PART 4 UPDATED INFORMATION ADDRESSING IDENTIFIED KNOWLEDGE GAPS

4.1 Stormwater Management

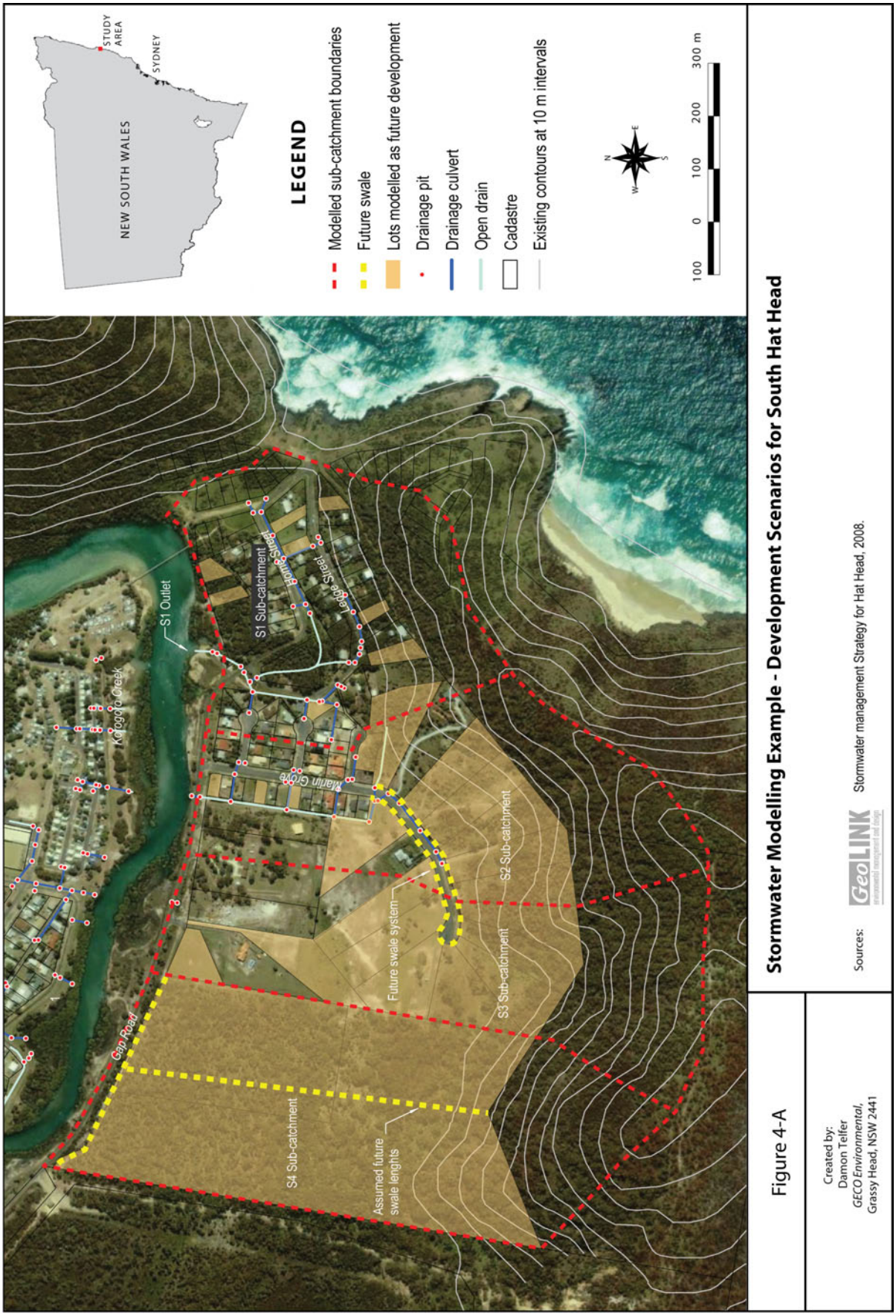
A Stormwater Management Strategy for Hat Head has been prepared by environmental and planning consultancy firm *Geo*LINK to address the identified lack of information on this issue (see *Appendix 2*). The strategy aims to investigate the need for improvements in the current stormwater infrastructure and to propose the most appropriate treatment concepts with consideration given to likely future growth scenarios for Hat Head.

The report notes that current stormwater management practices are relatively effective. Stormwater data (albeit limited) shows that pollutant levels are at the lower end of the expected spectrum from residential urban areas. This is considered to be a result of the low development density of the village and the excellent infiltration of waters into grassed swales and buffer strips over sandy soils (*Plates 1 and 2*).

Plates 1-2 Grassed swales and buffer strips have excellent infiltration characteristics and are important in reducing overall pollutant loads in stormwater entering Korogoro Creek (Source: *Geo*LINK, 2008)

Negative impacts to stormwater quality could be associated with future residential development or redevelopment without appropriate detention and treatment measures and with replacement of the existing grassed swales with kerbed and guttered street drainage. The potential effect of these changes to the current situation was investigated using the MUSIC model for stormwater conceptualisation (for example see *Figure 4-A*).

Infill development was found to potentially increase the loads of Total Nitrogen (TN), Total Phosphorus (TP) and Total Suspended Solids (TSS) by between 3% and 58% in 3 subcatchments in South Hat Head. Rural residential development in a 19ha area of South Hat Head currently zoned Rural Investigation has the potential to greatly increase pollutant loads compared to the current scenario. However, with appropriate grassed swales built in, the model indicates that TN and TSS concentrations in runoff could be reduced, relative to the current situation.


STUDY AREA
SYDNEY
NEW SOUTH WALES
LEGEND
Modelled sub-catchment boundaries
Future swale
Lots modelled as future development
Drainage pit
Drainage culvert
Open drain
Cadastre
Existing contours at 10 m intervals
100 0 100 200 300 m
S1 Outlet
Korogoro Creek
S1 Sub-catchment
Bowls Street
Ledge Street
Main Gate
Future swale system
S2 Sub-catchment
S3 Sub-catchment
S4 Sub-catchment
Assumed future swale lenghts
Gap Road
Figure 4-A
Stormwater Modelling Example - Development Scenarios for South Hat Head
Sources: GeoLINK Stormwater management Strategy for Hat Head, 2008.
Created by:
Damon Telfer
GECO Environmental,
Grassy Head, NSW 2441

Redevelopment scenarios in North Hat Head were also investigated, and an increase in pollutant loads of 12% to 13% was modelled when no changes to existing controls were made. The inclusion of rainwater tanks and reuse requirements into the modelled scenario yielded only slightly smaller increases in pollutant loads (9% to 10%). This was considered to be due to the capacity of the grassed swales to absorb increased pollutant levels rather than an indication of poor efficiency on the part of the control measures.

The impact of conversion from the current drainage network of grassed swales to a kerbed and guttered environment was the final scenario modelled. Modelling indicates that if all else remained equal, kerbing and guttering North Hat Head village could result in annual pollutant loads more than 100 times greater than existing levels. This figure highlights the importance of grassed swales in the overall management of stormwater from the Hat Head village.

Two potential stormwater treatment methods were considered for future upgrades of the current infrastructure. The first, gross pollutant traps (GPTs), have been raised by the community as a way of reducing litter in the creek. They could be installed on the North Hat Head stormwater outlets at a cost of approximately $20,000 (excluding maintenance costs) but were not considered cost effective for the following reasons;

- A large percentage of the litter that reaches Korogoro Creek waters may be dropped directly on the creek banks and not travel through the stormwater system;
- A large percentage of the litter that travels through the stormwater system may already be detained by features such as grassed swales and grated inlet pits.

An educational strategy including the installation of signs and bins, estimated to cost in the vicinity of $50,000, was considered to be a more effective method of reducing litter pollution from Hat Head reaching Korogoro Creek.

4.2 Groundwater Quality

Since the completion of the Estuary Processes Study an update of the water quality monitoring program for the Effluent Disposal Site (EDS) has been released (UNSW Water Research Laboratory, 2008). The most recent results show that groundwater levels directly underneath the EDS have increased significantly during the monitoring period (since 2002). Further monitoring is required to discern whether this is a direct result of effluent disposal or because of (for example) increased rainfall recharge of the aquifer. Regardless of the cause, continued rises in the groundwater levels could result in reduced efficiency of the dune disposal site.

Over the monitoring period a number of individual samples have shown aspects of poor water quality. The report, however, states that overall no clear trends of degrading groundwater quality are associated with effluent disposal to date. Despite the lack of a pattern, it is noted that high levels of ammonia, Kjeldahl Nitrogen (Total Nitrogen minus the organic component) and aluminium detected sporadically in groundwater samples warrant close attention. Whilst nitrogen based compounds such as ammonia are encountered naturally in some ground water, elevated levels are a sign of pollution. Ammonia is particularly toxic to aquatic organisms, particularly in alkaline waters (such as found in the estuary at high tide). Whilst ammonia is broken down by natural oxidative processes in surface waters, concentrated levels have the potential to cause a disturbance to aquatic fauna, particularly in the area where a mixing of groundwater from

under the EDS meets the creek. Aluminium, when found in high levels is also toxic to aquatic fauna, especially at low pH levels such as those found in the upper and middle section of the creek at low tide.

The monitoring of surface waters showed no direct impacts of the EDS though occasionally high levels of coliforms are a concern. Notably, coliform levels upstream of the EDS tend to be higher than downstream, indicating that perhaps the EDS is not the major contributor of faecal coliforms in the Creek. Sources of faecal coliforms might include for example, wildlife in the catchment, water birds, cattle grazing in and around the Swan Pool area and pet and human faeces washed in with stormwater. Sterol testing would be advisable if concern about the source of faecal coliforms exists.

4.3 Update on Climate Change Forecasts and Scenarios

4.3.1 Current Climate Change Predictions

The latest climate change predictions are that annual average temperatures for most of Australia will increase by **0.6-1.5°C** by 2030 and by **1.8 - 3.4°C** by 2070 compared to 1990 levels (CSIRO 2007). Predicting the exact level of temperature increase for specific regions is not currently possible but atmospheric scientists can say with a high degree of certainty that (Following CSIRO 2007 & DECC 2008);

- The future climate of the Northern Rivers area of NSW is likely to be 1-3°C warmer across all seasons by 2050;
- Increased rainfall in the Northern Rivers region is predicted for summer and autumn and decreased rainfall is predicted for the winter months;
- Predicted increases in evaporation across all seasons are also likely to result in drier conditions and soils in winter and spring;
- Other likely effects are increased heat waves, extreme winds and fire risk;
- Over the long term (2070) we are likely to see an increase in extreme rainfall events; and
- The most severe impacts of climate change are likely to be felt through extreme weather events such as hot days, bushfires, droughts and intense storms.

Predicted changes in the rainfall regime could affect Korogoro Creek in a number of ways. An increased percentage of runoff may reach the creek as storm flows, with associated effects on water quality, aquatic biodiversity and wetland health. Increased bushfire incidence may have adverse effects upon waterways through increase sediment loads and ash deposition (CSIRO 2007). Increased bushfire risk could also have dangerous consequences for Hat Head village. Existing stresses on aquatic flora and fauna, such as habitat removal, modified flow regimes and poor water quality may make them more susceptible to the above impacts of climate change (DECC 2008). Terrestrial flora and fauna may also be subject to negative effects such as ‘stranding’ (subject to increasingly small and isolated remnants of appropriate habitat) and increased stress associated with changing bushfire regimes.

The increased CO2 concentrations responsible for climate change are also likely to result in an acidification of ocean waters. The effects of this are the currently being researched but may include large changes in biodiversity due to negative impacts on crustaceans and

shelled molluscs owing to the increased solubility of calcium carbonate at lower pH values. The specific impacts of this upon estuarine fauna may depend upon the specific life history of each organism. For example, impacts might be felt amongst the fragile planktonic larvae of some crustaceans and molluscs that spend their juvenile stages in the open ocean. Despite being conditioned to regular changes in pH, estuarine organisms may not be immune to effects of sea water acidification. One study, currently being undertaken, has linked ocean acidification and ocean temperature changes to reduced growth and fertility of Sydney Rock Oysters (Gibbs 2008).

4.3.2 Current Sea Level Rise Predictions

The heat that has warmed the earth over the past century as a result of climate change has been largely stored by the oceans. The temperature of the worlds oceans rose during the 20th century and is predicted to continue rising throughout the 21st century. The thermal expansion associated with water temperature increases is expected to be the dominant force in sea level rise throughout the 20th century. Glacier and ice cap melt is predicted to contribute increasingly over the long term (CSIRO 2007).

The best estimates of global sea-level rise over the next century (until 2090 – 2099) are in the order of **18 – 79cm** relative to the average level from 1990 – 1999 (IPCC 2007). The actual sea level rise experienced is predicted to depend on atmospheric carbon dioxide concentrations. The predictions are conservative as a result of the way they measure contributions from ice melt. Furthermore, the estimates from the previous round of IPCC investigations were found to be lower than measured changes for the period from 1990 to 2007 (Rahmstorf *et al* 2007).

Macadam *et al.* (2008) used the best available information and modelling techniques to generate a range of climate change scenarios for the Wooli Wooli estuary (30km south-west of Grafton) and a minimum 60km radius. Their report represents the best available localised predictions for the Korogoro Creek estuary. Their models suggest that sea levels at the Wooli Wooli estuary will rise up to **12cm more than worldwide levels**. This means that actual sea level rise in the Northern Rivers region of NSW may be as much as **91cm** over the course of this century. The CSIRO models also indicate a possible 3% increase in the 1 in 100 year storm surge levels and a possible increase in the average speed of winds from the dominant direction. The information generated in their models is presently being used to forecast the range and extent of physical impacts, such as shoreline recession, that can be expected.

4.3.3 Impacts of Sea Level Rise

The possible impacts of rising sea level are many. General predictions include salt water intrusion into aquifers and estuaries, affecting coastal ecosystems, water resources and human settlements. Changes in drainage and groundwater levels, particularly on low lying floodplain areas may result in increased flood retention times, increased soil waterlogging and saline intrusion into groundwater drinking resources. With respect to this aspect, the operation of dune effluent discharge plants warrants attention. There will be changes in the distribution and extent of coastal wetlands, impacting upon agriculture and low lying urban settlements. There will be changed flushing behaviour of estuaries and changes to current sediment patterns. Coastal impacts are likely to be shoreline recession and realignment of beaches.

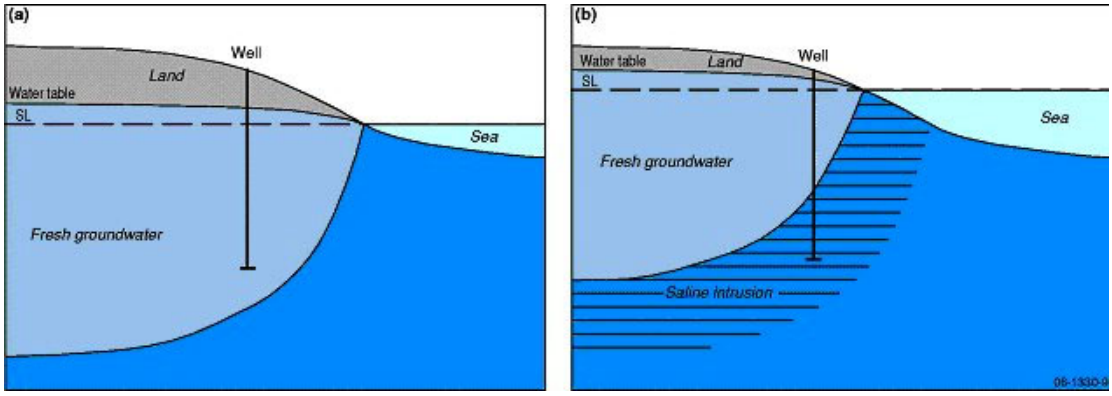
For Korogoro Creek specifically, definite changes in entrance hydrology and sediment distribution can be expected under current sea level rise predictions. These changes are likely to be followed by changes in the biodiversity and water quality of the estuary. The impacts of sea level rise upon aquatic habitats might be severe as the mangroves and saltmarsh that flourish in the estuary's intertidal zone are constrained in their movement due to the presence of the levee. Their survival will depend upon their ability to trap and colonise newly available sediments (vertical accretion) though a reduction in overall biodiversity and productivity of these habitats may be expected as some species adapt better than others.

As a low lying coastal village Hat Head can be considered to be high risk with regard to sea level rise. For Hat Head village a number of factors should be considered for future planning. These include;

- **Coastal erosion and shoreline realignment**. Rising sea levels, increased frequency and severity of storms and changes in wave and wind patterns have the potential to change shoreline profiles, aspects and barrier dune position and height. Changes in the narrow barrier dune system that divides Hat Head village from the sea could have large scale effects on the village as a whole. Average shoreline recession is expected to be approximately 50 – 100m per 1m of sea level rise.
- **Rising water levels in coastal wetlands**. The water levels in the many wetlands surrounding Hat Head village are likely to rise in conjunction with rising aquifer levels.
- **A reduction in the function of stormwater infrastructure**. A number of factors might contribute to this. A reduced ability of stormwater gates to open and let floodwaters out can be expected with higher high tide levels forecast. Higher water tables might lead to reduced rainfall infiltration, leading to longer stormwater retention times and more stormwater reaching creek surface waters. In addition, there is a possibility of increased sediment delivery and deposition, possibly directly reducing the function of floodgates.
- **Negative impacts on the flood mitigation scheme**. Rising sea levels will be translated into rising water levels in the upper estuary where the main floodgates are found. Higher water levels throughout the creek will reduce the volume of water Korogoro Creek can channel from the Swanpool area. The reduction in flood security is likely to be accompanied by an increase in the frequency and severity of floods.
- **Negative Impacts on the effluent disposal infrastructure**. Dune disposal of treated effluent relies upon the infiltration of effluent. The effectiveness of this might reduce with rising groundwater levels. The Hat Head dune disposal site could also be considered at risk from coastal erosion associated with sea level rise.
- **Negative Impacts on Groundwater Resources**. There may be significant implications for Hat Head's water supply should rising sea levels result in saline intrusion into the groundwater aquifer. (See *Figure 4-B* overleaf)
- **Damage to Underground Infrastructure**. Increased pressure due to rising ground water levels and salinity might cause damage to underground sewage and water services.
- **Village Inundation and subsequent property damage**. Under worse case scenario, long term forecasts the possibility of seawater inundation of the Hat Head village due to barrier dune erosion and storm surge should not be discounted. Public

infrastructure at risk includes the Hat Head Surf Club, Library, Caravan Park and local roads.

Figure 4-B Groundwater resources under current conditions (a) and under rising water tables and saltwater intrusion (b). (source: www.ozcoasts.org.au).



PART 5 REGIONAL SIGNIFICANCE and VALUES

5.1 Values and Significance of Korogoro Creek Estuary

The Korogoro Creek estuary is a valuable asset to the local and broader community. Korogoro Creek, though one of a network of small to medium sized estuaries on the mid north coast of NSW, is unique in a number of ways. It has been extensively modified but it represents a healthy estuary environment, with good water quality and a diversity of habitats, flora and fauna. Korogoro Creek attracts tourists to the area helping to support the town of Hat Head. It also plays a role in the Macleay Valley flood mitigation scheme.

5.1.1 Local and Regional Significance

Korogoro Creek forms a centrepiece to the village of Hat Head and is used in some way by most of the approximately 350 residents on a regular basis. It is also a major attraction for the large number of visitors who enjoy swimming, fishing and boating in its waters during the peak holiday seasons. The creek serves as a reliable access point to the open ocean for recreational and professional fishers via the boat ramp near its entrance. The creek also provides a scenic outlook from many parts of the village and provides a sense of open space.

Korogoro Creek is one of a number of small to medium sized estuarine water bodies found on the Mid North Coast of NSW. Other nearby estuaries of a similar size include Killick Creek to the south and Saltwater Creek, South West Rocks Creek and Oyster Creek to the north. These estuaries form a network of waterways that provide recreational opportunities, attract tourism, have extensive and varied aquatic habitats and support many commercially important fish and invertebrates.

Whilst representative of small estuarine water bodies on the mid-north coast, Korogoro Creek is unique in a number of ways. Unusually, for such a small estuary, Korogoro Creek is believed to have a permanently open, untrained entrance. This sets it apart from the otherwise similar ICOLLs (Intermittently open and closed lakes and lagoons) that are found nearby. The permanently open status of the entrance means that the water quality is consistently maintained at a level appropriate for primary contact recreation and environmental protection and that the residence times of catchment inputs are significantly lowered. It also means that the aquatic fauna of Korogoro Creek have permanent access to oceanic waters and species enhancing local biodiversity and the ecological functions of the estuary (Telfer, 2007).

5.1.2 Cultural Heritage Values

The coastal area of the Macleay Valley is part of the traditional area of the Djaingutti (or Thungutti) group of aboriginal people. The local area around Hat Head was also occupied by Bilpai and Goombaingirr people (R.Kelly, pers.comm.., in DPWS, 1999). Archaelogical site records data held by NPWS show three aboriginal sites in the vicinity of Korogoro Creek. The recorded sites include (DPWS, 1999);

- A shell midden located on Korogoro Headland near the creek entrance
- A former open campsite located within paperbarks on the southern side of Korogoro Creek, north of the footbridge
- A mythological site (large tree) within the grounds of the caravan park.

5.1.3 Recreational Values

The Korogoro Creek estuary supports a wide range of recreational activities for residents of Hat Head and for large numbers of visitors during holiday periods. Among the activities most frequently observed include:

- Excellent swimming opportunities though the water depth of low tides can be prohibitive. Safe swimming was ranked as the most important estuary value in a recent community survey (Telfer, 2007)
- Recreational boating, including small motorised craft, rowboats, canoes and kayaks.
- Recreational fishing and bait collection
- Ocean access for boaters, via the boat ramp.

The banks of the estuary are frequently used for passive recreation and the campsite provides an area for camping and caravanning. In addition to this, the wider Korogoro Creek catchment provides excellent opportunities for bush walking and bird watching and the nearby coastline for surfing, swimming, fishing and boating.

5.1.4 Scenic Values

The Korogoro Creek estuary provides a stunning visual backdrop to the Hat Head village. Views across the creek to the densely vegetated headland can be described as spectacular and are a great attraction for visitors. The Korogoro Creek estuary also provides a sense of open space to the village.

5.1.5 Water Quality Values

The permanently open entrance to the ocean means that the Korogoro Creek estuary receives a regular tidal flushing along its length (1-2 days flushing time upstream). The regular tidal flushing ensures that pollutants are quickly diluted and removed from the estuary into ocean waters. As such the Korogoro Creek estuary generally maintains good water quality levels for primary recreation and maintenance of environmental values.

A community survey in 2006 identified a healthy estuary ecosystem and safe swimming locations as very highly rated values aspects of the Korogoro Creek estuary (Telfer 2007). With respect to this, the water quality in Korogoro Creek is generally within ANZECC 2000 limits for healthy aquatic ecosystems and for primary contact recreation. The assembled body of water quality data at this point in time suggests that:

- Korogoro Creek becomes increasingly acid as you travel upstream
- Korogoro Creek suffers increasingly from elevated nutrient levels as you travel upstream, and
- There are no significant issues with faecal coliform contamination in Korogoro Creek

5.1.6 Ecological Values

Korogoro Creek estuary provides a number of estuarine habitat types including seagrass, saltmarsh, mangroves, intertidal muddy areas, channels, rocky reefs and boulder fields. Of these, Coastal Saltmarsh is considered an Endangered Ecological Community (EEC) under the *Threatened Species Conservation Act 1995* and as such warrants special protection. The diversity of habitat types is reflected by a high level of biodiversity (ie

numbers and types of flora and fauna species). A summertime survey of aquatic fauna recorded 60 fish, reptile and invertebrate species (Telfer, 2007).

In addition, due to the permanently open status of the creek the estuary maintains a high level of ecological exchange with the ocean. With particular reference to the saltmarsh, mangrove and seagrass habitats the estuary acts as a natural fish nursery. The warm subtropical waters encourage a summertime population of juvenile tropical fishes, many at or around the limit of their southern distribution.

Species of conservation significance have been identified in and around the Korogoro Creek estuary including the threatened loggerhead turtle and the osprey.

It warrants mention here that the ecological values of Korogoro Creek are heavily dependent on the entrance remaining open. It has been predicted that a significant closure would result in drastic changes in water quality, available habitat and associated biota (Telfer, 2007).

The broader Korogoro Creek catchment also has significant ecological value. Although impacted by drainage and flood mitigation works, Swan Pool is a regionally significant wetland and many other freshwater wetlands also occur (some designated under SEPP14 protected and others as Candidate Freshwater Wetland on Coastal Floodplains EEC). Other candidate Endangered Ecological Communities which are likely to occur in the catchment include Swamp Sclerophyll Forest on Coastal Floodplains (possibly occurring in riparian areas along the creek), Littoral Rainforest (again some designated under SEPP26) and Swamp Oak Floodplain Forest.

5.1.7 Socio-economic Values

As a local tourist drawcard the general scenic attractiveness, health of the estuary, and recreational opportunities available are important to the economic sustainability of the Hat Head village and the broader Kempsey Local Government Area. The estuary is particularly valued as a safe swimming location (especially for families), a safe open water access via the creek mouth, and a prime fishing, snorkelling, and picnicking spot. A local commercial fishing operation is based in Hat Head and the creek environment is an important breeding ground for many species of commercial and recreational interest.

The creek also has an important role in the general flood security of the greater Macleay floodplain. During periods of widespread flooding in the lower Macleay Valley, the flood mitigation scheme utilises the creek (through Korogoro cut) as an ocean outlet, providing an important mechanism for reducing flood damage in the towns and villages along the Macleay River below Kempsey.

5.2 Summary of Korogoro Creek Estuary Values

A summary of the values of the Korogoro Creek estuary is provide in *Table 3* below.

Table 3 Summary of Korogoro Creek Estuary Values

Local and Regional Significance	Cultural Heritage Values	Recreational Values	Scenic Values	Water Quality Values	Ecological Values	Socio-economic Values
• One of a network of small estuaries which are a focal point for local recreation and tourism	• Part of the traditional area of the Djaingutti (or Thungutti) group of aboriginal people.	• Safe swimming, particularly for young children and families	• Stunning visual backdrop to the village of Hat Head	• Well flushed (1-2 days)	• Supports a wide variety of fauna and flora in a variety of aquatic habitats	• Local tourist drawcard
• Different to other local ICOLLs as it has a permanently open, untrained entrance	• Local area around Hat Head was also occupied by Bilpai and Goombaingirr people	• Recreational boating including kayaks, canoes, and small motorised boats	• Surrounded by vegetated hills almost wholly contained in Hat Head National Park	• Generally within NHMRC (2008) guidelines for primary contact	• Has numerous areas of protected wetlands (SEPP14) and protected littoral rainforests (SEPP26)	• Recreational opportunities including safe swimming, quality fishing, easy open water access.

Continued next page…

Local and Regional Significance	Cultural Heritage Values	Recreational Values	Scenic Values	Water Quality Values	Ecological Values	Socio-economic Values
• Permanently open status means water quality is consistently suitable for primary contact and environmental protection	• 3 aboriginal culture sites recognised in the immediate vicinity of the estuary	• Recreational fishing and bait collection		• Generally within ANZECC guidelines for environmental protection	• Has several Endangered Ecological Communities in the catchment including Coastal Saltmarsh, Littoral Rainforests, Swamp Sclerophyll Forests, Swamp Oak Forests, and Freshwater Wetlands	• Part of the Macleay Valley flood mitigation scheme providing flood security for lower Macleay towns and villages
• Aquatic fauna have permanent access to oceanic water, enhancing biodiversity and ecological functioning.	• No formally recognised built heritage sites are recorded	• Relatively safe open water access via the boat ramp		• No significant issues with faecal contamination	• Supports several threatened and endangered species including the Loggerhead turtle and Osprey.	• Important nursery for fish species of both commercial and recreational interest

PART 6 ESTUARY MANAGEMENT OBJECTIVES & KEY MANAGEMENT ISSUES

6.1 Setting a Vision for Korogoro Creek Estuary Management

6.1.1 NSW State Government Estuary Management Policy

The general goal of the NSW Government's Estuary Management Policy is to achieve an integrated, balanced, responsible and ecologically sustainable use of the State's estuaries which form a key component of coastal catchments (NSW Government, 1992). Specific objectives of the policy are:

- Protection of estuarine habitats and ecosystems in the long-term, including maintenance in each estuary of the necessary hydraulic regime;
- Preparation and implementation of a balanced long-term management plan for the sustainable use of each estuary and its catchment, in which all values and uses are considered, and which defines management strategies for;
  - Conservation of aquatic and other wildlife habitats
  - Conservation of the aesthetic values of estuaries and wetlands
  - Prevention of further estuary degradation (e.g. water quality, bank erosion, biodiversity, etc)
  - Repair of damage to the estuarine environment, and
  - Sustainable use of estuarine resources, including commercial uses and recreational uses.

6.1.2 Healthy Rivers Commission Inquiry into Coastal Lakes Findings

The Healthy Rivers Commission (HRC, 2002) sets out guiding principles for the management of coastal lakes and estuarine creeks. For estuaries and lakes considered to be in *healthy modified condition* (such as Korogoro Creek estuary) the HRC recommends that the objective of management should be to '*rehabilitate and retain key natural processes and/or modified values and determine appropriate types and sustainable levels of human uses*'

In order to achieve this objective the Management Plan should determine;

- How existing activities must be managed (ie. encouraged, permitted, modified)
- The capability and limitations of an estuary and its catchment to sustain new development; and
- The most appropriate set of management tools and the responsibility and timing for their implementation.

Further, the management actions most likely to be required and most likely to be effective are also outlined by the Healthy Rivers Commission (HRC, 2002) and include;

- Controls on new development that keep impacts within the limits of sustainability for a specific estuary;

- Management of entrance intervention to protect critical ecosystem processes
- Implementation of an integrated cost-effective program to mitigation the effects of wastewater discharges
- Rehabilitation of natural riverine corridors
- Encouragement of best practice farming and forestry
- Management of commercial and recreational uses in ways that are commensurate with protecting estuary health

6.1.3 Community Views on the need to manage Korogoro Creek Estuary

The integration of local community views into estuary management planning is critical to the success of the planning process. The local community are a valuable source of local knowledge which has often been accumulated over years of observation and experience.

In most communities, individual views on estuary management issues vary and for Korogoro Creek this is apparent in the responses to the community surveys and in other forums such as community meetings. Despite this there is general agreement in the local community with the following key principles;

- The estuary is an important asset to the residents of Hat Head and is a strong drawcard for visitors to the area.
- The estuary is considered by most community members to be in good overall condition
- The estuary is used for a variety of passive and active recreational uses and usage needs to be managed to avoid conflict between users, to ensure safety of users, and to maintain the health of the estuary
- There is a strong desire for the estuary to be maintained in its current healthy condition and if possible improved.
- There is a strong desire for vehicle access directly to the creek bank to be managed. This is conditional on access to the estuary being maintained.

6.1.4 A Vision for Management of Korogoro Creek Estuary

Based on the guiding principles of management contained in the NSW Estuary Management Policy and Healthy Rivers Commission documents, and the common principles for management which have been determined through community consultation, it is possible to develop as an example a vision for the management of the Korogoro Creek estuary. A suggested Vision for management might be;

"To maintain the health of the Korogoro Creek estuary and where possible improve its condition in terms of its scenic beauty, natural habitats and ecosystems, whilst supporting sustainable and compatible recreational uses for the benefit of locals and visitors"

6.2 Objectives for Management of the Korogoro Creek Estuary

The following management objectives have been developed for the Korogoro Creek estuary. These objectives have been grouped by the main issue areas identified in *Section 3.1* and take into account the principles of the NSW Estuary Management Policy and Healthy Rivers Commission documents and the Vision for Management of the Estuary as detailed above.

6.2.1 Entrance Conditions and Hydrodynamics Objectives

A Maintain the entrance of the creek in a condition that meets the needs of recreational users whilst protecting the ecology and overall health of the estuary.

It has been noted in this study that the permanently open estuary mouth is critical to maintaining a range of hydrological, ecological, water quality, and recreational functions and processes in Korogoro Creek. Despite the fact that the creek mouth has not closed in living memory, the mouth has at times become significantly shoaled. To date, intervention has been limited to removal of sand in the vicinity of the boat ramp. In other small estuarine systems and ICOLLs, the issues surrounding entrance management are often contentious as intervention can have both positive and negative impacts. Although the issues are less significant in Korogoro Creek it is considered prudent to develop an agreed Entrance Management Strategy which outlines actions which might be considered should the entrance become excessively shoaled in the future.

6.2.2 Bank Stability and Sedimentation Objectives

B Minimise impacts upon estuary health resulting from bank erosion and associated sedimentation by managing activities that impact bank stability.

The threats to estuary health and function associated with bank erosion include a reduction in riparian habitat extent and quality, sediment deposition and gradual infill, and increased suspended sediment/turbidity with the associated threats to aquatic vegetation such as seagrasses and physical effects on fish and invertebrates such as gill clogging. Activities that can exacerbate or cause bank instability and erosion include clearing of riparian vegetation, concentration of surface water flows associated with vehicle and people tracks, undermining of the bank toe associated with wave action (predominantly wind generated as opposed to motorised watercraft), tidal flows, and high velocity flows associated with the operation of the flood mitigation scheme.

The intention of this objective is to identify activities which are currently contributing to bank instability in the creek and to manage those impacts in order to minimise bank erosion and further sedimentation.

C Improve estuary health by implementing appropriately designed bank stabilisation and rehabilitation works in high priority areas of bank erosion.

Time series aerial photographic analyses show that there has been a history of channel change in the Korogoro Creek estuary over the period 1942-2004. The area which shows the greatest rate of change is between the traffic bridge and footbridge. The major causes of bank erosion in this reach are associated with the direct effects of the flood mitigation works and the ongoing effects of its operation. Damage associated with access tracks, loss of riparian vegetation, tidal scour, and the effects of wind waves also contribute (Telfer, 2007). Despite community surveys consistently identifying bank stability as an issue of concern, no severely eroding sites were identified in the 2007 survey of bank erosion (defined as ongoing serious erosion with no evidence of natural recovery).

The intention of this objective is to determine priorities for rehabilitation of reaches of estuary bank identified as *Moderately Unstable* in order to improve bank stability in Korogoro Creek.

6.2.3 Ecological, Habitat and Biodiversity Objectives

D Protect terrestrial habitats of high ecological or conservation value (e.g. riparian vegetation, endangered ecological communities such as Coastal Saltmarsh, Freshwater Wetlands and Littoral Rainforests).

Within the Korogoro catchment there are a number of terrestrial habitats of high conservation value including riparian (creek bank) vegetation, coastal saltmarsh, swamp sclerophyll forest, littoral rainforest and wetlands. Some of these habitats are already protected within the Hat Head National Park or by State Planning instruments such as SEPP14 (wetlands) and SEPP26 (Littoral rainforest), while others are required to be protected as Endangered Ecological Communities under the *Threatened Species Conservation Act 1995* (Coastal Saltmarsh, Littoral Rainforest, Freshwater Wetlands, and Swamp Sclerophyll Forest). These habitats are important to the estuary's ecology and biodiversity but also because they contribute to other key ecosystem processes including filtering sediments and pollutants from catchment runoff and stabilising estuary banks. Some of these habitat types are under pressure from recreational and land use impacts or limited in their distribution.

This objective is aimed at protecting terrestrial habitats of high conservation or ecological value from degradation associated with human/land use impacts using existing legislative and policy frameworks and through community and visitor education.

E Restore terrestrial habitats of high ecological or conservation value by removing threats and through targeted rehabilitation (e.g. riparian vegetation, endangered ecological communities such as Coastal Saltmarsh, Freshwater Wetlands and Littoral Rainforests).

A variety of terrestrial habitats of high conservation value have been identified within the Korogoro Creek catchment (see *Objective D*). Presently, a variety of activities threaten the integrity and viability of some of these habitats including weed invasion, damage and soil disturbance from access tracks, and drainage. This management objective is aimed at the rehabilitation of sites with high ecological or conservation value where degradation (such as weed infestation) has occurred.

F Protect aquatic habitats of high ecological or conservation value and their associated biodiversity (e.g. Mangroves, seagrasses, tropical fish).

Mangroves and seagrasses have been identified as key habitats for fish. They are also important primary producers in the estuarine ecosystem and a link in the chain of good water quality. Other aquatic habitats identified in the estuary are important to specific species including tropical fish species. Under the *Fisheries Management Act 1994* aquatic habitats such as mangroves and seagrass beds are protected from harm and permits are required to damage them. Similarly, the NSW DPI Fisheries is responsible for regulating commercial and recreational fishing from the creek. Currently, spearfishing, netting and the collection of tropical fish from the creek are all regulated by Fisheries.

This objective is aimed at protecting aquatic habitats and associated biodiveristy of high conservation or ecological value from degradation using the existing legislative and policy frameworks and through community and visitor education.

G Restore aquatic habitats of high ecological or conservation value by removing threats and through targeted rehabilitation (e.g. Mangroves).

Aquatic habitats of high ecological and conservation value have been identified in Korogoro Creek (see *Objective F*). Present and past behaviours, including informal access tracks to the creek and increased erosive pressure resulting from the operation of the flood mitigation scheme have contributed to the degradation of some of these habitats in some areas. This management objective aims to identify areas of degraded aquatic habitat and develop priorities and strategies to rehabilitate these sites.

6.2.4 Water Quality Objectives

H Maintain the estuary water quality within National Health and Medical Research Council guidelines (NHMRC, 2008) for recreational use year round.

The water quality of the Korogoro Creek is generally acceptable for primary contact recreation. 90th percentile values of faecal coliform levels are consistently below the NHMRC trigger level for investigation and NHMRC criteria for further investigation have not been exceeded. However, during peak holiday periods and after heavy rain there are occasional spikes in faecal coliform concentrations. Catchment and stormwater management procedures may be effective in reducing levels of faecal contamination reaching the estuary. This objective aims to maintain estuary water quality within NHMRC guidelines year round by investigating options for improving catchment and stormwater management.

I Reduce urban stormwater pollutant loads entering Korogoro Creek

Stormwater from the Hat Head village may contain elevated levels of nutrients, sediment and faecal derived bacteria. Heavy rains after long dry periods or after peak holiday times are suspected to generate the worst quality stormwater. A stormwater management study (*Geo*LINK, 2008; see *Appendix 2*) shows that stormwater pollutant loads can be reduced. This objective is aimed at investigating options for reducing stormwater pollutants from reaching Korogoro Creek.

J Reduce the impact of the operation of Macleay Valley Flood mitigation scheme through implementing actions in Swan Pool.

The Macleay Valley flood mitigation scheme connects Korogoro Creek to a large wetland to its west known as the Swan Pool. During heavy flooding in the lower Macleay, flood waters are diverted into Swan Pool through Kinchella Creek. When the storage capacity of the Swanpool is exceeded, waters are released into Korogoro Creek via Korogoro Cut to drain floodwaters out to the ocean. The effects of large volume discharges of water from the Swan Pool are not well studied but are likely to include scouring of the channel and short-term effects on biodiversity (Telfer, 2007). There is also some evidence that low level daily influxes of poor quality water occur even when the flood mitigation scheme is not operating, delivering acidic, deoxygenated ‘black’ water into the upper reaches of the creek during low tides (Smith, 2002).

This objective aims to reduce the negative impacts of the flood mitigation scheme on Korogoro Creek by addressing the causes of poor quality waters in the Swan Pool.

K Maintain the water quality of groundwater aquifers in the vicinity of Hat Head township.

The groundwater table under the Hat Head village is relatively high and thus sensitive to poor quality recharge events. Treated effluent from the town's sewerage scheme discharges into the dunes north of Hat Head and makes its way to the creek through the groundwater system (DPWS, 1999). Groundwater is also used for the town water supply and is accessed directly by some residents using a spear and pump as an alternative to the town water system for watering backyards and for laundry. The protection of groundwater aquifers is required under State Government legislation.
This intention of this objective is support the continued monitoring of groundwater aquifers in and around Hat Head village to ensure that any changes to groundwater quality can be identified and addressed.

L Implement a long-term water quality monitoring program that allows for the identification of water quality issues and trends that may affect estuary health or recreational users of the estuary.

Good water quality is essential to the health and usability of the Korogoro Creek estuary. Whilst a large amount of water quality information has been collected from Korogoro Creek it has been collected under a variety of programs, which have analysed distinct sets of parameters from distinct locations within the creek. This reduces the usefulness of the data for making comparisons or identifying long term trends. This objective aims to set a practical long term surface water quality monitoring program that is in accordance with state guidelines to facilitate the early identification of trends and genuine water quality issues that are of interest to managers and the local community.

6.2.5 Recreational Use and Access Objectives

M Provide for a range of recreational opportunities compatible with the estuary's values (eg. Low key setting, family orientated, etc.) in a way that does not impact upon those values or estuary health.

Korogoro Creek is utilised for a range of recreational pursuits including swimming, snorkelling, fishing, walking, picnicking, and both non-motorised and motorised boating. Most activities are currently undertaken without impacts upon the estuaries values or the estuary health. However, some activities are associated with negative impacts or are perceived by some in the community as having negative impacts. Examples include impacts associated with vehicle access to the foreshore and conflict between swimmers and boaters at the creek mouth.

Additionally, the community has identified that facilities provided for some forms of recreation are considered inadequate. Poor provision for disabled access to the estuary, inadequate car parking on the southern side of the creek near recognised fishing spots, and issues associated with damage to vessels from the hard rock edges of the boat ramp are examples.

The aim of this objective is to facilitate and manage recreational use of the estuary to allow for a continuation of existing recreational uses but in a way that minimises negative social and environmental impacts.

N Manage access to the estuary foreshore in areas of high use to protect public safety and ensure estuarine health objectives are achieved.

The estuary and its foreshore are a significant asset to the local community being both a focal point for recreation and a drawcard for tourists to the area. However, the foreshore also contains sensitive environments which are important to the ecological processes and functions of the estuary. Some of these environments are protected under Threatened Species legislation (eg. Coastal Saltmarsh) or State Planning Policies (eg. Littoral Rainforests or wetlands). The community has consistently identified the need to manage high usage areas to ensure that recreational access does not significantly impact other important estuary values such as estuarine ecology, biodiversity, bank stability, or scenic amenity.

O Raise community awareness of estuarine processes and the sensitivities of the estuarine environment to increase the level of understanding of human usage impacts upon estuaries.

Korogoro Creek estuary is used for a broad range of passive and active recreational pursuits by both visitors and locals. There is potential for some of these uses to impact upon estuary values. For instance, the dumping of garden wastes onto the estuary foreshore can promote the spread of weed plants into the riparian zone, littering and discarding of used fishing line and bait packaging can negatively impact upon scenic amenity and injure or kill wildlife, and driving vehicles onto sensitive foreshore areas can damage vegetation and promote erosion. Raising awareness of these issues and the sensitivities of the estuarine environment through a community and visitor education campaign may assist in reducing some of these impacts.

6.2.6 Catchment Management Objectives

P Ensure that the potential future implications of climate change and sea level rise are incorporated into reviews of Kempsey Strategic Planning framework.

There is general agreement in the scientific community that climate change and associated changes in sea levels and weather patterns are likely to occur in the mid to long term (years 2030-2100; IPCC, 2007). However, there is currently little consensus on the probable magnitude of these changes as they are dependant upon a less than perfect understanding of climate and related processes and also upon a range of potential emission reduction scenarios that have yet to be agreed upon by the global community. What is known is that small coastal townships like Hat Head represent a high risk setting due to their proximity to the coast, extensive areas of development at low elevation, and their reliance on infrastructure designed to function under existing climatic and sea level conditions.

It is the intention of this objective to ensure that the potential impacts of climate change be recognised and planned for using best available information when reviewing the various Strategic Planning documents implemented by Council (eg. Local Environment Plan, Development Control Plans, Hazard Assessments under Coastal Zone Management Plans, etc).

Q Reduce impacts associated with poor water quality entering the creek via Korogoro Cut by implementing actions to remediate Acid Sulfate Soil Issues in the Swan Pool.

Swan Pool has been identified as a major contributor of low pH (acid) and low dissolved oxygen ("Black") water to the Korogoro Creek estuary during periods of operation of the flood mitigation scheme. The Swan Pool Drainage Management Plan Final Report (Smith, 2002) and Kinchella Lock Floodgate and North Weir Management Plan (NPWS, 2008) provide a number of recommendations to address these issues. Kempsey Shire Council and NSW NPWS have been progressively implementing actions that stem from these reports including modifications to "The Lock" structure on Kinchella Creek and changing of some landuse practices through land acquisitions (Alex Wyatt, NPWS, pers.comm., 2008).

The intention of this objective is to continue to implement the recommendations of the existing management plans in order to minimise the impacts on Korogoro Creek of poor water quality draining from Swan Pool.

6.3 Summary of Management Objectives

Table 4 provides a summary of the management objectives identified above, with priorities attributed (low, medium, high). The priorities have been determined through community and stakeholder consultation and by comparing the intent of the objective with those of the broader estuary management goals outlined in *Section 6.1*. The priorities allocated represent the current management planning timeframe (ie. 5 years to 2014) after which they should be reviewed and updated as necessary.

Table 4 Prioritised List of Korogoro Creek Management Objectives (2009 to 2014).

	Estuary Management Objective	***Priority***
B	Minimise impacts upon estuary health resulting from bank erosion and associated sedimentation by managing activities that impact bank stability.	HIGH
D	Protect terrestrial habitats of high ecological or conservation value (e.g. riparian vegetation, endangered ecological communities such as Coastal Saltmarsh, Freshwater Wetlands and Littoral Rainforests).	HIGH
F	Protect aquatic habitats of high ecological or conservation value and their associated biodiversity (e.g. Mangroves, seagrasses, endangered species, tropical fish).	HIGH
H	Maintain the estuary water quality within National Health and Medical Research Council guidelines (NHMRC, 2008) for recreational use year round.	HIGH
N	Manage access to the estuary foreshore in areas of high use to protect public safety and ensure estuarine health objectives are achieved.	HIGH

	Estuary Management Objective	***Priority***
O	Raise community awareness of estuarine processes and the sensitivities of the estuarine environment to increase the level of understanding of human usage impacts upon estuaries.	HIGH
A	Maintain the entrance of the creek in a condition that meets the needs of recreational users whilst protecting the ecology and overall health of the estuary.	MEDIUM
C	Improve estuary health by implementing appropriately designed bank stabilisation and rehabilitation works in high priority areas of bank erosion.	MEDIUM
E	Restore terrestrial habitats of high ecological or conservation value by removing threats and through targeted rehabilitation (e.g. riparian vegetation, endangered ecological communities such as Coastal Saltmarsh, Freshwater Wetlands and Littoral Rainforests).	MEDIUM
G	Restore aquatic habitats of high ecological or conservation value by removing threats and through targeted rehabilitation (e.g. Mangroves).	MEDIUM
J	Reduce the impact of the operation of Macleay Valley Flood mitigation scheme through implementing actions in Swan Pool.	MEDIUM
P	Ensure that the potential future implications of climate change and sea level rise are incorporated into reviews of Kempsey Strategic Planning framework.	MEDIUM
I	Reduce urban stormwater pollutant loads entering Korogoro Creek	LOW
K	Maintain the water quality of groundwater aquifers in the vicinity of Hat Head township.	LOW
L	Implement a long-term water quality monitoring program that allows for the identification of water quality issues and trends that may affect estuary health or recreational users of the estuary.	LOW
M	Provide for a range of recreational opportunities compatible with the estuary's values (eg. Low key setting, family orientated, etc.) in a way that does not impact upon those values or estuary health.	LOW
Q	Reduce impacts associated with poor water quality entering the creek via Korogoro Cut by implementing actions to remediate Acid Sulfate Soil Issues in the Swan Pool.	LOW

6.4 Key Estuary Management Issues

The key estuary management issues detailed below have been compiled using the following sources of information;

- Community consultation including resident and visitor surveys and feedback from the Korogoro Creek Working Group and open community meetings
- Direct consultations with industry and agency stakeholders, and
- Information and recommendations from the Korogoro Creek Data Compilation and Processes Study (Telfer, 2007).

6.4.1 Entrance Conditions and Hydrodynamics

Entrance Behaviour

1 Difficulty with launching larger vessels has at times necessitated the removal by Council of sand in the vicinity of the boat ramp.

Options for management of sedimentation in the vicinity of the boat ramp require investigation.

2 Shoaling at the entrance has at times almost closed the creek mouth

The creek mouth has not closed in living memory, however closure would cause significant impacts upon the existing ecological processes in the estuary. Development of an entrance management strategy may assist in providing guidance on appropriate actions if the entrance were to close.

Hydrodynamics

3 Effects of climate change and sea level rise on entrance behaviour, hydrology and estuary health.

Various scenarios of the possible effects climate change and sea level rise have been proposed. Hypothetical impacts on estuaries have also been proposed. The possible effects on Korogoro Creek should be considered as part of an entrance management strategy.

6.4.2 Bank Stability and Sedimentation

Bank Erosion

4 Bank erosion occurring between the traffic bridge and the footbridge.

Mapping of bank erosion has been completed. No severely eroding sites were recorded. Priorities and appropriate strategies for the rehabilitation of unstable creek banks need to be developed as part of the Estuary Management Plan.

Sedimentation

5 Effects of sedimentation and channel in-filling including loss of pools and associated habitat and loss of recreational opportunity.

The major source of sedimentation in the estuary is from marine derived sands which are pushed into the estuary through the creek mouth by tidal flows assisted by tidal and ocean

currents and wind and ocean waves (Telfer, 2007). Secondary sources include sediments sourced from eroding creek banks particularly between the traffic bridge and footbridge. Anecdotal evidence suggests that the creek used to contain deeper pools in some locations, particularly in the mid to lower sections of the estuary. Infilling of the estuary by marine derived sands is a natural long-term process that is not easily reversed, with intervention often being unsuccessful in the long-term.

6.4.3 Ecology, Habitat and Biodiversity

Estuary Ecology

6 Collection of tropical fishes from the creek for aquariums.

The collection of tropical fishes from Korogoro Creek has been prohibited by NSW DPI Fisheries since 2007. Although it is unclear whether tropical fishes which enter the creek during warmer months survive throughout the year, their removal for private aquariums reduces the amenity of others using the creek such as snorkellers. Proponents of collection assert that collection does not effect the presence of tropical fishes from year to year and that the prohibition reduces the opportunity of enthusiasts and school students to learn about marine life. Anecdotal reports suggest some collection continues.

7 Damage to oysters on the southern creek bank downstream of the footbridge.

Oysters are collected from the lower estuary for food, bait and burleying (the practice of feeding oysters to small fish). The potential for these practices to cause a safety hazard for swimmers and others and to impact to the oyster community have been raised as a concern during community consultation.

Riparian Vegetation

8 Damage to Coastal Saltmarsh Endangered Ecological Community on the southern creek bank foreshore.

Coastal Saltmarsh in the NSW North Coast bioregion has been determined by the NSW Scientific Committee to be an endangered ecological community under the Threatened Species Conservation Act 1995. The saltmarsh community that exists on the 'southern' creek bank foreshore is currently degraded as a result of vehicle access impacts. Impacts are worst between the traffic bridge and the footbridge but also extend into the National Park estate upstream of the traffic bridge.

9 Poor recruitment and regeneration of native vegetation on southern creek bank foreshore.

There is poor recruitment and regeneration of native riparian species on the southern creek bank foreshore with many older specimens of *Melaleuca quinquinervia* senescing. As a result habitat availability for species which utilise these trees and scenic amenity are likely to reduce over time unless this trend can be reversed.

10 Weed invasion in native vegetation communities along the estuary banks and foreshore.

The practices of dumping garden wastes onto the creek foreshore, particularly on the town side of the creek, has led to the establishment of many exotic plants including environmental weeds. Weed mapping completed in 2007 shows that bitou bush, lantana,

coastal morning glory, and various garden succulents are widespread particularly on the northern creek bank and foreshore.

Aquatic Habitats

11 Damage to aquatic habitats after operation of the Macleay Valley Flood Mitigation Scheme

Small ICOLLS (intermittently closed and open lakes and lagoons) and estuarine creeks like Korogoro Creek are important habitats for a diverse assemblage of juvenile fishes (some of commercial significance), crustaceans and other estuarine and marine fauna and flora (eg. Seagrasses). Typically, these systems have very low freshwater flow inputs relative to the significance of the tidal inputs. In Korogoro Creek's case, the hydrology is at times significantly influenced by the operation of the Macleay Valley Flood Mitigation Scheme which, during periods of extensive flooding in the broader Macleay Valley, can divert very large volumes of flood waters from the Swan Pool down the creek through the Korogoro Cut. As part of the Flood Mitigation Scheme, Korogoro Creek has been extensively leveed with flood heights also controlled by "The Choke". The Choke has the effect of diverting excess water that would otherwise result in the overtopping of the levees through Rowes Cut and into the ocean. The end result is that Korogoro Creek can from time to time experience extreme levels of flood scouring (many times in excess of what it may have naturally conveyed) which can scour away sensitive habitats such as intertidal mud flats and seagrass meadows.

6.4.4 Water Quality

Estuarine Water Quality

12 Low Dissolved Oxygen (DO) and high nutrient levels (particularly ammonia) have been recorded in the upper reaches of the estuary near the Korogoro Cut floodgates.

In general the Korogoro Creek estuary is well flushed and water quality in the estuary is generally good to very good. Despite this, issues with poorer quality water draining from the Swan Pool are occasionally identified during irregular sampling. The data is not sufficient to determine the extent of the issue.

13 Elevated Chlorophyll-a levels have been recorded in the upper reaches during periodic water quality sampling

The causes and effects of elevated Chlorophyll-a in Korogoro Creek are not well understood. Chlorophyll-a levels indicate phytoplankton productivity which is influenced by a range of factors including water temperature, nutrient availability and light availability. Phytoplankton live in the water column and excessive water column productivity can supply large amounts of organic matter to sediments. Decomposition of this biomass can in turn affect the acidity and dissolved oxygen content of the water column.

This issue has been combined with *Issue 12* for further discussion in the Estuary Management Plan (*Section 7*).

14 The current Water Quality (WQ) monitoring program is inadequate to determine trends in WQ over time.

At present, monitoring of chemical and physical surface water quality variables in Korogoro Creek is limited to one sampling event every six months with only one site

analysed. The Council's Beachwatch program conducts weekly Faecal coliform testing at one site in Korogoro Creek during the summer months. A more comprehensive sampling program would assist in determining trends in WQ over time and identifying WQ issues that warrant further attention.

Stormwater

15 Preliminary event-based stormwater quality testing indicates high levels of faecal coliforms are entering the estuary from the southern side of Hat Head after moderate rainfall events.

The results of the stormwater quality testing are preliminary and qualitative and need further investigation. Ongoing monitoring of stormwater quality during runoff events is required to more accurately define stormwater issues and to determine which mitigation measures might be appropriate.

Groundwater

16 Ongoing monitoring of the groundwater quality immediately below the Effluent Disposal Site has revealed some issues warranting closer attention.

Over the monitoring period a number of samples have shown aspects of poor water quality but overall no clear trends of degrading groundwater quality are associated with effluent disposal to date. Despite this, high levels of ammonia, Kjeldahl nitrogen and aluminium have been detected sporadically in groundwater samples.

6.4.5 Recreational Use and Access

Recreational Access

17 Hazards to swimmers resulting from damage to oysters on the southern creek bank downstream of the footbridge.

The potential risk to swimmers and snorkelers of cuts and abrasions from smashed oyster shells on the rocks on the southern creek bank in the lower estuary has been raised during community meetings. This issue relates closely to *Issue 7* above and the two issues have been combined for further discussion in the Estuary Management Plan (*Section 7*).

18 Impacts associated with the proliferation of access points and tracks on the southern creek bank foreshore between the traffic bridge and foot bridge.

There are currently 10 informal vehicle access points to the southern bank foreshore of the estuary in the approximately 1.8 km of creek length between the traffic bridge and the footbridge. Many informal vehicle tracks also exist with the highest concentration of vehicle tracks and accesses occurring in areas of easy access to the creek bank. Impacts observed included;

- Extensive damage to Coastal Saltmarsh, an *Endangered Ecological Community* listed under the Threatened Species Conservation Act 1995 (see Issue H above)
- Impacts on vegetation and low banks particularly where tracks cross small tidally inundated flats. Damage is worse where flow is concentrated during heavy rain and in boggy areas.
- Damage to the levee where vehicles attempt to negotiate the steep climb back onto Gap Road.

19 Lack of facilities for adequate vehicle access to the southern creek bank for fishing, etc. and resulting unsafe practices in relation to parking on the roadside between the traffic bridge and footbridge.

The proliferation of vehicle accesses and tracks on the southern creek bank foreshore is evidence of recreational users desire to access these areas for fishing, picnicking, and swimming. Demand appears to be highest in the vicinity of the traffic bridge where the estuary is known for its quality fishing. In blackfish season or during peak holiday periods both the foreshore and the verge of Gap Road can be packed with vehicles. Safety concerns have been raised during community consultation meetings as the narrow nature of Gap Road and the levee upon which it is located means that vehicles often are parked on both sides of the road and sometimes protruding into the roadway. Given the strong demand for access at this point it seems prudent to formalise some access options to the foreshore which improve safety, limit damage to the sensitive foreshore environment, and which do not interfere with the creek's flood mitigation functions.

20 Boat ramp design and facilities

The boat ramp and fish cleaning facilities near the mouth of the creek are considered to be generally acceptable. Some boaters are dissatisfied with the rocked edges of the ramp as they create a hazard to boats in peak periods and when strong currents are running. The proliferation of waterways signage has also been identified as an issue by agency stakeholders as the multitude of signs are seen as confusing and to detract from the amenity of the area.

Community Awareness and Education

21 Littering and dumping of rubbish and garden wastes reduce the scenic amenity and environmental quality of the estuary and its foreshore.

Concern about littering (including fishing tackle and bait packets, takeaway food and drink containers and wrappings, etc.) and the dumping of rubbish in the vicinity of the creek and its foreshore ranked highly in both Community Surveys. Improved community and visitor awareness may assist in reducing the incidence of littering and dumping around the estuary.

6.4.6 Catchment Management

Catchment Processes

22 Swan Pool Management and the effects of Swan Pool drainage on the estuary water quality and ecology

Swan Pool in the west of the catchment is a significant contributor of poor quality water into Korogoro Creek during periods of operation of the flood mitigation scheme. A large proportion of Swan Pool is contained within the Hat Head National Park however a history of drainage works to improve grazing capacity and to improve the broader Macleay Valley flood security has left a legacy or acid sulfate soil pollution and accompanying water quality issues. The Kempsey Shire Council Floodplain Management Program, the NSW NPWS, and some local landholders are actively implementing changes to the drainage system to try to alleviate these issues.

Climate Change

23 Risks associated with climate change and sea level rise are currently not well understood and are not currently addressed in Local or State Government policies or land use planning instruments.

Potential impacts of climate change and sea level rise include;

- Increasing risks in coastal areas including coastal erosion; increasing flood inundation extents and heights; impacts on infrastructure including dry weather inundation of roads, sewers, culverts and bridges; and saltwater incursion into groundwater aquifers. Densely populated and low-lying areas where adaptive capacity is relatively low are especially at risk.
- Impacts from sea level rise on coastal wetlands including salt marshes and mangroves especially where they are constrained on their landward side.
- Altered hydrodynamic regimes and geomorphic process which may result in changes to entrance conditions and location, changes to bank stability and sedimentation rates (i.e. sand shoals locations and shapes) and bank stability and erosion; and
- Extent of salt penetration as a result of increased tidal range and velocities, and associated impact on water supplies for human and animals, impact of salt on vegetative communities, etc.

There are currently no land use planning controls or instruments in place for addressing the predicted future impacts of climate change on the estuary or the township of Hat Head.

6.5 Ranked List of Key Estuary Management Issues

Table 5 ranks the Key Estuary Management Issues in terms of their priority for management over the next 5 years. Priorities have been attributed based on a matrices that considers the potential for the issue to impact on the identified objectives for management, the timeframe over which the impacts are likely to occur, the area likely to be affected by the issue, and the community rating of the issue derived from the 2008 community survey. The scoring system used to determine the rankings was based on the following;

- Potential for Impact on Stated Objectives for Management: low = 1, moderate = 3, high = 5
- Timeframe over which impacts occur: short (<3 years) =1, short-medium (3-5 years) = 2, medium (5-8 years) = 3, medium-long (8-10 years) =4, long (>10 years) = 5.
- Area affected: lower = 1, mid = 1, upper = 1, whole estuary = 3
- Community Rating: based on combination of values and threats rankings from the 2008 community survey. A *Value* ranking of 1-6 scored 3 points, 7-12 = 2 points, 13-19 = 1 point. A *Threats* rankings of 1-6 scored 3 points, 7-12 = 2 points, 13-18 = 1 point. The two scores were then averaged for the Combined Community Rating Score.

Table 5 Ranked List of Key Estuary Management Issues, Objectives impacted, and priority for management between 2009 and 2014.

	Key Estuary Management Issue	***Potential for Impact on Stated Objectives***	***Timeframe over which Impacts Occur***	***Area affected***	***Community Rating***	***Priority Ranking***
23	Risks associated with climate change and sea level rise are currently not well understood and are not currently addressed in Local or State Government policies or land use planning instruments.	HIGH	SHORT TERM	WHOLE ESTUARY	MODERATE	14.5
11	Damage to aquatic ecosystems and water quality after operation of the Macleay Valley Flood Mitigation Scheme.	HIGH	MEDIUM TERM	WHOLE ESTUARY	HIGH	14
18	Impacts associated with the proliferation of access points and tracks on the southern creek bank foreshore between the traffic bridge and foot bridge.	HIGH	MEDIUM TERM	MID ESTUARY	HIGH	11.5

	Key Estuary Management Issue	*Potential for Impact on Stated Objectives*	*Timeframe over which Impacts Occur*	*Area affected*	*Community Rating*	*Priority Ranking*
3	Effects of climate change and sea level rise on entrance behaviour, hydrology and estuary health.	HIGH	LONG TERM	WHOLE ESTUARY	MODERATE	11
19	Lack of facilities for adequate vehicle access to the southern creek bank for fishing, etc. and resulting unsafe practices in relation to parking on the roadside between the traffic bridge and footbridge.	MODERATE	SHORT TERM	MID ESTUARY	MODERATE	11
10	Weed invasion in native vegetation communities along the estuary banks and foreshore.	MODERATE	MEDIUM TERM	WHOLE ESTUARY	MODERATE	11
2	Shoaling at the entrance has at times almost closed the creek mouth.	LOW	SHORT TERM	WHOLE ESTUARY	MODERATE	11
16	Ongoing monitoring of the groundwater quality immediately below the Effluent Disposal Site has revealed some issues warranting closer attention.	MODERATE	MEDIUM TERM	MID to UPPER ESTUARY	HIGH	10.5
8	Damage to Coastal Saltmarsh Endangered Ecological Community on the southern creek bank foreshore.	MODERATE	SHORT - MEDIUM TERM	MID ESTUARY	HIGH	10.5
12	Low Dissolved Oxygen (DO) and high nutrients levels (particularly ammonia) have been recorded in the upper reaches of the estuary near the Korogoro Cut floodgates.	MODERATE	MEDIUM TERM	UPPER ESTUARY	HIGH	10
13	Elevated Chlorophyll-a levels have been recorded in the upper reaches during periodic water quality sampling. Combined with *Issue 12* for treatment within the EMP.	MODERATE	MEDIUM TERM	UPPER ESTUARY	HIGH	10
4	Bank erosion occurring between the traffic bridge and the footbridge.	MODERATE	MEDIUM TERM	MID ESTUARY	HIGH	9.5

	Key Estuary Management Issue	*Potential for Impact on Stated Objectives*	*Timeframe over which Impacts Occur*	*Area affected*	*Community Rating*	*Priority Ranking*
15	Preliminary event-based stormwater quality testing indicates high levels of faecal coliforms are entering the estuary from the southern side of Hat Head after moderate rainfall events.	MODERATE	MEDIUM TERM	LOWER ESTUARY	HIGH	9.5
22	Swan Pool Management and the effects of Swan Pool drainage on the estuary water quality and ecology.	LOW	MEDIUM TERM	WHOLE ESTUARY	HIGH	9.5
6	Collection of tropical fishes from the creek for aquariums.	LOW	SHORT TERM	LOWER ESTUARY	HIGH	9.5
14	The current Water Quality (WQ) monitoring program is inadequate to determine trends in WQ over time.	LOW	MEDIUM TERM	WHOLE ESTUARY	MODERATE	9
7	Damage to oysters on the southern creek bank downstream of the footbridge.	LOW	SHORT TERM	LOWER ESTUARY	MODERATE	9
17	Hazards to swimmers resulting from damage to oysters on the southern creek bank downstream of the footbridge. Combined with *Issue 7* for treatment in the EMP.	LOW	SHORT TERM	LOWER ESTUARY	MODERATE	9
5	Effects of sedimentation and channel in-filling including loss of pools and associated habitat and loss of recreational opportunity.	MODERATE	MEDIUM to LONG TERM	MID ESTUARY	MODERATE	8
1	Difficulty with launching larger vessels has at times necessitated the removal by Council of sand in the vicinity of the boat ramp.	LOW	SHORT TERM	LOWER ESTUARY	LOW	8
20	Boat ramp design and facilities.	LOW	SHORT TERM	LOWER ESTUARY	LOW	8

	Key Estuary Management Issue	*Potential for Impact on Stated Objectives*	*Timeframe over which Impacts Occur*	*Area affected*	*Community Rating*	*Priority Ranking*
9	Poor recruitment and regeneration of native vegetation on southern creek bank foreshore.	LOW	MEDIUM TERM	MID ESTUARY	HIGH	7.5
21	Littering and dumping of rubbish and garden wastes reduce the scenic amenity and environmental quality of the estuary and its foreshore.	LOW	MEDIUM TERM	MID ESTUARY	HIGH	7.5

PART 7 ESTUARY MANAGEMENT PRIORITIES AND POTENTIAL MANAGEMENT STRATEGIES

Table 6 lists potential management strategies for addressing the key estuary management issues identified in the preceeding section of this Study. The potential strategies will be further considered and developed (including actions required for implementation, estimated costs, responsibilities, funding sources, etc) in the Korogoro Creek Estuary Management Plan.

Table 6 Potential Estuary Management Strategies to be considered in the Estuary Management Plan

Management Issue and Strategy Number	Potential Estuary Management Strategies (to be considered in the Estuary Management Plan)	Objectives Addressed	Estimated Timeframe for Implementation (years)
23	Risks associated with climate change and sea level rise are currently not well understood and are not currently addressed in Local or State Government policies or land use planning instruments.		
23.1	Obtain sufficiently accurate elevation data to enable the determination of the potential risks to lands, built infrastructure and natural assets under various sea level rise scenarios.	**P**	1-3
23.2	Identify areas of land within the Korogoro Creek catchment at risk from predicted changes to sea level rise and changed weather patterns and use LEP and DCP instruments to manage future development.	**P**	1-5
23.3	Consider the impacts of climate change on existing assets, identify assets at risk, determine strategies for relocation, and identify lands suitable for relocation of at-risk assets and infrastructure and use LEP and DCP instruments to quarantine such land for potential use for asset and infrastructure relocation.	**P**	1-5
23.4	Model the impacts of higher sea levels on the operation of the Macleay Valley Flood Mitigation Scheme and associated infrastructure and develop strategies for adaptation.	**P**	1-5 (Requires review of entire scheme)

Management Issue and Strategy Number	Potential Estuary Management Strategies (to be considered in the Estuary Management Plan)	Objectives Addressed	Estimated Timeframe for Implementation (years)
11	Damage to aquatic ecosystems and water quality after operation of the Macleay Valley Flood Mitigation Scheme		
11.1	Undertake a 'dry time' review of the water quality effects of the flood mitigation scheme.	**F, G, J, Q**	Requires review of options
11.2	Schedule an event based assessment of the water quality effects of the flood mitigation scheme.	**B, F, G, J, Q**	Requires review of options
11.3	Undertake a simple ecological survey of the creek flora, fauna and habitats before and after flooding.	**F, G, J, Q**	Requires review of options
18	Impacts associated with the proliferation of access points and tracks on the southern creek bank foreshore between the traffic bridge and footbridge.		
18.1	Limit vehicle access to the area between the bank and the levee using a mixture of large rocks, bollards, other obstacles and existing native vegetation.	**D, B, N**	1-2
18.2	Allow vehicle access to the southern creek bank at a small number of defined locations.	**D, B, N**	1-2
18.3	Confine vehicle movement below the levee to 3 small locations, using a mixture of large rocks, bollards and native vegetation.	**D, B, N**	1-2
18.4	Employ strategies to educate creek users about the importance of protecting coastal saltmarsh and the necessity of changing previous arrangements.	**O**	1-2

Management Issue and Strategy Number	Potential Estuary Management Strategies (to be considered in the Estuary Management Plan)	Objectives Addressed	Estimated Timeframe for Implementation (years)
3	Effects of climate change and sea level rise on entrance behaviour, hydrology and estuary health.		
3.1	Assess the likely hydrological changes resulting from current Sea Level Rise scenarios. Aspects requiring investigation include tidal planes and phasing, tidal prism, a volumetric analysis, tidal flushing, and changes in shoaling behaviour and water levels throughout the estuary.	**B, A, P**	2-4
3.2	Assess the likely effects of hydrological changes on estuary water quality.	**H, P, K**	2-4
3.3	Assess the likely effects of hydrological changes on estuary ecology,	**F, P**	2-4
3.4	Plan to mitigate the negative effects of climate change on estuary behaviour and health.	**P**	5
19	Lack of facilities for adequate vehicle access to the southern creek bank for fishing, etc. and resulting unsafe practices in relation to parking on the roadside between the traffic bridge and footbridge.		
19.1	Provide informal parking on a small number of well defined areas on the southern bank below the levee as deemed acceptable by community and stakeholders.	**M, N**	See 18.1 and 18.2
10	Weed invasion in native vegetation communities along the estuary banks and foreshore.		
10.1	Develop a weed management strategy which prioritises areas of riparian foreshore to be treated and priority weeds to be targeted	**D, E**	1-2
10.2	Utilise specialist bush regeneration contractors to undertake primary weed control in priority areas.	**D, E**	2-5
10.3	Foster a local *Bushcare* group to undertake the secondary control or follow-up maintenance of areas treated by contractors.	**D, E**	2+

Management Issue and Strategy Number	Potential Estuary Management Strategies (to be considered in the Estuary Management Plan)	Objectives Addressed	Estimated Timeframe for Implementation (years)
2	Shoaling at the entrance has at times almost closed the creek mouth		
2.1	Develop an Entrance Management Policy that outlines protocols for intervention should the entrance close	**A**	Will form part of EMP
16	Ongoing monitoring of the groundwater quality immediately below the Effluent Disposal Site has revealed some issues warranting closer attention.		
16.1	Increase the frequency of monitoring groundwater levels underneath the dune disposal site.	**L, K**	Ongoing
16.2	Continue monitoring groundwater quality underneath and around the dune disposal site.	**K, P**	1-2
16.3	Investigate opportunities to relocate the dune disposal site for long term disposal of effluent off site.	**L, K**	Ongoing
8	Damage to Coastal Saltmarsh Endangered Ecological Community on the southern creek bank foreshore.		
8.1	Restrict vehicle access to areas of Coastal Saltmarsh.	**D, E, B, N**	1-2
8.2	Seek appropriate protection for areas of coastal saltmarsh in planning and policy documents.	**D**	2-5
8.3	Employ strategies to educate creek users about the importance of protecting Coastal Saltmarsh.	**D, O**	1-2
8.4	Begin active regeneration of vegetation along the levee.	**B, D, E**	
8.5	Actively regenerate areas of significantly degraded saltmarsh habitat	**B, E**	

Management Issue and Strategy Number	Potential Estuary Management Strategies (to be considered in the Estuary Management Plan)	Objectives Addressed	Estimated Timeframe for Implementation (years)
12	Low Dissolved Oxygen (DO) and high nutrients levels (particularly ammonia) have been recorded in the upper reaches of the estuary near the Korogoro Cut floodgates.		
12.1	Investigate the source of observed water quality issues in the upper estuary.	**L, Q**	2-5
12.2	If the source of poor quality water is found to be above the floodgates undertake appropriate actions.	**Q, J, H, G**	5 -10
12.3	Investigate other potential options for changes to the management of the Korogoro Cut, the floodgates and the Swan Pool.	**Q, J, G**	5 – 10
13	Elevated Chlorophyll-a levels have been recorded in the upper reaches during periodic water quality sampling		
13.1	Monitor chlorophyll-a levels as part of a regular water quality monitoring plan. Fluctuations in chlorophyll-a levels are a natural feature of estuarine systems. Persistently high levels can indicate a eutrophic system.	**L**	2-5
13.2	Investigate sources of nutrients. Persistently elevated chlorophyll-a levels are an indication of a eutrophic system.	**L**	2-5
13.3	Plan to reduce the nutrient load on the creek by managing stormwater inputs, managing inputs from the Swanpool area and by managing nutrient levels in disposed effluent.	**L, I, J, Q**	2-5
4	Bank erosion occurring between the traffic bridge and the footbridge.		
4.1	Develop rehabilitation options for high priority bank erosion reaches between the traffic bridge and the footbridge.	**B, C**	Will form part of EMP

Management Issue and Strategy Number	Potential Estuary Management Strategies (to be considered in the Estuary Management Plan)	Objectives Addressed	Estimated Timeframe for Implementation (years)
4.2	Monitor existing sites identified with moderate erosion and where possible take actions to encourage natural recovery mechanisms.	**B, C**	1-5
4.3	Raise awareness in the local community of estuarine processes and the causes and effects of bank erosion in the estuary. Strategies might include signs, brochures or other educational material.	**B, C, O**	1-2
15	Preliminary event-based stormwater quality testing indicates high levels of faecal coliforms are entering the estuary from the southern side of Hat Head after moderate rainfall events.		
15.1	Undertake a more thorough stormwater quality analysis.	**L**	1-3
15.2	Investigate the source of faecal matter in stormwater, if found in significant concentrations.	**L**	3-5
15.3	Undertake strategies to reduce the levels of faecal material in stormwater.	**H, I**	5-10
15.4	Undertake a public education campaign with the intention of reducing pollutants in stormwater.	**I, O**	1-2
22	Swan Pool Management and the effects of Swan Pool drainage on estuary water quality and ecology.		
22.1	Identify specific water quality and acid sulfate soils issues within the Swan Pool wetland that impact upon Korogoro Creek.	**H, J, Q**	
22.2	Continue existing efforts by Kempsey Council, NPWS and Landholders to address Acid Sulfate Soil issues and improve the quality of water entering Korogoro Creek during flood times.	**G, J, Q**	Ongoing
22.3	Consider further acquisition of Swan Pool area by DECC (NPWS).	**J, L, Q**	1-2

Management Issue and Strategy Number	Potential Estuary Management Strategies (to be considered in the Estuary Management Plan)	Objectives Addressed	Estimated Timeframe for Implementation (years)
6	Collection of tropical fishes from the creek for aquariums.		
6.1	Improve the documentation and public knowledge of the decision to close Korogoro Creek to the collection of tropical marine 'aquarium' fish.	**M, O, F**	2-5
6.2	Investigate the persistence of tropical marine 'aquarium' fishes in Korogoro Creek over the winter period.	**M**	5-10
14	The current Water Quality (WQ) monitoring program is inadequate to determine trends in WQ over time.		
14.1	Develop a water quality monitoring program for Korogoro Creek	**H, L**	1-2
14.2	Implement revised water quality monitoring program	**H, L**	2-4
7	Damage to oysters on the southern creek bank downstream of the footbridge.		
7.1	Assess the health of the Korogoro Creek wild oyster population over time.	**M**	2-5
7.2	Aim to educate the community about the role of oysters in healthy estuary ecosystems, current bag limits on oyster collection and appropriate methods of oyster harvest.	**O**	2-5
17	Hazards to swimmers resulting from damage to oysters on the southern creek bank downstream of the footbridge.		
17.1	See Strategy 7.2	**M**	See Strategy 7.2

Management Issue and Strategy Number	Potential Estuary Management Strategies (to be considered in the Estuary Management Plan)	Objectives Addressed	Estimated Timeframe for Implementation (years)
5	Effects of sedimentation and channel in-filling including loss of pools and associated habitat and loss of recreational opportunity.		
5.1	Sedimentation in the estuary is primarily the result of the continual ingression of marine-derived sands through the entrance of the estuary. The process is a long-term process and little can be done in the way of active management short of dredging to permanently remove sediments. Dredging has significant deleterious effects on other aspects of estuary health and is not considered an appropriate long-term strategy to alleviate sedimentation in Korogoro Creek. However, the strategic removal of sands under strict guidelines may be appropriate in the area of the boat ramp during periods of excessive shoaling. See Strategies 1.1 and 2.1 for details.	**A,B,C, M**	See 2.1 and 1.1
5.2	The main other source of within-channel sediment is bank erosion. Minimising non-marine sources of sedimentation by implementing strategies to reduce bank erosion along the estuary banks and foreshore will slow channel in-filling. Strategies to minimise bank erosion are detailed in Strategy 4.1, 11.1-11.3, and 18.1-18.4.	**B, C**	See 4.1, 11.1-11.3, and 18.1-18.4
1	Difficulty with launching larger vessels has at times necessitated the removal by Council of sand in the vicinity of the boat ramp.		
1.1	Develop protocols for removing sands from in the vicinity of the boat ramp in conjunction with Strategy 2.1	**A, M**	Will form part of EMP
20	Boat ramp design and facilities.		
20.1	Issues concerning the current design of the boat ramp have been raised in community forums. In particular the rock sidings are considered to be a potential risk to boat hulls. The potential for retrofitting of the ramp with graded concrete sidings could be considered by responsible agencies (ie. Kempsey Shire Council and NSW Maritime).	**M, N**	1-3

Management Issue and Strategy Number	Potential Estuary Management Strategies (to be considered in the Estuary Management Plan)	Objectives Addressed	Estimated Timeframe for Implementation (years)
20.2	The proliferation of signage in the vicinity of the boat ramp has been raised in community forums. The potential for consolidation of the signage should be considered by the responsible authorities (ie. DECC, NSW Maritime, NSW DPI Fisheries, Kempsey Shire Council)	**M, N**	1-3
9	Poor recruitment and regeneration of native vegetation on southern creek bank foreshore.		
9.1	Investigate the causes of poor recruitment (specifically of Swamp paperbarks, *Melaleuca quinquenervia*) and attempt to improve recruitment/regeneration using appropriate management strategies. These may include removal of impacts (associated with access tracks), assisted regeneration, or non-interference.	**D, E**	1-2
21	Littering and dumping of rubbish and garden wastes reduce the scenic amenity and environmental quality of the estuary and its foreshore.		
21.1	Aim to educate the community and visitors about the sensitivities of the estuary environment and the negative impacts of littering and dumping of garden waste on estuary aesthetics and health.	**O**	1-2
21.2	Investigate areas of concentration of litter and determine adequacy of existing bin infrastructure.	**O**	1-2

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GLOSSARY

The following glossary has been accumulated from a number of sources including the Manly Hydraulics Laboratory website (http://mhl.nsw.gov.au/www/tide_glossary.htmlx), Ozestuaries and Ozcoasts websites (http://www.ozcoasts.org.au/glossary.jsp), the Department of Environment and Climate Change Estuary Management website (http://dnr.nsw.gov.au/estuaries/index.shtml), and from Toedson *et al.*, (1994). For more detailed information please visit the sources listed above.

Acid sulfate soils (ASS)	are soils and other soft sediments that contain iron sulfides (mostly pyrite (FeS2)) with typically smaller quantities of iron monosulfides (FeS)).
AHD	Australian Height Datum
Algal bloom	proliferation of one or more phytoplankton species to high densities under favourable environmental conditions.
ANZECC	Australian and New Zealand Environment Conservation Council, most commonly referred to in term of the water quality guidelines set for environmental protection
Aquatic ecosystem/system	Any body of water including lakes, streams, wetlands, reservoirs or estuaries and associated living organisms and non-living components functioning as a natural system.
Aquifer	A geological formation, group of formations, or part of a formation that stores and/or allows movement of groundwater.
Biophysical	Relating to biological and physical processes.
Biota	Refers to all plant and animal life in an area.
BoM	Bureau of Meteorology
Catchment	The area of land which collects and transfers rainwater into a waterway.
Chlorophyll a	is a green pigment found in plants. It absorbs sunlight and converts it to sugar during photosynthesis. Chlorophyll a concentrations are an indicator of phytoplankton abundance and biomass in coastal and estuarine waters. They can be an effective measure of trophic status [1], are potential indicators of maximum photosynthetic rate (P-max) [2] and are a commonly used measure of water quality. High levels often indicate poor water quality and low levels often suggest good conditions. However,

	elevated chlorophyll a concentrations are not necessarily a bad thing. It is the long-term persistence of elevated levels that is a problem
Conceptual Model	A depiction or representation of the most current understanding of the major ecosystem features and processes (including biological, physical, chemical and geomorphic components) of a particular environment (e.g. estuaries).
DECC	Department of Environment and Climate Change
Deposition	The dropping of material which has been picked up and transported by wind, water, or other processes.
Dissolved oxygen	Measures of dissolved oxygen refer to the amount of oxygen contained in water, and define the living conditions for oxygen-requiring (aerobic) aquatic organisms.
Ebb tide	A falling tide - the phase of the tide between high water and the succeeding low water.
Ecosystem health	A term used to describe desired ecosystem conditions. the perception of health will vary depending on goals (i.e. production versus biodiversity).
EEC	An Endangered Ecological Community (EEC) is an ecological community listed as facing a very high risk of extinction in NSW under the Threatened Species Conservation Act 1995.
EMC	Estuary Management Committee
EMS	Estuary Management Study
EMP	Estuary Management Plan
Enterococci	Bacteria of the genus *Enterococcus* that may be used to determine the extent of faecal contamination of recreational waters. The *Enterococcus* group is a sub-group of faecal streptococci. It is differentiated from other faecal streptococci by growth at higher temperatures and salt concentrations in the laboratory, and by the ability to survive in marine waters under conditions that are unfavourable for most other faecal microorganisms.
Estuary	a coastal water body that receives inputs of water and sediment from fluvial and marine sources, and that is regularly or intermittently affected by tides. Generally formed through marine inundation of river valleys and other topographic depressions as a result of marine transgression or subsidence.

Eutrophication	Process of enrichment of nutrients, especially nitrogen and phosphorous.
Fecal coliform	The portion of the coliform bacteria group which is present in the intestinal tracts and faeces of warm-blooded animals. A common pollutant in water.
Fine sediment	A sediment comprising fine-grained material such as mud or clay particles.
Flood tide	A rising tide - the phase of the tide between low water and the next high tide.
Flood-tide delta	a type of tidal delta formed by the deposition of sandy sediment inward (landward) of an estuary entrance or a tidal inlet, primarily by flood-tidal currents.
Flushing	Exchange of water between an estuary or coastal waterway and the ocean.
Flushing rate	Time required for a volume of water equivalent to the estuary volume to mix with the ocean or the reservoir volume to be discharged.
Fluvial	Pertaining to a river or freshwater source
Geographic information system (GIS)	a computer-based system for the storage, manipulation, and analysis of spatial data.
Geomorphology/Geomorphic	The study of the nature and history of landforms and the processes which create them.
Groundwater	Water stored underground in rock fractures and pores.
Habitat	A specific type of place within an ecosystem occupied by an organism, population or community that contains both living and non-living components with specific biological, chemical and physical characteristics including life requirements (e.g. food, shelter and water).
Heavy metals	Metallic elements with relatively high atomic weights such as lead, cadmium, rsenic and mercury. Generally toxic in relatively low concentrations to plant and animal life.
ICOLLs	Acronym for *Intermittently Closed and Open Lakes and Lagoons*, referring to Coastal Lagoons and some Wave-Dominated Estuaries under low runoff conditions.
Intertidal mud flats	are un-vegetated, generally low gradient and low energy environments that are subject to regular tidal inundation, and that consist of poorly- to moderately-sorted sandy mud and muddy sand.
Intertidal zone	The zone between mean high water and mean

	low water, subject to regular submersions and emersions, important for species zonation.
IPCC	Intergovernmental Panel on Climate Change
KSC	Kempsey Shire Council
Levee	Natural or artificial ridge or embankment to prevent flooding or restrict movement of water.
Littoral drift	movement of sediment along a beach by swash and backwash of waves that approach the shore obliquely.
Longshore current	coast-parallel current that develops when waves approach the shoreline at an oblique angle. Longshore currents typically operate along extended and relatively straight sectors of sandy shorelines, and are an important agent of sediment transport in coastal barrier systems.
Longshore drift (littoral drift)	movement of sediment along a beach by swash and backwash of waves that approach the shore obliquely.
Macro-invertebrate	An animal without a backbone and large enough to be seen without magnification.
Mouth	The entrance of the coastal waterway, or the place where the sea meets or enters the coastal waterway.
Mud	Fine sedimentary material, typically comprising both inorganic (mineral) and organic material.
NHMRC	A set of water quality guidelines put together by the National Health and Medical Research Council for managing risks in recreational waters.
Organic material	Once-living material (typically with high carbon content), mostly of plant origin.
Rehabilitation, remediation	Action to return a landform, vegetation, or water body to as near as original condition as practical. Implies making land and water resources useful again after disturbance.
Rocky reefs	feature a hard substrate that may occur at supra-tidal to sub-tidal elevations. Surfaces are generally non-depositional and sometimes erosional, and are usually dominated by epifaunal and algal communities.
Run-off	The difference in quantity between precipitation and the combination of evaporation and transpiration. The resulting water that supplies rivers and lakes after evaporation and transpiration have occurred. Includes water that

	soaks into the earth and is available as groundwater. Surface run-off does not include groundwater.
Saltmarsh	A coastal saltmarsh is a community of plants and animals that grow along the upper-intertidal zone of coastal waterways.
Salt-wedge	An intrusion of sea water into a coastal waterway in the form of a wedge along the seabed. The lighter fresh water from riverine sources overrides the denser salt water
Sand	grains with diameters between 0.06 mm to 2 mm
Seagrass	Marine flowering plants which generally attach to the substrate with roots.
Sedimentary environment	Refers to a characteristic suite of sediment types defined by mineralogical composition and grain size that are deposited within specific landform and energetic environments. Also known as 'sedimentary facies'.
SEPP 14 Wetland	A wetland protected under State Environmental Planning Policy #14.
SEPP	State Environmental Planning Policy
Silt	grains with diameters between 0.002 mm to 0.06 mm
Stormwater	Stormwater runoff comprises all forms of runoff from urban areas. It is enhanced by the web of impervious surfaces, including roads, roofs, footpaths, car parks and other structures, and is conveyed to coastal waterways by natural and man-made conduits and drains.
Strandplain	a coastal lowland formed through progressive shoreline progradation. Generally consists of beach ridges and associated features.
Swale	a shallow topographic depression, particularly that associated with coastal barriers and alluvial plains.
Tidal Current	An alternating, horizontal movement of water associated with the rise and fall of the tide, these movements being caused by gravitational forces due to the relative motions of Moon, Sun and Earth.
Total Kjeldahl Nitrogen (TKN)	The sum of organic nitrogen and ammonia in a water body. Measured in milligrams per liter (mg/L). High measurements of TKN typically results from sewage and manure discharges to water bodies.
Total Nitrate and Nitrite	Nitrogen Nitrate (NO3) plus nitrite (NO2) as

	nitrogen. In lakes, most nitrate/nitrogen is in NO3 form. It is measured in milligrams per liter (mg/L). Elevated levels of nitrates/nitrogen are often caused by over application of fertilizers that leach into waterbodies.
Total Nitrogen (TN)	is the sum of nitrate (NO3), nitrite (NO2), organic nitrogen and ammonia (all expressed as N). Note that for laboratory analysis purposes, Total Kjeldahl Nitrogen (TKN) is a test performed that is made up of both organic nitrogen and ammonia.
Total Phosphorus (TP)	A nutrient essential to the growth of organisms, and is commonly the limiting factor in the primary productivity of surface water bodies. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particle form. Agricultural drainage, wastewater, and certain industrial discharges are typical sources of phosphorus, and can contribute to the eutrophication of surface water bodies. Measured in milligrams per litre (mg/L).
Turbidity	The condition resulting from the presence of suspended particles in the water column which attenuate or reduce light penetration.

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