, Appendix 3)	▪ Cotula coronopifolia (Water Buttons) ▪ Suaeda australia ▪ Sarcocornia quinqueflora subsp. quinqueflora ▪ Phragmites australia	▪ Revegetation of this area has been previously undertaken by Bankstown City Council
Mid Salt Pan Creek Reserve (Figure 8.3b photo 7, Appendix 3)	▪ Suaeda australia ▪ Sarcocornia quinqueflora subsp. Quinqueflora ▪ Juncus acutus	▪ Revegetation of this area has been previously undertaken by Bankstown City Council ▪ Current removal of Juncus acutus is being undertaken ▪

Location	Species recorded	Characteristics of the site
Lower Salt Pan Creek Reserve (Figure 8.3b photo 5, Appendix 3)	▪ Phragmites australia ▪ Suaeda Australia ▪ Sarcocornia quinqueflora subsp. Quinqueflora	▪ Managed by Bankstown City Council ▪ Possible impact from stormwater outlets to the north and south of the area. ▪ Evidence of heavy flows and rubbish (no GPTs on the stormwater pipes)
Reserve Opposite Great Moon Bay (Figure 8.3b photos 3&6, Appendix 3)	▪ Suaeda australia ▪ Sarcocornia quinqueflora subsp. quinqueflora (Samphire/Glasswort)	▪ Site is relatively isolated and undisturbed. However, there is some rubbish dumping and some of the Saltmarsh area has been defaced by people writing their names and drawing on the surface. ▪ Large areas of bare ground ▪ Juvenile mangroves encroaching on Saltmarsh.
Lime Kiln Bay (Figure 8.3b photo 8, Appendix 3)	▪ Sarcocornia quinqueflora subsp. Quinqueflora ▪ Suaeda Australia	▪ Small area between mangroves and a park/reserve. ▪ Species appear planted.
Neverfail Bay (Figure 8.3b photo 9, Appendix 3)	▪ Mustard weed ▪ Sarcocornia quinqueflora subsp. Quinqueflora ▪ Georges River Spinach	▪ Old Oyster depot then part of the bay was the old Riverkeeper office. Currently not used. ▪ Some residential houses set back from the foreshore. ▪ Some of the Saltmarsh plants appear planted (along the shoreline) others are an understorey to the She Oaks (Casuarina), this may have regenerated naturally.
Towra Point Nature Reserve (Figure 8.3c photos 1 &2, Appendix 3)	▪ Suaeda australia ▪ Sarcocornia quinqueflora subsp. Quinqueflora	▪ Good pristine site ▪ Possible Mangrove encroachment

Location	Species recorded	Characteristics of the site
	▪ Saltbush sp. ▪ Several species of Juncus including Juncus kraussii subsp. australiensis	
Towra Point Nature Reserve: (Figure 8.3c photos 3, Appendix 3)	▪ Suaeda australia ▪ Sarcocornia quinqueflora subsp. Quinqueflora ▪ Hydrocotyle bonariensis* (American penywort) ▪ Disphyma crassifolium subsp. Clavellatum (round-leaved pigface) ▪ Ficinia nodosa (Knobby Club-rush)	▪ Old derelict Oyster depot ▪ Possibly contaminated site from dumped tar ▪ Considerable number of invasive plants ▪ No management actions to clean up the site have been implemented since decommissioning of the oyster depot

Values

Coastal Saltmarsh in the NSW North Coast, Sydney basin and South East Corner Bioregions is listed as an endangered ecological community on Schedule 1 of the TSC Act. This listing includes saltmarshes of the intertidal zone of estuaries and lagoons. Coastal Saltmarsh consists of many unique salt-tolerant plants that are not found in other environments. It plays an important role in ecosystem food webs and provides habitat for a range of terrestrial and aquatic fauna such as crabs, insects including mosquitoes, molluscs and spiders, as well as for fish, birds and bats. Species of migratory birds protected under federal legislation and international treaties, such as the Sharptailed Sandpiper often roost and feed in Saltmarsh during their stay in Australia. It is also a breeding and nursery ground for marine life, and filters nutrients that would otherwise enter estuarine waters.

A recent study (Freewater, 2009) looked at the dietary composition of three fish species in saltmarsh within a large south-eastern Australian estuary (Brisbane Water). The study highlighted the importance of fringing saltmarsh for providing both protection and food resources for fish species during even short periods of tidal inundation by its provision of a superabundant food source (crab zoeae) and other prey. The conclusion reached was that if these saltmarsh habitats were to further decline in area as a result of anthropogenic events and/or mangrove encroachment (see Saintilan and Williams 1999), this would have substantial implications for the fish fauna typically resident in estuaries. This emphasises the need for management of saltmarsh, including recognition of saltmarsh in management plans for fish, both within the Georges River Estuary and in other estuaries throughout NSW.

Saltmarsh traps and binds sediments aiding in the process of land making (Cappo *et. al.* 1995). This process also protects coastal areas from erosive effects of storm events and extreme tides. Saltmarsh also acts as an ecological buffer, balancing nutrients and organic matter between saltmarsh and other interacting systems including mangroves, seagrass, open water systems and groundwater (Cappo *et a*l 1995).

Future Threats

As much as half of the original area of Saltmarshes in NSW may have been destroyed by clearing and landfill for coastal developments (Adam et al, 1988; Morrisey 1995b in (Keith, 2004), and the remaining Saltmarshes near urban areas are threatened by rubbish tipping, sedimentation and the uncrontrolled use of off-road vehicles. These disturbances also increase invasion by salt tolerant invasive plants, such as *Hydrocotyle bonariensis* (American Pennywort), *Stenotaphrum secundatum* (Buffalo Grass) (Keith, 2004) and *Juncus acutus* and lead to the expansion of persistent bare areas. Many examples of saltmarsh patches that remain in Sydney, particularly in the Georges River, are small in size, highly fragmented and patchy in distribution.

Major threats to this community include:

- Encroachment from mangroves caused by changes in sediment and nutrient loads;
- Decrease in salinity due to freshwater runoff through stormwater pipes;
- Reclamation of land;
- Invasive plant invasion by salt tolerant invasive plants outcompete native species;
- Pollution (heavy metals and oil spills);
- Unrestricted access by walkers, bike riders, vehicles; and
- Sea level rise.

Management

Management considerations arising from this study have identified the need to protect saltmarsh throughout the study area, the need to conserve species considered by their rarity to be "sensitive", as well as the need to remove the threat posed by invasive species, particularly *Juncus acutus*. It is important that future planning for the estuary and foreshore of the Georges River minimises the threats to, and protects the conservation value of saltmarsh.

A number of management actions to ameliorate threats to saltmarsh are listed in Table 8.8.

Table 8.8 – Threats and suggested management for saltmarsh

Threat	Suggested Management Actions
Water quality	▪ Control of pollution from point and diffuse sources such as sewage outlets, stormwater and runoff from golf courses ▪ Monitoring of water quality throughout the river, including sedimentation and nutrient levels
Land reclamation (foreshore development)	▪ Zoning of foreshore areas as reserves/recreation ▪ Incorporate sea level rise results by prioritising protection of foreshore areas that are vital for future inland migration of estuarine vegetation
Vandalism	▪ Install signage to warn of the fragility and importance of saltmarsh ▪ Install signage to warn of fines for illegal defacing of saltmarsh and enforcement of these fines where appropriate
Rubbish	▪ Signage and educational pamphlets to educate and discourage people dumping rubbish (including lawn clippings) ▪ Installation of GPTs and adequate ongoing maintenance ▪ Monitoring and enforcing fines for illegal dumping in saltmarsh areas ▪ Continued rubbish removal of hot spot areas identified in Figures 8.10a to e.
Interspecific Competition	▪ Frequent monitoring of saltmarsh areas to monitor Mangrove and Casuarina encroachment. This should include the delineation of zones whereby the maintenance of Mangrove/casuarina spread is monitored and maintained. ▪ Gain approval to undertake Mangrove/Casuarina removal/management where appropriate. ▪ Control of sources of sedimentation to minimize Mangrove habitat in existing saltmarsh areas
Trampling by walkers, bike riders,	▪ Restrict access to saltmarsh area by constructing fencing

Threat	Suggested Management Actions
vehicles	▪ Install signs to restrict access and inform the public about the importance of saltmarsh ▪ Locations where significant Saltmarsh plants, such as Wilsonia backhousei, occur should be monitored to ensure they are not trampled. In areas where they occur near public access they should be delineated with fencing and signage to inform of the fragile nature of the species
Invasive plant Invasion	▪ All saltmarsh areas should be monitored and have invasive plant removal undertaken where necessary ▪ Removal and management of the highly invasive plant, Juncus acutus, should be undertaken where necessary ▪ Education programs to inform the public about the implications on native flora of dumping grass clippings and garden matter
Altered hydrology	▪ Monitoring of freshwater species such as Phragmites australis (Common reed) and Typha spp. (Cumbungi) in areas adjacent to saltmarsh where freshwater influence is evident.
Sea level rise	▪ All areas of saltmarsh be prioritised for estuary vegetation management ▪ These areas should be continually monitored for distribution and diversity temporal changes ▪ Investigation into areas suitable for construction of saltmarsh/wetland habitat

8.2.4 Estuarine Reedland

Description

Estuarine Reedland is characterised by tall dense swards of the Common Reed (*Phragmites australis*). It is found in environments inundated by fresh, saline or brackish water. These include low-lying alluvium on riverbanks, riverflat depressions, and banks on coastal lagoons that are open to tidal influence. It is commonly encountered above Saltmarsh flats. Several salt tolerant species are shared between the Estuarine Reedland and Saltmarsh communities including Sea Rush (*Juncus kraussii*), Bare Twig-rush (*Baumea juncea*) and the small herb Creeping Brookweed (*Samolus repens*). Species composition of Estuarine Reedland consists of a canopy species of *Casuarina glauca* and ground cover of *Juncus kraussii*, *Samolus repens*, *Baumea juncea*, *Lobelia anceps*, *Phragmites australis*, *Alternanthera denticulata*, *Apium prostratum* and *Cyperus polystachyos.*

This community, along with Cumberland Swamp Oak Riparian Forest and Estuarine Swamp Oak Forest are the three communities that constitute Swamp Oak Floodplain Forest of the NSW North Coast Sydney Basin and South East Corner bioregions EEC.

Distribution

In the SMCMA this community is found patchily distributed along lagoon fringes and riverflats of the Georges, Parramatta and Hacking Rivers and in major brackish lagoons such as the Narrabeen lakes. The Common Reed can be a vigorous recolonising species in disturbed environments. Outside of the SMCMA it is common and widespread along estuarine environments of the NSW coastline (DECC 2009).

Estuarine Reedland occurs in pockets along the entire reach of the study area from Lake Moore Wetlands (Figure 8.1a, Appendix 3) to Woolooware Bay (Figure 8.1c, Appendix 3). It occurs in distinct pockets in the upper extent of Salt Pan Creek (Figure 8.1b, Appendix 3) and Lime Kiln Bay (Figure 8.1b, Appendix 3) and along parts of Williams Creek, Deadmans Creek and Mill Creek (Figure 8.1a, Appendix 3).

The study area has 23.28ha of Estuarine Reedland (Table 8.9). Sutherland LGA has the greatest area of this community with 11.98ha having large stands of this community at the southern side of Woolooware Bay and along Mill Creek. Bankstown LGA has the next largest area (5.54ha), then Liverpool (4.96ha) and Hurstville (0.80ha) (Table 8.9).

Approximately 66% of the total area of Estuarine Reedland occurs in a reserve, park or National Park. Of the LGA's that have this community in the study area, Liverpool has the least area occurring in a reserve, park or National Park with 57% and Hurstville has the most with 80% (Table 8.9).

This community grades into Estuarine Swamp Oak Forests in areas where there is less inundation by estuarine water e.g the foreshore of Riverlands Golf Course (Figure 8.1a, Appendix 3). In areas with greater tidal influences and hence higher salt water concentrations Estuarine Reedland graduates into Estuarine Saltmarsh e.g. Mill Creek (Figure 8.1b, Appendix 3).

Table 8.9 – Summary of Estuarine Reedland in the study area that is part of the Sydney Metropolitan Catchment Management Authority (SMCMA) Area vegetation mapping (DECCW 2009a)

LGA	Area within Study Area (ha)	Area (ha) within study area within Reserves, Parks and National Parks	% of total in Parks and Reserves
Bankstown	5.54	3.27	59.13
Hurstville	0.80	0.64	80.00
Liverpool	4.96	2.83	57.00
Sutherland	11.98	8.64	72.12
Total	**23.28**	**15.38**	**66.07**

Value

Estuarine Reedland is a vegetation community that forms part of the Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner bioregion endangered ecological community (EEC), listed under Schedule 1 of the TSC Act.

This community provides valuable habitat for several fauna species, particularly frogs such as the Green and Golden Bell frog, listed as threatened under the *Threatened Species Act*.

Threats

Threats to this vegetation community are moderate due to considerable areas previously reclaimed for foreshore development. Estuarine environments have been heavily cleared and modified in the SMCMA.

Estuarine reedlands are made vulnerable by changes in tidal inundation patterns due to land infill and sea level rise as a result of climate change. Stormwater runoff also changes the balance in the ratio of freshwater and saltwater (Sainty & Associates 2000 in (DECCW, 2009)). Several stands of reedlands mapped in the Sydney Metropolitan Catchment Management Authority (SMCMA) Area vegetation mapping (DECCW 2009a) were not present in 1947 (Department of Lands 2009) in (DECCW, 2009) indicating that the community has recolonised previously cleared environments or has responded to increased sedimentation along major waterways (DECCW, 2009).

Large amounts of rubbish can also have an impact on the condition of this community. Several areas of Estuarine Reedland were observed with considerable amounts of rubbish throughout the study area, particularly around Chipping Norton (refer to Figure 8.12b, Appendix 10).

Management

Key areas of management for Estuarine Reedland include:

- Integrate management with management of other estuarine vegetation communities of specifically those of Swamp Oak Floodplain Forest EEC;
- Monitoring the intraspecific competition of this community with saltmarsh;
- Monitoring changes in hydrological regimes and their associated response in vegetation;
- Controlling stormwater pollution from diffuse and point sources; and
- Continued and more extensive rubbish removal.

8.2.5 Swamp Oak Forest

Description

The composition of Estuarine Swamp Oak Forest is primarily determined by the frequency and duration of waterlogging and the level of salinity in the groundwater. Composition also varies with latitude. *Casuarina glauca* forms dense monospecific stands above a thick ground cover of salt tolerant herbs, rushes and sedges. The community is characterised by the following assemblage of species: a canopy of *Casuarina glauca*; sub canopy of *Casuarina glauca*, *Avicennia marina*, *Goodenia ovata*, *Suaeda australis*; groundcover of *Juncus kraussii*, *Baumea juncea*, *Samolus repens*, *Phragmites australis*, *Sporobolus virginicus*, *Atriplex australasica*; and ground creeper of *Tetragonia tetragonioides*.

This community, along with Estuarine Reedland and Cumberland Swamp Oak Riparian Forest are the three communities that constitute Swamp Oak Floodplain Forest of the NSW North Coast Sydney Basin and South East Corner bioregions EEC. The dense to sparse tree layer of *Casuarina glauca* is one key characteristic of this community. The composition of the ground stratum of this EEC varies depending on levels of salinity in the groundwater.

Distribution

Estuarine Swamp Oak Forest is widespread along the coast of the Sydney Basin where it is rarely found at elevations as it occurs as the initial community above tidal influence (DECCW, 2009). This community is the succession from mangroves to terrestrial sclerophyll and mesophyll forests and woodlands, Estuarine Swamp Oak Forest. It fringes the margins of saline waterbodies that include rivers, lagoons and tidal lakes.

Estuarine Swamp Oak is distributed along the whole of the study area from Lake Moore Wetlands to the area of land between Weeney Bay and Quibray Bay (Figures 8.1a-c). In the study area it is common to have Swamp Oak Floodplain Forest with Saltmarsh understorey e.g. Chipping Norton Foreshore, Prospect Creek, Little Salt Pan Creek, Mill Creek, Carina Bay, Neverfail Bay, Towra Point Nature Reserve, (Figures 8.1a-c). The boundaries between these communities are dynamic and may shift in response to changes in hydrological regimes, fire regimes or land management practices.

The study area has 126.15ha of Estuarine Swamp Oak Forest (Table 8.10). Sutherland LGA has the greatest area of this community with 75.95ha, with large stands of this community at Towra Point Nature Reserve and the southern side of Woolooware Bay. Following Sutherland LGA Liverpool and Bankstown have similar areas with 22.99 and 22.06ha respectively (Table 8.10). Hurstville and Kogarah have much smaller areas represented in the study area with 4.33ha and 0.82ha (Table 8.10).

Table 8.10 shows the amount of these areas that occur in reserves, parks and National Parks. Of the total area of Estuarine Swamp Oak Forest 76.30% occurs in a reserve, park or National Park. Of the LGA's that have this community in the study area, Hurstville has the least area occurring in a reserve, park or National Park 44.34% and Bankstown has the most with 96.87%.

Table 8.101 – Summary of Estuarine Swamp Oak in the study area that is part of the Sydney Metropolitan Catchment Management Authority (SMCMA) area vegetation mapping (DECCW 2009a)

LGA	Area within Study Area (ha)	Area (ha) within study area within Reserves, Parks and National Parks	% of total in Parks and Reserves
Bankstown	22.06	21.37	96.87
Kogarah	0.82	0.00	0.00
Hurstville	4.33	1.92	44.34
Liverpool	22.99	11.20	48.72
Sutherland	75.95	61.76	81.32
Total	**126.15**	**96.25**	**76.30**

Value

Estuarine Swamp Oak Forest is one of the three communities that form Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner bioregion

endangered ecological community, listed under Schedule 1 of the TSC Act. The value of this EEC is discussed in Section 8.3.3.

Swamp Oak also provides valuable habitat for fauna species such as the Glossy Black Cockatoo (*Calyptorhychus lathami lathami*) and Yellow tailed Black Cockatoo (*Calyptorhychus funereus*).

Threats

This community, along with other estuarine environments, has been extensively cleared for waterfront urban and industrial development. Remaining areas often support a high cover of exotic species such as Lantana (*Lantana camara*) and Buffalo Grass (*Stenotaphrum secundatum*) (DECCW, 2009).

Present and future threats to this community include:

- Land reclamation;
- Invasive plants; and
- Change hydrological regimes and sea level rise.

Management

The main area of management for this community is to monitor future hydrological changes and associated responses. The hydrological relationship between Swamp Oak Floodplain Forest, Coastal Saltmarsh and other endangered ecological communities on coastal floodplains means a co-ordinated planning and management approach across the whole of the catchments is needed.

The management of invasive plants should also be a high priority for this community, in particular, the control of Lantana (*Lantana camara*) and Buffalo Grass (*Stenotaphrum secundatum*).

8.2.6 Estuarine Vegetation Succession

In many undisturbed estuaries there is a natural vegetation succession from the land to the estuary of eucalyptus forest to Casuarina (Swamp Oak) Forest to Saltmarsh and then to mangroves (Keith 2004). Changes to these vegetation zones occur primarily when hydrological and sediment regimes (freshwater input, tidal flushing etc.) are altered. Of these three vegetation communities, Saltmarsh is the most sensitive and least competitive in the succession process. In recent decades the invasion of saltmarsh from both swamp oak and mangroves, and resulting decline in this vegetation zone has been well documented (Keith, 2004).

The following section details the historical changes in the distribution of the various estuarine communities that occur within the Georges River Estuary. It also discusses the specific successional changes that have occurred in the study area, and aims to identify the sources and therefore likely future changes to the distribution and abundance of these estuarine communities as a result of natural and anthropogenic influences such as sea-level rise.

Distribution and Historical Succession

To carry out an assessment of the past temporal change of estuarine vegetation and to provide insight into succession of these communities, SMEC's modelling staff utilised the Land Change Modeller (LCM) GIS package (Clark Labs , 2009). LCM is a suite of tools used

to analyse and explain land cover change over time. Historical estuarine vegetation data (DECCW, 2009) based on aerial photograph interpretation and vegetation mapping from 1951, 1971, 1986 and 2005 was imported into LCM to analyse and map both the loss and gain of these vegetation types and the change in average area of each vegetation community over this period.

It is assumed that the same methods for the identification and classification of the different communities within the mapping were used by DECC (2009a), and as such the location and distribution of these communities can be compared over time. It should be noted that historical data for estuarine vegetation was only available for seagrass, mangroves (including mangroves with a saltmarsh understorey) and saltmarsh and not for swamp oak forest or estuarine reedland. Therefore the results were not able to provide insight into Saltmarsh/Swamp Oak/Estuarine Reedland succession in the study area.

The results of the analysis are presented in Figures 8.2, 8.3 and 8.4.

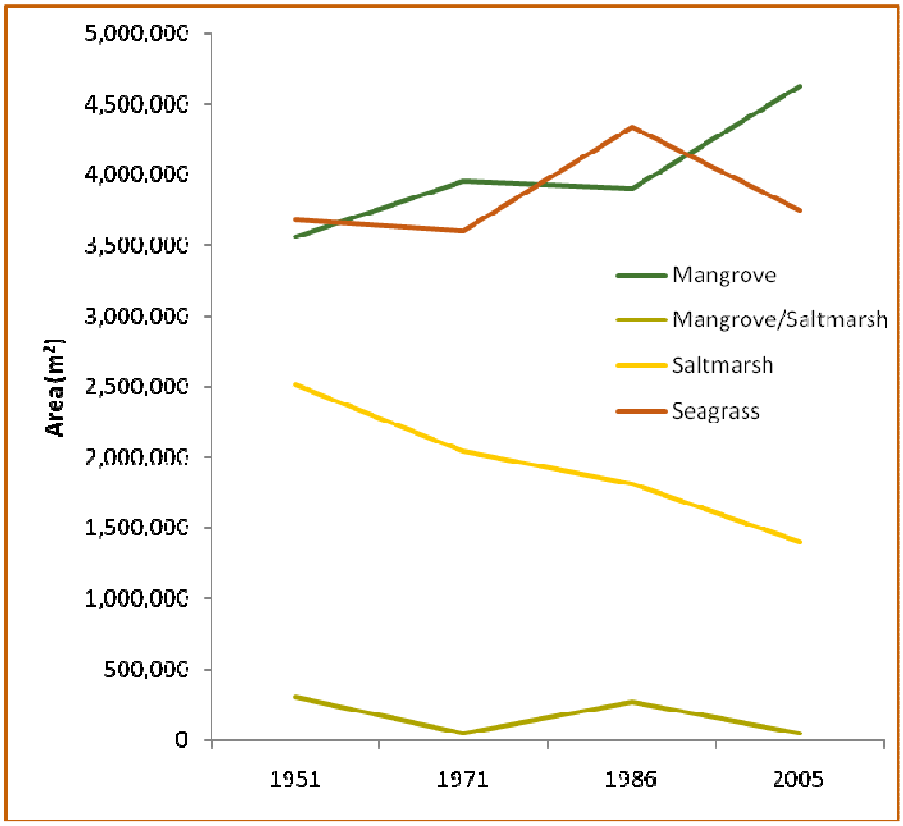

Figure 8.2 – Change in total area of vegetation communities from 1951, 1971, 1986 and 2005 (I&I 2009)

Figure 8.2 shows fluctuations in seagrass area and mangroves with a saltmarsh understorey. The figure shows a steady increase in mangroves and a steady decrease in saltmarsh area vegetation since 1951 within the estuary.

The marked increase in mangroves between 1986 and 2005, coupled with the decrease of mangroves with a saltmarsh understorey, was investigated further to understand the succession between these communities. Figure 8.3 shows that all communities had gains and losses over this time which shows the natural contraction and expansion of vegetation depending on environmental variables. The highest area of gains and losses were seen in seagrass and the no data or unvegetated category (i.e. open water, mud flats and land)

(Figure 8.3). Figure 8.4 summarises the results of Figure 8.3 by showing the total net loss/gain of each vegetation community during this period. Overall Seagrass had the greatest loss in area (60 ha) and mangroves the greatest increase in area (72h a) (Figure 8.4).

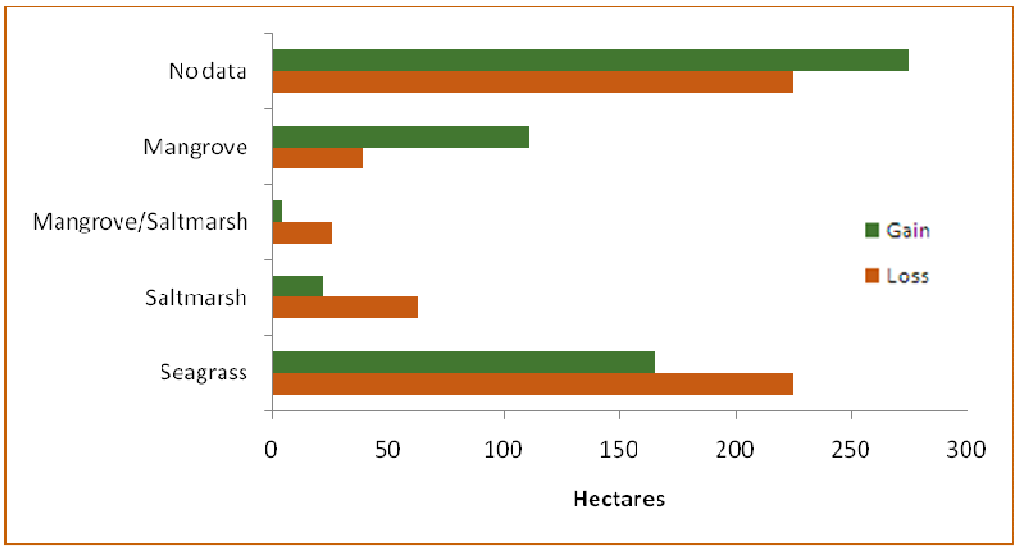

Figure 8.3 – Gains and losses of vegetation communities between 1986 and 2005 (I&I 2009)

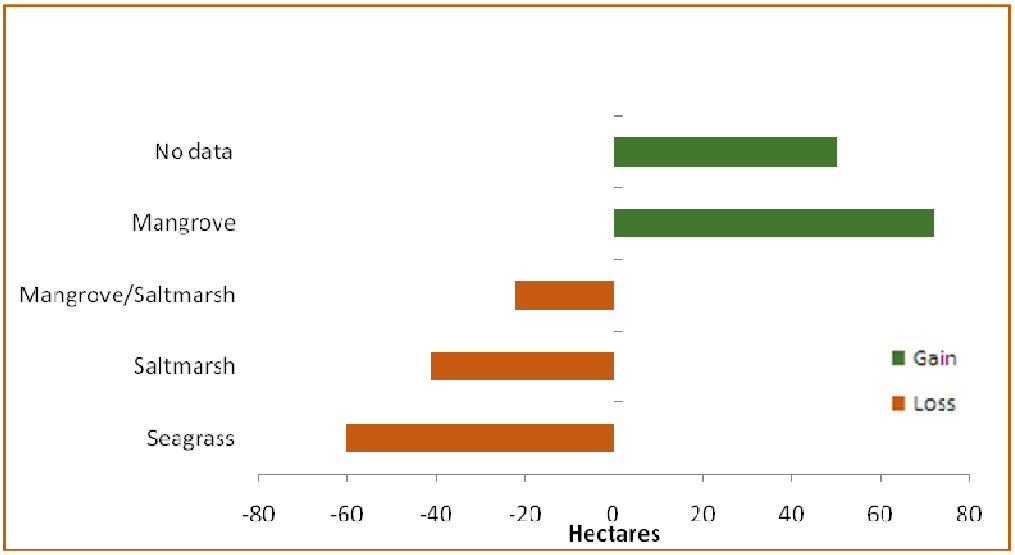

Figure 8.4 – Net change in vegetation communities between 1986 and 2005 (I&I 2009)

Changes in Seagrass Meadows

Seagrass had a gain of 165 ha and loss of 225 ha (Figure 8.3) from 1986 to 2005 within the study area, which reflects the dynamic habit of species in this community. Major areas where gains of seagrass can be seen are at the western entrance of Kogarah Bay, the entrance of Salt Pan Creek and Gwawley Bay and at the northern end of Lady Robinson Beach (Figure 8.4b, Appendix 3).

Overall, during this period (1986-2005), there was a net loss of 60 ha of seagrass (Figure 8.4). This net change was a loss of approximately 8 ha to Mangrove and 51 ha to no data (land, open water, mud flats) (Table 8.11). Loss of seagrass was scattered throughout the foreshore of the lower study area however a large component of this loss can be seen around Towra Point and particularly in Weeney Bay (Figure 8.4b, Appendix 3).

The fluctuations of seagrass cover in the study area from 1951 may be attributed to disturbance of the river substrate during the period when the oyster farming industry was booming in the estuary. Oyster production in the Georges River increased after World War II to a peak in 1971, with production slowly dropping through the 1980's. The reduction in output coincides with upgrading in 1983 of the Glenfield Sewage Treatment Plant for partial phosphorus removal from its effluent, and in 1985 with the diversion of dry weather flow from the Glenfield and Liverpool treatment plants to the Malabar cliff-face ocean outfall (Rish 1992; Florence et al. 1999 in (Williams, 2004)). The relationship between oyster production, nutrient levels in the river, effluent discharge and the correlation with seagrass distribution has not been widely researched.

Another cause in Seagrass decline could be attributed to development and erosion in Botany Bay. Dredging for Port Botany, the oil wharf at Kurnell, shipping channels and for the Third Runway at Sydney Airport has changed swell influence in the Bay (refer to Section 4.7). These works have reduced the wave climate along Lady Robinson Beach but increased the wave height along the southern shore. This also changed the wave climate creating a westward longshore current along Towra Point, eroding this section of the shoreline.

Changes in Saltmarsh Areas

Between the years of 1986 and 2005 there was a 41ha loss of saltmarsh (Table 8.11). This loss is attributed to the transition of these areas into mangrove/saltmarsh (1 ha), mangroves (26 ha) and disturbance or other anthropogenic or natural influences (14 ha of open water/tidal flats/land) (Table 8.11). Figure 8.4e shows two main areas where saltmarsh has transitioned to mangroves, Towra Point and the upper reach of Little Salt Pan Creek. The loss of these areas and subsequent gain in mangroves is discussed in the following section.

Changes in Mangrove Areas

Mangroves gained 111 ha of area with a loss of 39 ha (Figure 8.3) between 1986 and 2005. Overall this was a net gain of 73 ha (Figure 8.4). The gain in Mangrove area is broken down into a net gain of 8 ha that was Seagrass, 26 ha of Saltmarsh, 22 ha of Mangrove/Saltmarsh, and 17ha from non-vegetated areas (Table 8.11).

The main areas where succession can be seen is at Towra Point, Weeny Bay, Quibray Bay and Little Salt Pan Creek (Figure 8.4e). In Little Salt Pan Creek there has been landward expansion in the upper reach of the river. Landward and seaward expansion has occurred at Towra Point, particularly in Weeny Bay and Quibray Bay. The sediment accretion and decrease in tidal flux in these bays has gradually lead to the expansion of land, a process that has helped the seaward expansion of mangroves in these areas. With these conditions, along with a decrease in wave direction and magnitude and an increase in stationary water

in the bays (refer to Section 4, Figure 4.6), it is foreseen that unless the mouth of the bay is opened, the process of mangrove succession will close the opening to the bay and in turn make the two bays an estuarine lagoon.

Mangroves are known to be pioneer colonisers in areas of sedimentary deposition in shallow intertidal waters and have been seen to be persistent throughout the past half century. The growth in mangroves over time and their current distribution appears to be occurring at the expense of Saltmarsh species (Figure 8.4e, Appendix 3). The transition from mangrove/saltmarsh to mangroves was 22 ha (from 1989 to 2005) with only one hectare converting to saltmarsh (Table 8.11). This suggests a primary one way transition over time from saltmarsh, to mangroves with a saltmarsh understorey to purely mangroves. It also appears that once mangroves have started to become established in an area that the vegetation is unlikely to transition back to saltmarsh unless there are considerable changes to bathemethry and hydrology of the landscape.

A minimal area of mangrove (including mangrove with a saltmarsh understorey) transitioning to saltmarsh can be seen along the eastern foreshore of Woolooware Bay and some small areas throughout Towra Point (Figure 8.4e, Appendix 3). This is most likely due to changes in inundation of this area due to movement of sediment in the bay, causing changes to the salinity of the soil.

Table 8.112 – Gains and losses in area of seagrass, saltmarsh and mangroves from 1989 to 2005 (output from Temporal Vegetation Change data, I&I 2009)

Vegetation Community	Seagrass	Saltmarsh	Mangrove/ Saltmarsh	Mangrove	No Data	Total Loss/Gain (ha)
Seagrass	-	0	0	-8	-51	-59
Saltmarsh	0	-	-1	-26	-14	-41
Mangrove/ Saltmarsh	0	1	-	-22	-1	-22
Mangrove	8	26	22	-	17	73
No data	51	14	1	-17	-	49

Changes in Estuarine Vegetation Patch Size

In addition to the decline in the spatial distribution of estuarine vegetation over the last half century, the average area or patch size of each community also appears to have declined. Mangrove patch size was relatively stable between 1951 and 2005, However, mangrove with a saltmarsh understorey, Saltmarsh and Seagrass all decreased in patch size over this time (Figure 8.5). This decrease in patch size is most probably due to direct (fragmentation of vegetation due to development) and indirect (increased sedimentation from landuse) effects of the steady growth in urbanisation and industry along the foreshore since the 1950's.

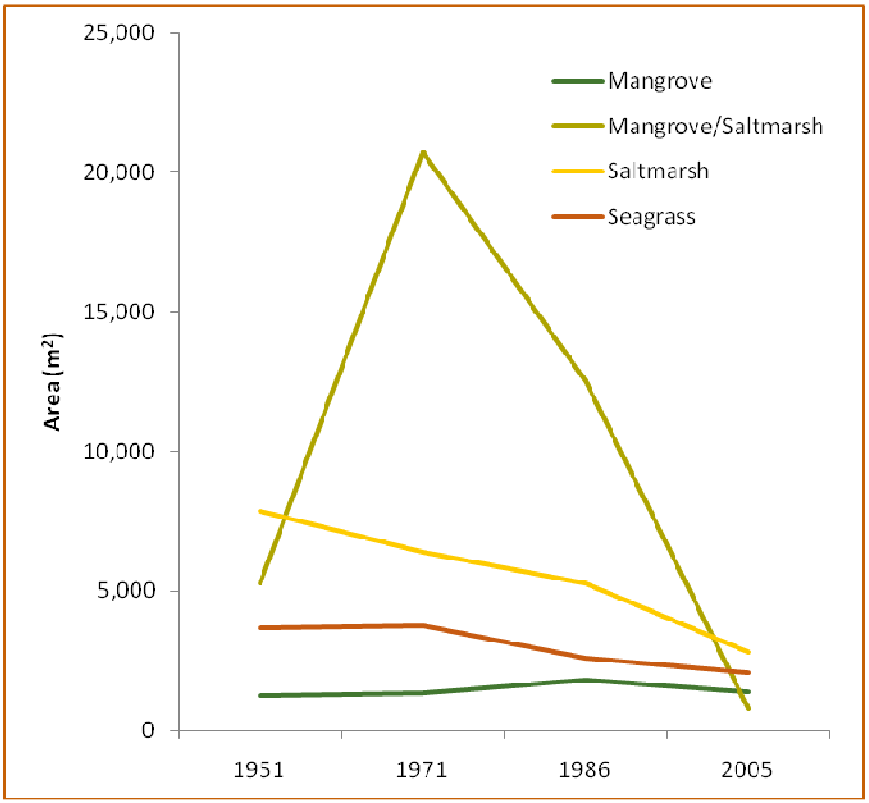

Figure 8.5 – Change in average area of vegetation communities patch size from 1951, 1971, 1986 and 2005 (I&I 2009)

Predicted Future Succession

Future patterns of estuarine vegetation succession will be greatly affected by changes in environmental variables as a result of climate change. These variables include: high water events; storminess; precipitation; temperature; atmospheric CO_2 concentration; ocean circulation patterns; health of functionally linked neighbouring ecosystems; and rise in sea level. Sea-level rise in particular will play a direct role in changing the distribution of estuarine vegetation by creating inter-specific competition. The general trend of estuarine vegetation will be to migrate inland/upslope where this is possible.

Sea level rise was estimated in the study area to deduce potential future temporal changes in estuarine vegetation distribution and abundance. Mapping contour levels, in line with the NSW Governments Draft Sea Level Rise Policy Statement, for a 40cm rise by 2050 and a 90cm rise by 2100, it was possible to see which areas will be more affected from sea level rise (Figures 8.5 a-c, Appendix 3). The results can assist in identifying potential areas for future management based on the likelihood that successional changes occur for those communities most at threat. A number of assumptions accompany the GIS data and modelling undertaken for this part of the project, Refer to Appendix 7 for details on these limitations.

Figures 8.5 a-c (Appendix 3) identify a number of locations in the study area where sea level rise is likely to impact on estuarine vegetation. The main areas where the effects of sea level rise are predicted to occur include:

- Towra Point Nature Reserve (specifically the large areas of Saltmarsh between Woolooware and Weeny Bay, refer to Figure 8.5c, Appendix 3); and

- Low lying areas with flat topography such as Deadmans Creek, Williams Creek and along the foreshore near Riverwood Golf Course (refer to Figure 8.5a, Appendix 3) as well as the mouth of Mill Creek (refer to Figure 8.5b, Appendix 3).

These same low-lying areas are also more likely to see changes in the composition of the estuarine communities due to existing favourable landuse and topography. Areas where estuarine vegetation will be inundated and where there is no area for landward migration of these communities include Carina Bay and some sections of Georges River National Park (refer to Figure 8.5a, Appendix 3) This is primarily due to the presence of seawalls, steep topography, and current landuse (presence of houses and industry). It is predicted that where there is room for landward migration of vegetation communities, saltmarsh will be the most affected as it is likely to be outcompeted by mangroves and swamp oak forest.

Besides the direct rise of the water level, the effects of erosion need to be taken into consideration. The sea level 'rule of thumb' for the effects of sea-level rise on erosion is that for each 1cm of rise in sea level results in about 1m of coastal recession (Nichollas *et.al.* 2007). However, the actual amount of coastal recession as a result of sea level rise is variable, depending on the wind and wave environment in the region, the long shore currents, the nearshore topography and the nature of the sediments on the coast and estuaries (Nichollas *et.al.* 2007). In order for accurate predictions of the extent of the impacts sea-level rise will have on estuarine vegetation, all the environmental variables need to be included. This is an output that a program such as LCM would be able to calculate to be incorporated into future management plans.

Threats

Major threats to estuarine vegetation from sea level rise include:

- Change in hydrology and tidal flows (changes salinity);
- Further changes in sediment and nutrient loads;
- Landward encroachment of mangroves; and
- Limitations to the area of land available for future retreat of vegetation due to current land uses.

Management

The outcomes from this study confirm the transitional trends from saltmarsh to mangroves and highlight the importance of closely monitoring the interaction between these communities. However, given the dynamic hydrological relationship between estuarine vegetation communities, it is apparent that future management of these communities through water and tidal flows may result in the expansion of one community at the expense of another.

- Recommendations for integrated estuarine vegetation management include:
- Thoroughly investigate impacts management actions may have on other vegetation communities before these actions are put in place;
- Management options in response to sea-level rise should be developed in conjunction with the report released on the 29th October 2009 by The House of Representatives Climate Change, Water, Environment and the Arts Committee, *Managing our Coastal Zones in a Changing Climate: the Time to Act is Now* and other current research in this area;
- Further studies into the temporal and spatial succession of estuarine vegetation communities;

- Encroachment above the high water level mark of estuarine vegetation due to sea-level rise should be incorporated into land use options and planning decisions; and
- Changes in distribution of seagrass, saltmarsh and mangroves are important indicators of environmental change for State of the Environment Reporting undertaken by local councils. Therefore, these communities should be a priority for management within the Georges River Estuary.

8.2.7 Estuarine Vegetation Management Priorities

Management recommendations for estuarine vegetation communities have been detailed in the sections above. Further, Section 8.6 provides detailed management measures for specific areas within each of the LGAs along the estuary in relation to estuarine vegetation. In addition to these recommendations the following broad areas and issues should be specifically addressed or considered in future management planning:

- Much of the Towra Point saltmarsh is protected by the planning controls and management plans associated with the Nature Reserve and adjacent Towra Point Aquatic Reserve. However, not all of Towra Point is in public ownership and Saltmarsh on private land may be at risk, particularly from disturbance by activities such as horse riding and the driving of off-road vehicles. It also appears that some areas of Towra Point in public ownership are yet to have government departments take ownership for the management of these areas, including cleaning up from past industries such as the old oyster depot between Weeny Bay and Quibray Bay.
- Seagrass tend to grow on the shallower areas of the estuary, such as those areas that are exposed during low tide. These areas are indirectly protected by signage informing boat drivers to go to the left/right of a shallow area. Despite this, a number of seagrass beds still display defined ‘scars’ in the meadows where boat propellers have obviously cut through the meadow. It is recommended that signage and more clear direction for boat users be integrated with ‘no go’ areas for boats to protect the remaining Seagrass beds of the Georges River. Due to the nature of shifting sediment and associated change in distribution of seagrasses the location of these direction and signage should be frequently reviewed and updated.
- Liverpool Council should take steps to acquire the remaining 46% of saltmarsh that is not located in a park, reserve or National Park. Private land owners that have saltmarsh on their land should be provided with education packages to describe the community and its importance in the estuary ecosystem and given options of how to best protect and manage this community.
- Outcomes of vegetation mapping and modelling from this study have confirmed the historical transitional trends between saltmarsh to mangroves. This result highlights the importance of closely monitoring the interaction between these communities, particularly their response to climate change pressures. These predictions can be made using modelling programs such as Land Change Modeller. By incorporating these programs into future management studies this helps drive innovative management recommendations and outcomes to the next stages of the project through efficient and accurate future predictions of catchment interactions.

In conclusion, the most important management recommendation for estuarine vegetation is for a co-ordinated planning and management approach across the whole catchment. This is required to address and resolve priorities between different management objectives of each LGA and yet get the best outcome for the catchment.

8.3 Riparian Vegetation

For the purposes of this study, riparian vegetation is that vegetation that occurs above the mean HWM to 50m inland. Types of riparian vegetation within the study area include freshwater wetlands, riparian forest and coastal dune communities. The total area of remnant riparian vegetation within each of the LGA areas investigated is provided in Table 8.12. Sutherland Shire has by far the greatest amount of remnant terrestrial vegetation within the study area, with Rockdale containing the least. However the council with the greatest percentage riparian vegetation within the study area is Hurstville Council (Table 8.12).

The study area contains a range of remnant terrestrial vegetation within the riparian zone. Detailed vegetation mapping, compiling all mapping projects within the wider Sydney Basin area, has been recently released by the Department of the Environment, Climate Change and Water (DECCW) (note the mapping is currently still in draft form). The mapping incorporates terrestrial, estuarine (aquatic) and tidal vegetation and covers the entire Georges River study area. The vegetation communities found within the riparian area have been described in Table 8.14 (Appendix 4).

Table 8.123 – Total amount of remnant native vegetation within each of the LGA areas within the study area (DECCW 2009a)

LGA	Total Riparian Vegetation within the LGA (ha)	%study area with remnant riparian vegetation
Bankstown	72.36	43
City of Kogarah	28.04	30
Hurstville	70.72	70
Liverpool	80.79	52
Rockdale	3.14	11
Sutherland Shire	250.68	31

8.3.1 Vegetation Communities

Ten (10) vegetation communities with more than 5ha represented occur within the study area (Table 8.13). Some of these communities occur in a number of LGAs across the study area such as Coastal Enriched Sandstone Sheltered Forest, Coastal Flats Swamp Mahogany Forest and Woronora Sandstone Exposed Bloodwood Woodland, with only two communities being represented solely within the Sutherland LGA.

Coastal Enriched Sandstone Sheltered Forest, Cumberland Riverflat Forest (part of River Flat Eucalypt Forest EEC) and Coastal Sand Littoral Forest (part of Kurnell Dune Forest EEC) dominate the vegetation within the riparian zone of the study area (50m of the HWM). However, it is of note that some of the vegetation community types (some of which may not have been included in the table below due to their small area) are woodland and forest vegetation types that occur outside the zone of influence of the estuary as a result of topography and geology.

For example, Woronora Sandstone Exposed Bloodwood Woodland occurs chiefly on the Woronora Plateau with an elevation extending from 50m to 400m. As such it is outside the

riparian zone, though is still within 50m of the HWM due to the presence of sandstone escarpments and outcrops adjacent to gorges associated with the watercourses of the study area.

As can be seen in Table 8.13, many of the vegetation communities occurring within the study area have a much wider distribution and coverage throughout the larger Sydney Metropolitan CMA area.

Less than 50% of Coastal Flats Swamp Mahogany Forest, Coastal Enriched Sandstone Sheltered Forest and Hinterland Flats Eucalypt Forest vegetation communities are represented within reserves (this includes reserves, parks and gardens) within the study area (50m of the HWM). However these communities are also well represented outside of the study area within the Sydney Metropolitan CMA area (Table 8.15).

Conversely, those communities that have a large representation within the study area of their total area within the CMA (Coastal Sand Littoral Forest and Coastal Tea-tree-Banksia Scrub) are well represented within reserved within the study area and therefore are a lower priority for protection and conservation. However, it is of note that some of the reserved areas include parks and gardens which may not afford protection to the vegetation communities present. It is recommended that the protection status of these areas is investigated further within the next stages of estuary management planning for the Georges River.

Table 8.134 – Summary of vegetation communities in the study area (where occurrence was greater than 5ha) and their representation in each LGA, in reserves and within the Sydney Metropolitan CMA (DECCW 2009a).

Vegetation Community	LGA	Amount of Vegetation (ha)				
		LGA Study Area	Combined Study Area	% Reserved* Study Area	SMCMA Area^	% Study Area of SMCMA Area
Coastal Enriched Sandstone Moist Forest	Bankstown	0	6	83%	804	1%
	Kogarah	1				
	Hurstville	1				
	Sutherland	4				
Coastal Enriched Sandstone Sheltered Forest	Bankstown	19	112	47%	2617	4%
	Kogarah	18				
	Hurstville	37				
	Sutherland	38				
Coastal Flats Swamp Mahogany Forest (Swamp Sclerophyll Forest on Coastal Floodplains EEC)	Bankstown	1	5	20%	83	6%
	Kogarah	0				
	Hurstville	0				
	Liverpool	0				
	Sutherland	4				
Coastal Freshwater Swamp Forest (Sydney Freshwater Wetlands EEC)	Bankstown	3	9	56%	68	13%
	Liverpool	1				
	Sutherland	4				

Vegetation Community	LGA	Amount of Vegetation (ha)				
		LGA Study Area	Combined Study Area	% Reserved* Study Area	SMCMA Area^	% Study Area of SMCMA Area
Coastal Sand Littoral Forest (Kurnell Dune Forest EEC)	Sutherland	68	68	94%	175	39%
Coastal Tea-tree-Banksia Scrub	Sutherland	33	33	100%	166	20%
Cumberland Riverflat Forest (River Flat Eucalypt Forest EEC)	Bankstown	25	91	58%	786	12%
	Hurstville	1				
	Liverpool	56				
	Sutherland	10				
Hinterland Flats Eucalypt Forest (River Flat Eucalypt Forest EEC)	Liverpool	1	6	33%	163	4%
	Sutherland	5				
Hinterland Sandstone Gully Blackbutt-Apple Forest	Bankstown	6	49	67%	4802	1%
	Hurstville	12				
	Liverpool	3				
	Sutherland	29				
Woronora Sandstone Exposed Bloodwood Woodland	Bankstown	4	24	63%	4037	1%
	Kogarah	0				
	Hurstville	10				
	Liverpool	0				
	Sutherland	9				

* Reserved areas includes all areas designated as parks, reserves and recreational areas. ^SMCMA area refers to the amount of vegetation within the Sydney Metro SMA area (DECCW 2009). Key to shading: Largest area of each Vegetation Community within a Local Government Area (LGA) is shaded in orange.

8.3.2 Endangered Ecological Communities

A number of the communities identified as occurring within the riparian/terrestrial zone of the study area are consistent with endangered ecological communities (EEC's) listed under the TSC Act. Sutherland Shire Council (187ha) contains the largest amount of riparian/terrestrial EEC within the study area (50m of the HWM), followed by Liverpool City Council (91ha) (Table 8.14). Bankstown City Council has considerably less (59ha) as does Hurstville (8ha). The smallest amount of vegetation considered likely to represent endangered ecological communities occurs within the City of Kogarah LGA (0.85ha) and Rockdale City Council which has no identified threatened communities occurring (Table 8.14).

The association of vegetation communities with listed endangered ecological communities has been derived from the Sydney Metropolitan CMA mapping project. As such, the condition of the remnant patches of the riparian zones needs to be verified on the ground to finalise these figures.

Over a quarter of the extent of riparian/terrestrial EEC extent within the Sydney Metropolitan CMA area (DECCW 2990a) occurs within the study area for Kurnell Dune Forest and Swamp Oak Floodplain Forest (Table 8.14). Thus, these communities are considered to be significant within the study area and should be prioritised for management actions. The largest areas of these communities occur within the Sutherland LGA, with this being the only location of Kurnell Dune Forest within the study area. Sizable areas also occur within the Liverpool and Bankstown LGAs for Swamp Oak Floodplain Forest.

Table 8.145 – Endangered Ecological Communities present within each LGA and their area (ha) within the LGAs, Study Area and SMCMA Area. Data source: DECCW (2009a)

EEC	Area (ha)								% of SMCMA in Study Area	% in Reserves*
	Bankstown	Hurstville	Kogarah	Liverpool	Rockdale	Sutherland	Total Study Area	CMA Area		
Cumberland Plain Woodland	1	-	-	-	-	1	2	2033	0%	98%
Kurnell Dune Forest	-	-	-	-	-	68	68	175	39%	94%
Littoral Rainforest	-	-	-	-	-	2	2	126	2%	95%
River Flat Eucalypt Forest	25	1	-	57	-	15	97	949	10%	65%
Shale Gravel Transition Forest in the Sydney Basin Bioregion	-	-	-	4	-	2	6	920	1%	67%
Swamp Oak Floodplain Forest	29	5	1	28	-	88	151	587	26%	77%
Swamp Sclerophyll Forest on Coastal Floodplains	1	1	-	-	-	6	9	450	2%	46%
Sydney Freshwater Wetlands	3	-	-	1	-	4	9	104	8%	62%

EEC	Area (ha)								% of SMCMA in Study Area	% in Reserves*
	Bankstown	Hurstville	Kogarah	Liverpool	Rockdale	Sutherland	Total Study Area	CMA Area		
Sydney Turpentine-Ironbark Forest	-	1	-	-	-	-	1	609	0%	0%
TOTAL	59	8	1	91	-	187	346	5953		

Note: Grey cells in the table represent those EECs with more than ¼ of their area within the Sydney Metropolitan CMA area within the Study Area. Green shading represents where significant amounts of EEC occur within the study area when compared to the CMA distribution.

As the EECs which are inadequately reserved (less than 50% in reserved) in the study area are contained in small patches spread over the study area, it is considered that additional reservation is not a priority for these communities. Only 46% of the Swamp Sclerophyll Forest on Coastal Floodplain is within reserved areas within the study area. However, the area within the study area (1ha) represents only 2% of the distribution of the community within the Sydney Metropolitan CMA. Similarly Sydney Turpentine-Ironbark Forest has only 1ha within the study area which equates to a percentage of zero within the CMA and none is reserved. However, it is not considered that this is significant given the wider representation of the community in the CMA.

Further analysis is recommended to investigate the distribution of each EEC within the study area and ensure that each riparian vegetation community attributed to an EEC is correct and relevant on the ground, to ensure that priorities are correctly placed for future management.

8.3.3 Vegetation Condition Assessment

Vegetation disturbance severity was ranked into five categories, based on data from DECCW (2009a) which combined data from recent aerial imagery (2007 & 2009) with data obtained from historic vegetation photographs (see Table 8.15). The factors that contributed to disturbance ranking are a range of disturbance types including the presence of invasive plants, erosion and canopy gaps. Additional factors are included in Table 8.15.

From field investigation, it was determined that the mapped vegetation condition did not always reflect present condition. This is due to one of the disturbance types representing historical clearing (previously cleared 1943). Sites that were cleared prior to 1943 may score poorly for vegetation condition when in fact healthy regeneration has occurred since, meaning the site is now in good condition. For example, along Little Salt Pan Creek the area was classified as Very High Intensity Disturbance Pattern" for the majority of its area due to the area being previously cleared in 1943 (see Figures 8.7d). However, this area shows a functioning estuarine mangrove ecosystem with dense healthy mangroves.

Data from historical mapping (Figures 8.7a – g) provides useful data to predict current condition for many factors (eg regrowth, plantings and invasive plants) however, it needs ground truthing, particularly in areas where disturbance severity is largely based on historical clearing.

Table 8.156 – Disturbance mapping severity code and disturbance type (Source: DECCW 2009a)

Disturbance severity code	Disturbance type
Not Assessed	- Not assessed - Roads/trails - Not used - Invasive plants - Canopy gaps - Regrowth - Grazing - Rural res subdivision - Erosion - Clearing/Part Clearing - Previously cleared 1943 - Pioneering shrubs - Fire - Plantings - Urban Mixed use - Edge Disturbances only - Dieback - Pittosporum - Bare earth - Urban Rural Landuse - Soil disturbance - Parkland open understorey - Olive - Hard surfaces present - Evidence of cultivation - Profuse Allocasuarina Regrowth - No visible
Low (generally <10% area affected)	
Moderate (generally (10-30% area affected)	
High (generally (30-70% area affected)	
Very High Intensity Disturbance Pattern based on landscape rather than native species (few visible elements remain) (generally >70% affected)	

The vegetation within the study area is classified predominantly as having either a "Very High Intensity Disturbance Pattern" or a "Low" level of disturbance (Table 8.16). Low levels of disturbance are predominantly found where larger areas of bushland occur, including the Georges River National Park, Towra Point Nature Reserve and Oatley Bay Park, where there are greater areas of natural vegetation to buffer the impact from surrounding urban areas.

Table 8.167 – Area of vegetation classified within study area for each disturbance severity code

Disturbance severity code	Area classified within study area (m^2)
Very High Intensity Disturbance Pattern based on landscape rather than native species (few visible elements remain) (generally >70% affected)	187.79
High (generally (30-70% area affected)	114.91
Moderate (generally (10-30% area affected)	141.79

Disturbance severity code	Area classified within study area (m^2)
Low (generally <10% area affected)	175.53

The areas where there are high to very high levels of disturbance occur throughout the urbanised and industrialised area of the Georges River Estuary including Cabramatta Creek, Prospect Creek and Moore Lake. The riparian vegetation around Moore Lake and Bulba Dibeen Island has the disturbance severity code of “Very High Intensity Disturbance Pattern” due to historical clearing. This area was observed in the field as currently being disturbed due to a high density of invasive plant species.

Invasive plant infestations were recorded as the main type of disturbance threatening the health of the riparian vegetation during field investigations. The DECCW mapping (2009a) showed a moderate to high level of disturbance classification along the majority of Cabramatta Creek (Figure 8.7a) due to invasive plant species. This was observed in the field for this area as well as for Harris Creek, which has a classification of high to moderate disturbance due to the presence of invasive plant species. The riparian vegetation along Williams Creek is classified within a range of severity codes, though is predominantly Moderate to High. Major disturbance types were historic clearing, regrowth and invasive plants (Figure 8.7b). In the field the vegetation in this area was recorded as being in good condition, with minor invasive plant cover. A tributary of Williams Creek, Harris Creek was observed to have a greater density of invasive plant cover. This location has been classed as a invasive plant hot spot, which is discussed in Section 8.3.5.

The contrasting condition of the two sides of Mill Creek was observed in the field and in the disturbance mapping (Figure 8.7c, Appendix 3). The downstream portion of Mill Creek is located within the Georges River National Park. The western side was previously military land and extends further away from the creek compared to the eastern side, which borders an urbanised area. The disturbance on the western side is classified as low to moderate due to no signs of disturbance and invasive plants, which was verified in the field with the vegetation noted to be of a good condition. This is in comparison with the eastern side near the confluence with the Georges River which is classified as having a high level of disturbance due to primarily consisting of regrowth. This regrowth area would act as a buffer to the urbanised area at the top of the slope, however during field investigations invasive plant species and sedimentation were recorded in this area. This is considered to demonstrate the importance of a buffer between the river and urban areas as well as the impact that urban areas have on natural bushland areas.

Overall, the condition of riparian vegetation was found to be predominantly of a good quality with minimal invasive plant invasion during the site visits. Areas that were more prone to invasive plant invasion and other threats such as erosion were communities located in the upstream areas on more erodible soils, located near stormwater outlets, close to urban areas and where rubbish collected due to the river flow direction. The Cumberland Riverflat Forest (River Flat Eucalypt Forest EEC) contained the highest levels of invasive plant invasion.

Management of the condition of riparian communities is important, especially as poor management can affect areas upstream and downstream due to the tidal nature of the system. Parts of the study area have been observed where one side of the river is predominantly invasive plant free, while the opposite side is highly invaded. As invasive plant seeds are easily spread by water and wind, these present future management issues.

Condition and thus disturbance levels can be utilised as a management tool within the estuary management process as part of the next step for the study area. Areas identified as having less disturbance should be prioritised for improvement and for future management in reserved areas if not already reserved, and those areas with moderate disturbance maybe targeted for active restoration activities within the study area. As such, this should be investigated further in relation to future management and investigations for the Georges River Estuary.

Further detailed investigation into the condition of riparian vegetation communities of the study area is required. This is the next step of the estuary management process to further prioritise sites identified in this study. By prioritising sites according to condition and level of rehabilitation and regeneration required, this would assist in the conservation and persistence of this vegetation into the future. It is likely that most works associated with the terrestrial vegetation associations of the study area would be concentrated within those areas that individual Council's have management or ownership rights. This will guide future prioritisation for grants and funding for restoration activities within the study area. A preliminary investigation of prioirity areas has been undertaken and these are identified in the site specific management recommendation maps (Appendix 3). These areas are recommended to have further investigation and condition assessments undertaken to identify the most appropriate areas for improvement works such as regeneration to improve their current condition and increase their habitat value.

Further analysis may consist of:

- Investigating the amount of each vegetation community within the study area compared to the amount within each LGA to ensure a broader understanding of distribution and reservation can be attained; and
- Investigating the location of each vegetation community in terms of its conservation status with data gained on the amount within the formal conservation reserve system, within informal conservation areas and other tenures.

8.3.4 Threatened Flora Species

The terrestrial ecosystems within the Georges River study area provide habitat for a range of rare and significant flora species. This includes a range of flora species listed as threatened in NSW under the TSC Act and Federally under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), as well as species listed as Rare or Threatened Australian Plants (ROTAP species). The following section details the likely occurrence and conservation significance of flora species within the riparian zone.

A search of threatened and rare species recorded within the NSW Wildlife Atlas (DECCW 2010) was undertaken for the Georges River study area (Table 8.17, Appendix 5). A total of 10 threatened species were recorded within the riparian zone. From these 10 species, eight are also listed as ROTAP species. Apart from one species, all have been recorded since the 1960s, with only the Coast Groundsel (*Senecio spathulatus*) being recorded within Towra Point Nature Reserve prior to 1960. This species is potentially locally extinct within the reserve as the most recent record is from 50 years ago. Common threats to the persistence of the listed threatened species recorded include habitat loss, urban development, invasive plants and appropriate fire frequency (Table 8.17, Appendix 5). These threats are due to the highly urbanised nature of the land surrounding the Georges River, with this land use encroaching on the remaining natural areas.

Over two thirds of the records for threatened species within the riparian zone occur out side of reserved areas that are National Parks, Nature Reserves, Reserves and Parks. This is of concern as with increasing urbanisation the role of these bushland areas to preserve current threatened species as well as common species will become increasingly important. As part of the next stage of the estuary management process, it will be necessary to confirm the records of threatened species on the ground and the amount and condition of available habitat within these unreserved areas for future planning strategies for the catchment.

The majority of significant flora species and records occur within Bankstown CC, followed by Sutherland SC and Liverpool CC (Table 8.17, Appendix 5). It is interesting to note that although Bankstown City Council has the largest number of threatened species and records

of these, they also have the largest number of recorded species occurring within reserves and parks. Hurstville CC had one of its two recorded species in a park. It is noted that the accuracy of the records varies between species and recorded locations and as such this information needs to be confirmed on the ground. The variation in accuracies may be due to locations being recorded using different techniques which have different accuracies. For example a Global Positioning Satellite (GPS) device versus locating on a map.

Due to the small amount of recorded threatened species occurring within bushland and more importantly reserved bushland, it is recommended that the potential locations for threatened flora species is investigated further based on their habitat preference. Ground truthing of existing records is also recommended due to many being pre 1980. The aim of this investigation would be to determine management priorities for known threatened species within the study area to reduce their risk of becoming locally extinct. Further by reserving and preserving their existing habitats it is anticipated that this will protect habitat values for many native species that still commonly occur, reducing their potential to be listed as a threatened species in the future.

8.3.5 Invasive Plant Species

An invasive plant species is any plant that requires some form of action to reduce its effect on the economy, the environment, human health and amenity (Commonwealth of Australia 2007). An invasive plant can be an exotic species or a native species that colonises and persists in an ecosystem in which it did not previously exist. They are often excellent at surviving and reproducing in disturbed environments and are commonly the first species to colonise and dominate in these conditions (Commonwealth of Australia 2007).

The study area occurs in an urbanised catchment, making it highly vulnerable to invasive plant invasion. This threat is increased by the dominance of the aquatic environment, which acts as a transporter for invasive plant species. Therefore if an area is managed in the lower reaches, the success of the works can easily be threatened by an unmanaged vegetation area in the upper reaches of the river. Due to this it is important to manage invasive plant species at a broader scale then the local one when a river system is part of the management area. Especially as once invasive plants become established, their control and removal becomes increasingly difficult (Bankstown City Council and Eco Logical Australia Pty Ltd 2002).

Invasive plant species have been mapped within the study area (see Figures 8.6a – g, Appendix 3), reported in local council reports and management plans and are generally a common occurrence throughout the study area. Invasive plant species compete with native species, reducing the diversity of flora species in an area, therefore reducing the structural diversity of habitat and the diversity of fauna species that can be supported. Invasive plant species are usually more abundant on the edges of a vegetation remnant, though are also found in the core bushland areas after being transported by stormwater, recreational users, birds or airborne dispersal (Bankstown City Council and Eco Logical Australia Pty Ltd 2002). Stormwater acts not only as a movement mechanism for invasive plant species but also changes the soil nutrient level and moisture by containing pollution from pavement runoff, sewerage and drainage overflow (Webb 1996 In Bankstown City Council and Eco Logical Australia Pty Ltd 2002 & Eco Logical Australia Pty Ltd 2003).

Invasive plant species recorded during the field investigations are listed in Table 8.20 (Appendix 4). It was noted that dominance of invasive plant species varies throughout the riparian environment in the study area. Hot spots for invasive plant species were identified and are shown in Figures 8.10a to 8.10d (Appendix 3). The hot spots were:

- Near Liverpool Weir – on Sewage Treatment Plant and along McMillan Park (Liverpool CC);
- McMillian Park – including the vegetation islands in this area (Liverpool CC);
- Harris Creek northern side (Liverpool CC);
- Warwick farm (Liverpool CC);
- Cabramatta Creek (Liverpool CC and Fairfield CC);
- Upstream area of Prospect Creek (upstream of Liverpool Golf Club);
- Riparian edge near old tip site on Salt Pan Creek (Canterbury CC);
- Beauty Point – invasive plants encroaching from urban edge with Lantana (*Lantana camara*) dominating the understory of the Swamp Oak Floodplain Forest, *Juncus acutus* (Bankstown CC); and
- Oyster Depot – Towra Point (Sutherland SC).

An invasive plant hot spot that was once linked to the study area is Yeramba Lagoon, within Georges River National Park. This freshwater lagoon, which was once estuarine, is regularly infested with invasive plants (Carla Ganassin, I&I NSW *pers. comm* 26 March 2010). A masterplan for Yeramba Lagoon was completed in August 2009 (Eco Logical 2009) and includes actions to control invasive plant infestations. Prior to this masterplan, Bankstown City Council identified that to improve water quality in the lagoon an ongoing aquatic weed management plan should be established (NSW DIPNR 2004a).

Different vegetation communities were found to be more prone to invasive plant infestations than others. For example invasive plant species were not identified within the Estuarine Mangrove Forest, due to high salinity and water inundation, and were minimal within Swamp Oak Floodplain Forest. It was found that the presence of Casuarina species suppressed invasive plant invasion, and where invasive plants were present, they occurred in small numbers and were more likely to occur within the canopy in the form of vines. This is consistent with findings in other areas where *Casuarina* species occur (Swearingen 2009). They form a monoculture, changing the soil characteristics for their benefit which restricts the growth of other plant species (Swearingen 2009).

An invasive plant species that presents a common threat in saltmarsh areas is Sharp Rush (*Juncus acutus*). This species is widespread in the Sydney metropolitan area and its eradication is difficult (Williams *et. al.* 2004). Along the Georges River it causes the greatest threat to the saltmarsh areas (which are listed as an endangered ecological community), including displacing the native Sea Rush (*Juncus kraussii*) and invading adjacent communities where it forms dense stands (Williams *et.al.* 2004). It is well-established in a number of the saltmarsh areas in the study area, however the spread of this species is being managed in some areas (Williams *et.al.* 2004). At Beauty Point Reserve (Bankstown City Council) this species is being controlled by hand removal, after which it is left in situ to dry out and break down (see Appendix 8, Plate 1). A different control method is being utilised at Stuart Street Reserve (Bankstown City Council) for this species. The plants have been slashed and then herbicide was applied (Cameron Lownds Bankstown City Council *pers. comms.* 29 April 2010). Although regrowth was recorded from some of the treated plants (see Appendix 8, Plate 2a and 2b) follow up control has ensured a good success rate of control (Cameron Lownds Bankstown City Council *pers. comms.* 29 April 2010).

American Pennywort (*Hydrocotyle bonariensis*) is also known to occur in saltmarsh communities and is often considered an indicator of disturbance in an area. This species was recorded during the current study with extensive cover at Towra Point at an Old Oyster

Depot (see Appendix 8, Plate 3 and 4). The occurrence of this species was also recorded by the Georges River Biodiversity Study (Williams *et al* 2004) in Sylvania and Woolooware Bay.

Terrestrial invasive plant species that were found to be common within the study area include Balloon Vine, Lantana, Small-leaved Privet and Morning Glory. In particular, vines were dominant along the Georges River near Liverpool Weir. Within Towra Point Nature Reserve the most common invasive plant species is Lantana (NPWS 2001c). Bitou Bush (*Chrysanthemoides monilifera*) and African Olive (*Olea europaea* subsp*. cuspidata*). Invasive plant control at Towra Point Nature Reserve has been undertaken by 'Friends of Towra', Conservation Volunteers Australia and Greencorp team (NPWS 2001c).

A number of noxious invasive plants are known to occur within the study area or were located within the Georges River Estuary during the current investigation. Noxious invasive plants are species that are considered to pose a serious threat and by law are required to be controlled by all landholders in an area (I&I NSW 2005a). Noxious invasive plant species are listed under the NSW *Noxious Weeds Act 1993* (I&I NSW 2005a). Table 8.19 includes the Noxious invasive plants identified within the current study within the study area. It is noted that due to the limited field assessments undertaken for this study, this list is probably significantly longer. Future work is recommended to determine the location and distribution of noxious invasive plant species for future management.

Table 8.17 – Recorded noxious invasive plants in study area

Scientific name	Common Name	Location	Council Area	Control requirements
Opuntia stricta	Common Prickly Pear	Near Liverpool Weir (south side) Bulba Gong Island (Liverpool)	Liverpool City Council Liverpool City Council	Class 4 This is an all of NSW declaration
Ricinus communis	Castor Oil Plant	Salt Pan Creek (east side) Old Tip site	Canterbury City Council	Class 4
Ligustrum sinense	Small-leaved Privet	Cabramatta Creek (Fairfield side)*	Fairfield City Council	Class 4
Olea europaea subsp. cuspidata	African Olive	Towra Point – Oyster Depot*	Sutherland Shire Council	Class 4
Cestrum parqui	Green Cestrum	Salt Pan Creek (east side) Old Tip site	Canterbury City Council	Class 3
Parietaria judaica	Pellitory/ Asthma weed	Salt Pan Creek (east side)	Hurstville City Council	Class 4*
Lantana camara	Lantana	Salt Pan Creek (east side)	Hurstville City Council	Class 4*
		Beauty Point	Bankstown City Council	Class 4*
		Towra Point	Sutherland Shire Council	Class 4*

Scientific name	Common Name	Location	Council Area	Control requirements
		Riparian edge next to Liverpool Sewage Treatment Plant McMillian Park Cherrybrook Park (Liverpool side) (and south of Warwick Farm Racecourse) South Park (Liverpool) Bulba Gong Island (Liverpool)	Liverpool City Council	Class 4*
		Cabramatta Creek (Fairfield side)	Fairfield City Council	Class 4*

Table Note: Class 3: The plant must be fully and continuously suppressed and destroyed; Class 4: The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed; Class 4*: The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority.

Aquatic invasive plant species are not unexpected in a river system that is part of a highly developed catchment area. An aquatic invasive plant species that is considered to pose a serious threat to waterways is Alligator weed (*Alternanthera philoxeroides*). This species is a declared noxious weed in the entire study area and are also classed as a Weed of National Significance (WONS). WONS include a list of 20 introduced plants that are considered to be the worst invasive plants in Australia due to their invasiveness, potential for spread, and environmental and economic impacts (I&I NSW 2005a).

Aquatic invasive plant species have been previously recorded within the study area and have been recorded by the Georges River Biodiversity Study (Williams et al 2004). This includes Alligator weed being recorded in the saltmarsh at Moon Bay, Lugarno. Older records exist with infestations of Alligator weed recorded in Cabramatta Creek (Muston & Associates 1999). During recent field investigations no aquatic invasive plant species were recorded, however this is not considered to reflect their absence.

Invasive plant management is required as a continual management action in natural areas management. The study area includes seven different LGAs (including Fairfield City Council). This increases threats to the study area when there are different priorities and resources for management. It is recommended:

- Management and control of aquatic and terrestrial invasive plant species through bush regeneration programs including bushcare groups;
- Co-ordination between Councils on opposite sides of creeks to manage invasive plants to reduce transfer between banks and downstream into estuary (eg Cabramatta Creek – Liverpool and Fairfield, Prospect Creek – Bankstown and Fairfield, Salt Pan Creek – Bankstown and Hurstville); and

- Invasive plant control in River-Flat Eucalypt Forest EEC in LGAs where this community occurs (Bankstown, Hurstville, Liverpool, Sutherland), particularly for Liverpool where greater than 50% of this community is located within the study area.

8.3.6 Riparian Vegetation Management Priorities

The riparian vegetation communities are faced with many threats in their current environment. The most common threats include urban development, clearing, invasive plant invasion, rubbish dumping, recreational pressures, fire and inappropriate frequencies and trail bike riding.

Management priorities for riparian vegetation are summarised below. These are further detailed more specifically within Section 8.6 of this document for each LGA area.

- Identification of sites for rehabilitation and regeneration ensuring appropriate reservation of riparian communities within the study area based on remnant size and distribution within SMCMA;
- Identification of sites for rehabilitation and regeneration of EECs ensuring appropriate reservation of riparian communities within the study area based on remnant size and distribution within SMCMA;
- Appropriate reservation and management of remnants of Swamp Oak Floodplain Forest EEC and Kurnell Dune Forest EEC which have large remnants occurring within the study area compared to their distribution with the SMCMA (25% and 40% respectively);
- Further investigation of threatened flora species within the study area, including ground truthing of existing records;
- Reservation and preservation of existing threatened flora species habitats;
- Continual invasive plant management including co-ordination between neighbouring LGAs with a focus on areas where River-Flat Eucalypt Forest EEC occurs; and
- Formulate a bush regeneration strategy to ensure that the spread of invasive plant species along the riparian corridor is minimised to decrease the potential of invasive plants spreading into large areas of bushland (with particular attention on the invasive plant hot spots).

8.4 Fauna

A variety of fauna species inhabit the estuarine environment of the study area including fish, decapods including crabs, and molluscs including snails. A recent study of the Georges River found that the estuarine fish community present is comparatively diverse and abundant compared to other NSW estuaries (Williams *et.al.* 2004). The study recorded 87 different fish, decapods and molluscs species. Seagrass was found to be very important habitat for estuarine species with two thirds of the catch taken from these areas even with a reduced number of hauls (Williams *et.al.* 2004).

A number of terrestrial fauna associated with the riparian areas and semi-aquatic areas also occur within the study area. The Georges River Corridor has been identified as one of the major fauna movement corridors in the Sydney area, playing an important role in linking numerous species with the coast, Western Sydney and the Woronora Plateau (Eco Logical 2002). This includes a range of significant fauna species and populations that are listed as

threatened under NSW and Federal legislation or are included within international conventions (such as migratory birds).

8.4.1 Fauna Habitat

A number of different fauna habitats occur within the Georges River Estuary and surrounding areas. As discussed in the vegetation section above, two main forms of vegetation occurs within the study area, estuarine vegetation (those areas that are inundated by tidal movements or within the channel) and terrestrial riparian vegetation. These two broad vegetation communities form a mosaic of fauna habitat throughout the study area.

One of the most significant fauna habitats within the study area is estuarine wetlands and associated zones. This includes areas of saltmarsh, mangrove and tidal flats and transitional zones between estuarine vegetation and terrestrial riparian vegetation. Wetlands and associated tidal mudlflats provide important fauna habitat, in particular for migratory bird species (SPCC 1979).

Few of these areas currently occur within the study area, mainly as a result of the intensive use of the area for industry, housing and other development since settlement. However, a large area of estuarine wetland remains within the southern part of Botany Bay (on the Kurnell Peninsula) within the study area. The large and significant wetland, Towra Point Nature Reserve, is internationally recognised (Ramsar, JAMBA, CAMBA and ROKAMBA agreements) for its habitat features, particularly for migratory birds (see 8.5.2).

Two smaller wetland areas are found within the Georges River National Park, on the southern side of the river opposite Picnic Point. Management actions are being undertaken to protect the saltmarsh vegetation and to provide habitat for fauna species in these areas. One of the wetland and saltmarsh areas had been damaged by the use of trail bikes and 4WD (Simon Annabel NSW I&I 19 November 2010). To rehabilitate the area, fencing was installed to restrict access and revegetation with native plant species. Further, interpretive signage has been erected to educate the local community on the importance of the area as a wildlife habitat. Plates 5 and 6 depict rehabilitation efforts currently being undertaken within this wetland (Appendix 8).

Towra Point

Towra Point Nature Reserve and Towra Point Aquatic Reserve form the largest and most diverse estuarine wetland complex remaining in the Sydney area (DECCW n.d) and are considered to be of high conservation value for fauna habitat. Towra Point Nature Reserve currently encompasses 386.4 hectares, including the bed and foreshores of Weeney Bay and lands at Quibray Bay (NSW NPWS 2001a). This reserve is composed of important remnant terrestrial vegetation and wildlife habitats and is surrounded by aquatic vegetation communities including seagrass beds, mangroves and habitat for migratory wading birds (DECCW n.d) which form Towra Point Aquatic Reserve.

The Towra Point wetland systems are physically important to the Georges River system by acting as a drainage buffer during floods, trapping sediment and pollution and by reducing currents and wave energies reaching the shore (NSW NPWS 1994). Biologically, these environments are critical as they contribute to estuarine productivity and recycling, and to the transfer of nutrients to the soil and adjacent waters (NSW NPWS 1994).

Towra Point contains approximately 50 per cent of Sydney's remaining mangrove communities and 90 per cent of the city's remaining saltmarsh communities. This makes these wetlands a particularly good representative example of this wetland type within the Sydney Basin bioregion. Several species and communities listed as threatened or

endangered in NSW are also found within the Nature Reserve. These include saltmarsh, Swamp Oak Forest and littoral rainforest communities. These communities form a variety of fauna habitat for a range of common and rare wildlife.

Bird species are abundant within Towra Point nature reserve where approximately 200 species have been recorded (DECCW n.d). A large proportion of these species are migratory, identifying this area as important foraging and staging areas for these species during their migration period.

An ecological character description (ECD) has been undertaken by DECCW (2008) for Towra Points and is being finlaised and is due for release this year (John Dahlenburg, SMCMA *pers. comm*. 26 March 2010). The assessment is being carried out due to the listing of Towra Point wetlands as a wetland of international significance under the Ramsar agreement (SPCC 1979) and will document the condition of the at the time of listing and now and include threats to this ecologically sensitive area (John Dahlenburg, SMCMA *pers. comm*. 26 March 2010). It is recommended that this report be reviewed during the Estuary Management Plan stage. This is to gain a greater understanding of the estuary in this significant area and to consider if any of the management actions recommended are relevant to the Georges River estuary as a whole.

8.4.2 Fauna Groups

Zooplankton

Zooplankton are floating or weakly swimming animals that rely on water currents to move any great distance. There are two major types of zooplankton: those that spend their entire lives as part of the plankton (called Holoplankton) and those that only spend a larval or reproductive stage as part of the plankton (called Meroplankton) (Australian Museum 2009a). Zooplankton include a large range of organisms including: foraminiferans; radiolarians; dinoflagellates; cnidarians (i.e. jellyfish); crustaceans (i.e. copepods and krill); chaetognaths (e.g. arrow worms); molluscs (e.g. pteropods); and chordates (e.g. salps and juvenile fish).

The wide range of zooplankton organisms has feeding behaviour of filter feeding, predation and symbiosis. Zooplankton feed on bacterioplankton, phytoplankton and other zooplankton detritus. As a result, zooplanktons are primarily found in surface waters where food resources (phytoplankton or other zooplankton) are most abundant. Through their consumption and processing of phytoplankton (and other food sources), zooplankton play an important role in aquatic foodwebs, both as a resource for consumers on higher trophic levels, such as fish, and also plays a role in nutrient cycling of the water column. As such, zooplankton are of limited use as environmental indicators, but are useful as an element of biotic indices that relate to trophic groups.

Benthic Invertebrates

Benthic invertebrates are organisms with no back bone that live on the bottom of a water body or in soft muddy bottom substrates. They range from microscopic (e.g. microinvertebrates, <10 microns) to a few tens of centimetres or more in length (e.g. macroinvertebrates, >50 cm) (OzCoasts 2010a). Benthic invertebrates live either on the surface of rock, coral or sediment or within sedimentary deposits and comprise of several types of feeding groups including: deposit-feeders; filter-feeders; grazers; and predators.

Benthic invertebrates are an important component of the estuary ecosystem, particularly from the perspective of nutrient cycling and transfer of energy through the food web. Benthic organisms are a direct source of food for fauna including fish and many internationally recognised migratory birds.

Benthic invertebrates, such as deposit-feeding polychaetes, build burrows and tubes that help mix the sediment and enhance aerobic decomposition of organic matter (Bird 1994). Organic matter is a source of food and energy, and its nutritional balance (Total Organic Carbon:Total Nitrogen:Total Phosphate ratio) plays an important role in material flow through ecosystems (OzCoasts 2010b). If organic matter, and the nutrient balance is not maintained, this can lead to eutrophication. The process and implications of eutrophication have been discussed in Section 6.2.5.

The abundance, diversity, biomass and species composition of benthic invertebrates can be used as indicators of changing environmental conditions. Several processes likely to cause changes in benthic invertebrate assemblages are:

- Physical parameters (substrate composition, water temperature, depth, dissolved oxygen concentrations, pH, salinity, and hydrography);
- Biological factors (e.g. primary productivity, competition and acclimatisation);
- Heavy metals and toxicants can bioaccumulate and have several lethal and sub-lethal effects on benthic organisms. Under contaminated conditions, communities tend to become simplified and some species can get physical abnormalities (ANZECC & ARMCANZ 2000);
- Flood events and associated scour of sediment in the river bed;
- Salinity. There is a tendency for estuaries to have maximum species richness at salinities of >30 ppt, and a minimum number of species at salinities of ~5-8 ppt (Remane and Schlieper 1971 in WBM 2006);
- Dredging can smother organisms by settling silt; increase depth beyond the euphotic zone; increase in water turbidity; changes in water quality; and changes in water movement patterns (SPCC 1979);
- Introduced marine pests can displace indigenous species by predation and competition or by changing physical, biological and structural components of exiting habitat;
- Low pH runoff from acid sulfate soils has also been known to cause mass mortalities of crustaceans and shellfish (Sammut et al 1995 in OzCoasts 2010a); and
- Supply of organic matter (e.g. seagrass wrack) and it's breakdown leading to anoxic conditions.

Benthic invertebrates are likely to occur throughout the majority of the estuarine areas of the study area. However, very few studies have been undertaken in the study area using benthic invertebrates to detect environmental change. This is possibly because the cost of such biological monitoring is higher than physical or chemical monitoring due to its labor intensive sampling and sorting techniques.

One study, undertaken by Kogarah Council, assessed the potential impacts of contaminants associated with stormwater runoff and leachate from the Moore Reserve on the benthic sediment and associated fauna in Oatley Bay. The primary contaminants considered likely to be impacting upon Oatley Bay as a consequence of the previous surrounding land use were heavy metals such as copper, lead, zinc, chromium, mercury, arsenic and nutrients such as nitrogen and phosphorus. The study used other sites in the area, Neverfail Bay, Connels Bay, Kyle Bay and Oyster Bay as reference and comparison sites.

The sediment composition in Oatley and Oyster Bays were found to be outside the health based guidelines and were similar to each other despite the faunal assemblages differing (GHD 2006). Oatley Bay had in-fauna communities that were similar to the other bays, however the benthic sediment had elevated levels of a number of heavy metals (GHD 2006). Though, the similarity to Oyster Bays sediment composition made it difficult to determine whether the contamination levels in Oatley Bay are therefore directly attributable to the past land uses at the Bay and additional survey would be required to determine temporal changes in the Bay and determine the landuses that are potential drivers of elevated metals. The Georges River Riverhealth Monitoring Program is currently being undertaken over two years and is funded by a Federal Government Grant (GRCCC 2010a). This study is being run by the GRCCC, SMCMA and Streamwatch and is the first one to assess the regional health of the Georges River with the aim of identifying priority areas for future conservation works (GRCCC 2010a). The program monitors water quality, riparian and estuary vegetation and macroinvertebrates (GRCCC 2010a). The first sampling period was conducted over four weeks encompassing 42 sites in October and November 2009 (GRCCC 2010a). The report of this sampling event, the River Health Monitoring Report Card was released for viewing during preparation of this report (GRCCC 2010b). It is recommended that this report and future reports are reviewed and priority areas are included as management recommendations during the Estuary Management Plan stage.

Molluscs

Molluscs are invertebrates with a body made up of a head and a muscular foot, and include species with a wide range of body forms including clams, snails, squids and chitons (Pollard & Pethebridge 2002). Molluscs inhabit the estuary environment within the study area and were observed in saltmarsh (See Appendix 8, Plates 7 and 8). A study of pest species in Botany Bay recorded the mollusc species in this area (Pollard & Pethebridge 2002). Seventy four mollusc species were captured from Botany Bay, however compared to the 500 species identified to date in the Bay this is only considered to be a small number (Pollard & Pethebridge 2002).

Some mollusc species have experienced reductions in their distribution and/or abundance due to habitat degradation in Botany Bay, with some potentially absent (Pollard & Pethebridge 2002). The bivalve *Hiatella australis* was caught in high numbers within Botany Bay. This species habitat is the crevices of rocks or other shells (Altoff &Falconer 2008). Along the foreshore of the study area around Botany Bay and upstream where it was rocky there is potential habitat for molluscs that prefer a rocky environment. Hairy Mussels (*Trichomya hirsuta*) were also recorded in large numbers. A species whose habitat includes intertidal areas including in estuaries, *Cymatium parthenopeum,* was recorded in this study (Beechey 2009).

Crustaceans

Crustaceans are found both within the Georges River and Botany Bay in the study area. They are found along the riparian edge grazing, particularly within mangrove forests and saltmarsh areas which support a high level of productive and organic composition, which provide foraging resources. Crab and snail species encountered during field work are shown in Appendix 8, Plate 9.

The Graspid Crab (*Helograpsus haswellianus*) commonly inhabits mangroves and saltmarsh areas where they make burrows in the soft sediment (Breitfuss 2003 *in* Price *et.al.* 2007). Another common species inhabiting mangroves as well as estuaries is the Semaphore Crab (*Heloecius cordiformis*) (Australian Museum n.d). Their diet includes small particles of dead plants and animals as well as algae and micro-organisms (Australian Museum 2009b). Crabs provide a food source to birds and fish species (Australian Museum 2009b).

Apart from crabs, fish also feed on the snails that inhabit the saltmarsh area during high tide when these areas are inundated (Price *et. al.* 2007). Snails form an important part of the cycle of estuarine environments by grazing on algae and detrital material (Price *et.al.* 2007). Two snail species which have adapted to inhabiting this highly saline environment include Salinator solida and Ophicardelus ornatus (Price *et.a*l. 2007). Both of these species have been recorded at Towra Point (Roach 1998).

Fish

Estuarine fish habitats occur where fresh water from rivers and streams mixes with salty ocean water. There are a number of fish species that are dependent on estuary habitats, with 70% of coastal fish species in south-eastern Australia requiring estuaries to complete their life cycle (Copeland & Pollard 1996 in I&I NSW 2005). Estuaries and tidal creeks are important for fish providing shelter, and feeding, breeding and nursery habitats for a number of fish species during all, or some of their life cycle. Habitat utilised by fish include mangroves, seagrass and mud of sand flats. Artificial habitats such as jetties, concrete culverts, pipes and fauna friendly seawalls may also be utilised by some fish species.

A number of fish species use multiple habitat areas within an estuary during different stages of their lifecycle and during different seasons. For example Dusty Flathead (*Platycephalus fuscus*) use seagrass beds as spawning grounds. They utilise seagrass beds, mangroves and shallow mud as small juveniles, as large juveniles they move to deep mud, and as adults they utilise seagrass habitat during summer and winter but also use deep mud during winter (NSW DECCW 2010).

There have been a number of studies and reports of the fish of Botany Bay and the Georges River. However, these have primarily been focused on the habitat and species in Botany Bay, with few studies extending into the estuary. The biodiversity study of the Georges River (Williams 2004) was one of the first comprehensive fish studies of the length of the Georges River estuary.

Results from this study showed the greatest fish catch numbers for the Eastern Striped Trumpeter (*Pelates sexlineatus*) and the Port Jackson Glassfish (*Ambassis jacksoniensis*).The Sandy Sprat (*Hyperlophus vittatus*), Sand Whiting (*Sillago ciliata*) and Fortescue (*Centropogon australis*) were also caught in large numbers (Williams et al 2004). A large portion of the fish recorded was of commercial/recreational significance such as Dusky Flathead and Tailor (*Pomatomus saltatrix*). Two threatened species were considered likely to occur in the area, the Black Cod (*Epinephelus daemelii*) and Green Sawfish (*Pristis*

zijsron), however, no threatened species were captured in this study. One of the recommendations of the study was that a more vigorous sampling effort would be needed to confirm the presence of these threatened species in the estuary.

The biodiversity study also found that a greater number of fish were found in the vegetated sites (i.e. seagrass areas) in comparison to the non vegetated sites (mud or sand flats). As a result of this, there were fewer fish in the upper reaches of the estuary where there were less seagrass meadows present. The upper part of the estuary, the Riverine Channel, had considerably less numbers, species and fewer commercial/ recreational fish than the Marine Tidal Delta, Central Mud Basin and the Fluvial Delta. These results confirm the importance of seagrass meadows for fish habitat.

Several important fish nurseries have been identified in the study area, one of these is Scarborough Ponds, located in the central section of the Rockdale Wetlands Recreation Corridor (Rockdale City Council date unknown). Fish have been found to travel from Botany Bay to Scarborough Ponds through pipes, with species recorded by I&I NSW including juvenile bream and mullet (Rockdale City Council n.d).

The level of rubbish and dumped items in the estuary, as well as the history of landuse along the river, has an effect on fish health. Industrial land uses and rubbish within the estuary leads to poor water quality and the accumulation of heavy metals in fish tissue. This is evident particularly in the upper reaches of the river where there is less tidal flushing of the water and sediment. For example, a sign directed at recreational fisherman in the upper reaches of Salt Pan Creek (under Henry Lawson Drive Bridge) states 'Do not eat fish', which is a reflection of the health of fish residing in this area.

Future fish populations in the Georges River will be influenced by the changes in environmental conditions of the estuary as a result of climate change. CSIRO has undertaken modelling to identify impacts of climate change on Australia's fisheries and aquaculture (CSIRO 2008). Changes include: temperature; ocean currents; winds; nutrient supply; rainfall; ocean chemistry; and extreme weather conditions. As a result of this, one of the major predictions (being changes in temperatures, current patterns, and primary and secondary production) may affect larval fish health and transport thereby influencing recruitment potential (CSIRO 2008).

Birds

The study area provides habitat for a diverse range of bird species, including foraging, staging, roosting and nesting habitat. This includes species utilising the estuarine environment such as Dusky Moorhens (*Gallinula tenebrosa*), White-faced Heron (*Egretta novaehollandiae*), Striated Heron (*Butorides striatus*), Darters (*Anhinga melanogaster*) and Cormorant species (*Phalacrocorax* species). The riparian edge within the study area also provides habitat for range of birds including the Bell Miner (*Manorina melanophrys*), Australian Raven (*Corvus coronoides*) and all of the previously mentioned species which use the edge as roosting and nesting habitat.

The study area provides important habitat for migratory species, in particular at Towra Point Nature Reserve, where a large wetland habitat area occurs. Towra Point is known to provide habitat for 31 of the 66 species presently listed in the Japan-Australia Migratory Birds Agreement, as well as a number of species listed in the China-Australia Migratory Birds Agreement and the Republic of Korea–Australia Migratory Bird Agreement. The Towra Point wetlands provide both saltwater and freshwater swamps habitats and are listed as a wetland of international significance as a result of this habitat under the Ramsar agreement (SPCC 1979).

The Towra Point area is an important Little Tern (*Sterna albifrons*) breeding area (NSW NPWS 2003). This species is listed as threatened in NSW. National Parks and Wildlife Service carries out monitoring for this species. Recent monitoring (NSW NPWS 2003) confirmed the importance of Towra Spit lsland for the conservation of this species.

Bulba Gong Island in Chipping Norton Lake is mapped as containing the EEC River-Flat Eucalypt Forest on Coastal Floodplains and was noted to be in good condition with a healthy canopy cover, variety of species and providing habitat around the edges for waterbirds in the form of pockets of reed. The Striated Heron was observed on this island during field work. This island is being managed by the GRCCC with the assistance of Conservation Volunteers, who are currently undertaking invasive plant control. With ongoing management this island is considered to provide high quality habitat for waterbird species for roosting and breeding.

Other Terrestrial Species

The study area provides habitat for other terrestrial fauna species including reptiles, mammals and invertebrates that may utilise the riparian and estuarine edge habitats present. Such species are able to utilise the study area for foraging within the water, along its edge and amongst the fringing and riparian vegetation.

Reptile species that were observed during this study included the Eastern Water Dragon (*Physignathus lesueurii*), which was observed along Williams Creek, and the Common Tree Snake (*Dendrelaphis punctulata*), which was observed moving along a boardwalk and through mangroves on Salt Pan Creek. It is likely that the Red-bellied Black Snake (*Pseudechis porphyriacus*) would also occur in these areas as well as common skinks such as the Eastern Water Skink (*Eulamprus quoyii*).

Common mammal species that may utilise the study area include Bush Rat (*Rattus fuscipes*), Common Brushtail Possum (*Trichosurus vulpecula*), Common Ringtail Possum (*Pseudocheirus peregrinus*), Swamp Wallaby (*Wallabia bicolor*), Short-beaked Echidna (*Tachyglossus aculeatus*) and Brown Antechinus (*Antechinus stuartii*). The riparian areas provide abundant foraging resources for such species, as well as vegetation for arboreal mammal roosts and nests, and dense cover for ground-dwelling mammals.

Amphibians such as the Common Eastern Froglet (*Crinia signifera*), Brown Striped Marsh Frog (*Limnodynastes peronii*) and Peron's Tree Frog (*Littoria peronii*) are likely to occur within riparian vegetation and associated with smaller freshwater wetlands and tributaries of the estuarine study area.

8.4.3 Threatened Fauna

A total of 72 threatened and protected species under the *Threatened Species Conservation Act 1995* (TSC Act) and *Environment protection and Biodiversity Conservation Act 1999* (EPBC Act) have been previously recorded within the study area (as per the DECCW Atlas database (2010) and of the DEWHA Protected Matters Search Tool (2010)). Of these, it is estimated that suitable habitat occurs within the study area for 39 species, including 2 fish, 3 reptiles and amphibians, 25 bird and 9 mammal species. The likelihood for potential habitat to occur within the study area for each of these species is discussed in Table 8.22 (Appendix 5).

Figures 8.11a - c (Appendix 3) show the location of threatened fauna species records within the study area. Avifauna was the dominant fauna group with potential habitat for threatened species occurrence within the study area. In general, threatened avifauna species were found to have wide habitat requirements and thus the potential to occur throughout the

estuary. However, some species were more specialised in habitat requirements throughout the study area, with potential habitat limited to certain fauna habitat areas. Such species include:

- Wetland species - Australasian Bittern (*Botaurus poiciloptilus*) and Blue-billed Duck (*Oxyura australis*);
- Intertidal mudflats - Great Knot (*Calidris tenuirostris*) and Greater Sand Plover (*Charadrius leschenaultii*);
- Sandy Beaches - Little Tern (*Sterna albifrons*);
- Mangrove/Saltmarsh habitat - Black-necked Stork (*Ephippiorhynchus asiaticus*), Broad-billed Sandpiper (*Limicola falcinellus*) and Orange-bellied Parrot (*Neophema chrysogaster*); and
- Riparian habitat - Gang-gang Cockatoo (*Callocephalon fimbriatum*) and Swift Parrot (*Lathamus discolour*).

These species included aquatic and terrestrial species. Threatened aquatic species included the Dugong (*Dugong dugon*) and the Australian Fur Seal (*Arctocephalus pusillus doriferus*). These species have been recorded within the study area, which is considered to provide foraging habitat for them.

The Green Sawfish (*Pristis zijsron*) is listed in NSW as presumed extinct, with the last record in NSW in 1972 (I&I NSW 2007a). Williams *et al* (2004) recommends management actions for this species in a recent aquatic biodiversity study of the Georges River. However at this time the Green Sawfish was listed as an endangered species, with the listing being changed to presumed extinct in January 2008 (FSC 2008).

The Black Cod (*Epinephelus daemelii*) and Australian Grayling (*Prototroctes maraena*) are considered to have potential habitat within the estuary. Juvenile Black Cod have been recorded around rocky shores within estuaries (I&I NSW 2007b) and there are management recommendations for this species in the study by Williams *et al* (2004). A draft recovery plan for this species has been written with the objective of preventing the extinction of the Black Cod and to ensure this species recovery and continuing viability of NSW populations (I&I NSW 2009). This plan includes targeted measures to recover this species (Carla Ganassin, I&I NSW pers. comm 26 March 2010). The Australian Graylings lifecycle includes migrations between rivers, their estuaries and coastal seas (Backhouse *et. a.l* 2008).

Threatened mammal species recorded previously within the study area included the Eastern Freetail-bat (*Mormopterus norfolkensis*) recently recorded within Salt Pan Creek, Koala (*Phascolarctos cinereus*) with multiple records particularly near Deadmans Creek, and the Grey-headed Flying-fox (*Pteropus poliocephalus*) with species recorded within the study area most likely originating from the colony that inhabits a riparian area along Cabramatta Creek.

From the nine reptile and amphibian species recorded previously within the study area that were investigated further, there was potential habitat for three species within the study area. The Green and Golden Bell Frog (*Litoria aurea*) and Red-crowned Toadlet (Pseudophryne australis) were recorded within Georges River National Park and the Green Turtle (*Chelonia mydas*) recorded at Taren Point. The Green and Golden Bell Frog has been recorded throughout the estuary, including in upstream areas along Williams Creek and in freshwater swamps at Kurnell. The Green Turtle settles in shallow benthic foraging habitat such as inshore seagrass beds when they are older than five to ten years (DEWHA 2010b).

8.4.4 Pests and Introduced Species

The largely urbanised nature of the Georges River Estuary makes it more susceptible to invasion by pest and introduced species. A number of introduced fauna species have been

recorded within the area. This includes mammals such as the European Fox (*Vulpes vulpes*), Domestic Cat (*Felis catus*), Dog (*Canis familiaris*), European Rabbit (*Oryctolagus cuniculus*), and Brown Hare (*Lepus capensis*) (Bankstown City Council & Eco Logical Australia Pty Ltd 2002; NSW NPWS 1994; Environmental Partnership Pty Ltd (1996)); bird species including the Indian Myna (*Acridotheres tristi*s) and Feral Pigeon (*Columba livia*); and even insects such as the European Wasp (*Vespula germanica*) and European Honeybee (*Apis mellifera*) (Bankstown City Council & Eco Logical Australia Pty Ltd 2002).

European Fox baiting is currently carried out regularly at Towra Point Nature Reserve, with permanent baiting stations established (NPWS 2001c). This species is the main pest animal in the reserve and is known to pose a threat to the Little Tern during breeding season in the area. Foxes have the capacity to wipe out all of the eggs/and or chicks in the area within a single night (NPWS 2001c).

Introduced aquatic species are abundant within Botany Bay as a result of the high use of this area for shipping. A recent study by Pollard & Pethebridge (2002) investigated the introduced marine species found within the Bay. Prior to the study approximately a dozen species had been identified including four species of crustaceans, three molluscs, several worm species, toxic dinoflagellates, three goby species and the Japanese sea bass. The 2002 study found that there had been an increase in the number previously recorded, identifying an additional 18 introduced species and 15 of an unknown origin (cryptogenic) within the Bay. Identified species included:

- Two species of polychaetes (*Boccardia chilensis* and *Capitella capitata*);
- Four species of crustaceans (*Corophium ascherusicum*, *Corophium acutum*, *Paracerceis sculpta* and *Megabalanus rosa*);
- Eleven species of bryozoans (*Amathia distans*, *Bowerbankia sp.*, *Zoobotryon verticillatum*, *Conopeum seurati*, *Bugula flabellata*, *Bugula neritina*, *Bugula stolonifera*, *Cryptosula pallasiana*, *Schizoporella unicornis*, *Tricellaria occidentalis* and *Watersipora subtorquata*); and
- One ascidian (*Botrylloides leachi*).

The species of unknown origin included:

- Two species of algae (*Caulerpa filiformis* and *Pterosiphonia bipinnata*);
- Four hydrozoans (*Clytia hemisphaerica*, *Obelia dichotoma*, *Phialella quadrata* and *Antenella secundaria*);
- One anthozoan (*Culicia c.f. tenella*);
- Six species of crustaceans (*Megabalanus tintinnabulum*, *Megabalanus zebra*, *Caprella equilibra*, *Paracorophium excavatum*, *Pseudosphaeroma campbellense* and *Palaemonella rotumana*); and
- Two species of bryozoans (*Electra tenella* and *Fenestrulina sp.*).

According to the study by Pollard and Pethebridge (2002) there are three ways in which these exotic marine species were introduced into Botany Bay port Natural range expansion of species introduced to other areas of the south-eastern coast:

- Directly to the port by shipping use, either in ballast water or by hull fouling; and
- Domestic translocation via commercial fishing and recreational vessels.

In addition to these known mechanisms for introduction, domestic release of water invasive plants, fish and snail species from aquariums also has the potential to introduce exotic species to the estuary (John Dahlenburg, SMCMA *pers. comm*. 26 March 2010).

A marine pest known to occur within the study area is Caulerpa (*Caulerpa taxifolia*) (I&I NSW 2009). This marine macroalga plant species was identified first in NSW in 2000 in Port Hacking, leading to its listing as a Class 1 noxious species in 2001 under the *Fisheries Management Act 1994* (I&I NSW 2009). Since this first recording, Caulerpa has been identified in 14 lakes and estuaries including Botany Bay (I&I NSW 2009). The rapid growth of this species is of concern as it may out-compete native seagrass, as well as its ability to grow from small fragments into new plants (I&I NSW 2009). A management action includes controlling netting over infestation areas, with the Botany Bay Recreational Fishing Haven being closed to commercial netting (I&I NSW 2009). A recommendation from the Georges River Biodiversity Study (Williams *et al* 2004) was the integration of pest species management plans, including for Caulerpa, into planning instruments.

The Pacific Oyster (*Crassostrea gigas*) is listed as a Class 2 noxious species in all waters in NSW excluding Port Stephens where an established and important oyster farming industry for this species is located (I&I NSW 2005b). This species is very difficult to control when environmental conditions are suitable, and they are able to expand their range facilitated by their planktonic eggs and larvae dispersing naturally (I&I NSW 2005b). To reduce the spread of the Pacific Oyster in NSW the NSW Department of Primary industries (I&I NSW) has implemented a closure including strict criteria controlling their movement between estuaries as well as prohibiting movement into some areas (I&I NSW 2005b). It was enacted on the 4th December 2009 and includes the Georges River (NSW Government Gazette No. 189 2009).

8.4.5 Fauna Management Priorities

The estuary provides habitat for a range of threatened and common fauna species. The greatest threats to these species are to the extent and quality of their habitat within the study area and beyond. Threats include:

- Clearing of habitat historically for agriculture and more recently for urban development;
- Degradation of habitat due to encroaching urban development including invasive plant invasion, dumping, vandalism and pest species;
- Degradation of habitat due to increased erosion and sedimentation, nutrient runoff and stormwater overflow; and
- Increases in stormwater and therefore freshwater flow into the estuary effecting species that are adapted to, or require the presence of brackish water for their lifecycle.

All of these processes threaten fauna species' ability to inhabit the estuary system. Further, clearing and degradation leads to habitat fragmentation, reducing the ability of fauna to move throughout home range or to patches of suitable habitat and resource availability.

It is considered that one of the priorities for the study area is to protect, manage and conserve fauna species within the estuary, by focusing on habitat. It is recommended to continue to protect and manage existing natural bushland areas in line with any current management plans (ie Council bushland management plans) and the measures specified within this document (see Section 8.6). Nearly half of the vegetation within the study area is located within reserves, parks and national parks. It is therefore recommended to, where possible, increase the reservation of natural bushland areas within the estuary. This will decrease the potential for habitat areas to be further degraded through development and land use changes and also improve the existing habitat values of the study area, Reservation should focus on creating wildlife corridors throughout the Georges River catchment, which could also have multiple uses for recreational activities for the local community and also act as buffers for future sea level rise and associated likely succession

of estuarine vegetation. Management actions in existing bushland areas would include bush regeneration, pest control and litter collection.

It is important to know which species occur within an area to be able to inform management actions. As the current study is mainly desktop-based and preliminary in terms of fauna assessment, it is recommended to further investigate the faunal diversity and habitats that occur within the estuary, particularly for threatened fauna species. Some LGAs in the study area have already undertaken such investigations (Bankstown City Council and Eco Logical Australia Pty Ltd 2002), however a catchment-wide/estuary-wide approach would ensure that the linkages of fauna habitats and wildlife corridors were fully considered within any such assessment.

The quality of aquatic fauna habitat is influenced by water quality, pollution sources etc entering the estuary from surrounding land use. Due to the highly urbanised nature of the Georges River catchment, water quality management is important to ensure that the quality of the aquatic environment is maintained for fauna species. It is recommended that water quality monitoring being undertaken by the GRCCC in association with the SMCMA and Streamwatch (GRCCC 2010a) be incorporated into any future management of the estuary to provide environmental managers with the ability to assess the efficacy of management measures instated to minimise water pollution and to determine areas that requires water improvement actions.

These management priorities and recommendations are outlined in further detail in Section 8.6. This section breaks down the management priorities into each LGA area.

8.5 Management Priorities

Management priorities for the Georges River estuary have been identified using a risk assessment based process. Risk assessment provides a means of categorising the frequency and magnitude of potential impacts and provides a basis for the application of different degrees of mitigation and management measures.

In order to provide confidence to the risk assessment methods, category descriptions have been developed to guide the determination of risk likelihood and risk consequence in relation to current conditions within the estuary (see Table 8.18). The category descriptions provide a means of regulating and standardising the categorisation of risk likelihoods and risk consequences, which is typically a subjective undertaking. In this way, the risk prioritisation matrix removes some of the subjective and interpretive nature that is endemic to the risk assessment processes. Confidence can be placed in the assessment outcomes as a result.

Ultimately the risk prioritisation matrix determines an empirical value for each risk. This value is related to the specific impacts potential significance. As such, within this report, the risk assessment approach has been utilised to gauge which management priorities are important to mitigate and manage the current risk to ecological factors within the estuary. The risk assessment outcomes are detailed in Table 8.19 below.

The following ecological issues were considered to be a high priority within the Georges River estuary as a result of the risk assessment process:

- Seagrass;
- Saltmarsh;
- Endangered Ecological Communities (EECs);
- Threatened flora;

- Threatened fauna;
- Migratory birds;
- Pest species (aquatic and terrestrial);
- Invasive plants; and
- Sea level rise.

Of these, seagrass and saltmarsh were considered to be at the highest risk within the study area as a result of current anthropogenic impacts, and are thus considered to be of the highest priority for future management planning. Management recommendations for specific areas throughout the catchment and the LGA areas are proposed within this report with an aim to mitigate and minimise the potential risks to these ecological factors to an acceptable level (Table 8.21). Further, indicative costs and benefits of management priorities identified have been considered for those measures outlined within Tables 8.21-8.27 and Figures 8.12a-u (Appendix 3), to ensure that the most appropriate techniques are recommended.

The risk ratings identified for the Georges River estuary (Table 8.21) have been utilised as a basis for individual prioritising of more specific management recommendations for each of the LGA areas within the study area. The table provides a provisional indication of the range of issues identified for the estuary. A provisional indication of priority has been allocated to each of the identified ecological issues. This has been done with regard to significance and magnitude. As such, priorities for each LGA are presented in Tables 8.21 - 8.27. Examples of locations where management resources should be focused are also included in these tables. For specific management areas with high to medium priority recommendations are shown on Figure 8.12a-u (Appendix 10). Before these management recommendations are included in the next stage of the Estuary Management Process (the Estuary Management Plan) there should be input from the GRCCC and stakeholders.

Table 8.18 – Risk Assessment Categories utilised for Management Priority Identification for the Georges River Estuary Study Area

	CONSEQUENCE								
		Ecological Consequence Descriptions		Impacts such as localized or short term effects on habitat, species or environmental media	Localized, long term degradation of sensitive habitat or widespread, short-term impacts to habitat, species or environmental media	Impacts such as localized but irreversible habitat loss or widespread, long-term effects on habitat, species or environmental media	Widespread and persistent changes in habitat, species or environmental media	Persistent reduction in ecosystem function on a landscape scale or significant disruption of a sensitive species	Loss of a significant portion of a valued species or loss of effective ecosystem function on a landscape scale
	Likelihood Descriptions		Ranking	Incidental	Minor	Moderate	Major	Severe	Catastrophic
		Ranking	Index	6	5	4	3	2	1
LIKELIHOOD	Consequence can reasonably be expected to occur in life of the estuary management plan	Likely	1	6	5	4	3	2	1
	Conditions may allow the consequence to occur during the estuary management plan lifetime, or the event has occurred within similar projects	Occasional	2	7	6	5	4	3	2
	Exceptional conditions may allow consequences to occur within the estuary management plan lifetime	Seldom	3	8	7	6	5	4	3
	Reasonable to expect that the consequence will not occur during this plan though has occurred several times in industry	Unlikely	4	9	8	7	6	5	4
	Has occurred once or twice within industry	Remote	5	10	9	8	7	6	5
	Rare or unheard of	Rare	6	10	10	9	8	7	6

10: Low risk, management may be applied	**9:** Low risk, management may be applied	**8:** Low risk, management may be applied	**7:** Low risk, management may be applied	**6:** Risk is tolerable if reasonable management is in place	**5:** Further risk reduction is required	**4:** Risks are unacceptably high and management must be applied	**3:** Risks are unacceptably high and management must be applied	**2:** Risks are unacceptably high and management must be applied	**1:** Risks are unacceptably high and management must be applied
LOW RISK				**MODERATE RISK**		**HIGH RISK**			

Table 8.19 – Priority ranking of management issues for Georges River estuary study area

Key Management Categories	Likelihood	Consequence	Risk Rating	Threats	Justification for risk ranking
Seagrass	1	2	2	▪ Water Quality ▪ Boat Moorings ▪ Development (marinas, jetties) ▪ Boat propellers ▪ Dredging ▪ Altered Hydrology and sea level rise	▪ Almost half of the total distribution of seagrass in the Sydney metropolitan catchment area occurs within the study area (374ha was calculated in the study area and 776 ha was calculated for the Sydney metropolitan area (DECCW 2009a)) ▪ Stability and condition of beds is highly dependant on both anthropogenic and natural conditions ▪ Important habitat for fish and crustaceans as they provide food and shelter resources. ▪ Function as fish 'nurseries' for commercial fish species ▪ Play an important role in the estuary by binding sediment ▪ Impacts on seagrass would have significant negative effects on several components of the estuary ecosystem
Mangroves	2	5	6	▪ Bank erosion ▪ Water quality ▪ Land reclamation (foreshore development ▪ Vandalism ▪ Rubbish	▪ A large area of mangrove vegetation occurs in the study area ▪ Several areas where mangroves have been illegally removed occur, however, these areas are small when compared to the total area of mangroves in the study area. ▪ The consequence of negative impacts on mangroves would not be regionally

Key Management Categories	Likelihood	Consequence	Risk Rating	Threats	Justification for risk ranking
				▪ Sea level rise	significant (except where it occurs in key estuarine habitat such as towra point) but may be seen as locally significant
Saltmarsh	1	1	1	▪ Water quality ▪ Land reclamation (foreshore development) ▪ Vandalism ▪ Rubbish ▪ Interspecific competition ▪ Trampling by walkers, bike riders, vehicles ▪ Invasive plant invasion (particularly *Juncus acutus*) ▪ Altered hydrology ▪ Sea level rise	▪ 222 ha of estuarine saltmarsh occur in SMCMA (DECCW 2009a) and 145 ha of this occurs in the study area ▪ Coastal Saltmarsh is a listed EEC on Schedule 1 of the TSC Act ▪ Coastal Saltmarsh is threatened because where it naturally occurs is very limited due to the required environmental conditions and there are many anthropogenic demands on where they are typically found ▪ Restricted habitat areas occur in the study area ▪ Provides important habitat for crustaceans, birds and bats ▪ Several species that make up this community are threatened or sensitive species
Estuarine vegetation (Estuarine Reedland and Estuarine Swamp Oak Forest)	2	5	6	▪ Land reclamation ▪ Altered hydrology (through both changes in tidal inundation and increased stormwater) ▪ Invasive plants ▪ Rubbish	▪ 72 ha of estuarine reedland occurs in SMCMA of which 23 ha occurs in the study area ▪ 840 ha of estuarine swamp oak forest occurs in the Sydney basin, 290 ha of this in in the SMCMA and 96 ha of this occurs in the study area. Therefore it is a regionally

Key Management Categories	Likelihood	Consequence	Risk Rating	Threats	Justification for risk ranking
					well represented community. ▪ No threatened flora species are part of these communities however they do provide habitat for threatened fauna species such as the Glossy Black cockatoo (Calyptorhychus lathami lathami) and Green and Golden Bell frog (Litoria aurea).
Riparian vegetation	2	5	6	▪ Clearing for urban and industrial development ▪ Clearing and tree pruning for views ▪ Mowing ▪ Small patch size/isolation ▪ Invasive plant invasion; pest species ▪ Rubbish dumping ▪ Alterations to drainage and water flow patterns; stormwater and urban runoff pollution ;water pollution ;increased sedimentation ▪ Inappropriate fire frequency ▪ Land filling/land reclamation ▪ Recreational pressure (trampling; high use); Illegal trail riding ▪ Sea level rise and associated changing saline conditions	▪ Riparian vegetation covers 39.5% of study area (refer toTable 8.13) ▪ Cleared areas were observed as part of this study ▪ Management of disturbed riparian vegetation is possible due to location of the majority of communities within reserves and open space (refer to Table 8.15)

Key Management Categories	Likelihood	Consequence	Risk Rating	Threats	Justification for risk ranking
Endangered Ecological Communities (EECs)	2	2	3	▪ Clearing for urban and industrial development ▪ Mowing ▪ Small patch size/isolation ▪ Invasive plant invasion; pest species ▪ Rubbish dumping ▪ Alterations to drainage and water flow patterns; stormwater and urban runoff pollution ;water pollution ;increased sedimentation ▪ Inappropriate fire frequency ▪ Land filling/land reclamation ▪ Recreational pressure (trampling) ▪ Sea level rise and associated changing saline conditions	▪ These vegetation communities are recognised as being threatened under state legislation ▪ The observed clearing of the study area for development and potential future development is a threat to the existing EECS ▪ Over a quarter of the extent of riparian/terrestrial EEC within the Sydney Metropolitan CMA area (DECCW 2990a) occurs within the study area for Kurnell Dune Forest and Swamp Oak Floodplain Forest (Table 8.16). Thus, these communities are considered to be significant within the study area and should be prioritised for management actions.
Threatened Flora	1	2	3	▪ Habitat loss due to clearing for urban and industrial development ▪ Small patch size/isolation of habitat ▪ Habitat degradation (mowing; invasive plant invasion; rubbish dumping) ▪ Disturbances within reserves due to increase moisture and nutrients caused by changes in runoff quality and quantity	▪ Further information required on status of threatened flora species due to: ▪ Small number of records of which many are old, therefore verification required ▪ Records spread out within study area in reserves, properties and areas with potential for future development ▪ Less than 50% of records occur outside reserves ▪ Current records may be inaccurate due to

Key Management Categories	Likelihood	Consequence	Risk Rating	Threats	Justification for risk ranking
					urbanisation- verification recommended ▪ Records of threatened flora predominantly outside of riparian zone
Threatened Fauna	2	3	4	▪ Habitat loss due to clearing for urban and industrial development ▪ Small patch size/isolation of habitat ▪ Habitat degradation (mowing; invasive plant invasion; rubbish dumping)	▪ Habitat threatened by current level of disturbance and potential future clearing ▪ Some roosting and nesting sites for threatened species are located in the study area ▪ Most threatened fauna species are highly mobile
Aquatic Fauna and Habitat	2	4	5	▪ Water quality ▪ Destruction of habitat e.g. seagrass and benthic substrate	▪ Certain conditions such as pollution or sedimentation of the water may affect aquatic fauna directly e.g. fish kills or indirectly, degrade seagrass habitat. The consequence of this would be localised and the species present are found in other catchments in the Sydney basin.
Migratory Birds	3	2	4	▪ Destruction of habitat e.g. nest sites and food resources ▪ Pest species	▪ Main foraging and breeding habitat is currently reserved under National Parks at Towra Point ▪ Impacts on these species are seasonal depending on when they inhabit and utilise the area ▪ Currently migratory birds are monitored in this area by National Parks and Birds Australia

Key Management Categories	Likelihood	Consequence	Risk Rating	Threats	Justification for risk ranking
Terrestrial Fauna and Habitat	2	5	6	▪ Habitat loss due to clearing for urban and industrial development ▪ Small patch size/isolation of habitat ▪ Habitat degradation (mowing; invasive plant invasion; rubbish dumping)	▪ Large proportion of study area is riparian vegetation covering 39.5% of the study area (refer to Table 8.13) ▪ However cleared areas were observed as part of this study and future development may reduce the existing habitat available for fauna species
Pest Species (aquatic and terrestrial)	2	2	3	▪ Predation on native fauna species ▪ Competition with native fauna species for resources	▪ Outbreaks of pest species in sensitive areas can have large repercussions (eg fox predation on Little Tern in Towra Point Nature Reserve) ▪ Pest control programs by LGAs and DECCW in place. ▪ Aquatic pest species introduction aided by ease of movement through aquatic system and high level of boat traffic to and from Botany Bay
Invasive plants Species	1	3	3	▪ Reduce biodiversity of flora and fauna by smothering and out competing with native species and reducing vegetation structure	▪ Widespread throughout catchment with invasive plant hot spots concentrated in the upstream part of the study area (see Figures 8.10 a-d, Appendix 3) ▪ Consequence of not managing has impacts on other vegetation communities that have minimal or no invasive plant cover ▪ Aquatic systems aids their spread between river banks and from upstream to downstream areas

Key Management Categories	Likelihood	Consequence	Risk Rating	Threats	Justification for risk ranking
Sea level rise	2	2	3	▪ n/a	▪ More detailed and accurate mapping is needed to determine possible impacts on the estuaries by sea-level rise. However, information available at the time of writing this report indicates that there may be significant impacts to a number of species and vegetation communities ▪ Saltmarsh has been identified as being of most risk, of the current vegetation communities, from sealevel rise. This is due to the lack of suitable area for species of this community to 'retreat' to. Most of the areas bordering saltmarsh are higher and it is forseen that saltmarsh will be outcompeted by other estuarine communities.

Table 8.20 –8 Key Ecological Management Recommendations for Liverpool LGA

	Main management categories	Specific management areas	Specific Location	Priority Ranking of management categories	Management Recommendations
LIVERPOOL LGA	Seagrass	Stabilisation of beds	Deadmans Creek (Figure 8.5h, Appendix 3) Williams Creek (Map 3.1)	High	▪ Monitor sediment build up at the mouth of the creeks and associated seagrass expansion or contraction in size. ▪ Management options such as dredging may need to be considered if sediment is restricting flow of the creek.
		Viability of bed	Georges River (Refer to Figure 8.12d, Appendix 3)	High	▪ Future management of seagrass in these areas should be based of determination of the viability of the bed for expansion.
	Mangroves	Restore mangrove continuity	Foreshore of Georges River	Moderate	▪ New seawalls to be environmentally friendly. ▪ Educate private land owners on the environmental benefits of installing these types of walls and provide details of the planning process for instillation.
	Saltmarsh	Saltmarsh protection	Southern side of Deadmans Creek (Figure 8.5h, Appendix 3)	High	▪ Monitoring of this site to ensure integrity of the vegetation community and maintain its good condition ▪ Note: The saltmarsh at Deadmans Creek is one of the only suitable areas identified in the whole catchment where saltmarsh may be able to 'retreat' from rising sea level
			Georges RiverNational Park (Figure 8.12h, Appendix 3)	High	▪ Management of $WD acess to the site and revegetation of saltmarsh species by NPWS. ▪ Construct fencing and educational signage to deter 4wd damage and trampling.

LIVERPOOL	Main management categories	Specific management areas	Specific Location	Priority Ranking of management categories	Management Recommendations
		Protection of *Selliera radicans*	Williams Creek (Figure 8.5e, Appendix 3)	High	▪ Verify records ▪ Install signs and protective fencing if in an area frequented by the public ▪ Monitor health of the population
	Estuarine vegetation (Estuarine Reedland and Estuarine Swamp Oak Forest)	Integrity of estuarine vegetation communities	Williams Creek (Figure 8.5e, Appendix 3) Deadmans Creek (Figure 8.5h, Appendix 3)	High	▪ Monitor the integrity and condition of the estuarine vegetation communities as shown in Figure 8.1a (Appendix 3) to determine present and/or future anthropogenic impacts resulting in intraspecific competition between these communities.
		Rubbish hotspot: Removal of rubbish from Estuarine Reedland	Chipping Norton Lake (south) (Figure 8.12.c)	High	▪ Regular removal and monitoring of rubbish along the foreshore and in riparian vegetation.
	Riparian vegetation (Figures 8.12a-h, Appendix 3)	Management and protection of Cumberland Riverflat Forest (part of the River Flat Eucalypt Forest EEC)	Deadmans Creek; Lt Cantello Reserve	Medium	▪ Detailed condition assessment to guide future management actions; Utilise bush regeneration best practice guidelines to improve vegetation condition
			Various Private Property locations	Medium	▪ Inform property owner of the importance of EEC and investigate potential for conservation agreement
		Stormwater effects on riparian vegetation condition	Williams Creek	High	▪ Landuses of this large catchment should be appropriately managed to protect water quality and riparian habitat. ▪ Appropriate stormwater management and water quality testing is recommended, particurarly after heavy rain.
	Endangered Ecological	Management and protection of Swamp Oak	Lt Cantello Reserve/Williams Creek;	High	▪ Detailed condition assessment to guide future management actions.

LIVERPOOL	Main management categories	Specific management areas	Specific Location	Priority Ranking of management categories	Management Recommendations
	Communities (EECs) (Figures 8.12a-h, Appendix 3)	Floodplain Forest	Thomas Moore Park		▪ Utilise bush regeneration best practice guidelines to improve vegetation condition
			Various Private Property Locations (Liverpool Golf Club)	Medium	▪ Inform property owner of the importance of EEC and investigate potential for conservation agreement
		Management and protection of River Flat Eucalypt Forest	Deadmans Creek; Lt Cantello Reserve	Medium	▪ Detailed condition assessment to guide future management action. ▪ Utilise bush regeneration best practice guidelines to improve vegetation condition.
			Various Private Property locations (Williams Creek, Georges River opposite Riverwood Golf Course)	Medium	▪ Inform property owner of the importance of EEC and investigate potential for conservation agreement.
		Management and protection of Regeneration of River Flat Eucalypt Forest understorey	Pleasure Point Reserve	Medium	▪ Regenerate understorey with River Flat Eucalypt Forest EEC species
			Private Property (including Warwick Farm Racecourse, refer to Figure 8.12a, appendix 3)	Medium	▪ Inform property owner of the importance of EEC and investigate potential for conservation agreement aimed at regenerating understorey ▪ Discuss revegetation works with Warick Farm Racecourse and seek their active involvement in the regeneration process. ▪ Investigate incorporating foreshore revegetation works in future bank stabilization works along Warick Farm Racecourse.

LIVERPOOL	Main management categories	Specific management areas	Specific Location	Priority Ranking of management categories	Management Recommendations
		Management and protection of Sydney Freshwater Wetlands	Deadmans Creek	Medium	▪ Detailed condition assessment to guide future management actions. ▪ Utilise bush regeneration best practice guidelines to improve vegetation condition.
			Private Property	Medium	▪ Inform property owner of the importance of EEC and investigate potential for conservation agreement
		Management and protection of Swamp Sclerophyll Forest on Coastal Floodplains	Deadmans Creek	Medium	▪ Detailed condition assessment to guide future management actions; Utilise bush regeneration best practice guidelines to improve vegetation condition
	Threatened Flora	Protection	*Persoonia nutans* (Private property – Voyager Point and Williams Creek) (Figures 8.12g-h, Appendix 3)	Medium	▪ Contact land manager to discuss the potential to ground truth threatened flora record and discuss conservation agreements where appropriate.
	Threatened Fauna	Protection	Black-chinned Honeyeater (Chauvel Park) (Figure 8.12c, Appendix 3) Little Lorikeet (Chauvel Park) (Figure 8.12c, Appendix 3) Green and Golden Bell Frog (Lt Cantello Reserve) (Figure 8.12e, Appendix 3)	Medium	▪ Ground truth threatened fauna species habitat (after consultation with private land owner if the record is on pricate property). ▪ If habitat occurs, investigate condition and health and monitor and manage in consultation with DECCW.

LIVERPOOL	Main management categories	Specific management areas	Specific Location	Priority Ranking of management categories	Management Recommendations
			Koala (Holsworthy Sewage Treatment Plant, Holsworthy Military Base and) (Figure 8.12e and h, Appendix 3)		
		Control of Pest Species	Georges River National Park	Medium	▪ Continue pest management program
	Aquatic Fauna and Habitat	Water Quality	Throughout estuary system	High	▪ Water quality results from GRCCC program to guide aquatic fauna management
		Seagrass habitat	Deadmans Creek (Figure 8.5h, Appendix 3) Williams Creek (Map 3.1)	High	▪ See Seagrass management recommendations above
	Migratory Birds	There are no priority areas determined for this category in this LGA	n/a	n/a	n/a
	Terrestrial Fauna and Habitat	Fauna Habitat – degradation and loss	Throughout catchment, particularly where urban areas encroach on foreshore and there is heavy invasive plant (i.e near Lake Moore Wetlands Harris Creek	Medium	▪ Habitat protection of current reserves ▪ Increase areas of natural bushland protected for conservation, particularly adding to existing patches to minimise edge effects and fragmentation ▪ Survey and research into fauna species occurring within the estuary, particularly threatened species ▪ Habitat modeling to determine priority conservation areas ▪ Protection of wetlands and other significant fauna habitat

LIVERPOOL	Main management categories	Specific management areas	Specific Location	Priority Ranking of management categories	Management Recommendations
					areas
		Fauna Habitat protection and creation	Along foreshore and between significant habitat areas	Low	▪ Reservation of vegetation to provide a continuous wildlife corridor along the foreshore or between significant habitat areas ▪ Identification of wildlife corridors along the estuary as well as to surrounding reserves and habitat areas
	Pest Species (aquatic and terrestrial)	Control	n/a	Low	▪ Co-ordination between LGAs for pest control, particularly for the European Fox
	Invasive plants	Hot Spot	Cabramatta Creek;	High	▪ Detailed condition assessment to guide future management actions. ▪ Integrated invasive plant control program including neighbouring council.
			Haigh Park; Harris Creek; Mc Millan Park; Warwick Farm Racecourse; Lake Moore Wetlands/Mc Millan Park; Chipping	High	▪ Detailed condition assessment to guide future management actions. ▪ Utilise bush regeneration best practice guidelines to improve existing vegetation condition.

LIVERPOOL	Main management categories	Specific management areas	Specific Location	Priority Ranking of management categories	Management Recommendations
			Norton Lake South Islands.		▪ Possible areas for Conservation Volunteers or Local bush regeneration groups to undertake regeneration works. ▪ Discuss revegetation options with private landowners and seek their active involvement in the regeneration process.
			Various Private Property locations (Refer to Figure 8.12c, Appendix3)	Medium	▪ Inform property owner of the importance of EEC and investigate potential for conservation agreement.
		Invasive plant removal to control the spread of invasive plants along the foreshore	Angel Park and private property (refer to figure 8.12c, Appendix 3)	Medium	▪ Removal of *Lantana camara* and other invasive plant species in Angel Park ▪ Inform private landowners about the value of native vegetation (including benefits of bank stabilization) and information and suggestions for invasive plant removal, revegetation methods and suitable native species to plant.
	Sea level rise	Preservation of land to ensure areas for landward retreat of estuarine vegetation due to rising sea levels	Georges River near Williams Creek (Figure 8.5a, Appendix 3) Deadmans Creek (Figure 8.5a, Appendix 3)	High	▪ Ensure future protection of vegetation communities and topography of the site

Table 8.21 – Key Ecological Management Recommendations for Fairfield LGA

	Main Issues	Specific management focus	Specific Location	Priority Ranking of Main Issue	Management Recommendations
FAIRFIELD LGA	Seagrass	n/a	There is no seagrass mapped in this LGA in the study area	n/a	▪ n/a
	Mangroves	Retaining foreshore vegetation	Prospect Creek	Medium	▪ Inform land owners about the value of retaining and promoting native vegetation, including the benefits of foreshore vegetation for bank stabilization. ▪ Provide information to landowners about invasive plant removal and revegetation methods and suitable species.
		Restore mangrove continuity	Foreshore of Georges River	Moderate	▪ New seawalls to be environmentally friendly. ▪ Educate private land owners on the environmental benefits of installing these types of walls and provide details of the planning process for instillation.
	Saltmarsh	n/a	There are no saltmarsh mapped in this LGA in the study area	n/a	▪ n/a
	Estuarine vegetation (estuarine reedland and estuarine swamp oak	Management through conservation	Liverpool Golf Club	Medium	▪ Inform property owner about the importance of this EEC and investigate potential for ccnservation agreement.
		Rubbish hotspot: Removal of rubbish from	Chipping Norton Lake (Figure 8.12.b)	High	▪ Regular removal and monitoring of rubbish along the foreshore and in riparian vegetation.

FAIR FIEL	Main Issues	Specific management focus	Specific Location	Priority Ranking of Main Issue	Management Recommendations
	forest)	Estuarine Reedland and Sawmp Oak Forest			
	EECs	Management and protection of River Flat Eucalypt Forest	Chipping Norton Islands	High	▪ Monitoring of future invasive plant levels and native flora condition of areas that have undergone regeneration. Prompt action for removal of invasive plants is recommended.
		Riparian Vegetation invasive plant management	Prospect Creek	High	▪ Utilise bush regeneration best practice guidelines to improve existing vegetation condition. ▪ Possible areas for Conservation Volunteers or Local bush regeneration groups to undertake regeneration works.
	Threatened Flora	No ground truthing recommended due to threatened flora species being either historical or outside of study area	n/a	n/a	▪ n/a
	Threatened Fauna	Management of Flying Fox Colony	Cabramatta Creek	High	▪ Continued management of the flying fox colony to ensure minimal disturbance to this species.
	General estuarine and riparian vegetation	Management of estuarine and riparian vegetation	Cherrybrook Park	Medium	▪ The area could be used for educational purposes due to the high public usage of the wharf and boat launch facilities. ▪ Education on responsible use of watercraft, value of estuarine and foreshore vegetation and causes and outcomes of foreshore erosion.

Table 8.22 –9 Key Ecological Management Recommendations for Bankstown LGA

	Management Categories	Specific management focus	Specific Location	Priority ranking of management categories	Management Recommendations
BANKSTOWN LGA	Seagrass	Seagrass protection	Mouth of Saltpan Creek (Figure 8.5j, Appendix 3)	High	▪ Increased signage and education to minimize boat propeller damage ▪ Coordinate management actions with Hurstville Council
	Mangroves	Restoration of mangrove growth	Foreshore of Georges River, Salt Pan Creek	Moderate	▪ Installation of mangrove friendly seawalls to increase habitat provided by mangroves and aid bank stabilisation particularly where illegal clearing has been undertaken ▪ Education of private land owners on the benefits of installing mangrove friendly seawalls ▪ Enforce more strict fines for illegal clearing of estuarine vegetation.
			Salt Pan Creek (Henry Lawson Drive)	Moderate	▪ Investigate options for removal of the fill under Henry Lawson Drive bridge and restore the bank to the pre-bridge construction extent. ▪ Remediate new bank once fill is removed.
		Preservation of mangroves	Salt Pan Creek (Refer to figure 8.12i, Appendix 3)	Moderate	▪ Removal of large rubbish items such as tyres and car parts. Regular removal and monitoring of rubbish throughout this area, particurarly after heavy rain.
	Saltmarsh	Landward migration of mangroves into saltmarsh areas	Little Salt Pan Creek	High	▪ Monitor growth and control where mangroves are encroaching on saltmarsh
			Salt Pan Creek (Figure 8.5i, Appendix 3)	High	▪ Monitor landward migration of mangroves particurarly in areas where saltmarsh is present

BANKSTOWN	Management Categories	Specific management focus	Specific Location	Priority ranking of management categories	Management Recommendations
					▪ Coordinate with Canterbury Council
		Protection of *Gahnia filum*	Lambeth reserve (Figure 8.5h, Appendix 3) Salt Pan Creek (Figure 8.5i, Appendix 3)	High	▪ Verify records ▪ Install signs and protective fencing if in an area frequented by the public ▪ Monitor health of the population
		Protection of *Wilsonia backhousei*	Little Salt Pan Creek (Figure 8.5j, Appendix 3) Salt Pan Creek (Figure 8.5i, Appendix 3)	High	▪ Verify records ▪ Install signs and protective fencing if in an area frequented by the public ▪ Monitor health of the population
		Revegetation of saltmarsh	Beauty Point (Figure 8.5j, Appendix 3)	High	▪ Continued and integrated revegetation of this site to encourage saltmarsh growth, including invasive plant removal and replanting of saltmarsh species ▪ Investigate feasibility of leveling land to a suitable level for tidal inundation and saltmarsh establishment
			Several locations along Salt Pan Creek	High	▪ Continued regeneration works in these areas ▪ Monitoring of mangrove/casuaria encroachment
	Estuarine vegetation (Estuarine Reedland and estuarine Swamp	Integrity of estuarine vegetation communities	Prospect Creek Little Salt Pan Creek	High	▪ Monitor the integrity and condition of the estuarine vegetation communities as shown in Figure 8.1a (Appendix 3) to determine present and/or future anthropogenic impacts resulting in intraspecific competition between these communities.

BANKSTOWN	Management Categories	Specific management focus	Specific Location	Priority ranking of management categories	Management Recommendations
	Oak Forest)	Maintenance	Kelso Park	High	▪ Regular removal and monitoring of rubbish along the foreshore and throughout the foreshore vegetation , particularly after heavy rain.
	Riparian vegetation (Figures 8.12b, d-f, h-j Appendix 3)	Management and protection of Cumberland Riverflat Forest (part of the River Flat Eucalypt Forest EEC)	Alan Ashton Foreshore Reserve	Medium	▪ Create linkage along foreshore and to Georges River National Park; Detailed condition assessment to guide future management actions; Utilise bush regeneration best practice guidelines to improve vegetation condition
			Georges River National Park	Medium	▪ Continued management and protection as part of Georges River National Park management - with aim to increase EEC linkage along foreshore
			Deepwater Regional Park	Medium	▪ Detailed condition assessment to guide future management actions; Utilise bush regeneration best practice guidelines to improve vegetation condition
	Endangered Ecological Communities (EECs) (Figures 8.12b, d-f, h-j Appendix 3)	Management and protection of Swamp Oak Floodplain Forest	Kelso Park; Lambeth Reserve; Little Salt Pan Creek; Mirambeen Regional Park; Monash Reserve	High	▪ Detailed condition assessment to guide future management actions ▪ Utilise bush regeneration best practice guidelines to improve vegetation condition
			Upper Salt Pan Creek	High	▪ Detailed condition assessment to guide future management actions ▪ Utilise bush regeneration best practice guidelines to improve vegetation condition ▪ Integrated invasive plant control program including neighbouring properties and councils

BANKSTOWN	Management Categories	Specific management focus	Specific Location	Priority ranking of management categories	Management Recommendations
					▪ Maintenance of existing public recreation areas including boardwalks and educational signage.
			Georges River National Park	High	▪ Continued management and protection as part of Georges River National Park management
			Private Property (Riverlands Golf Course)	Medium	▪ Inform property owner of the importance of EEC and investigate potential for conservation agreement
		Management and protection of River Flat Eucalypt Forest	Alan Ashton Foreshore Reserve	Medium	▪ Create linkage along foreshore and to Georges River National Park ▪ Detailed condition assessment to guide future management actions ▪ Utilise bush regeneration best practice guidelines to improve vegetation condition
			Georges River National Park	Medium	▪ Continued management and protection as part of Georges River National Park management - with aim to increase EEC linkage along foreshore
			Deepwater Regional Park	Medium	▪ Detailed condition assessment to guide future management actions ▪ Utilise bush regeneration best practice guidelines to improve vegetation condition
			Mirambeen Regional Park	Medium	▪ Detailed condition assessment to guide future management actions ▪ Utilise bush regeneration best practice guidelines to

BANKSTOWN	Management Categories	Specific management focus	Specific Location	Priority ranking of management categories	Management Recommendations
					improve vegetation condition ▪ Area should be a focus for a local bush regeneration group
		Management and protection of Swamp Sclerophyll Forest on Coastal Floodplains	Little Salt Pan Creek;	Medium	▪ Detailed condition assessment to guide future management actions ▪ Utilise bush regeneration best practice guidelines to improve vegetation condition
		Management and protection of Sydney Freshwater Wetlands	Kelso Park; Salt Pan Creek; Yeramba Lagoon	Medium	▪ Detailed condition assessment to guide future management actions ▪ Utilise bush regeneration best practice guidelines to improve vegetation condition
		Management and protection of Cooks River / Castlereigh Ironbark Forest	Salt Pan Creek	High	▪ Undertake bushland regeneration activities within remnant Cooks River/Castlereagh Ironbark Forest as detailed in Salt Pan Creek Corridor Masterplan Report. Vegetation height to be considered when in close proximity to overhead powerlines.
	Threatened Flora	Protection		High	▪ Follow guidelines in recovery plan for A*cacia pubescens*
			Acacia pubescens (Deepwater Regional Park, upper Salt Pan Creek and Kelso Park) (Figure 8.12e, 8.12f and 8.12i, Appendix 3) *Pterostylis saxicola*	Medium	▪ Ground truth threatened flora species record - If species and/or habitat occurs, investigate condition and health and monitor and manage in consultation with DECCW. ▪ Install signage and protective fencing if in an area frequented by the public.

BANKSTOWN	Management Categories	Specific management focus	Specific Location	Priority ranking of management categories	Management Recommendations
			(Lambeth Reserve) (Figure 8.12h, Appendix 3) *Acacia prominens* (middle reaches Salt Pan Creek) (Figure 8.12i, Appendix 3) Gahnia filum (refer to Figure 8.12h, Appendix 3)		
	Threatened Fauna	Protection	Square-tailed Kite (Deepwater Regional Park) (Figure 8.12e, Appendix 3)	Medium	▪ Ground truth threatened fauna species breeding habitat within Deepwater Regional Park - If habitat occurs, investigate condition and health and monitor and manage as required.
			Powerful Owl (GRNP Picnic Pt) (Figure 8.12h, Appendix 3) Powerful Owl (GRNP Little Salt Pan Creek) (Figure 8.12j, Appendix 3) Black-chinned Honeyeater (GRNP Picnic Pt) (Figure 8.12h, Appendix 3) Red-crowned Toadlet (GRNP Padstow	Medium	▪ Ground truth threatened fauna species habitat - If habitat occurs, investigate condition and health and monitor and manage in consultation with DECCW.

BANKSTOWN	Management Categories	Specific management focus	Specific Location	Priority ranking of management categories	Management Recommendations
			Heights) (Figure 8.12j, Appendix 3)		
			Grey-headed Flying-fox & Powerful Owl (Salt Pan Creek) (Figure 8.12i, 8.12j and 8.12k, Appendix 3)	Medium	▪ Ground truth threatened fauna species habitat; Mangroves are known habitat for Grey-headed Flying-fox; Hinterland Sandstone Gully Blackbutt-Apple Forest potential roosting habitat for Powerful Owl. If habitat occurs, investigate condition and health and monitor and manage in consultation with DECCW.
			Grey-headed Flying-fox & Eastern Freetail-bat (Salt Pan Creek) (Figure 8.12k, Appendix 3)	Medium	▪ Ground truth threatened fauna species habitat - If habitat occurs, investigate condition and health and monitor and manage as required.
			Salt Pan Creek	Medium	▪ Salt Pan Creek Corridor Masterplan Report identifies terrestrial fauna species that occur, or are likely to occur, in the vicinity of Salt Pan Creek, including Regent Honeyeater *Xanthomyza phrygia,* Bush Stone Curlew *Buirhinus grallanus,* Grey Goshawk *Accipter novaeholliandiae,* Crested Tern *Platycercus bergii,* Great Egret *Ardea alba,* White Bellied Sea Eagle *Haliaeetus leucogaster*. Ground truth threatened fauna species habitat - If habitat occurs, investigate condition and health and monitor and manage as required.
			Pest species management (GRNP)	Medium	▪ Continued pest management program

BANKSTOWN	Management Categories	Specific management focus	Specific Location	Priority ranking of management categories	Management Recommendations
	Aquatic Fauna and Habitat	Water Quality	Throughout estuary system	High	▪ Water quality results from GRCCC program to guide aquatic fauna management
		Seagrass habitat	Mouth of Saltpan Creek (Figure 8.5j, Appendix 3)	High	▪ See Seagrass management recommendations above
	Migratory Birds	There are no priority areas determined for this category in this LGA	n/a	n/a	▪ n/a
	Terrestrial fauna and Habitat	Fauna Habitat – degradation and loss	Throughout catchment, particularly where urban areas encroach on foreshore and there is heavy invasive plant invasion particularly Beauty Point Wetland	Medium	▪ Habitat protection of current reserves ▪ Increase areas of natural bushland protected for conservation, particularly adding to existing patches to minimise edge effects and fragmentation ▪ Survey and research into fauna species occurring within the estuary, particularly threatened species ▪ Habitat modeling to determine priority conservation areas ▪ Protection of wetlands and other significant fauna habitat areas
		Fauna Habitat protection and creation	Where Cooks River / Castlereigh Ironbark Forest located along Salt Pan Creek	High	▪ Engage fauna consultant to locate and install nest boxes and create artificial habitat for fauna species including frogs and reptiles

BANKSTOWN	Management Categories	Specific management focus	Specific Location	Priority ranking of management categories	Management Recommendations
			Along foreshore and between significant habitat areas	Low	▪ Reservation of vegetation to provide a continuous wildlife corridor along the foreshore or between significant habitat areas ▪ Identification of wildlife corridors along the estuary as well as to surrounding reserves and habitat areas
			Rorie Reserve, Salt Pan Creek	Medium	▪ Creation of wetland habitat and revegetation as recommended in Salt Pan Creek Corridor Masterplan Report
			Stuart Street Reserve, Salt Pan Creek	Medium	▪ Habitat creation strategy as recommended in Salt Pan Creek Corridor Masterplan Report
			Cutting Reserve, Salt Pan Creek	Medium	▪ Habitat creation strategy as recommended in Salt Pan Creek Corridor Masterplan Report ▪ Engage fauna consultant to find suitable locations and install nestboxes suitable for target species Continue bush regeneration within Cutting Reserve and along pathway through Salt Pan Reserve as recommended in Salt Pan Creek Corridor Masterplan Report
	Pest Species (aquatic and terrestrial)	Pest Species Control	Georges River National Park	Medium	▪ Continue pest management program
			n/a	Low	▪ Co-ordination between LGAs for pest control, particularly for the European Fox
	Invasive plants	Hot Spot	Beauty Point; Mirambeen Regional	High	▪ Detailed condition assessment to guide future management actions

BANKSTOWN	Management Categories	Specific management focus	Specific Location	Priority ranking of management categories	Management Recommendations
			Park		▪ Utilise bush regeneration best practice guidelines to improve vegetation condition ▪ Invasive plant removal at Beauty Point to focus on *Juncus acutus* and *Lantana camara* removal
			Salt Pan Creek	High	▪ GRCCC to liaise with Canterbury LGA and inform them of the high degree of disturbance in this area and recommend the utilisation of bush regeneration best practice guidelines to improve vegetation condition
		Invasive plant control	n/a	High	▪ Target weeding of Juncus acutus and Kikuyu within Salt Marsh
	Sea level rise	Preservation of land to ensure areas for landward retreat of estuarine vegetation due to rising sea levels	Georges River near Riverwood Golf Course (Figure 8.5a, Appendix 3)	High	▪ Ensure future protection of vegetation communities and topography of the site

Table 8.23 –10 Key Ecological Management Recommendations for Hurstville LGA

	Management categories	Specific management focus	Specific Location	Priority Ranking of Main Issues	Management Recommendations
HURSTVILLE LGA	Seagrass	Protection of seagrass	Mouth of Saltpan Creek (Figure 8.12j, Appendix 3)	High	▪ Increased signage and education to minimize boat propeller damage ▪ Coordinate management actions with Hurstville Council
	Mangroves	Restoration of mangroves along the foreshore	Salt Pan creek (Figure 8.12k, Appendix 3)	Medium	▪ Education program with landowners about illegal estuarine pruning and the value of this vegetation in the area. ▪ More strict enforcement of fines for illegal clearing of estuarine vegetation
			Foreshore of Georges River near Great Moon Bay (Figure 8.12l, Appendix 3)	Medium	▪ New seawalls are to be ecologically friendly ▪ Education program with landowners on the environmental benefits of installing these types of seawalls.
		Viability of stands for management options	Gungah Bay (Figure 8.12m, Appendix 3)	Medium	▪ Investigate the viability of the stand, specifically rate of recruitment, for consideration in future management options.
		Rubbish hotspot: Removal of rubbish from mangroves	Downstream of the mouth of salt pan creek (Figures 8.12j and Figures 8.12l, Appendix 3)	Medium-high	▪ Regular removal and monitoring of rubbish
	Saltmarsh	Landward migration of	Salt Pan Creek (Figure 8.12i,	High	▪ Monitor growth and control where mangroves are

HURSTVILL	Management categories	Specific management focus	Specific Location	Priority Ranking of Main Issues	Management Recommendations
		mangroves	Appendix 3) Lime Kiln Bay (Figure 8.12m, Appendix 3) Great Moon Bay (Figure 8.12l, Appendix 3)		encroaching on saltmarsh
		Defacing	Great Moon Bay (Figure 8.12l, Appendix 3)	High	▪ Install signage to educate people about what saltmarsh is and the value of it in estuarine ecosystems
	Estuarine vegetation (estuarine reedland and estuarine swamp oak forest)	Integrity of estuarine vegetation communities	Oatley Bay (Figure 8.12k, Appendix 3)	High	▪ Monitor the integrity and condition of the estuarine vegetation communities to determine present and/or future anthropogenic impacts resulting in intraspecific competition between these communities.
	General estuarine and riparian vegetation	Value of this vegetation in the local area	Salt Pan Creek (Figure 8.12i, Appendix 3)	High	▪ Use area for education due to high public usage of the boat launching facility ▪ Install informative signage on the responsible use of watercraftand the causes and outcomes of foreshore erosion.
	Riparian vegetation (Figures 8.12i-m Appendix 3)	There are no priority areas determined for this category in this LGA	n/a	n/a	n/a
	Endangered	Management and	Oatley Heights;	High	▪ Detailed condition assessment to guide future

HURSTVILL	Management categories	Specific management focus	Specific Location	Priority Ranking of Main Issues	Management Recommendations
	Ecological Communities (EECs) (Figures 8.12i-m Appendix 3)	protection of Swamp Oak Floodplain Forest	Riverwood Park (Salt Pan Creek)		management actions ▪ Utilise bush regeneration best practice guidelines to improve vegetation condition ▪ At Oatley Park monitor the interface of vegetation communities to determine if mangroves are retreating into these communities. If this is the case management of mangroves, such as pruning is recommended.
		Co-ordinated management and planning for Swamp Oak Floodplain Forest	North of Riverwood Park (Salt Pan Creek, Figure 8.12i, Appendix 3)	Medium	▪ Hurstville Council and GRCCC to liase with Canterbury Council about the high level of invasive plants in this area that spread into the surrounding LGA areas where bush regeneration is being undertaken in EEC communities. ▪ A coordinated approach to invasive plant removal is recommended as well as discussions about the possible expansion of Swamp Oak Floodplain Forest to link this community along the foreshore.
		Management and protection of Swamp Sclerophyll Forest on Coastal Floodplains	Myles Dunphy Bushland Reserve and Great Moon Bay (Figure 8.12l, Appendix 3)	Medium	▪ Detailed condition assessment to guide future management actions ▪ Utilise bush regeneration best practice guidelines to improve vegetation condition
			Georges River National Park	Medium	▪ Continued management and protection as part of Georges River National Park management
	Threatened flora	Protection	*Persoonia hirsuta* (Oatley Park) (Figure 8.12k & m,	Medium	▪ Ground truth threatened flora species record within Oatley Park - if species and/or habitat determined to be present investigate condition, monitor and

HURSTVILL	Management categories	Specific management focus	Specific Location	Priority Ranking of Main Issues	Management Recommendations
			Appendix 3)		manage as required.
			Acacia pubescens (Boggywell Creek) (Figure 8.12k, Appendix 3)	Medium	▪ Ground truth threatened flora species record within reserve surrounding Boggywell Creek - If species and/or habitat occurs, investigate condition and health and monitor and manage as required.
	Threatened fauna	Protection	Powerful Owl (Oatley Park) (Figure 8.12k & m, Appendix 3)	Medium	▪ Ground truth threatened fauna species habitat within Oatley Park. If habitat occurs, investigate condition and health and monitor and manage as required.
	Aquatic fauna and habitat	Water Quality	Throughout estuary system	High	▪ Water quality results from GRCCC program to guide aquatic fauna management
		Seagrass habitat	Mouth of Saltpan Creek (Figure 8.12j, Appendix 3)	High	▪ See Seagrass management recommendations above
	Migratory Birds	There are no priority areas determined for this category in this LGA	n/a	n/a	n/a
	Terrestrial fauna and habitat	Fauna Habitat – degradation and loss	Throughout catchment, particularly where urban areas encroach on foreshore and there is heavy invasive plant	Medium	▪ Habitat protection of current reserves ▪ Increase areas of natural bushland protected for conservation, particularly adding to existing patches to minimise edge effects and fragmentation ▪ Survey and research into fauna species occurring within the estuary, particularly threatened species ▪ Habitat modeling to determine priority conservation areas

HURSTVILL	Management categories	Specific management focus	Specific Location	Priority Ranking of Main Issues	Management Recommendations
					▪ Protection of wetlands and other significant fauna habitat areas
		Fauna Habitat protection and creation	Along foreshore and between significant habitat areas	Low	▪ Reservation of vegetation to provide a continuous wildlife corridor along the foreshore or between significant habitat areas ▪ Identification of wildlife corridors along the estuary as well as to surrounding reserves and habitat areas
	Pest species	Control	n/a	Low	▪ Co-ordination between LGAs for pest control, particularly for the European Fox
	Invasive plants	There are no priority areas determined for this category in this LGA	n/a	Low	▪ Monitor vegetation for invasive plant infestations and control when identified to prevent spread
	Sea level rise	Preservation of land to ensure areas for landward retreat of estuarine vegetation due to rising sea levels	Gungah Bay (Figure 8.5b, Appendix 3) Salt Pan Creek	High	▪ Ensure future protection of vegetation communities and topography of the site

Table 8.24 –11 Key Ecological Management Recommendations for Kogarah LGA

	Key management categories	Specific management focus	Specific Location	Priority ranking of main issues	Management Recommendations
KOGARAGH LGA	Seagrass	Seagrass protection	Kogarah Bay (Figure 8.12o, Appendix 3) Shipwrights Bay (Figure 8.12o, Appendix 3) Kyle Bay (Figure 8.12n, Appendix 3) Connells Bay (Figure 8.12n, Appendix 3)	High	▪ Monitoring of the size and health of seagrass meadows ▪ Installation of seagrass friendly moorings
			Kyle Bay (Figure 8.12n, Appendix 3)	High	▪ Monitoring of the size and health of seagrass meadows ▪ Provide landowners with private jetties information on the value of seagrass and ways to minimize impacts on this community.
	Mangroves	Mangrove revegetation	Oatley Bay	Medium	▪ Installation of mangrove friendly seawalls
			All foreshore areas with seawalls	Medium	▪ New seawalls to be environmentally friendly. ▪ Educate private landowners on the environmental benefits of installing these types of walls.
	Saltmarsh	Stabiliastion of saltmarsh species in marginal habitat	Neverfail Bay (Figure 8.12m, Appendix 3)	High	▪ Revegetate using local saltmarsh species in this area, including appropriate cleared areas and create no mow zone to protect revegetation using signage and/or other physical barriers

KOGARAGH	Key management categories	Specific management focus	Specific Location	Priority ranking of main issues	Management Recommendations
					▪ Monitoring of mangrove and swamp oak encroachment ▪ Removal of dumped large rubbish items such as couches and tyres and removal of tar from past land uses. This will enable the estuarine vegetation, including saltmarsh, to naturally establish in this area.
	Estuarine vegetation (Estuarine reedland and estuarine swamp oak forest)	Integrity of estuarine vegetation communities	Kyle Bay (Figure 8.1c, Appendix 3)	High	▪ Monitor the integrity and condition of the estuarine vegetation communities as shown in Figure 8.1a (Appendix 3) to determine present and/or future anthropogenic impacts resulting in intraspecific competition between these communities. ▪ Work with relevant landowners to address significant EEC's within private property.
	Riparian vegetation (Figures 8.m-n Appendix 3)	Management and protection	Poulton Park where natural progression from estuarine to riparian vegetation occurs(Figure 8.1n, Appendix 3)	Medium	▪ Survey to determine boundaries of vegetation communities within estuarine/riparian transition zone ▪ Detailed condition assessment of estuarine/riparian transition zone to guide future management actions ▪ Utilise bush regeneration best practice guidelines to improve vegetation condition
	Endangered Ecological Communities	Management and protection of Swamp Oak Floodplain Forest	Kyle Williams Reserve, Neverfail Bay	High	▪ Detailed condition assessment to guide future management actions ▪ Utilise bush regeneration best practice

KOGARAGH	Key management categories	Specific management focus	Specific Location	Priority ranking of main issues	Management Recommendations
	(EECs) (Figures 8.m-n Appendix 3)				guidelines to improve vegetation condition ▪ Work with relevant landowners to address significant areas of EEC's within private property.
			Poulton Park	High	▪ Survey to determine presence of this community within study area as not included in SMCMA mapping
	Threatened Flora	Protection	*Tetratheca neglecta* (Poulton Park) (Figure 8.12n, Appendix 3)	Medium	▪ Ground truth threatened flora species record within Poulton Park - if species and/or habitat determined to be present investigate condition, monitor and manage as required
	Threatened Fauna	Protection	Within councils study area	Medium	▪ Complete a study to investigate possible species and locations of other rare or vulnerable species that may be present. The Gang-gang Cockatoo has been recorded within the study area, however core habitat is not considered to be available within this LGAs study area and this species is also highly mobile
	Aquatic Fauna and habitat	Water Quality	Throughout estuary system	High	▪ Water quality results from GRCCC program to guide aquatic fauna management
		Seagrass habitat	Kogarah Bay (Figure 8.12o, Appendix 3) Shipwrights Bay (Figure 8.12o, Appendix 3) Kyle Bay (Figure 8.12n,	High	▪ See Seagrass management recommendations above

KOGARAGH	Key management categories	Specific management focus	Specific Location	Priority ranking of main issues	Management Recommendations
			Appendix 3) Connells Bay (Figure 8.12n, Appendix 3)		
	Migratory birds	Protection of habitat	Kyle Bay & Connells Bay	Low	▪ Habitat protection of intertidal mud flat where birds forage
	Terrestrial Fauna and Habitat	Fauna Habitat – degradation and loss	Throughout catchment, particularly where urban areas encroach on foreshore and there is heavy invasive plant invasion (i.e Connels Bay on western side, Shipwrights Bay Reserve and Oatley Bay, Poulton Park)	Medium	▪ Habitat protection of current reserves ▪ Increase areas of natural bushland protected for conservation, particularly adding to existing patches to minimise edge effects and fragmentation ▪ Survey and research fauna species occurring within the estuary, particularly threatened species ▪ Habitat modeling to determine priority conservation areas ▪ Protection of wetlands and other significant fauna habitat areas
		Fauna Habitat protection and creation	Along foreshore and between significant habitat areas	Low	▪ Review and develop the current GreenWeb planning document ▪ Reservation of vegetation to provide a continuous wildlife corridor along the foreshore or between significant habitat areas ▪ Identification of wildlife corridors along the estuary as well as to surrounding reserves and habitat areas

KOGARAGH	Key management categories	Specific management focus	Specific Location	Priority ranking of main issues	Management Recommendations
	Pest Species (aquatic and terrestrial)	Control	n/a	Low	▪ Co-ordination between LGAs for pest control, particularly for the European Fox
	Invasive plants	There are no priority areas determined for this category in this LGA	n/a	Low	▪ Monitor vegetation for invasive plant infestations and control when identified to prevent spread
		Protection of areas identified as having high biodiversity	Oatley Bay, Kyle Bay and Shipwrights Bay (Figures 8.12n and 8.12o, Appendix 3)	Medium	▪ Prioritisation and identification of areas of highest biodiversity for bush regeneration activities ▪ Monitoring of weed infestations adjacent to areas of high biodiversity value that are not currently affected ▪ On ground works to address areas identified as top priority
	Sea level rise	Preservation of land to ensure areas for landward retreat of estuarine vegetation due to rising sea levels	Oatley Bay Kyle Bay	High	▪ Ensure future protection of vegetation communities and topography of the site ▪ Build resilience in existing communities to allow adaptation to disturbances such as rising sea level.

Table 8.25 –12 Key Ecological Management Recommendations for Sutherland LGA

	Key management categories	Specific management focus	Specific Location	Priority Ranking of management categories	Management Recommendations
SUTHERLAND LGA	Seagrass	Seagrass protection	Mill Creek (Figure 8.12l, Appendix 3) Mouth of the Woronora River (Figure 8.12p, Appendix 3) Gwawley Bay (Figure 8.12q, Appendix 3) Woolooware Bay (Figure 8.12t, Appendix 3) Towra Point (Figure 8.12s, Appendix 3) Weeney Bay (Figure 8.12u, Appendix 3) Quibray Bay (Figure 8.12u, Appendix 3)	High	▪ Monitor sediment deposition at the mouth of the creeks and associated seagrass expansion or contraction in size ▪ Seagrass distribution, diversity and health should be monitored when activities are such as dredging are undertaken in Botany Bay to determine its response to changed bathymetry and sediment. ▪ Installation of seagrass friendly moorings
	Mangroves	Mangrove health and clearing	Quabray Bay at Towra Point (Figure 8.12u, Appendix 3) Mangrove islands near Ovens Reach (Figure 8.12p, Appendix 3)	Medium	▪ Monitor health of stands ▪ Enforced removal of illegal jetties to restore continuation of mangrove stands along the foreshore
			All foreshore areas where seawalls are present, particurarly Sylvania Waters and new development at Woolware Bay	Medium	▪ New seawalls are to be ecologically friendly. ▪ Education program with private landowners on the environmental benefits od installing these types of walls.
		Rubbish hotspot: Removal of rubbish from mangrove vegetation	Opposite the mouth of salt pan creek (Figures 8.12j, Appendix 3)	Medium-High	▪ Regular removal and monitoring of rubbish

SUTHERLAND	Key management categories	Specific management focus	Specific Location	Priority Ranking of management categories	Management Recommendations
	Saltmarsh	Saltmarsh revegetation	Georges River National Park – Southern Side of the Georges River between Deadmans Creek and Mill creek (Figure 8.12j, Appendix 3)	High	▪ Management of 4wd access to the site and revegetation of saltmarsh species ▪ Construct fencing and educational signage to deter 4wd damage and trampling
			Oyster Bay, Kareela Golf Club	High	▪ Liase with Kareela Golf Course about revegetation of the foreshore area incorporating saltmarsh species to promote the spread of this community.
		Encroachment of mangroves into saltmarsh areas	Mill Creek (Figure 8.12l, Appendix 3) Oyster Bay Woolooware Bay (Figure 8.12t, Appendix 3) Towra Point (Figure 8.12s, Appendix 3) Weeney Bay (Figure 8.12u, Appendix 3) Quibray Bay (Figure 8.12u, Appendix 3)	High	▪ Monitor intraspecific competition between saltmarsh and other estuarine vegetation communities ▪ At Towra Point, Weeney Bay and Quibray Bay coordinate management actions with all landowners and managers
		Construction of saltmarsh habitat	Oyster Bay (Figure 8.12p, Appendix 3) Scylla Bay (Figure 8.12m, Appendix 3)	High	▪ Possible area for saltmarsh construction in response to sea level rise
		Invasive plant control	Mill Creek (Figure 8.12l, Appendix 3)	High	▪ Removal of invasive plant species within estuarine vegetation in this reserved area
		Clean up of oyster depot to revegetate native flora, particurarly	Foreshore between Weeney Bay and Quibray Bay (Figure 8.12u, Appendix 3)	High	▪ Clean up site including contamination assessment for dumped tar and removal of all stakes and rubbish

SUTHERLAND	Key management categories	Specific management focus	Specific Location	Priority Ranking of management categories	Management Recommendations
		saltmarsh			▪ Invasive plant removal ▪ Revegetation
		Rubbish hotspot: Removal of rubbish from saltmarsh vegetation	Opposite the mouth of Salt Pan Creek (Figures 8.12j, Appendix 3)	High	▪ Regular removal and monitoring of rubbish
	Estuarine vegetation (estuarine reedland and estuarine swamp oak forest)	Integrity of estuarine vegetation communities	Mill Creek (Figure 8.1b, Appendix 3) Oyster Bay (Figure 8.1p, Appendix 3)	High	▪ Monitor the integrity and condition of the estuarine vegetation communities as shown in Figure 8.1b (Appendix 3) to determine present and/or future anthropogenic impacts resulting in intraspecific competition between these communities.
		Rubbish hotspot: Removal of rubbish from estuarine vegetation	Opposite the mouth of salt pan creek (Figures 8.12j, Appendix 3)	Medium-high	▪ Regular removal and monitoring of rubbish
	Riparian vegetation (Figures 8.12j, l-n, p-u)	Management and protection of Coastal Sand Littoral Forest (part of the Kurnell Dune Forest EEC)	Towra Point Nature Reserve	High	▪ Continued management and protection as part of Towra Point Nature Reserve management
		Management and protection of Coastal Tea-tree Banksia Scrub	Towra Point Nature Reserve	High	▪ Continued management and protection as part of Towra Point Nature Reserve management

SUTHERLAND	Key management categories	Specific management focus	Specific Location	Priority Ranking of management categories	Management Recommendations
		Management and protection of Cumberland Riverflat Forest (part of the River Flat Eucalypt Forest EEC)	Deadmans Creek; Mill Creek	Medium	▪ Detailed condition assessment to guide future management actions ▪ Utilise bush regeneration best practice guidelines to improve vegetation condition
		Management and protection of Coastal Freshwater Swamp Forest (part of the Sydney Freshwater Wetlands)	Mill Creek	Medium	▪ Detailed condition assessment to guide future management actions ▪ Utilise bush regeneration best practice guidelines to improve vegetation condition
			Towra Point Nature Reserve	Medium	▪ Continued management and protection as part of Towra Point Nature Reserve management
	Endangered Ecological Communities (EECs) (Figures 8.12j, l-n, p-u)	Management and protection of Kurnell Dune Forest EECs	Towra Point Nature Reserve	High	▪ Continued management and protection as part of Towra Point Nature Reserve management
		Management and protection of Swamp Oak Forest EEC	Mill Creek	High	▪ Detailed condition assessment to guide future management actions; Utilise bush regeneration best practice guidelines to improve vegetation condition
			Towra Point Nature Reserve	High	▪ Continued management and protection as part of Towra Point Nature Reserve management
			Georges River National Park	High	▪ Continued management and protection as part of Georges River National Park management

SUTHERLAND	Key management categories	Specific management focus	Specific Location	Priority Ranking of management categories	Management Recommendations
		Management and protection of River Flat Eucalypt Forest	Deadmans Creek; Mill Creek	Medium	▪ Detailed condition assessment to guide future management actions; Utilise bush regeneration best practice guidelines to improve vegetation condition
		Management and protection of Swamp Sclerophyll Forest on Coastal Floodplains	Mill Creek	Medium	▪ Detailed condition assessment to guide future management actions; Utilise bush regeneration best practice guidelines to improve vegetation condition
			Towra Point Nature Reserve	Medium	▪ Continued management and protection as part of Towra Point Nature Reserve management
			Georges River National Park	Medium	▪ Continued management and protection as part of Georges River National Park management
		Management and protection of Sydney Freshwater Wetlands	Mill Creek	Medium	▪ Detailed condition assessment to guide future management actions; Utilise bush regeneration best practice guidelines to improve vegetation condition
			Towra Point Nature Reserve	Medium	▪ Continued management and protection as part of Towra Point Nature Reserve management
	Threatened Flora	Protection	*Acacia pubescens* (Georges River National Park – Alfords Point) (Figure 8.12j & l, Appendix 3)	Medium	▪ Ground truth threatened flora species record within Georges River National Park - If species and/or habitat occurs, investigate condition and health and monitor and manage as required.
	Threatened	Protection	Towra Point Nature Reserve (Figure 8.12r-	High	▪ Continued protection and monitoring of bird

SUTHERLAND	Key management categories	Specific management focus	Specific Location	Priority Ranking of management categories	Management Recommendations
	Fauna		u, Appendix 3)		habitat
			Koala (Georges Rive National Park, Holsworthy) (Figure 8.12h, Appendix 3)	Medium	▪ Ground truth threatened fauna species habitat - If habitat occurs, investigate condition and health and monitor and manage as required.
			Pied Oystercatcher (near Thompsons Bay Reserve) (Figure 8.12m, Appendix 3)	Medium	▪ Ground truth threatened fauna species habitat along inter tidal area (public foreshore area) - If habitat occurs, investigate condition and health and monitor and manage as required.
			Green Turtle (Taren Point) (Figure 8.12q, Appendix 3)	Medium	▪ Ground truth threatened fauna species habitat - If habitat occurs, investigate condition and health and monitor and manage as required.
			Pied Oystercatcher (Woolooware Bay, Hurstville Bay, Illawong) (Figure 8.12q & m, Appendix 3) Black-necked Stork (Hurstville Bay Illawong) (Figure 8.12m, Appendix 3) Little Tern (Taren Point) (Figure 8.12q and r, Appendix 3) Broad-billed Sandpiper & Terek Sandpiper (Woolooware Bay) (Figure 8.12q & t, Appendix 3) Australasian Bittern (Woolooware Bay) (Figure 8.12t, Appendix 3)	Medium	▪ Ground truth threatened fauna species habitat along inter tidal area - If habitat occurs, investigate condition and health and monitor and manage as required.

SUTHERLAND	Key management categories	Specific management focus	Specific Location	Priority Ranking of management categories	Management Recommendations
			Threatened Wader Bird Habitat: Pied Oystercatcher, Sooty Oystercatcher and Great Knot (Woolooware Bay) (Figure 8.12q & t, Appendix 3)	Medium	▪ Ground truth threatened wader bird habitat along inter tidal area. If habitat occurs, investigate condition and health and monitor and manage as required.
	Aquatic Fauna and habitat	Water Quality	Throughout estuary system	High	▪ Water quality results from GRCCC program to guide aquatic fauna management
		Seagrass habitat	Mill Creek (Figure 8.12l, Appendix 3) Mouth of the Woronora River (Figure 8.12p, Appendix 3) Gwawley Bay (Figure 8.12q, Appendix 3) Woolooware Bay (Figure 8.12t, Appendix 3) Towra Point (Figure 8.12s, Appendix 3) Weeney Bay (Figure 8.12u, Appendix 3) Quibray Bay (Figure 8.12u, Appendix 3)	High	▪ See Seagrass management recommendations above
	Migratory birds	Protection of migratory bird habitat	Towra Point Woolooware Bay	High	▪ Protection and restoration of breeding and foraging habitat for migratory bird species

SUTHERLAND	Key management categories	Specific management focus	Specific Location	Priority Ranking of management categories	Management Recommendations
	Terrestrial fauna and habitat	Fauna Habitat – degradation and loss	particularly Towra Point Nature Reserve and freshwater wetlands at Kurnell, two wetlands in Georges River National Park between Deadmans Creek and Mills Creek, and Oyster Depot at Kurnell	High	▪ Throughout catchment, particularly where urban areas encroach on foreshore and there is heavy invasive plant invasion
		Fauna Habitat protection and creation	Along foreshore and between significant habitat areas	Low	▪ Reservation of vegetation to provide a continuous wildlife corridor along the foreshore or between significant habitat areas ▪ Identification of wildlife corridors along the estuary as well as to surrounding reserves and habitat areas
	Pest species	Pest Species Control	Towra Point Nature Reserve	High - large number of migratory bird species and a breeding population of the Little Tern	▪ Towra Point Nature Reserve - Continue pest management program
	Invasive plants	Hot Spot	Georges River National Park	High	▪ Georges River National Park -Continue pest management program
			n/a	Low	▪ Co-ordination between LGAs for pest control, particularly for the European Fox
			Towra Point Nature Reserve	High	▪ Detailed condition assessment to guide future management actions; Utilise bush regeneration best practice guidelines to improve vegetation

SUTHERLAND	Key management categories	Specific management focus	Specific Location	Priority Ranking of management categories	Management Recommendations
					condition
	Sea level rise	Preservation of land to ensure areas for landward retreat of estuarine vegetation due to rising sea levels	Towra Point (Figure 8.5c, Appendix 3) Oyster Bay (Figure 8.5b, Appendix 3) Mill Creek (Figure 8.5b, Appendix 3)	High	▪ Ensure future protection of vegetation communities and topography of the site

Table 8.26 – Key Ecological Management Recommendations for Rockdale LGA

	Main Issues	Specific management focus	Specific Location	Priority Ranking of Main Issue	Management Recommendations
ROCKDALE LGA	Seagrass	Seagrass protection	Sandringham Bay (Figure 8.12r and v, Appendix 3) Lady Robinson Beach (Figure 8.12v, Appendix 3)	High	▪ Seagrass distribution, diversity and health should be monitored when activities are such as dredging are undertaken in Botany Bay to determine its response to changed bathymetry and sediment. Specifically, monitoring should be undertaken to determine seagrass response to the current runway works at Sydney International Airport
	Mangroves	n/a	There are no mangroves mapped in this LGA in the study area	n/a	▪ n/a
	Saltmarsh	n/a	There are no saltmarsh mapped in this LGA in the study area	n/a	▪ n/a
	Estuarine vegetation (estuarine reedland and estuarine swamp oak forest)	n/a	There is no estuarine reedland and estuarine swamp oak forest mapped in this LGA in the study area	n/a	▪ n/a
	Riparian vegetation	There are no priority areas determined for this category in this LGA	n/a	n/a	▪ n/a
	EECs	There are no EECS	n/a	n/a	▪ n/a

ROCKDALE	Main Issues	Specific management focus	Specific Location	Priority Ranking of Main Issue	Management Recommendations
		occurring within this LGA			
	Threatened Flora	No ground truthing recommended due to threatened flora species being either historical or outside of study area	n/a	n/a	▪ n/a
	Threatened Fauna	Protection	Little Tern (Sandringham Bay & Cooks Park near Cooks River mouth) (Figure 8.12r & v, Appendix 3) Pied Oystercatcher (Cooks Park near Cooks River mouth) (Figure 8.12v, Appendix 3)	Medium	▪ Ground truth threatened fauna species habitat along inter tidal area . If habitat occurs, investigate condition and health and monitor and manage as required.
			Australian Fur-seal (Figure 8.12v, Appendix 3)	Medium	▪ Ground truth threatened fauna species habitat.
	Aquatic Fauna and habitat	Fish	Botany Bay (Figure 8.12v, Appendix 3)	High	▪ Ensure use of pipes from Botany Bay (at Florence Street) to Scarborough Ponds continues
		Water Quality	Throughout estuary system	High	▪ Water quality results from GRCCC program to guide aquatic fauna management
		Seagrass habitat	Sandringham Bay (Figure 8.12v, Appendix 3) Lady Robinson Beach (Figure 8.12v, Appendix 3)	High	▪ See Seagrass management recommendations above

ROCKDALE	Main Issues	Specific management focus	Specific Location	Priority Ranking of Main Issue	Management Recommendations
	Migratory birds	Protection of migratory bird habitat	Sandringham Bay Near Cooks River mouth	Low	▪ Habitat protection of intertidal mud flat where birds forage
	Terrestrial Fauna and habitat	Fauna Habitat – degradation and loss	Throughout catchment, particularly where urban areas encroach on foreshore and there is heavy invasive plant	Medium	▪ Habitat protection of current reserves ▪ Increase areas of natural bushland protected for conservation, particularly adding to existing patches to minimise edge effects and fragmentation ▪ Survey and research into fauna species occurring within the estuary, particularly threatened species ▪ Habitat modeling to determine priority conservation areas ▪ Protection of wetlands and other significant fauna habitat areas
		Fauna Habitat protection and creation	Along foreshore and between significant habitat areas	Low	▪ Reservation of vegetation to provide a continuous wildlife corridor along the foreshore or between significant habitat areas ▪ Identification of wildlife corridors along the estuary as well as to surrounding reserves and habitat areas
	Pest Species (aquatic and terrestrial)	Control	n/a	Low	▪ Co-ordination between LGAs for pest control, particularly for the European Fox
	Invasive plants	There are no priority areas determined for this category in this LGA	n/a	Low	▪ Monitor vegetation for invasive plant infestations and control when identified to prevent spread

ROCKDALE	Main Issues	Specific management focus	Specific Location	Priority Ranking of Main Issue	Management Recommendations
	Sea level rise	n/a	There is no estuarine vegetation mapped in this LGA except seagrass. Management recommendations for seagrass have been identified above in this table.	n/a	▪ n/a

9 HUMAN USAGE, RECREATION AND IMPACTS

This section of the report describes historical and present day land use and planning within the Georges River Estuary, waterway and foreshore usage, recreational and commercial activities, as well as social and heritage aspects of the study area.

9.1 Land Use And Planning

The type of land use along the foreshore of the study area and throughout the LGAs influences the health of the river system in different ways. The highly urbanised and industrialised use has and continues to put increasing pressure on the river ecosystem and has resulted in degraded estuarine health. While, a healthy riparian edge creates a buffer, protecting the river from surrounding land uses which may cause pollution and water quality issues.

9.1.1 Historical Land Use

The Georges River catchment has changed since European settlement. Clearing of low lying, sparsely vegetated areas with rich soil occurred for agricultural use of the land after settlement. The upstream part of the study area where the soils include alluvial deposits, sand, silt, clay and gravel would have been suitable for agriculture (Figure 2.7). The sandstone soil which occurs approximately from Moorebank to Botany Bay (Figure 2.7) is less suitable for agriculture due to it poor nutrient content and in some parts rockiness and higher elevation. Historical uses of the estuary include sand mining at Chipping Norton Lakes and a significant oyster industry.

9.1.2 Present Land use

Today a variety of land uses are present throughout the study area, including urban, bushland, parkland and commercial. The study area includes two large areas reserved for conservation. These areas are Georges River National Park and Towra Point Nature Reserve.

In addition the Department of Defence utilises a large area of land adjacent to the estuary for military training, at the Holsworthy Military Reserve. The Holsworthy Military Reserve is a relatively undisturbed area due to relatively low impact use from defence operations. The area has significant conservation value, including a diversity of vegetation types and species, with over 400 species recorded within the area (DEWHA 2004). Parts of the military reserve have a high fauna diversity, and several flora and fauna species recorded in the area are of local and national significance (DEWHA 2004).

The main industries along the river include sewage treatment plants at Liverpool and Holsworthy and industrial areas at Moorebank, Caringbah and Kurnell. Closeby to the study area are airports, at Bankstown and Botany Bay, and a sewage treatment plant at Cronulla. Other uses of the estuary include recreational fishing, a reduced oyster industry and until recently commercial fishing.

The different land uses of the larger Botany Bay catchment are shown in Figure 9.1. The study area is part of this catchment and is highlighted on this map. The dominant land use surrounding the estuary is urban, which includes a mix of residential and commercial land use. Threats from urban areas on estuary health include invasive plant invasion, pollution

from diffuse (i.e. stormwater runoff) and point sources (i.e. overflows from sewage pipes), clearing, illegal dumping, vandalism and pest species. Threats from commercial use include land contamination. In the study area an old tip site is located in the upper reaches of Salt Pan Creek. The riparian edge in this previously disturbed area was dominated by invasive plants species, including those declared as noxious. These threats have contributed to the estuary classified as being in an extensively modified condition under the Australia-wide National Land and Water Resources Audit.

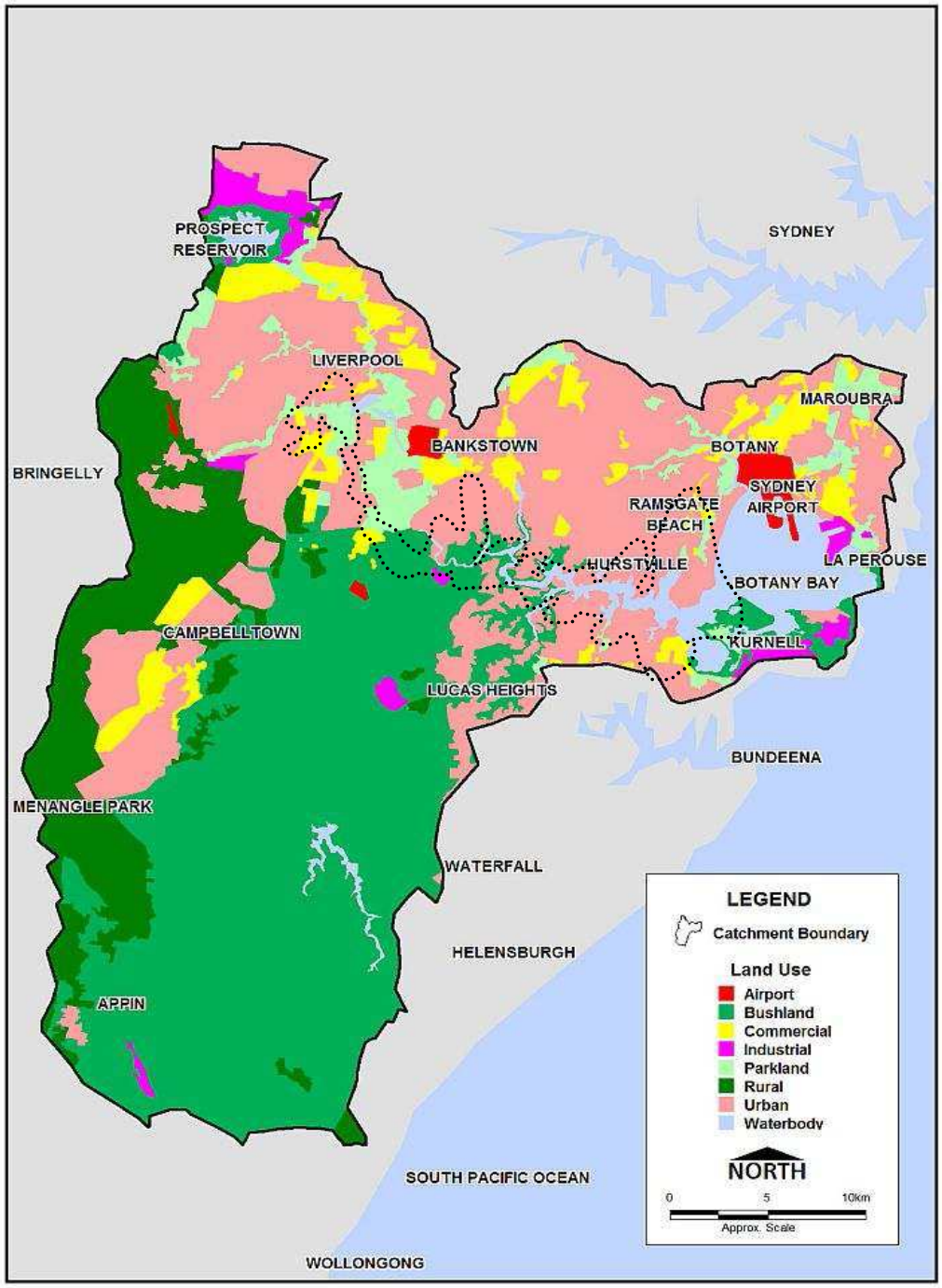

Figure 9.1 – Botany Bay Catchment land use (SMCMA 2007)

9.1.3 Planning

Strategic Regional Planning

The Georges River catchment covers a large proportion of the Sydney Metropolitan area. The catchment includes parts of 14 LGAs, covering a significant portion of the Greater Metropolitan Region (NSW DoP 2009). Due to this large area and the multiple governing inputs, strategic planning is required at a regional scale. In addition, the complexities of managing an extensive natural environment require strategic regional plans. These plans include the entire estuary and aid land managers during planning to benefit the entire estuary system.

Two strategic planning documents for the Georges River catchment have been formulated (NSW DoP 2009). They include:

- Southern Sydney Catchment Blueprint (2002) – this document details an action plan with the aim of improving the catchments of southern Sydney. This includes the Georges River catchment as well as the catchments of Eastern Beaches, Botany Bay and Cooks River.
- Shaping the Georges River Catchment (1999) – this is a strategic action plan and details the regional environmental plan (Greater Metropolitan Regional Environmental Plan No 2—Georges River Catchment) providing a strategic planning framework for environmental management related with all new development within the catchment. This action plan has been superseded by the Southern Sydney Catchment Blueprint.

Whilst Regional Environmental Plans (REPs) are no longer part of the hierarchy of environmental planning instruments in NSW, the Greater Metropolitan Regional Environmental Plan No 2—Georges River Catchment is now deemed a State Environmental Planning Policy (SEPP). The general objectives of the plan are to improve the water quality and environmental quality of the catchment and ensure a consistent approach to environmental planning along the Georges River. The plan sets out the planning controls that must be adhered to when a council prepares an LEP, a consent authority determines a development application, or when works which do not require development consent but which has the potential to adversely affect the water quality, river flows, flood regime or ecosystems within the Catchment.

In addition to these strategic documents a Water Quality Improvement Plan is currently being prepared for the Botany Bay catchment by the SMCMA which includes the study area (John Dahlenburg, SMCMA *pers. comm.* 26 March 2010). This plan is being prepared as part of the Botany Bay Water Quality Improvement Program.

Strategic Regional Planning for the Georges River catchment includes a number of government initiatives (NSW DoP 2009):

- Embrace the diversity of the catchment – this includes the natural, social and economic diversity;
- To identify, protect and provide for the improvement of significant natural and cultural heritage values;
- Improve natural resource management;
- Promote interest in catchment resources; and
- Forge stronger communities.

Strategic planning for the Georges River Catchment is supported by a number of studies and guidelines (NSW DoP 2009). These include:

- Biodiversity of the Georges River Catchment – (Steller & Bryant 2004; Williams *et al* 2004)

  - Including a terrestrial and aquatic biodiversity assessment aimed at providing a regional context for biodiversity planning; and

  - These comprehensive documents give land managers an understanding of the environmental value of the estuary environment and recommends management actions. A combined estuary management approach following the recommendations from this study would benefit the health of the estuary ecosystem;

- Georges River Catchment Built Environment and Foreshore Access Study (NSW DIPNR 2004a)

  - Incorporating planning and management actions to improve the aesthetic environment and access to the waterways

  - This study informs land managers of the value of the study area and details foreshore access. A combined estuary management approach following the recommendations from this study would increase access to the Georges River and appreciation by the local community and visitors; and

- Georges River Catchment: Guidelines for Better Practice in Foreshore Works (NSW DIPNR 2004b) –

  - Guidelines to help practitioners during the planning and implementation of works along the foreshore of the Georges River and its tributaries.

A draft Catchment Action Plan has been completed by the SMCMA which will guide their activities and form the basis for partnerships with the community, business, industry and government (SMCMA 2010). This plan will help to identify priority areas where natural resource management projects are to be carried out and that their outcomes have the best outcome for both the environment and the community (SMCMA 2010).

Local Environmental Plans

Local Environmental Plans (LEP) prepared by councils guide planning decisions for local government areas. Through zoning and development controls, they allow councils to supervise the ways in which land is used. The study area falls under seven local council jurisdictions; Liverpool, Fairfield, Bankstown, Sutherland, Hurstville, Kogarah and Rockdale. The LEPs that are presently in use for each of these LGAs is listed below:

- Liverpool - Liverpool Local Environmental Plan 2008 -;
- Fairfield - Fairfield Local Environmental Plan (LEP) 1994;
- Bankstown - Bankstown Local Environmental Plan 2001 and Bankstown Development Control Plan 2005;
- Sutherland - Sutherland Shire Local Environmental Plan 2006;
- Hurstville - Hurstville Local Environmental Plan 1994;
- Kogarah - Kogarah Local Environmental Plan 1998; and
- Rockdale - Rockdale Local Environmental Plan 2000.

An investigation into planning documents for each LGA did not find any specific local plans for the estuary and adjacent riparians areas. Multiple land use planning documents for the estuary may inhibits its management for protection and conservation. Due to this it is

important to have an over arching management plan that can be developed in line with strategic guidelines for the larger catchment area.

Note that when a council prepares an LEP or a consent authority determines a development application, the planning controls of the Greater Metropolitan Regional Environmental Plan No 2—Georges River Catchment must be taken into consideration. These controls guide a wide range of elements such as Caravan Parks, Extractive Industry, Flood Control Works, Housing Development and Marina and Slipways.

9.2 Waterway And Foreshore Usage

9.2.1 Recreational Uses

The Georges River is an important recreational area in the wider Sydney metropolitan area (NSW DIPNR 2004a). The study area provides access to a number of land and water based recreational activities. Popular water sports include boating, fishing, kayaking, canoeing, sailing and swimming. Land based sports undertaken in the area include walking, cycling, 4 wheel driving, quad and dirt biking, mountain biking, shore fishing and golf. There are also a range of sporting areas, including those for tennis, bowls and soccer adjacent to the estuary.

Recreational landuse has been mapped in Figure 9.2. This map shows the variety of open space within the study area including national parks, golf courses and parks and gardens. There are a number of areas of public open space within the river corridor, including small local parks, such as Lieutenant Cantello Reserve, to large parkland areas at Chipping Norton Lakes and Mirambeena Regional Park, and the extensive bushland of the Georges River National Park (NSW DIPNR 2004a). These areas are frequented for gatherings, bbqs and picnics. Georges River and Towra Point Nature Reserve are two large conservation areas within the study area. Towra Point Nature Reserve is located within Botany Bay and Georges River National Park in the middle of the Georges River estuary. These reserved areas are also popular for bird watching, with the former offering several tracks for bushwalking and bike riding and provides access for launching of water craft and areas for shore fishing. However, the use of motored vehicles in the National Park is not permitted.

A study in 1978 by the State Pollution Control Commission concluded that Botany Bay is a regionally important area for water based recreation, particularly by families. The main reasons for usage of this area and Kogarah Bay were attributed to the ease of access, the safety of the area and the availability of parking (SPCC 1978). A recent report, of the Georges River and its tributaries, aimed to improve the environmental, recreational and public access qualities of the foreshore areas (NSW DIPNR 2004a). The study recommended improving physical and visual access to the river, enhancement of the foreshore experience, promoting general awareness of the river environment and education (NSW DIPNR 2004a). This included recommendations to extend the existing trail network around the foreshore. During desktop investigation it was determined that the extensions to the track network have begun.

The popularity of water based recreation is highlighted by the multiple mooring locations throughout the study area (Figure 9.2). They predominantly occur from Salt Pan Creek downstream to Botany Bay, with large marinas located at San Souci, Kogarah Bay (St Kilda Point Marina) and at Sylvania (Tom Ugly's Bridge Marina).

A recent study undertaken by the Sydney Metropolitan Catchment Management Authority (SMCMA) (2008) as part of the BBCCI determined the environmental values of Botany Bay and its catchments. The most popular catchment activities that had been undertaken five years prior to 2008 by respondents were walking, party/picnic, bushwalking and sightseeing with visitors (SMCMA 2008).

Though recreational use of the study area is beneficial to the local community and visitors, it also has the potential to cause damage to the natural environment. Four wheel driving, and the use of quad and dirt bikes, impact riparian areas, causing sedimentation and erosion issues and trampling impacts. Wetlands in the Georges River National Park have been damaged by these recreational activities. Damage has also been caused by boating to seagrass beds. This has been observed where moorings are located within seagrass beds and where boats have driven across beds during low tides. In addition to this, marinas and boating are identified as one of the main sources of pollution (Florence *et.al.* 1999).

9.2.2 Commercial Industries

Tourism

The high recreational use of the waterway potentially adds to the local tourism industry. Tourists hire boats, berths and moorings and purchase fishing supplies (i.e. bait and tackle) that are available at marinas. There are also restaurants and cafes located alongside marinas.

There are several golf courses located alongside or near the Georges River and its tributaries. This includes Fairfield Golf Club between the Georges River and Prospect Creek, Riverwood Golf Course, New Brighton Golf Course and Riverlands Golf Course along the Georges River, Hurstville Golf Course near Lime Kiln Bay and Beverley Park Golf Course in Kogarah Bay. Their location near the natural setting of the Georges River would be aesthetically pleasing.

Several sports clubs are located close to or within the study area, often with ovals along the foreshore. This includes clubs for sailing, motor boating, tennis, bowling, softball, rowing, touch football, squash, soccer and rugby league. Panania Diggers (previously Panania East Hills RSL Club) is located adjacent to Kelso Creek.

Commercial Fishing

In 2002 commercial fishing in Botany Bay and all its tributaries was prohibited, including Georges River (Williams *et al* 2004; WBM 2007). The exception to this closure is the taking of lobster and abalone (Williams *et al* 2004). Prior to this closure the study area had been utilised for commercial fishing by up to 60 commercial fishers (I&I NSW 2001), who were mainly concentrated within Botany Bay commonly using haul netting, mesh netting, prawn trawling and fish tapping methods (Williams *et al* 2004). Prior to the 2002 closure there were 13 other types of closures throughout the Georges River in place of four different types, conservation, amenity, human health and safety (Williams *et al* 2004). These closures were small and localised in nature with the two larger ones for prawn trawling and to protect the Australian Bass (*Macquaria novemaculata*) during their reproductive migration (Williams *et al* 2004). A recent aquatic study of the Georges River found that a large portion of the fish recorded were of commercial/recreational significance such as Dusty Flathead (*Platycephalus fuscus*) and Tailor (*Pomatomus saltatrix*).

Commercial Oyster Leases

Harvesting of oysters is undertaken within the study area. The Georges River has a long history associated with the oyster industry, beginning in the late 1870s (Williams *et al* 2004). The first area utilised was at the back of Sylvania Waters, known at the time as Gawley Bay, for the harvesting the Sydney Rock Oyster (*Saccostrea commercialis*) (Williams *et.al.* 2004). Various techniques have been used to grow these oysters, including *clairs*, modelled on French production methods, use of artificial substrata including stones and mangrove sticks and the intertidal rack growing system which is used today (Williams *et al* 2004). The use of

racks, lead to a growth in production, peaking in 1971 with the production of 41, 068 bags (Williams *et al* 2004). This industry would be valued at approximately $7 million today (Williams *et al* 2004).

A drop in production occurred in 1983, this was potentially due to changes in nutrient levels in the estuary system resulting from upgrades to the Glenfield STP, including partial phosphorous removal from effluent from 1983 and the diversion of dry weather flow from this STP and the Liverpool STP to the Malabar cliff-face ocean outfall (Williams *et.al.* 2004). However, the effects of nutrient levels in the river and effluent discharge on oyster production have not been studied (Williams *et.al.* 2004). Demand for oysters dropped due to a series of food poisoning scares and subsequent loss of consumer confidence between the late 1960s to late 1980s (Williams *et.al.* 2004). Mandatory purification procedures were introduced, though the industry did not return to previous output levels.

The industry was further weakened in the early 1990s due to an outbreak of Qx disease, killing many oysters including 80% upstream of Tom Uglys Bridge (Williams *et.al.* 2004). The spread of this disease has led to industry being nearly removed from the estuary with few oyster leases remaining, including those in Woolooware Bay, Towra Point and Quibray Bay (Williams *et al* 2004). The use of the estuary for oyster harvesting has impacted the health of the estuary. The use of tar to treat the sticks that make up the racks has polluted the river environment and many racks has polluted the river environment and many racks and sticks have been left after the industry decreased. Remnants of the industry were observed at Neverfail Bay where tar is present on top of the sandy sediment and at Oyster Depot in Towra Point with a multitude of racks and debris from oyster farming is left behind. Examples can be seen in Appendix 8, Plates 10 to 12. A government funded clean-up program of derelict oyster leases is in progress (Williams *et al* 2004).

9.2.3 Social significance

The Georges River and its tributaries wind through many suburbs throughout the study area and form part of the local environment for local residents. The close proximity of the estuary is likely to increase contact and connection by residents, potentially forming a connection to and an interest in the river environment. The environmental values survey conducted in the Botany Bay catchment (SMCMA 2008) highlighted this connection by the response of community members and stakeholder when asked what aspects or activities they were concerned about losing from their waterways. The top seven aspects or activities were either natural or non-anthropogenic (John Dahlenburg, SMCMA *pers. comm.* 26 March 2010). The strongest environmental values relate to visual and natural amenity, recreational areas, quiet environment, aquatic and terrestrial wildlife with the greatest concern pertained to pollution and threats to water quality (SMCMA 2008).

Bush regeneration in progress

The social significance of the natural features of the study areas are highlighted by the number of bush care groups. Bush regeneration activities are undertaken throughout the catchment organised by local councils. The location of current bush regeneration groups is shown Figures 9.1 a –c. Scattered throughout the study area there are approximately 30 bushcare groups. In addition to these groups there is a group working at Towra Point Nature Reserve called the ‘Friend of Towra’ whose activities include bush regeneration, seed collection, vegetation surveys and habitat creation for the Little Tern (SSEC 2008). Previously bush regeneration activities have been also coordinated by the Georges River Catchment Management Committee as part of working bee activities (Georges River Catchment Management Committee 1997).

Conservation Volunteers are also working in the study area. During the field investigation for the current study, they were observed working on Bulba Gong Island in Chipping Norton Lake. The island is being managed for wildlife habitat/refuge program. Works being undertaken include bush regeneration including invasive plant control. The island is protected from direct urban impacts due to isolation from the foreshore. Conservation Volunteers also undertake bush regeneration and litter collection works at other sites along the Georges River.

In addition to volunteers assisting with regenerating the natural environment, there are other programs to help restore the estuary presently underway. The GRCCC is involved with a monitoring program (GRCCC 2010a) that includes between 30 to 40 groups undertaking catchment bi-annual sampling for macroinvertebrates and of water quality (John Dahlenburg, SMCMA pers. comm. 26 March 2010).

9.2.4 Management Issues & Recommendations

Encourage the use of the study area for recreational activities in an environmentally sensitive way (ie avoidance of seagrass beds by water craft)

Map the recreational opportunities within the study area including showing the walking trail network to inform residents and visitors of the these opportunities and promote their use

9.3 Heritage

A desktop Aboriginal and Cultural Heritage Report has been undertaken by Kayandel Archaeological Services for the Georges River Estuary to investigate the indigenous and cultural heritage significance, issues and future management for the study area (Appendix 6). The Georges River Estuary has a rich history with the presence of a range of Aboriginal and cultural heritage sites recognised within the study area.

9.3.1 Aboriginal Heritage

To identify known Aboriginal heritage sites and previous archaeological studies conducted within the Georges River Estuary several avenues of potential information were examined. The main sources of information were the AHIMS Site Register and Report Catalogue managed by DECCW. In accordance with DECCW policy, the study area was restricted in lateral extent so that the total number of recorded sites would be limited to less than 120. Between Liverpool Weir and Kogarah Bay the search area was restricted to a strip 80m wide on either side of the Georges River. Area searches were then conducted along Lady Robinsons Beach, and around Botany Bay, Woolooware Bay and around Towra Point. A site list was compiled and constraints on this data were outlined in the report (Appendix 6).

A total of 112 Aboriginal sites (included 27 sites which consisted of more than one recorded element) have previously been recorded within the study area, and 18 reports related directly to the study area. The Georges River Estuary contains a substantial Aboriginal heritage, but it is apparent that there are substantial gaps in the available information. Overall, middens were most frequent, making up more than half (57%) of the elements. These were followed by pigment art (20%) and lithic artefacts (15%) (Table 9.1). Engraved art and grinding grooves were rare.

Table 9.1 – Aboriginal Sites by Type within the Study Area (from AHIMS Search)

Element	Total Elements
Art (pigment)	28
Artefacts	21
Burial	1
Engraved art	3
Grinding grooves	1
Midden	79
PADs	3
Scarred tree	3
Total	**139**

The physical condition of many sites was recorded. Nine sites were said to be in good condition with four others suffering some graffiti or weathering. However, most sites had been disturbed, often by construction, excavation or landscaping works, and by vehicle or walking tracks. Many sites exhibited graffiti, especially those with sandstone surfaces suitable for Aboriginal pigment and engraved art are also suitable for modern marking. The deposits at several sites were eroding whilst the condition of 35 sites was unknown.

Many of the sites have not been formally recorded for several decades; there is potential for sites to occur within the study area which have not yet been recorded; there is insufficient knowledge of the current physical condition and likely threats to many of the recorded Aboriginal sites; and there is insufficient knowledge of Aboriginal historic sites/places.

Some sites appeared to be located immediately above sea level[2]. These sites could potentially be affected by rising sea level associated with climate change, which could increase the elevation at which shoreline erosion occurs. One engraving site was located below high tide level.

H. Goodall and A.Cadzow have recently published a book “Rivers and Resilience” which deals with Aboriginal history along the Georges River. This book discusses Aboriginal occupation of the River during the historic period and points the reader to several potential site locations. Some site locations were also referred to in the Sutherland Shire Council Aboriginal Cultural Heritage Study Georges and Woronora Rivers 2004 by Mary Dallas Consulting Archaeologists (MDCA 2004a). Summary information on these potential Aboriginal historic sites is included in section 3.1.3 of the Heritage report in Appendix 6.

Consultation with Aboriginal communities and groups along the Georges River and/or with historical ties to the River was not part of the scope of the current study. However, consultation must be carried out to broaden understandings of the cultural significance of the River and its heritage sites.

[2] estimates were based on the 1:25,000 topographic map sheet, assuming grid references were correct, and the precise elevations were not checked by field inspection

9.3.2 European Heritage

To identify European heritage sites and reports relevant to the Georges River Estuary zone, the following avenues of investigation were used:

- A search of the Heritage Office online database (including State Heritage Listings, items listed under Local Environmental Plans and items listed under the National Trust of Australia);
- A search of the Marine Heritage Online database (Shipwreck Search); and
- A search of the Heritage Office library in Parramatta.

The results of these searches were narrowed down to reports and sites relevant to the Georges River Estuary in terms of either a physical association (sites within a 200m proximity to the river) or a thematic association. It is important to note that the lists of items identified by the search of the Heritage Office online database should not be considered as a complete record of all historic heritage items and potential archaeological deposits within the Georges River Estuary. While it may be fairly representative of known extant built historic heritage (although items may exist that have not been nominated for a listing yet), it is significantly less representative of potential surviving archaeological material: archaeological deposits may exist in areas where no built historic heritage survives.

In total, 62 sites were identified within 200m of the Georges River (between Botany Bay and Liverpool Weir) using the Heritage Office online database. These results are presented in Appendix 6.

The results of the Marine Heritage 'Shipwreck Search' search where narrowed down to items lost within Botany Bay or Kogarah Bay. However, the results of this search are problematic, as an exact location cannot be pinpointed for each site (i.e. they could lie beyond the estuary).

The 'Shipwreck Search' search of the Maritime Heritage Online Database produced a total of four entries. No entries were found listed as being lost in the Georges River itself. These results are presented in Appendix 6.

9.3.3 Management Issues & Recommendations

The main management issues and recommendations for heritage within the Georges River Estuary can be summarised as follows:

- Heritage sites/places occur on land or in waterways that are owned or managed variously by state government agencies, local councils, private companies and/or individuals. This means that individual people, private and public organizations, and different levels of government may have responsibilities for the management of heritage sites. The development of management strategies for both Aboriginal and historic[3] heritage should lead to a more co-ordinated approach to heritage management within the study area.

- Management strategies should be developed that take into account legislative requirements relating to heritage and which address potential difficulties posed by diverse individuals, private companies, public groups, local councils, and state government agencies who may own or manage land or waterways which contain heritage items.

- The review has highlighted that there is insufficient knowledge of both Aboriginal and historic (European) heritage within the study area. Many of the Aboriginal sites have not been recorded for several decades. Further, the current physical

[3] Aboriginal sites contemporary with European occupation and dating from 1788.

condition and threats to many of the recorded sites (both Aboriginal and historic) are unknown.

- Historic Aboriginal heritage places have been a neglected area of heritage management and priority should be given to the potential places identified during this study (see Appendix 6). This should include field inspection to ascertain whether physical evidence may survive, and if further research is appropriate.

- Field inspections of previously recorded sites (Aboriginal and historic) should be carried out to ascertain their current physical condition and threats. Priority should be given to rare types of sites and to those which were last recorded before 2000.

- There is potential for sites or places to exist which have not previously been recorded within the study area. There are biases in the existing information with preference given to recording large and/or visible sites, such as Aboriginal shell middens and shelter art sites, and to heritage items including built structures and large houses. Buried archaeological sites (both Aboriginal and historic) are likely to be present which have not yet been identified. Aboriginal historic sites/places are particularly poorly known; 13 potential places were noted in the literature and further research (especially field inspection) should be carried out.

- Consultation with relevant Aboriginal community groups along the Georges River should be carried out regarding this and future stages of the project. Consultation should include assessment of Aboriginal cultural significance of the study area as a whole, and of particular heritage places/sites. Aboriginal cultural values should inform the management of heritage values more generally; and
- The management strategy may include commemoration of sites and public interpretation. This could be developed if requested and/or agreed to by Aboriginal community groups and should include Aboriginal cultural values of the Georges River estuary.

10 CONCLUSIONS

This report has been commissioned by the Georges River Combined Councils Committee and documents a Data Compilation and Estuary Processes Study for the Georges River Estuary. It identifies and collates key data and reports on the Georges River Estuary, encompassing relevant physical, ecological, social and economic, and land use planning activity characteristics.

The extents of threats and pressures on estuarine and riparian vegetation have been documented and mapped. Foreshore erosion, seawall assessments for the estuary, water quality, and existing gross pollutant traps and stormwater outlets have also been mapped and documented. The report documents viable specific management actions for the parts of the estuary which are degraded and priorities for protection of significant value areas.

The work presented herein has been carried out in accordance with the NSW Government Estuary Management Manual (1992), the NSW Estuary Management Policy, and the NSW Sea Level Rise Policy Statement.

Many studies have been undertaken along the Georges River over the last 150 years. This report collates all key data and reports on the Georges River Estuary from the numerous data sources available. Hydrodynamics and sedimentary processes, the ecology, water quality, as well as the social, economic, heritage and land use characteristics were comprehensively described.

Hydrodynamics and sedimentary processes have been significantly influenced by human factors within the Georges River catchment and were subject to important changes over the last decades. Tides, wave and wind climates have been detailed as well as sediment transport.

Water quality is a significant issue within the Georges River Estuary due to the degree of urbanisation along the river generating runoff, sewer overflow discharges and other pollution sources. ANZECC guidelines have been reported to be exceeded many times in several areas. Water quality data has been collated and analysed where possible. Water quality monitoring programs currently operating in the estuary have been described.

Foreshore erosion, seawalls and stormwater outlets were observed, assessed and mapped. Management actions for specific locations were proposed, prioritised, mapped and recommended for each local government area and for the Georges River Estuary as a whole, with some possible solutions suggested to improve the foreshore condition.

The estuary hydrodynamics are still responding to management practices carried out prior to the 1980s. The estuarine morphology is currently stabilising and adjusting to a new equilibrium state in response to the several dredging and reclamation works which occurred in the river channel, in particular the construction of the Chipping Norton Lakes. Therefore, erosion in the Georges River is likely to continue in the upper reaches and erosion problems in some areas would be difficult to solve.

Anthropogenic factors have also contributed to degraded health of the estuarine and riparian vegetation within the Georges River Estuary and surrounding area. Water quality, in particular sedimentation and erosion, directly influences the occurrence and successional stages of estuarine vegetation communities by changing the tidal influence and sedimentary processes of the estuary. However, large areas of high quality estuarine vegetation occur throughout the estuary, particularly within Towra Point Nature Reserve and the Georges River National Park.

Recommendations for closing data gaps, future work and potential management options for the Georges River Estuary study area have been identified for the various processes operating within the study area. The management actions for specific areas have been mapped within Appendix 2 and 3 and cover erosion, foreshore structures, endangered

ecological communities, estuarine vegetation, threatened flora/fauna and sea level rise. These management actions have been identified on the basis of a risk assessment to identify the highest priority issues and highest priority locations requiring management actions.

11 REFERENCES

Altoff, L and Falconer, A. (2008) Bivalvia http://www.bluering.org.au/Bivalvia.htm Accessed January 2010

ANZECC & ARMCANZ. (2000). Australian and New Zealand guidelines for fresh and marine water quality. October 2000. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australia.

Australian Museum (2009a) Beyond the reef: zooplankton http://beyond.australianmuseum.net.au/zooplankton/ Website viewed 12.1.2010

Australian Museum (2009b) Semaphore crab http://australianmuseum.net.au/image/Semaphore-Crab-Illustration Accessed 7 January 2010

Australian Museum (2008) Birds in backyards bird finder: Australasian Bittern http://www.birdsinbackyards.net/bird/224 Accessed January 2010

Australian Museum (no date) Semaphore crab http://australianmuseum.net.au/Semaphore-Crab Accessed 7 January 2010

Australian Museum Business Services (AMBS) (2001) Identification and analysis of autumn macroinvertebrate samples. For Bankstown City Council

Australian Museum Business Services (AMBS) (2000) Macroinvertebrate survey report. For Bankstown City Council

Australian Native Plants Society (Australia) (ANPSA) (2009) Threatened flora lists http://asgap.org,au/coding.html Accessed 17 January 2010

Australian Wetlands Pty Ltd (2006) Salt Pan Creek corridor masterplan report. Prepared for Bankstown City Council

Backhouse, G., Jackson, J. and O'Connor, J. (2008) National Recovery Plan for the Australian Grayling *Prototroctes maraena*. Department of Sustainability and Environment, Melbourne.

Bankstown City Council and Eco Logical Australia Pty Ltd (2002) Biodiversity strategy

Bankstown City Council (date unknown a) Macroinvertebrate survey report

Bankstown City Council (date unknown b) Kelso Creek estuary management plan

Bankstown City Council (date unknown c) Little Salt Pan Creek estuary management plan

Bankstown City Council (2009) Evaluation of Macrophyte Bed and Constructed Wetlands in Bankstown

Bankstown Municipal Council (1978) Channel changes in the Georges River between 1959 and 1973/1976 and their implications

BBCCI (2007) Modelling the Catchments of Botany Bay

BBCCI (2008) Environmental Assessment of Botany Bay: Sediments, Sediment Geochemistry and Foraminifera

BBCCI (2008) Modelling the Catchments of Botany Bay – Predicted Future Landuse Changes (2030 & 2070) E2 Modelling results

BBCCI (2008) Modelling the Catchments of Botany Bay – Council Pollutant Loads E2 Modelling Results

BBCCI (2008) Water Sensitive Urban Design Adoption Strategy for the Botany Bay Catchment

BBCCI (2009) Results of a multi-dimensional receiving water quality model for Botany Bay (Sydney, Australia)

Beechey, D. (2009), The seashells of New South Wales - Cymatium parthenopeum (von Salis, 1793) http://seashellsofnsw.org.au/Ranellidae/Pages/Cymatium_parthenopeum.htm Accessed January 2010

Bewsher Consulting (2004), Georges River Floodplain Risk Management Study and Plan

Birch, G.F. (1993) Sediment-bound Metallic Contaminants in Sydney's Estuaries and Adjacent Offshore, Australia

Birch, G.F., D. Evenden, M.E. Teutsch (1996) Dominance of Point Source in Heavy Metal Distributions in Sediments of a Major Sydney Estuary (Australia)

Bird, F.L. 1994. The effects of bioturbation in Port Phillip Bay. Technical Report No.14, CSIRO Port Phillip Bay Environmental Study, Melbourne, Australia, pp. 22.

Brown, G. & W. Maher (1992) The occurrence, distribution and sources if PAHs in the sediments of the Georges River estuary

Cappo, M., Alongi, D.M., Williams, D, and Duke, N. 1995. A review and synthesis of Australian Fisheries Habitat Research: Major threats, issues and gaps in knowledge of coastal and marine fisheries habitats (and references within). Fisheries Research and Development Corporation. In http://www.ozcoasts.org.au/indicators/changes_Saltmarsh_area.jsp

Commonwealth of Australia (2007) Department of Environmental, Water, Hertiage and the Arts. What is a weed? http://www.weeds.gov.au/weeds/what.html Accessed 8/09/10

Connell Wagner (2009) Southern Sydney Freight Line-Acid Sulfate Soils Management Plan

Copeland C., & Pollard D. (1996) The value of NSW commercial estuarine fisheries, Internal Report - NSW Fisheries, Cronulla. In http://www.dpi.nsw.gov.au/fisheries/habitat/aquatic-habitats/estuarine

Creese R.G., Glasby T.M., West G., Gallen C. (2009) Mapping the habitats of NSW estuaries. Industry and Investment NSW, PortStephens Fisheries Institute.

CSIRO 2008. CSIRO website http://www.csiro.au/resources/ClimateChangeAndFisheries.html Viewed 4.1.2010

Department of Environment, Climate Change and Water (DECCW) (2009a) The native vegetation of the Sydney Metropolitan Catchment Management Authority Area (Draft). Department of Environment and Climate Change NSW, Hurstville.

Department of Environment, Climate Change and Water (DECCW) (2009b) Threatened species website http://www.threatenedspecies.environment.nsw.gov.au/index.aspx Accessed December 2009

Department of Environment, Climate Change and Water (DECCW) (2009b) Environmentally Friendly Seawalls – A Guide to Improving the environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries

Department of Environment, Climate Change and Water (DECCW) (2005) Threatened species website – species profiles http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/search_simpleform.aspx Accessed January 2010

Department of Environment, Climate Change and Water (DECCW) (date unknown) Towra Point Nature Reserve http://www.environment.nsw.gov.au/NationalParks/parkHome.aspx?id=N0551 Accessed 7 January 2010

Department of the Environment, Water, Heritage and the Arts (DEWHA) (2010a) [Online Database] Environment Protection and Biodiversity Conservation Act Protected Matters Search Tool http://www.environment.gov.au/erin/ert/epbc/index.html, Accessed January 2010

Department of the Environment, Water, Heritage and the Arts (DEWHA) (2010b). Threatened species profiles in Species Profile and Threats Database, Department of the Environment, Water, Heritage and the Arts, Canberra. http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl Accessed January 2010

Department of the Environment, Water, Heritage and the Arts (DEWHA) (2004). Review of the Conservation Values of Commonwealth land in Western Sydney. [Online]. Canberra: Department of the Environment and Heritage (DEH). Available from: http://www.environment.gov.au/biodiversity/publications/w-sydney/index.html. Accessed: January 2010

Department of the Environment, Water, Heritage and the Arts (DEWHA) (2001) National recovery plan for albatrosses and giant-petrels. Wildlife Science Advice, Natural Heritage Division, Environment Australia http://www.environment.gov.au/biodiversity/threatened/publications/recovery/albatross/foraging.html#section3.12 Accessed January 2010

DLWC (1997) Georges River Flood Behaviour - Status Report

Eco Logical Australia Pty Ltd (2009) Yeramba Lagoon catchment masterplan Prepared for Bankstown City Council August 2009

Eco Logical Australia Pty Ltd 2003) Liverpool City Council biodiversity strategy

Environmental Partnership Pty Ltd (1996) Chipping Norton riverside park draft plan of management Prepared for Department of Urban Affairs and Planning and Liverpool City Council

Fisheries Scientific Committee (FSC) Final determination: *Pristis zijsron* – green sawfish January 2008 Ref. No. FD31 File No. FSC 00/10 http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/251357/FD31-green-sawfish.pdf Accessed April 2010

Florence *et al* (1999) An assessment of the health of the Georges River

GHD 2006. Benthos Sampling Report. GHD report prepared for Kogarah bay council April 2006.

Georges River Combined Councils Committee (GRCCC) (2010a) River Health Monitoring Program http://www.georgesriver.org.au/River-Health-Monitoring-Program.html Accessed April 2010

Georges River Combined Councils Committee (GRCCC) (2010b) Community river health monitoring program: report card – spring 2009 http://www.georgesriver.org.au/IgnitionSuite/uploads/docs/georges%20river%20report%20web%202010%201.pdf Accessed April 2010

Georges River Combined Councils Committee (GRCCC) (2010c) Riverkeeper Program http://www.georgesriver.org.au/Riverkeeper-Program.html Accessed April 2010

Georges River Catchment Management Committee 1997 Meeting minutes

Haradasa, D., S. Wylie & E. Couriel (1991). "Design Guidelines for Water Level and Wave Climate at Pittwater", Australian Water and Coastal Studies Pty Ltd Report 89/23, March, 1991.

Harbourwatch (2008) Sydney Metropolitan Area Harbour Swimming Sites – Lower Georges River

Industry and Investment NSW (I&I NSW) (2009) Black cod (*Epinephelus daemelii*) draft recovery plan. Fisheries Conservation and Aquaculture Branch, Port Stephens Fisheries Institute, I&I NSW

Industry and Investment NSW (I&I NSW) (2007a) Primefact 7: Green Sawfish *Pristis zijsron* March 2007 http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0018/5085/Primefact-7-Green-Sawfish.pdf Accessed January 2010

Industry and Investment NSW (I&I NSW) (2007b) Primefact 189: Black Cod Epinephelus daemelii March 2007 http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/144154/black-cod.pdf Accessed January 2010

Industry and Investment NSW (I&I NSW) 2009. *Historic Assessment of Estuarine Macrophytes in Botany Bay and the Georges River.* NSW Department of Industry and Investment. Port Stephens Fisheries Centre, Taylors Beach, NSW Australia.

Industry and Investment NSW (I&I NSW) (2005a) Weed definitions & FAQs: Noxious weeds http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/definition Accessed 5 January 2010

IPCC (2007). "*Climate Change 2007 – The Physical Science Basis, Fourth Assessment Report of Working Group 1 of the Intergovernmental Panel on Climate Change*", Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2007.

Kinhill Pty Ltd (1999) Mid-Georges River Stormwater Management Plan

Leigh, J., Briggs, J and Hartley, W. (1981) Rare or threatened Australian plants Australian National Parks and Wildlife Service, Special Publication 7

Lord, D.B. & M. Kulmar (2000). "The 1974 storms revisited: 25 years experience in ocean wave measurement along the south-east Australian coast", Proc. 27th ICCE, ASCE, Sydney, July, 2000, 559-572.

Media Release (2008) Minster for Primary Industries, Minister for Energy, Minister for Mineral Resources and Minister for State Development 7 December 2008

Mitchell, W., Chittleborough, J., Ronai, B. and Lennon, G. 2001, 'Sea Level Rise in Australia and the Pacific', in Proceedings of the Pacific Islands Conference on

Climate Change, Climate Variability and Sea Level Rise, Linking Science and Policy, eds. M. Grzechnik and J. Chittleborough, Flinders Press, South Australia.

Muston and Associates (1999) Liverpool district stormwater management plan. Prepared for Liverpool City Council

Nicholls et al. (2007) Coastal systems and low-lying areas. Climate Change 2007: Impacts, adaptation and vulnerability. In managing our Coastal Zones in a Changing Climate: the Time to Act is Now

NSW Department of Infrastructure, Planning and Natural Resources (NSW DIPNR) (2004a) Georges River Catchment: built environment and foreshore access study. Prepared for the department in October 2001 by PPK Environment & Infrastructure Pty Ltd (now Parsons Brinckerhoff Australia Pty Ltd) and Clouston Pty Ltd. Revised and updated by the department, July 2004

NSW Department of Infrastructure, Planning and Natural Resources (NSW DIPNR) (2004b) Georges River catchment: guidelines for better practice in foreshore works http://www.planning.nsw.gov.au/plansforaction/pdf/grc_better_practice_guideline.pdf Accessed January 2010

NSW DNR 2010. New South Wales Department of Natural Resources website http://www.naturalresources.nsw.gov.au/estuaries/factsheets/habitat/habitat_types.shtml Viewed 14.1.2010

NSW Department of Commerce (2003) Georges River Foreshore Improvement Programme – Strategic Bank Stabilisation Plan 1

NSW Department of Planning (DoP) 2009 Georges River Catchment: overview of the catchment http://www.planning.nsw.gov.au/PlansforAction/CatchmentsandWaterways/GeorgesRiverCatchment/tabid/226/Default.aspx Accessed January 2010

NSW Fisheries (2001). Estuary general fishery—environmental impact statement. NSW Fisheries: Sydney In Williams, R.J., Bryant, A. and Ledlin, D. (eds) (2004) Biodiversity of the Georges River catchment: Aquatic biodiversity. Department of Infrastructure, Planning and Natural Resources, Sydney.

NSW Government (1990). “Coastline Management Manual”, ISBN 0730575063, September 1990.

NSW Government (1992) “Estuary Management Manual”

New South Wales National Parks and Wildlife Service (NSW NPWS) (2010) Wildlife Atlas Database, Accessed January 2010. Department of Environment, Climate Change and Water

New South Wales National Parks and Wildlife Service (NSW NPWS) (2001a). Towra Point nature Reserve Plan of Management. NSW National Parks and Wildlife Services, Sydney

New South Wales National Parks and Wildlife Service (NSW NPWS) (2001b) Threatened species information: Giant burrowing frog *Heleioporus australiacus* http://www.environment.nsw.gov.au/resources/nature/tsprofileGiantBurrowingFrog.pdf Accessed January 2010

New South Wales National Parks and Wildlife Service (NSW NPWS) (2001c) State of the Parks 2001 NSW National Parks and Wildlife Service http://www.environment.nsw.gov.au/resources/parks/StateOfTheParks2001Q-Z.pdf Accessed January 2010

New South Wales National Parks and Wildlife Service (NSW NPWS) (1994) Georges River National Park plan of management February 2009

OzCoasts 2010a. http://www.ozcoasts.org.au/indicators/benthic_inverts.jsp Website viewed 10.1.2010

OzCoasts 2010b. http://www.ozcoasts.org.au/indicators/sediment_org_matter.jsp Website viewed 10.1.2010

Palacios, S. & R.C. Zimmerman (2007) Response of eelgrass *Zostera marina* to CO2 enrichment: possible impacts of climate change and potential for remediation of coastal habitats. Mar. Ecol. Prog. Ser. 344: 1–13.

Patterson Britton and Partners (PBP) (1996) Chipping Norton Lake Scheme – Heron Park - Assessment of Proposed Beach Alignment

Pollard, D.A. and Pethebridge, R.L (2002) Report on Port of Botany Bay Introduced Marine Pest Species Survey NSW Fisheries

Price C., Golusc C. And Waetlake M. (2007) Wetland Assessment Techniques Manual for Australian Wetlands 2007. Wetland Care Australia, Ballina NSW.

PWD (1966) Report on Georges River Flood Mitigation - Floods in the Lower Georges River

PWD (1983) Moorebank-Milperra floodway study, City of Liverpool

PWD (1990) Georges River Salinity and Temperature Data - May 1979 - September 1986

Remane, A.C. and Schlieper, C. (1971) Biology of Brackish Water. Wiley, New York. 271 pp. In WBM (2008) Woronora River estuary management plan. WBM Oceanics Australis Pty Ltd. Broadmeadow, Newcastle. Prepared for Sutherland Shire Council

Rish, S. (1992) Analysis of Long Term Georges River Water Quality data 1969-1990

Rockdale City Council (date unknown) Environment: Rockdale's bushland and wetlands areas http://www.rockdale.nsw.gov.au/environment/Pages/Environment_Bushwetland.aspx Accessed April 2010

Robinson, S. (2003) Field Guide to the Native Plants of Sydney (Ed. 3). Kangaroo Press Roseville, NSW.

Sammut, J., Melville, M.D., Callinan, R.B. and Fraser, G.C. 1995. Estuarine acidification: Impacts on aquatic biota of draining acid sulphate soils. Australian Geographical Studies 33(1), 89-100. In OzCoasts 2010a. http://www.ozcoasts.org.au/indicators/benthic_inverts.jsp. Viewed 10.1.2010

Sinclair Knight & Partners (1978) Flood Hazards to Developments along the Lower Georges River - Liverpool to East Hills

Sinclair Knight & Partners (1981) New South Wales Coastal Rivers Flood Plain Management Studies - Georges Valley

Stacker, M. (Date unknown) The Chipping Norton Lake Scheme – A Case Study

State Pollution Control Commission (SPCC)(1979). Effects of Dredging on Macrobenthic infauna of Botany Bay. Environmental Control Study of Botany Bay. State Pollution Control Commission. Sydney, Australia March 1979.

State Pollution Control Commission (SPCC)(1978) The Study and the Regiono – environmental Control Study of Botany Bay

State Pollution Control Commission (SPCC) (1980) Environmental control study of Botany Bay - Summary report

State Pollution Control Commission (SPCC) (1979) Wetlands of Botany Bay and its Tidal Waters – Environmental Control Study of Botany Bay

State Pollution Control Commission (SPCC) (1979) Environmental Control Study of Botany Bay – Water Movement and Salinity in Georges River

State Pollution Control Commission (SPCC) (1987) Georges River Reborn - A supplement to environmental bulletin 2 pollution control in Sydney's waterways

Steller, D and Bryant, A. (eds) (2004) Biodiversity of the Georges River catchment: terrestrial biodiversity. Department of Infrastructure, Planning and Natural Resources, Sydney.

Sutherland Shire Environment Centre (SSEC) (2008) Towra Point Nature Reserve: current activities
http://www.ssec.org.au/our_environment/our_bioregion/towra/activities/index.htm
Accessed January 2010

Sydney Metropolitan Catchment Management Authority (SMCMA) (2008). Determining the Environmental Values of Botany Bay and its Catchments: A Descriptive Analysis of the Botany Bay Catchment Environmental Values Questionnaire. Sydney: Botany Bay Coastal Catchments Initiative (BBCCI)

Sydney Metropolitan Catchment Management Authority (SMCMA) (2007) Modelling the Catchments of Botany Bay. Sydney: Botany Bay Coastal Catchments Initiative (BBCCI)

Sydney Water Corporation (2008) Sewerage Treatment System Impact Monitoring Program (2008-2011)

Sydney Water Corporation (1998) Licensing sewerage overflows environmental impact statement volume 2 Georges River and southern beaches

Warner R.F., G. Pickup (1973) Channel deterioration in the Georges River between Liverpool Weir and Little Salt Pan Creek

Warner R.F., G. Pickup (1976) Channel changes in the Georges River between Picnic Point and Lugarno, 1959-1974 and related studies

Water Board Sydney-Illawarra-Blue Mountains Clean Water Programme (1993)

WBM (2007) Woronora River estuary processes study. WBM Oceanics Australis Pty Ltd. Broadmeadow, Newcastle. Prepared for Sutherland Shire Council

WBM (2006) Woronora River Estuary Processes Study. WBM Oceanics Australis Pty Ltd. Broadmeadow, Newcastle.

WBM (2003) Botany Bay Integrated Conceptual Understanding of Environmental Patterns

Webb, H (1996) Urban Bushland under Threat Volume 1: Review of Urban Bushland and Recommendations for its Protection. A joint project by the Nature Conservation Council of NSW, Inc and Total Environment Centre, Inc. In Bankstown City Council and Eco Logical Australia Pty Ltd (2002) Biodiversity strategy and Eco Logical Australia Pty Ltd (2003) Liverpool City Council biodiversity strategy

Williams, R.J., Bryant, A. And Ledlin, D. (eds) (2004) Biodiversity of the Georges River catchment: Aquatic biodiversity. Department of Infrastructure, Planning and Natural Resources, Sydney.

WRL (1967) The Georges River Hydraulic Hydrologic and Reclamation Studies

WRL/PWD (1991) Georges River Flood Study

Zimmerman, R.C. et al. (1997) Impacts of CO2- enrichment on productivity and light requirements of eelgrass. Plant Physiol. 115: 599–607.