PART 2 EXISTING DATA - COMPILATION AND REVIEW

Korogoro Creek estuary is located on the NSW north coast approximately 350 km north of Sydney and 80 km south of Coffs Harbour. Korogoro Creek is a small-sized estuary with no significant tributaries which runs to the ocean at the coastal village of Hat Head. The estuary entrance is untrained and is permanently open. The estuary is approximately 5.4km long and has a water surface area of approximately 0.2 km^2. The catchment area is approximately 18 km^2 which includes Swan Pool to the west, low sand hills and swamps to the south west, the village of Hat Head to the east and south, and a proportion of the headland to the south east of Hat Head (see Figure 1-E, p.9).

Prior to flood mitigation works in the late 1960s the creek was approximately 3.2 km long and culminated in an extensive series of swamps located behind the coastal dune fringe. Flood mitigation works (including the construction of drains, floodgates, and levees on the creek) have now significantly altered the form and function of the creek. Today the creek is approximately 5.3 km long with the main channel culminating at floodgates which control tidal incursion into the swan pool wetland.

Although considered part of the Macleay River catchment it is mostly only linked to the broader catchment during periods of significant flooding when the creek is used as an ocean release for floodwaters accumulated in Swan Pool. In order to protect the village from flooding during such releases levees have been constructed along the length of the creek and a “Choke” installed to moderate flood heights in the creek. The “Choke” is a control structure which moderates flow down the channel to below the constructed levee height and diverts excess flood waters through Rowes Cut to the ocean (see Figure 1-E, p.9).

The catchment area is mostly undeveloped except for the small village of Hat Head which occupies approximately 4% of the catchment. 63% of the catchment is protected in the Hat Head National Park. The catchment vegetation is predominantly swamp sclerophyll and shrubby dry forests on the low sand hills; heathland, arid and semi arid shrublands on sand and peat plains and parts of the headland; freshwater and saline wetlands in low swamp areas; and with small occurrences of littoral rainforest and wet sclerophyll forests in protected headland and back dune locations.

Hat Head has a resident population of approximately 350 but the population swells during the peak holiday seasons due to the areas popularity as a holiday destination. Swimming, surfing, camping, fishing and boating are popular recreational pursuits of residents and visitors alike. The town has been sewered since 2001 with the treated effluent piped to a dune disposal site north of the village.

The following sections summarise the existing data on Korogoro Creek and have been drawn from various sources including State and Local Government Agencies, published and unpublished reports and studies, local residents, and resources available on the internet.

2.1 Climate data

Weather and climate impact upon hydrodynamic processes, geology, geomorphological processes and ecological processes and therefore are important forcing factors driving many estuarine processes.

The closest longterm weather monitoring site is maintained by the Bureau of Meteorology (BoM) at Smoky Cape near South West Rocks (records from 1939 –2007). Data extracted from the BoM website database are summarised in Figure 2-A (p.27).

In general, the data show that the prevailing climate at Korogoro Creek is warm and temperate with a maritime influence demonstrated by the increased wind speed in the afternoons of the warmer months of the year and stronger morning winds in the cooler months. Figure 2-B (p.28) shows Wind Rose diagrams which indicate the prevailing wind directions and show a strong seasonal pattern. Summer winds are predominantly from the southwest or north in the mornings and strongly onshore from the

north and north-east in the afternoons. Winter winds are from the west and south west in the mornings and south-west and south in the afternoons.

Mean monthly rainfall data (Figure 2-A, p.27) also show a strong seasonal pattern with generally wet late summers and early autumns and dry winters and early springs. Annual rainfall is around 1470mm per year but is dependant upon longer-term climatic influences such as the Southern Oscillation Index (SOI). The SOI gives an indication of the likelihood of rainfall deviating from average with negative values in a year indicating likely drier years and positive values indicating likely wetter years. Sustained values of less than –10 indicate an El Nino Southern Oscillation (ENSO) event and dry weather across northern and eastern Australia. Figure 2-C (p.29) shows the monthy SOI plotted from January 1990 to June 2007. The sustained drought experienced in Australia between 1992 and 1994 is reflected in the chart which also indicates that on average the years 1998-2001 were wetter than average whilst 2002-2007 have been drier than average.

Mean monthly evaporation data (extracted from the Coffs Harbour BoM site) is typical of temperate climate areas with higher values in summer and lower values in winter (Figure 2-A, p.27). The monthly figures also show an excess of evaporation over rainfall over the period from August to February and the reverse during March to July. If evaporation greatly exceeds rainfall then excessive drying can occur which potentially exposes and oxidises sulphidic sediments causing acid sulphate soil problems (MHL, 2006).

2.2 Catchment Processes

Land use and zoning

The catchment area is mostly undeveloped except for the small village of Hat Head which occupies approximately 4% of the catchment. 63% of the catchment is protected in the Hat Head National Park with the remainder of the catchment zoned as either 1(a1) Rural - 12.6%, 8 (b) Proposed National Park – 17%, 1(d) Rural Investigation - 2%, 6(a) Open Space - 1%, or 7(f1) Coastal Lands Protection – 0.2% (Figure 2-D, p.30).

Catchment landuse reflects the above statistics. Table 2 shows the landuse categories and associated areas and percentage of catchment figures with the distribution of landuse types depicted in Figure 2-E (p.31).

Table 2 *Landuse categories and associated areas and percentage of catchment figures for Korogoro Creek catchment (Source: derived from DNR Multiattribute mapping, 1999)*

Landuse Category	Area (ha)	Area of Catchment (%)
Bushland	738.0	39.66%
Caravan Park	4.7	0.25%
Dune Complex	13.3	0.71%
Extraction	3.6	0.20%
Improved Pasture	0.4	0.02%
Residential	36.7	1.97%
Road	25.0	1.34%
Rural Residential	16.8	0.91%
Semi Natural Recreation Area	16.4	0.88%
Swampland	961.8	51.68%

Landuse Category	Area (ha)	Area of Catchment (%)
Unimproved Pasture	32.1	1.72%
Waterway	12.2	0.66%
TOTALS	1861.0	100.00%

Stormwater management

Robyn Tuft and Associates (1999) reported that the major source of faecal coliforms to the estuary, prior to 1999, was stormwater carrying septic tank overflow. In 2001 the town was sewered which from anecdotal reports has improved the water quality of the creek (Vince Jordan, *pers.comm.*,2007).

The Kempsey Shire Urban Stormwater Management Plan 2004-2009 (KSC, 2004) assesses issues related to stormwater management in urban catchments of the shire and identifies actions for addressing these issues including a proposed budget for the 2004-2009 period.

The township of Hat Head is identified as an urban catchment within the Plan. The Plan lists drainage from the urban residential area and caravan park into Korogoro Creek as a potential issue. It suggests that $5,000 be allocated annually to incorporate water sensitive design for Council infrastructure and to monitor water quality for public health and recreation criteria, and a once-off $10,000 to undertake a stormwater treatment review.

The lack of gross pollutant traps on stormwater pipes discharging directly into the creek and pollution caused by the washing of vehicles and caravans in the caravan park were raised as issues by community members during the creek walk in August 2006.

Flood mitigation

Flood mitigation works on Korogoro Creek are a part of the flood mitigation and drainage scheme for the Belmore/Kinchella area of the Macleay River floodplain. The system is designed to drain parts of the low lying swamp areas of the Swanpool through Korogoro Creek during minor floods and to operate as an ocean discharge during large floods.

Works on Korogoro Creek include the Korogoro Cut floodgates at the very upstream end of Korogoro Creek, a control levee fitted with a control culvert (known as “The Choke” or “The Throttle”) approximately 2km upstream of the Hat Head Road bridge, an ocean breakout spillway known as Rowes Cut, and levees along both sides of the creek to protect Hat Head village with minor floodgates and stormwater outlets providing for local drainage (Figure 1-E, p.9). Most works were completed in 1968 although maintenance works have been periodically undertaken since then.

When floodwaters in Kinchella Creek are likely to exceed the height of the Kinchella Creek levees and floodgates, floodwaters are released into Swan Pool via the Kinchella east sluicegates (Smith, 2002). During high stages of flooding in the Swanpool, water is released into Korogoro Creek via the Korogoro Cut floodgates. During major flooding the Choke becomes operational and water is diverted through Rowes Cut to the ocean and down Korogoro Creek. The discharge through Korogoro Creek is kept at a controlled height below the village and south bank levees to protect Hat Head village. Both levees have a minimum crest level of 2.35-2.39m AHD (Webb, McKeown & Associates, 1994).

Major flooding on the Macleay floodplain lasts for several days during which time the Korogoro Creek drainage system discharges at a fairly constant rate (Webb, McKeown & Associates, 1994). The effects of the prolonged discharge include significant scouring of the entrance and channel. In the March 2001 flood it has been anecdotally reported that the flood discharge had a significant negative impact on the

creek system delivering poor quality water into the creek (black water originating from decomposed plant material and swamp sediments in the Swanpool and tannin stained water from the northern coastal wetlands; pers.comm., Ron Kempsey, 2007).

2.3 Geology, Geomorphology, Soils and Sediments

Geology

The underlying geology of the Korogoro Creek catchment is part of the tectonic provenance of the New England Fold Belt. The New England Fold Belts comprise a diverse suite of deformed sedimentary, volcanic, and intrusive rocks of Cambrian to Permian ages (Scheibner & Basden 1998 in Troedson et al., 2004) but the exposed rock at Hat Head is mostly formed of fine-grained conglomerates and gravelly sandstones of what are known as the Kempsey Beds. These rocks were formed during the Permian period between 248-286 millions years ago (Atkinson, 1999).

Extensive quaternary alluvium deposits overly the bedrock. Korogoro Creek cuts through this alluvium but is contained between an Inner Pleistocene Barrier system and a Holoscene outer barrier which forms the dunes of the present day coastline (Figure 2-F, p.32). Although undated it is estimated that the inner barrier was deposited sometime between 350,000 to 120,000 years ago during one of the several glacial highstands that occurred within this time range. The Holocene material which makes up the contemporary bed and banks of the creek has been deposited in the period between about 6,500 and present when the sea level has been relatively constant within 1-2 metres (Troedson et al., 2004; Figure 2-G, p.33).

Soils

Soil distribution in the catchment is related to the physiographic features of the area. The Korogoro Creek catchment is part of the larger Limeburners Barrier Dunefields which extend from Port Macquarie to north of Hat Head and are characterised by Pleistocene backbarrier plains, low barrier beach ridge systems, high transgressive dunes (such as north east of Korogoro Creek), and Holocene beach, foredune and backbarrier swamp systems (such as those found adjacent to the estuary; Atkinson, 1999).

Consequently the soil types found reflect the predominance of aeolian and barrier landscapes including Killick (ki), Korogoro (kr) and O'Connors (oc); barrier swamp landscapes including Hat Head (hh) and McGuires Crossing (mc) and swamp landscapes including Belmore (bl); and beach landscapes such as Goolawah (go) and North Shore (ns). Typical soils in these landscapes are Podzols, Humus Podzols, Acid Peats, Siliceous Sands and Calcareous Sands (Atkinson, 1999).

In addition minor occurrences of estuarine landscapes including Blackmans Point (bp) and erosional landscapes including Crescent Head (ch) in the south east corner of the catchment. Typical soils in these landscapes are Calcareous Sands in the estuarine reaches and Podzolic soils above bedrock on Hat Head (Atkinson, 1999).

Figure 2-H (p.34) shows the distribution of Soil Landscape Process Groups in the Korogoro Creek catchment while Figure 2-I (p.35) shows the distribution of identified Soil Landscapes Units.

Acid Sulphate Soils

Acid sulphate soils (ASS) are sediments deposited under estuarine conditions (i.e. close to sealevel), and which contain the sulphidic mineral pyrite. ASS are found underlying many coastal floodplains, in coastal wetlands, and as bottom sediments in coastal estuaries. As long as ASS are not disturbed or drained, these materials are relatively harmless and are termed potential ASS. However, if the

sediments are exposed to air, the pyrite is oxidised, and sulphuric acid is generated (Talau and Naylor, 1999).

Known adverse effects of ASS include (http://www.ozestuaries.com.au);

- poor water quality (heavy metal toxicity, low pH, low dissolved oxygen),
- Fish kills and fish disease,
- loss of critical habitat areas, reduced aquaculture production, fish stocks and wetland biodiversity
- acid damage to infrastructure and reduced amenity
- the need to rehabilitate disturbed areas

Acid sulphate soils are known to occur within the Korogoro Creek catchment. Engineered drainage and flood mitigation works in the Kinchella and Swan Pool area have led to the oxidisation of large areas of ASS with scalds reported as far back as the 1950s (Talau and Naylor, 1999). The Belmore, Frogmore and Kinchella districts have been identified as an ASS Priority Management Area since 1999 (Figure 2-J) and as a result some remedial works have been undertaken since that time. As of June 2007, remedial works are being undertaken on "The Lock" at Kinchella Creek to install a sill designed to prevent overdrainage of the swan pool into Kinchella Creek below 0.0m AHD (Ron Kemsley, pers.comm., 2007).

Of more relevance to this study, ASS Risk Mapping has been undertaken by DLWC which indicate that significant areas of actual ASS and potential ASS also occur adjacent to Korogoro Creek (Figure 2-K, p.36).

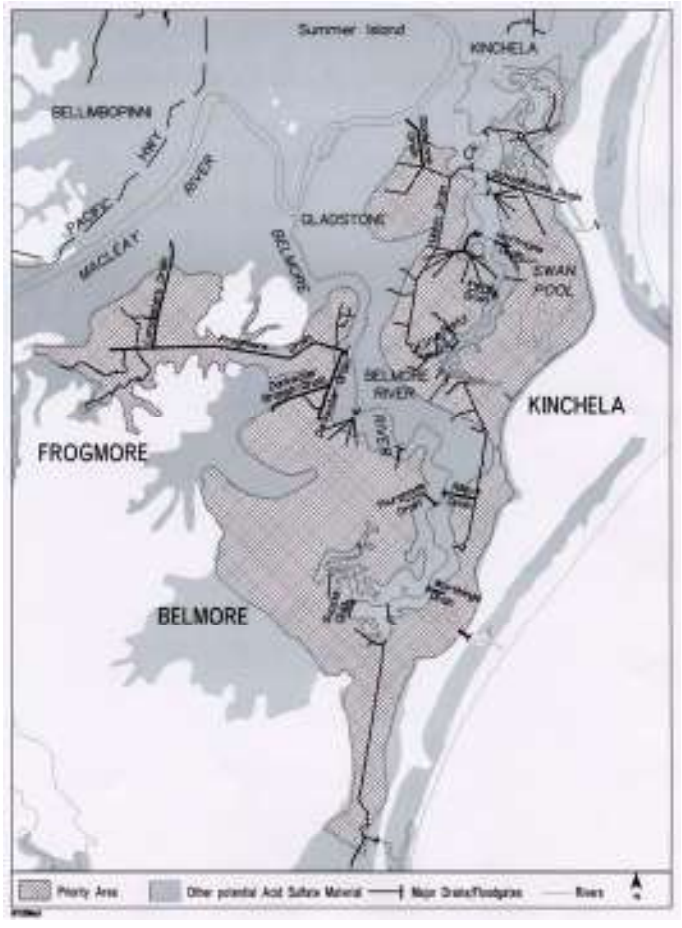
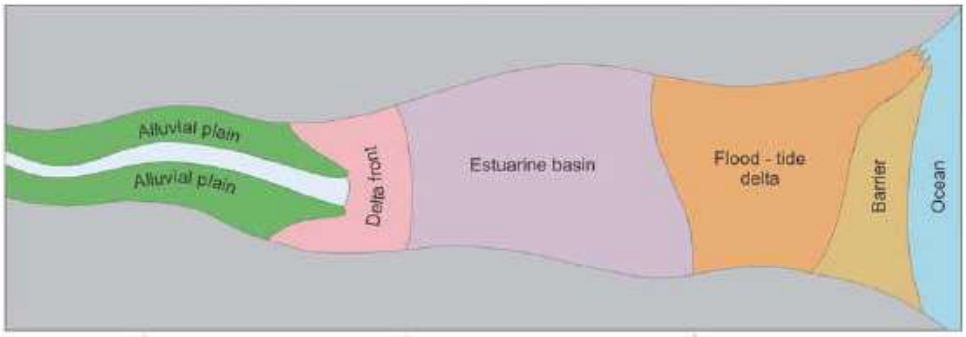


Figure 2-J *Macleay ASS Hotspot program: Belmore, Frogmore and Kinchela Acid Sulphate Soil Management Priority Areas (source: Tulau and Naylor, 1999).*

Estuary Classification and Geomorphology

Korogoro Creek estuary is classified as a strandplain-associated coastal creek (National Land and Water Resources Audit Estuarine Condition Assessment, 2002). Strandplain-associated estuaries are characterised by having small, shallow basins with very low to negligible freshwater input and narrow and generally shallow water bodies. They occur on wave-dominated coasts and are generally oriented parallel to the coast, developing on prograding dunes, beach ridges, and barriers (http://www.ozestuaries.com.au).

Estuaries are able to be described conceptually in terms of the relative influence of various fluvial, tidal and marine processes (see Figure 2-L). In strandplain-associated estuaries the alluvial plain and delta front do not occur due to the very limited supply of fluvial sediments thus limiting the differentiation of the estuary into the Estuarine Basin and Flood-tide Delta/Barrier zones. Figure 2-M (p.37) shows the distribution of process zones in the Korogoro Creek Estuary.



	FLUVIAL DELTA	ESTUARINE BASIN	TIDAL DELTA / BARRIER
Sediment source	fluvial	fluvial	marine
Depositional energy	moderate - high, variable	low	high
Depositional processes	fluvial discharge, tide	suspension settling	tide, wave
Sediment texture	coarse - fine	fine	coarse

Figure 2-L *Conceptual model of estuary zonation (after Roy,1984a and Dalrymple et al., 1992. Source: Troedson et al, 2004)*

Flood mitigation works undertaken in 1968 resulted in significant modification to the natural character of Korogoro Creek. Figure 1-D (p.8) shows comparative aerial photographs of Korogoro Creek in 1942 and 2003 that demonstrate that the construction of drains, floodgates, and levees on the creek have significantly altered its form. Of note, the length of the creek has been increased by ~2100m through excavation, the channel has been significantly widened upstream of the Hat Head Road bridge by a factor of 4-5 times, the flood capacity increased through construction of levees, and the estuary volume increased substantially. The effects of these changes on the creek system have not been documented prior to this study and are the subject of discussion in Section 4.3 of this report.

Sedimentation

A search of available literature and datasets was unable to uncover any quantitative or qualitative information on sediment types or loads specific to Korogoro Creek. However, the estuary's classification as a strandplain-associated creek combined with what is known of the local coastal

processes provides some guidance as to typical sediment types and rates and processes of sedimentation.

The lack of significant freshwater input and the presence of strong tidal currents result in the entrances of strandplain-associated coastal creeks often being either intermittently or permanently closed to the ocean. However, in Korogoro Creek's case the orientation of the headland immediately to the south and east of the entrance reduces both wave action and the delivery of sands through littoral and longshore transport. Thus the potential for berm development at the creek mouth is less than for a typical estuary of this type. As a result, although the entrance to Korogoro Creek is sometimes restricted by shoaling it rarely closes completely.

Under natural conditions sediment supply to strandplain estuaries is low and as a result channel infilling processes are very slow. As freshwater input is minimal, fluvial sediment input is also very limited with most catchment-derived sediment inputs into the creek resulting from sheet runoff or aeolian inputs (wind-blown). Marine-derived sediments are a more dominant source of sediment supply into the channel when the estuary entrance is open (Boyd et al., 1992).

2.4 Estuary hydrodynamics

Three existing sources of information relevant to the hydrodynamics of the Korogoro Creek estuary have been identified.

In 1998, the Water Research Laboratory (University of New South Wales) was commissioned to provide an estimation of tidal flushing rates for the estuary to assist in determining the potential impacts on water quality of the then proposed Hat Head Dune disposal option for the town's treated sewerage effluent (DPWS, 1999). The estimate was based on 15 cross-sections of the creek (but with only 2 "mean" cross-sections adopted for the purpose of modelling) and water level data collected at the Hat Head Road bridge during the period April to July 1998. The modelling estimated that the estuary volume fluctuated between 171ML at low tide to 578ML at mean spring high tide. The tidal prism was estimated to range between 93ML on the neap tide and 407ML on the spring tide with a mean tidal exchange of 243ML, resulting in percentage tidal exchange figures of 33%, 55%, and 67% for respective tides. The tidal flushing times were then extrapolated to be between one to two days or 1.5 to 3.2 tidal cycles. The study concluded that actual flushing rates for groundwater recharge to the creek would depend on diffusion/dispersion (mixing) characteristics of the creek but that due to the short exchange times it would be anticipated that groundwater flows to the creek would have a relatively short residency time within the creek (UNSW 1998).

As part of the State's Estuary Program support to Council, Manly Hydraulics Laboratory undertook a tidal gauging survey on Korogoro Creek in 2005 with the aim of understanding the hydraulic processes operating in the estuary (MHL, 2005). Water level, water quality and tidal flow measurements were measured over two data collection periods in mid 2004 and early 2005. In terms of hydrodynamics, the study found that the hydraulics of the system were relatively simple with the estuary exhibiting characteristics similar to a typical small river system. Tidal range of 2.07 m recorded at the ocean gauge at Crowdy Head decreased to 1.41 m at the footbridge, then to 1.39 m at the bridge and 1.34 m at the Korogoro Cut floodgates. Tidal lags also varied with the mean lag of 44 minutes after ocean tide at the footbridge, 75 minutes at the bridge, and 100 minutes at the floodgates. A flood tidal prism at the footbridge of 180ML and ebb tidal prism of 200ML was estimated based on a single tidal cycle on 10 March 2005.

A detailed hydrographic survey was undertaken by Department of Infrastructure Planning and Natural Resources in November 2005 (DIPNR, 2005). This data was collected specifically to assist in the preparation of the Korogoro Creek Estuary Management Plan. The survey data has been utilised for the preparation of a more detailed assessment of the estuary hydrodynamics presented in Section 4.5 of this report.

2.5 Entrance behaviour and management

Korogoro Creek entrance is permanently open and untrained (MHL, 2005). The channel usual position is against the bedrock on the southern side of the channel, although depending on shoaling patterns this can change. Korogoro Headland and the proximity of the continental shelf have a major influence on along shore currents in the area, which in turn influence the transport of sand to the entrance. Unlike many other small coastal creeks in the vicinity, sands at the entrance tend to build under southerly swell conditions and reduce under north-easterly swells and winds (Vince Jordan, pers.comm..,2007), although tidal currents also play a major role in entrance behaviour and conditions.

Although permanently open, shoaling at the entrance has at times caused concern to those wishing to access the ocean through the use of the boat ramp some 100m south of the mouth (eg. May 1999). During these times, the beach has been used to launch boats. Excess sand build up in the vicinity of the boat ramp has also been periodically removed by council.

Major floods in the Macleay catchment can also affect entrance conditions in Korogoro Creek. Once the flood mitigation system commences operation and floodwaters are directed through Korogoro Cut, the creek and creek mouth can become significantly scoured such as post the March 2001 flood event.

2.6 Water quality

The following sources of information were identified as being relevant to water quality in the Korogoro Creek estuary. The list of references is believed to be complete.

- Australia and New Zealand Environment and Conservation Council (ANZECC) (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality
- Department of Land and Water Conservation (DLWC) (1999) Guidelines for Establishing a Groundwater Monitoring Program for Effluent Irrigation Sites (draft).
- Kempsey Shire Council Water Laboratory (1994 – current) Korogoro Creek Water Quality Data.
- Manly Hydraulics Laboratory (MHL) (2005) DIPNR Korogoro Creek Tidal Data Collection May-August 2004 and March-April 2005. Report MHL 1343
- NSW Department of Public Works and Services (DPWS) (1999) *Hat Head Sewerage Scheme – Review of Environmental Factors*. Prepared for Kempsey Shire Council and the NSW Department of Land and Water Conservation.
- Robyn Tuft and Associates (1999) Water Quality Assessment: Hat Head Sewerage Scheme. For DPWS. In DPWS (1999) Review of Environmental Factors: Hat Head Sewerage Scheme.
- University of New South Wales (UNSW) Water Research Laboratory (1998) Korogoro Creek, Hat Head – Tidal Flushing Volumes.
- UNSW Water Research Laboratory (2003) Hat Head Dune Effluent Disposal Site Baseline Groundwater Monitoring. Technical Report 2002/45
- UNSW Water Research Laboratory (2004) Hat Head Dune Effluent Disposal Site Post Commissioning Groundwater Monitoring. Draft Technical Report 2004/27
- UNSW Water Research Laboratory (2006) Hat Head Effluent Disposal Site – First Year of Ongoing Monitoring.
- EPA Beachwatch Partnership Program – Kempsey LGA (2005-07) Korogoro Creek monitoring.

A summary of the major programs that relate to Korogoro Creek estuary is provided below;

- Kempsey Shire Council Water Laboratory has collected water quality data from Korogoro Creek under a variety of sampling and analysis regimes since 1994. From January 1994 to April 1995 they monitored pH, dissolved oxygen (DO), total dissolved solids (TDS), chloride, ammonia, total phosphorus (TP) turbidity and faecal coliforms weekly at 6 sites in Korogoro Creek. From January 1997 to June 1998 they monitored TP, faecal coliforms, DO, pH and conductivity weekly at 3 sites. From July 2000 to November 2000 they monitored ammonia, conductivity, DO, faecal coliforms, nitrate, nitrite, pH, total Kjeldahl nitrogen (TKN), total nitrogen (TN), TP,

total suspended solids (TSS) and turbidity fortnightly at 3 sites. Ongoing monitoring of faecal coliforms occurs weekly at one site under the EPA Beachwatch Partnership Program, occasionally analysing faecal streptococci or enterococci as well as or instead of faecal coliforms.

- MHL (2005) measured physical water quality parameters at high and low water over a single tidal cycle. They also measured tidal velocities and planes, using the data to calculate tidal prism at the footbridge and tide phase differences at the footbridge, traffic bridge and floodgates.

- UNSW (2003 and 2004) monitored groundwater quarterly for two years at 6 sites around the effluent disposal location, 4 sites in the Hat Head township and surface water at 2 sites within the creek. At each site around the effluent disposal location they had one deep, and one shallow, water measuring bore. They analysed a comprehensive set of parameters including physical properties, major cations, major anions, heavy metals and trace elements, nutrients, organochlorine pesticides and coliforms. The first year of analysis gathered baseline water quality data before the implementation of the dune disposal of effluent and the second year monitored changes in water quality after implementation. It should be noted that all creek water samples for this study were taken at or near low tide.

  Ongoing monitoring of groundwater (4 sites, 2 bores per site) and surface water (1 site) is being undertaken twice yearly. Specific parameters of concern have been chosen for ongoing monitoring based upon the results of baseline and post commissioning studies. UNSW (2006) details the results of the first year of this data. The next update is expected in April/May 2007.

- Robyn Tuft and Associates (1999) summarised existing water quality data and predicted the likely effects of sewage treatment and the dune disposal of effluent on the Korogoro Creek system. They also calculated a nutrient budget based upon the concentration of nutrients in the creek water which is discussed further in Section 4.2 Catchment Processes and Nutrient Loadings.

The ANZECC 2000 Guidelines advocate a risk-based approach to water quality assessment and management. That is, the intensity of assessment of current water quality status or impacts on water quality should reflect the risk of impacts on the achievement/protection of the water quality objective. Trigger values are the numeric criteria that if exceeded indicate potential for harmful environmental effects to occur. The default trigger values provided in ANZECC 2000 Guidelines are essentially conservative and precautionary. If they are not exceeded, a very low risk of environmental damage can be assumed. If they are exceeded, further investigation is "triggered" for the pollutant concerned. Assessing whether the exceedance means a risk of impact to the Water Quality Objective requires site-specific investigation, using decision trees provided in the Guidelines.

An analysis of the findings and implications in terms of water quality standards (particularly in terms of ANZECC) of the various programs is provided in Section 4.6 of the report.

2.7 Estuarine ecology

The following data sources contain information specific to the ecological processes of Korogoro Creek. The list itself is small and often the relevant information within the identified sources is limited.

- NSW Department of Public Works and Services (1999) *Hat Head Sewerage Scheme – Review of Environmental Factors*. Prepared for Kempsey Shire Council and the NSW Department of Land and Water Conservation.
- NSW DPI Fisheries (2006) Aquatic Habitats - GIS Data Set
- West, R. J. et al. (1985) An Estuarine Inventory for New South Wales, Australia. *Fisheries Bulletin 2*, Department of Agriculture, Sydney.
- NSW National Parks and Wildlife Service (NPWS) (2006) Hat Head National Park Vegetation Mapping.

- NSW Scientific Community (2004) Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions – Endangered ecological community determination – final DEC (NSW) Sydney http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Coastal_Saltmarsh_endangered
- Robyn Tuft and Associates (1999) Water Quality Assessment: Hat Head Sewerage Scheme. For DPWS. In DPWS (1999) Review of Environmental Factors: Hat Head Sewerage Scheme.
- NSW National Parks and Wildlife Service (2001) Water Habitats of the Nambucca, Macleay and Hastings Catchments. Report 3, For the Mid North Coast Water Management Committee.
- The Ecology Lab Pty. Ltd. (1996) Lower Macleay Floodplain Management Study: Aquatic Ecology and Fisheries. Review of Existing Information. For Web McKEown & Associates Pty. Ltd. Consulting Engineers
- NSW DPI Fisheries (2006a), *Estuarine Habitats*, http://www.fisheries.nsw.gov.au/aquatic_habitats/estuarine, Accessed January 2007.
- NSW DPI Fisheries (2006b), *Fishing the Macleay River District* http://www.fisheries.nsw.gov.au/recreational/places_to_fish/fishing_guides/macleay_river_district, Accessed January 2007

Existing Records of Vegetation

Estuarine Flora

National Parks and Wildlife Service (2001) identified a relatively small area of estuarine wetland located along the lower reaches of Korogoro Creek. They note that the majority of estuarine wetlands around the village of Hat Head are reserved within Hat Head National Park. They also note that threats to the integrity of estuarine habitats in the general coastal Macleay subcatchment cluster include unsustainable water use in the general Macleay Catchment, development for residential purposes and potential and actual acid sulphate soils.

West *et. al.* (1985) identified 0.013 km^2 of mangroves, 0.014 km^2 of saltmarsh habitat and no seagrass in the Korogoro Creek estuary. The only mangrove species identified was *Avicennia marina*, no inventory of saltmarsh species was taken and it is likely that the resolution of their study (1:25000) was unable to detect small patches of seagrass within Korogoro Creek.

NSW DPI Fisheries (2006) identified 0.058 km^2 of mangroves, 0.040 km^2 of saltmarsh and 0.0004 km^2 of seagrass. No mangrove or saltmarsh species were defined in their study and the only seagrass species identified was *Zostera sp.*. The distribution of estuarine vegetation types as mapped by DPI Fisheries is shown in Figure 2-N (p.38). The increase in the area of seagrass, saltmarsh and mangroves identified relative to West *et. al.* (1986) can be largely attributed to the higher resolution of their study (1:10000) though there is likely to have been some increase in the density, size and area of mangroves during the years between 1985 and 2006.

NSW DPWS (1999) identified some habitat aspects of the Korogoro Creek estuary. In terms of the ecology of the region, their report primarily documented the vegetation and fauna of the dune disposal site but briefly described the riparian habitat of Korogoro Creek upstream of the traffic bridge as 'modified' due to the widening of the channel and construction of levees for flood mitigation.

Information describing riparian vegetation in the Korogoro Creek Estuary is limited.
Robyn Tuft and Associates (1999) provide a very limited description of the aquatic flora of Korogoro Creek, stating that eelgrass (*Zostera sp.*) occurs in patches and that it was not covered with epiphytic algae. It also mentions the presence of the grey mangrove (*Avicennia marina*), reeds and levee vegetation including Melaleuca, Casuarina, *Banksia integrifolia*, lantana and bitou bush.

It is important to note that coastal saltmarsh in the NSW North Coast Bioregion is listed under the *Threatened Species Conservation Act 1995* as an endangered ecological community.

Other Catchment Vegetation

NSW DPWS (1999) noted that most of the streets and landholdings within the village area (particularly the more established area to the North of Korogoro Creek) contain exotic plantings though there are some mature forest trees throughout the caravan park, open space areas and small recreation reserves. Their report also listed heath and littoral forest on the protected hind dunes, eucalypt forest away from the sand dunes, swamp and wet heath in the low lying area and Port Jackson Pine (*Callitris rhomboidea*) in the open forest areas. Other plants mentioned include, *Banksia* sp., *Acacia* sp., *Hibbertia* sp., marram, spinifex and pigface. In addition to this, they named species of conservation interest known from, or likely to occur within Hat Head National Park. This information is summarised in Table 3 although none of these species are considered likely to occur within the estuarine environment.

Table 3 *Flora of significance identified by NSW Department of Public Works (1999)*

Species Name	Common Name	Habitat	Status
Durringtonia paludosa	Durringtonia	sedgeland near coastal swamps	Vulnerable
Cynanchum elegans		Littoral Rainforest	Endangered
Thesium australe	Austral Pillwort	grasslands on coastal headlands	Vulnerable
Baeckea citriodora		coastal heath	Vulnerable (3)
Leptospermum whitei	Tea Tree	swampy heath	Vulnerable (3)
Shoenus scabripes		wet heath	Vulnerable (3)
Darwinia leptantha		heath	N Limit of Distribution
Hakea teretifolia		swampy schlerophyll scrub	N Limit of Distribution
Burmannia disticha		coastal swamp	N Limit of Distribution
Coelocaryx gracilis		dry heath	S Limit of Distribution
Litsea leefeana		Littoral Rainforest	S Limit of Distribution
Hodgkinsonia ovata		Littoral Rainforest	S Limit of Distribution
Leucopogon deformis		dry heath	
Callitris rhomboidea	Port Jackson Pine	open forest	
Melaleuca squamea		wet heath	

There are 11 State Environmental Planning Policy 14 (SEPP 14) wetlands within the Korogoro Creek catchment (Figure 2-O, p.39). Of these, the largest is SEPP 14 Wetland # 458, commonly known as the Swanpool. The other large wetlands on the western side of the creek are # 467 and #469. These wetlands provide habitat for migratory birds and other local wildlife. Due to floodplain management, which includes the construction of levees and installation of floodgates and unidirectional drains, these areas do not provide spawning habitat for estuarine fish and invertebrates. No information is available with respect to the biology of these systems and how they interact with the Korogoro Creek estuary.

There are no designated SEPP 26 areas within the Korogoro Creek Catchment. There is a small region of undesignated littoral rainforest on the Southern side of Korogoro Creek within the HHNP (DPWS 1999).

The vegetation of Hat Head National Park has been mapped in detail (Figure 2-P, p.40; NSW NPWS 2006 with additions from Telfer and Kendall, 2006). The mapping shows lowland swamp, melaleuca, swamp oak and swamp mahogany communities dominate the lowland areas within the catchment. Elevated areas tend to be dominated by blackbutt-bloodwood/apple communities.

Existing Records of Fish, Birds, and other Fauna

Fish and Other Aquatic Fauna

There is very little information relating to the aquatic fauna of the Korogoro Creek Estuary.

Robyn Tuft and Associates (1999) stated that 'blackfish, mullet, bream, garfish, flathead, sand whiting and toadfish' were observed in the creek, that it is home to 'oysters, mussels, prawns and various shellfish' and that crabholes were evident along the creek.

The Korogoro Creek estuary is closed to all commercial fishing activities, spear fishing and the use of nets of any description with the exception of landing nets (NSW DPI Fisheries 2006b).

One of the issues raised at the community meeting was the collection of fish for the aquarium trade. There is general concern that this unregulated activity is substantially affecting the ecology of the creek and is heavily impacting upon the numbers of attractive tropical and sub-tropical fish species in the creek. At present, NSW DPI (Fisheries) regulates the collection of aquarium species by issuing permits. There is no management plan currently in place for the collection of aquarium species. Fisheries strongly encourage that excessive collection of aquarium species be reported to local officers (Marylin Wilkes, *pers comm.*).

The Ecology Lab Pty. Ltd. (1996) stated that fish kills have been reported in Korogoro Creek. Small-scale fish kills have been observed by locals (Vince Jordan, *pers comm.*). NSW DPI Fisheries maintain a database of all reported fish kills. They have no record of fish kills within Korogoro Creek (Alan Lugg, *pers comm.*).

Avifauna

Birds are an essential part of estuarine ecosystems, most often as predators. Robyn Tuft and Associates (1999) identified that birds such as pelicans, cormorants, herons and egrets frequent the Korogoro Creek estuary.

NSW DPWS (1999) also lists a number of bird species of conservation significance known and likely to inhabit Hat Head National Park including migratory bird species subject to treaties between Australia and Japan (JAMBA) and Australia and China (CAMBA). Species of conservation significance known or likely to occur within the Korogoro Creek estuary and catchment are listed in Table 4.

Table 4 *Bird species of conservation significance identified by NSW Department of Public Works. Emboldened species are considered most likely to occur within estuarine environments.*

Species Name	Common Name	Status	Notes*
Actitus hypoluecos	**Common Sandpiper**	**JAMBA/CAMBA**	**Likely**
Calidris acuminata	**Sharp-Tailed Sandpiper**	**JAMBA/CAMBA**	**Likely**
Calyptorhynchus lathami	Glossy Black Cockatoo	Threatened	Known
Coracina lineata	Yellow eyed Cuckoo-shrike	Threatened	Likely
Ephippiorhynchus asiaticus	Black Necked Stork	Threatened	Known
Gallinago hardwickii	**Lathams Snipe**	**JAMBA/CAMBA**	**Likely**
Haematopus fuliginosus	**Sooty Oystercatcher**	**Threatened**	**Known**
Haematopus longirostris	**Pied Oystercatcher**	**Threatened/JAMBA/CAMBA**	**Known**
Haliaectus leucogaster	**White-Bellied Sea Eagle**	**JAMBA/CAMBA**	**Likely**
Haliastur indus	**Brahiminy Kite**	**JAMBA/CAMBA**	**Likely**

Species Name	Common Name	Status	Notes*
Lophoictinia isura	Square-tailed Kite	Threatened	Likely
Merops ornatus	**Rainbow Bee-Eater**	**JAMBA/CAMBA**	**Likely**
Ninox strenua	Powerful Owl	Threatened	Likely
Numenius phaeopus	**Whimbrel**	**JAMBA/CAMBA**	**Likely**
Pachycephala oliveacea	Olive Whistler	Threatened	Likely
Pandion haliaetus	**Osprey**	**Threatened/JAMBA/CAMBA**	**Known**
Pezoporus wallicus	Ground Parrot	Threatened	Likely
Sterna albifrons	**Little Tern**	**Threatened/JAMBA/CAMBA**	**Known**
Tringia glareola	Wood Sandpiper	JAMBA/CAMBA	Likely
Tringia nebularia	Common Greenshank	JAMBA/CAMBA	Likely
Tringia stagnatalis	**Marsh Sandpiper**	**JAMBA/CAMBA**	**Likely**
Tyto capenis	Eastern Grass Owl	Threatened	Likely
Tyto novaehollandiae	Masked Owl	Threatened	Likely
Xenus cinereus	**Terek Sandpiper**	**Threatened/JAMBA/CAMBA**	**Known**

* This column refers to the likelihood of occurrence within Hat Head National Park. Emboldened records are considered most likely to occur in estuarine environments.

Mammals, marsupials, reptiles and amphibians

NSW DPWS (1999) also lists a number of fauna of conservation significance known and likely to inhabit Hat Head National Park. Species of conservation significance known or likely to occur within the Korogoro Creek estuary and catchment are listed in Table 5.

Table 5 *Species of conservation significance identified by NSW Department of Public Works.*

Species Name	Common Name	Status	Notes*
Crinia tinnula	Wallum Froglet	Threatened	Known
Dasyurus maculatus	Spotted-tailed Quoll	Threatened	Known
Hoplocephalus stephensi	Stephen's Banded Snake	Threatened	Likely
Petaurus norfolcensis	Squirrel Glider	Threatened	Likely
Phascogale tapoatafa	Brush Tailed Phascogale	Threatened	Known
Phascolarctus cinereus	Koala	Threatened	Known
Planingale maculata	Common Planingale	Threatened	Likely
Psuedomys gracilicaudatus	Eastern Chestnut Mouse	Threatened	Known
Synconyteris australis	Queensland Blossom Bat	Threatened	Known

* This column refers to the likelihood of occurrence within Hat Head National Park.

NSW Wildlife Atlas Records

A search of the NPWS Atlas of NSW Wildlife was undertaken, for species records within the catchment boundaries. The full species list for sightings within 10km of Korogoro Creek is reproduced in Appendix 1. Species most likely to live, feed or breed within the estuarine and riparian habitats of Korogoro Creek are highlighted. They include:

- Loggerhead Turtle, *Caretta caretta*.
- Osprey, *Pandion haliaetus*.
- Great Egret, *Ardea alba*.
- Cattle Egret, *Ardea ibis*.
- Striated Heron, *Butorides striatus*.
- White Faced Heron, *Egretta novaehollandiae*.
- White Bellied Sea Eagle, *Haliaeetus leucogaster*
- Brahminy Kite, *Haliastur indus*.
- Silver Gull, *Larus novaehollandiae*.
- Rainbow Bee-eater, *Merops ornatus*
- Little Pied Cormorant, *Phalacrocorax melanoleucos*.
- Great Cormorant, *Phalacrocorax sulcirostris*.
- Little Black Cormorant, *Phalacrocorax carbo*.
- Royal Spoonbill, *Platalea regia*.

Fauna of Conservation Interest (EPBC Act)

A search of the federal government Department of Environment website revealed matters of National Environmental Significance that fall under the *Environment Protection and Biodiversity Conservation Act 1999*. In summary, the report lists:

- 34 Threatened Species
- 36 Migratory Species
- 55 Marine Species
- 13 Whales and other Cetaceans
- 1 National Park (Hat Head National Park)

Of the species listed, the most likely to be found living feeding or breeding in the estuarine habitats of Korogoro Creek include:

- The Painted Snipe, *Rostratula benghalensis*, listed as Vulnerable.
- The Loggerhead Turtle, *Caretta caretta*, listed as Endangered.
- White Bellied Sea Eagle, *Haliaeetus leucogaster*, listed as Migratory.
- Latham's Snipe, *Gallinago hardwickii*, listed as Migratory.
- Little Tern, *Sterna albifrons*, listed as Marine.
- Girdled Pipefish, Festucalex cinctus*, listed as Marine.*
- *Tiger Pipefish, Filicampus negris*, listed as Marine.
- White's Seahorse, *Hippocampus whitei*, listed as Marine.
- Wide-bodied Pipefish, *Stigmatopora nigra*, listed as Marine.
- Hairy Pipefish, *Urocampus carinirostris*, listed as Marine.
- Mother-of-pearl Pipefish, *Vanacampus margaritifer*, listed as Marine.

Other listed species most likely to be found living, breeding or feeding in the general catchment of Korogoro Creek include

- The Swift Parrot, *Lathamus discolor*, listed as Endangered.
- The Regent Honeyeater, *Xanthornyza phrygia*, listed as Endangered
- White Throated Needletail, *Hirundapus caucodactus*, listed as Migratory.
- Rainbow Bee-eater, *Merops ornatus*, listed as Migratory.

- Spectacled Monarch, *Monarcha trivirgatus*, listed as Migratory.
- Black-faced Monarch, Monarcha melanopsis, listed as Migratory.
- Satin Flycatcher, Myiagra cyanoleuca, listed as Migratory
- Rufous Fantail, *Rhipidura rufifrons*, listed as Migratory
- Great Egret, White Egret, Ardea alba, listed as Marine (flyover).
- Cattle Egret, *Ardea ibis*, listed as Marine (flyover).

A comparison of the NSW NPWS Atlas of NSW wildlife revealed only one threatened species not covered in the above lists. This was the Osprey, *Pandion haliaetus*, which is listed as Vulnerable.

2.8 Recreational and cultural use

Recreational Use

No documents relating to visitor numbers or recreational pursuits specific to Korogoro Creek are available. However, Hat Head and its surrounds are known as a popular recreational destination for both locals and holidaymakers. Peak seasons coincide with school holiday periods when the caravan park can at times operate at maximum capacity. The estuary provides opportunities for safe swimming, snorkelling, recreational line fishing, bird watching, boating including deepwater ocean access, and general relaxation.

Cultural Use

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.

In terms of built heritage, there are no known historic sites or heritage listed buildings within the village area, hind dunes, or at O'Connors Hill (Peter Johnson, KSC, pers.comm., 2007).

2.9 Climate change and sea level rise

There are no known sources of information relating to the specific effects of climate change or sea level rise on Korogoro Creek or its catchment.

In 2002 The Healthy Rivers Commission recommended that PlanningNSW assess the social, economic and ecosystem risks that may result from a rise in sea level and change in storm events for coastal lakes and estuaries (HRC, 2002). At the time, this recommendation was based on CSIRO's 2001 predictions on climate change. These predictions have since been further reinforced in "*Climate Change in New South Wales – Part 2 Projected changes in climate extremes"* (Hennesy et al, 2004) and most recently by the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report *Climate Change 2007: Impacts, Adaptation and Vulnerability - Summary for Policymakers.*

The IPCC summary report (http://www.ipcc.ch/SPM13apr07.pdf) notes that;

- Coasts are projected to be exposed to increasing risks, including coastal erosion, due to climate change and sea-level rise. The effect will be exacerbated by increasing human-induced pressures on coastal areas.

- Coastal wetlands including salt marshes and mangroves are projected to be negatively affected by sea- level rise especially where they are constrained on their landward side, or starved of sediment.
- Densely-populated and low-lying areas where adaptive capacity is relatively low, and which already face other challenges such as tropical storms or local coastal subsidence, are especially at risk.

Engineers Australia (2004) outline the major aspects of concern of climate change and sea level rise for the Australian coastal zone;

- Inundation and displacement of wetlands and lowlands
- Eroded shorelines
- Increased coastal flooding by storms
- Salinity intrusion into estuaries and aquifers
- Altered tidal ranges, prisms and circulation in estuarine systems
- Changed sedimentation patterns
- Decreased light penetration into the water column.

Engineers Australia (2004) also note that while it is instructive to devise relatively simple models of land-sea boundary shifts based on water level changes alone, the actual impacts of sea level rise at specific locations are likely to be very complex. For example the responsiveness of geomorphological and ecological processes will largely dictate the local outcomes, necessitating a consideration of the specific coastal environments that are at risk. For sedimentary coasts, sandy beaches, barriers and dunes it is likely that under future sea level rise there will be a tendency for currently eroding shorelines to erode further, stable shorelines to begin to erode and accreting coasts to wane or stabilise.

It is not known whether Kempsey Council or any State-based planning Authority has adopted any standard to address predicted rises in sea level or increase in extreme storm events.

2.10 Community values, expectations, and issues

The main sources of existing information on contemporary issues relating to the estuary prior to the commencement of this study are from complaint files held by the Kempsey Shire Council and the Department of Environment and Climate Change (previous Department of Land and Water Conservation), and from the community meeting held in March 2006.

The major issues identified include (not in order of priority);

- *Tourism related:* Pressures on the creek during peak holiday periods including bait collection in the creek, access impacts, general foreshore impacts, rubbish and litter including bits of tackle.
- *Fishing related:* Excessive collection of subtropical fishes for aquariums, inappropriate bait collection in the creek, illegal spearfishing in the creek.
- *Water Quality related:* Stormwater inputs, potential sewerage impacts, poor water quality coming from swan pool drainage.
- *Bank Erosion related:* recreational impacts through uncontrolled access, boat wash impacts during summer holidays, vehicle access impacts on the southern side of the creek, effect of flood mitigation works.
- *Creek Entrance related:* shoaling at the entrance and sand in the vicinity of the boat ramp

- *Boating related:* increased usage by large recreational vessels, rocked edge of boat ramp sometimes hazardous, safety issues with minor conflict between powered vessels and swimmers at entrance.
- *Flood Mitigation related:* anecdotal reports of fish kills post 2001 flood event

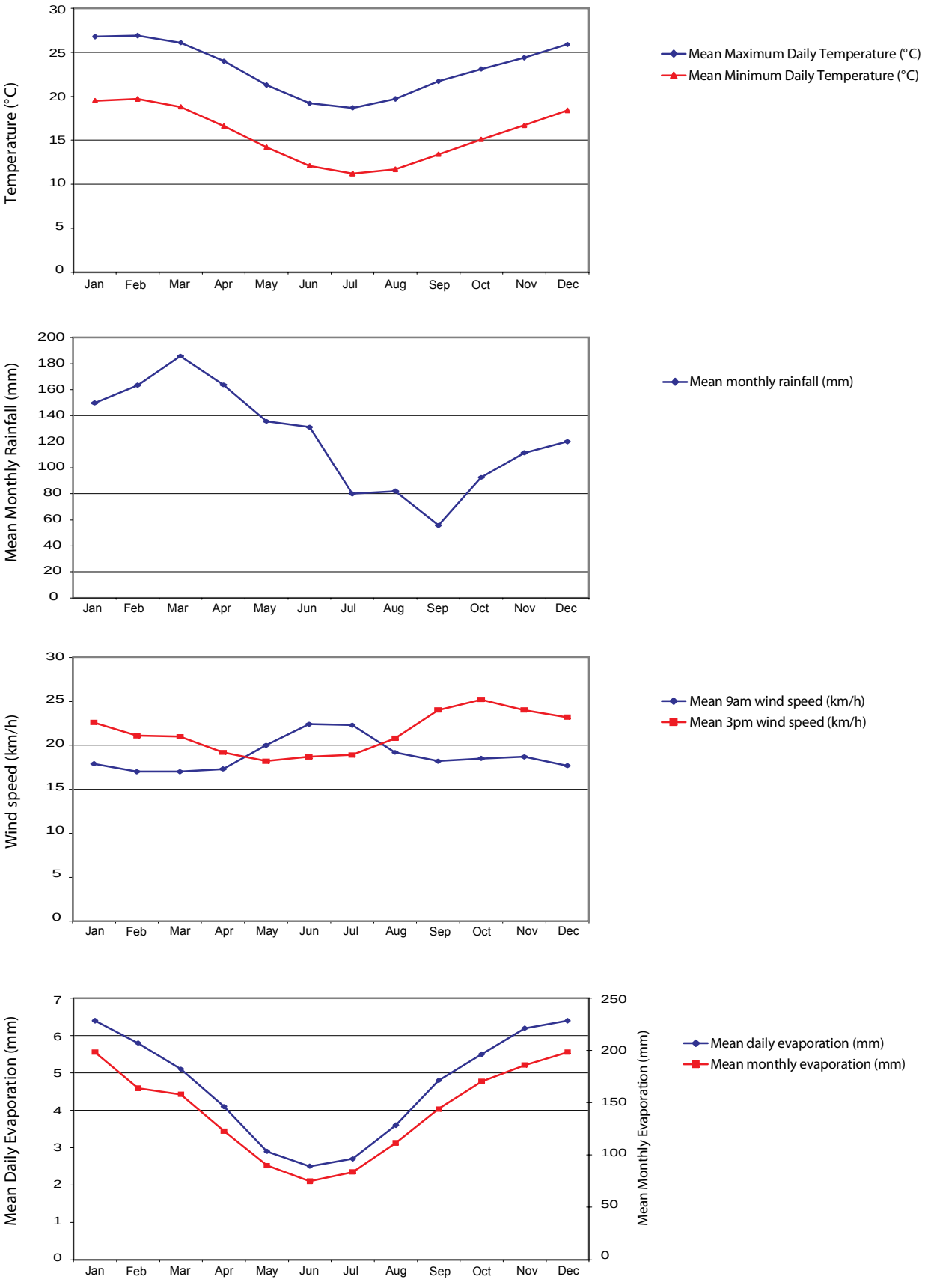
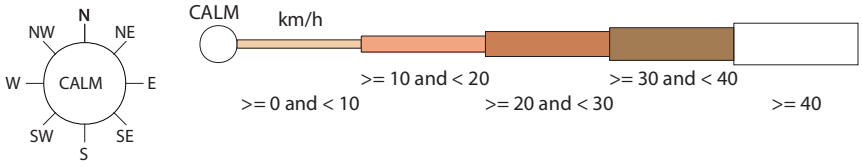


Figure 2-A

Source:
Bureau of Meterology

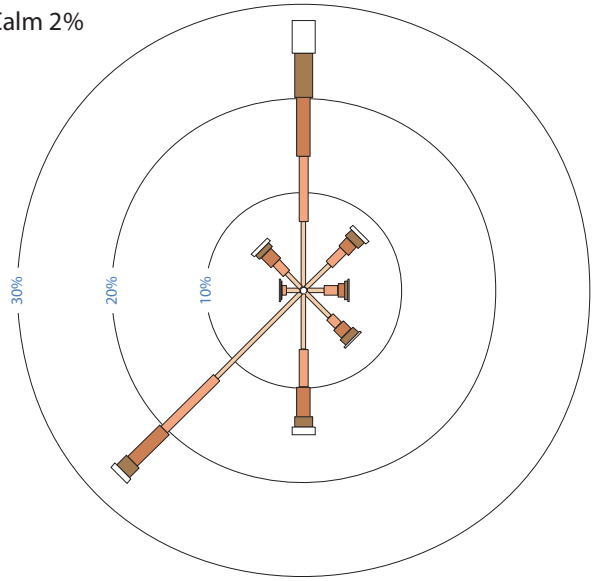
Climatic indicators for Korogoro Creek
(1939 to 2007)
SOUTH WEST ROCKS (SMOKY CAPE LIGHTHOUSE)
Site No: 059030 • Opened Jan 1939 • Still Open • Latitude: -30.9225° • Longitude: 153.087° • Elevation 117m

Refer http://www.bom.gov.au/climate/averages/ for more information.



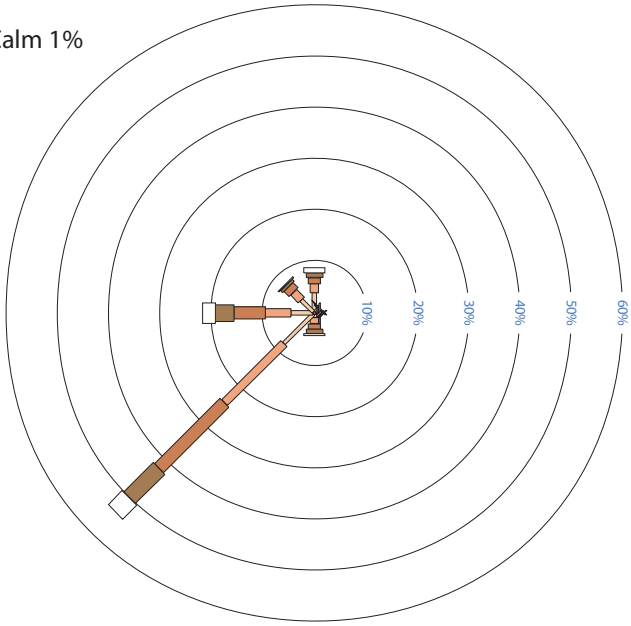
9 am January
1519 Total Observations

Calm 2%



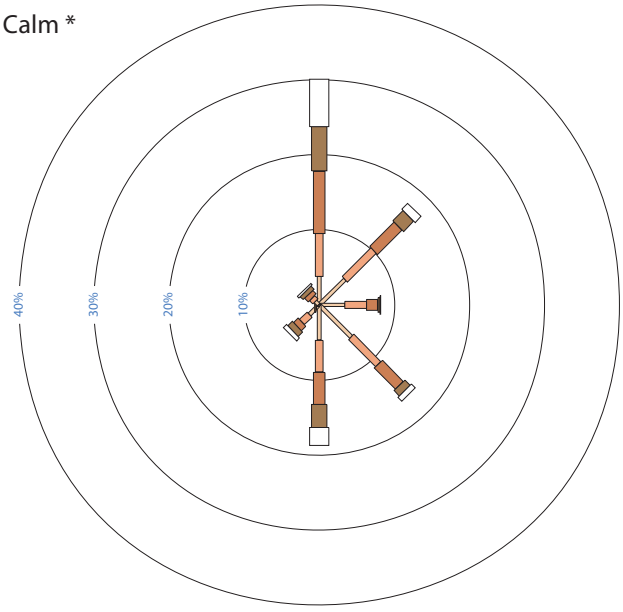
9 am July
1546 Total Observations

Calm 1%



3 pm January
1515 Total Observations

Calm *



3 pm July
1545 Total Observations

Calm 1%

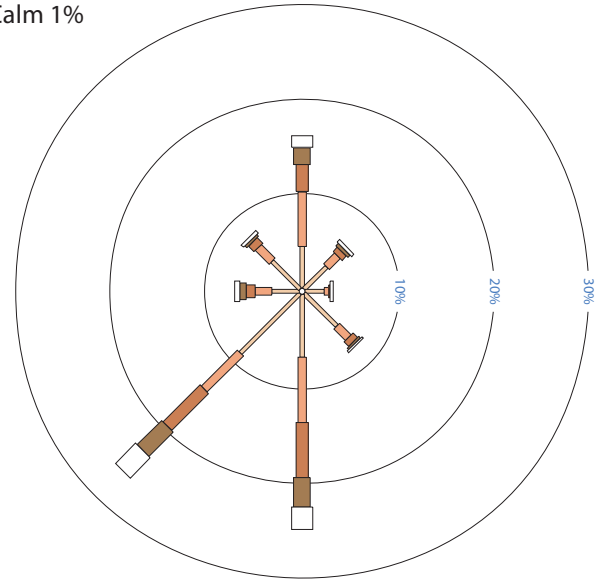


Figure 2-B

Source:
Bureau of Meterology

Rose of Wind Direction versus Wind Speed in km/h
(01 Jan 1957 to 31 Dec 2006)
SOUTH WEST ROCKS (SMOKY CAPE LIGHTHOUSE)
Site No: 059030 • Opened Jan 1939 • Still Open • Latitude: -30.9225° • Longitude: 153.087° • Elevation 117m

An asterisk (*) indicates that calm is less than 0.5%.
Refer http://www.bom.gov.au/climate/averages/ for more information.

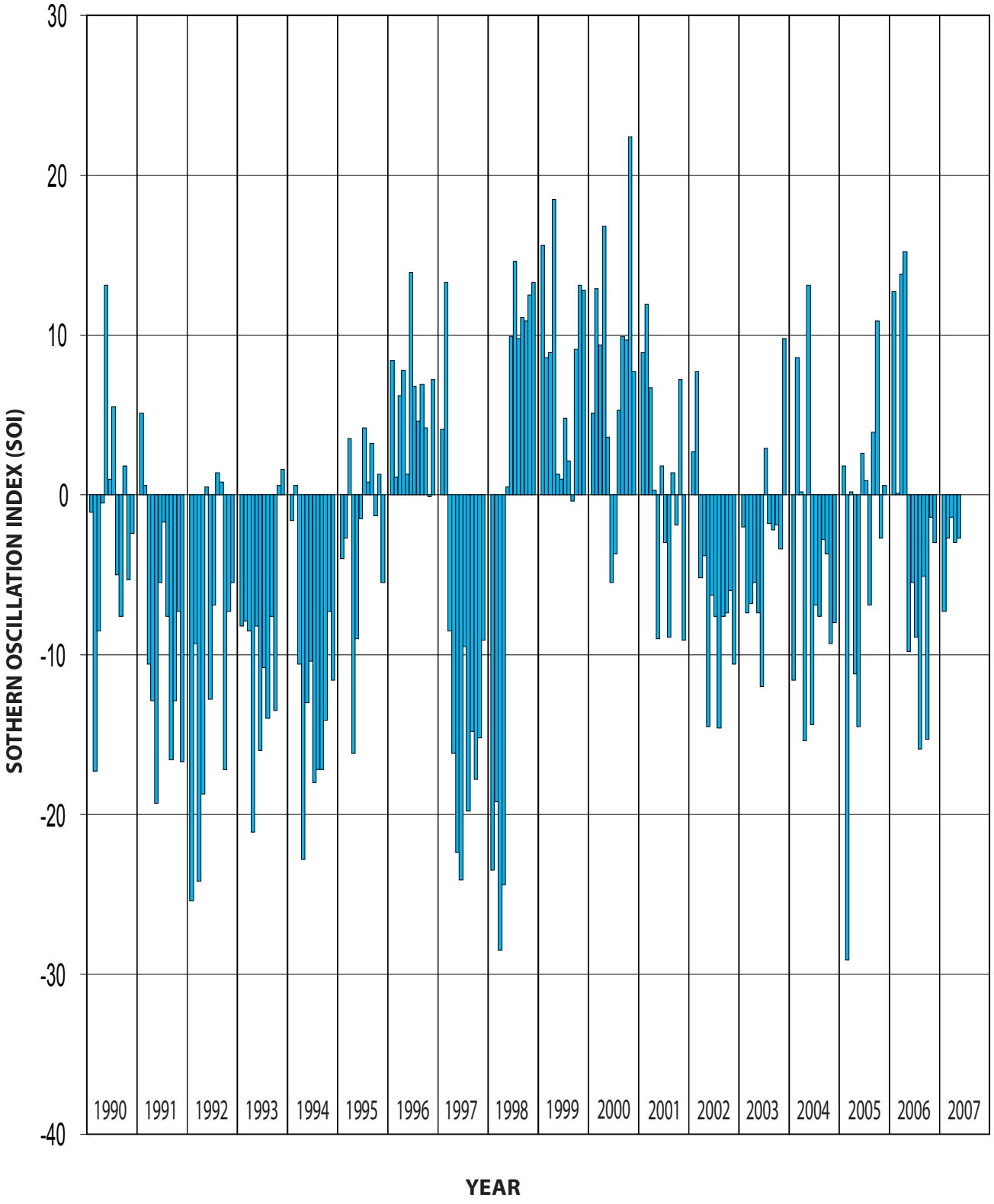
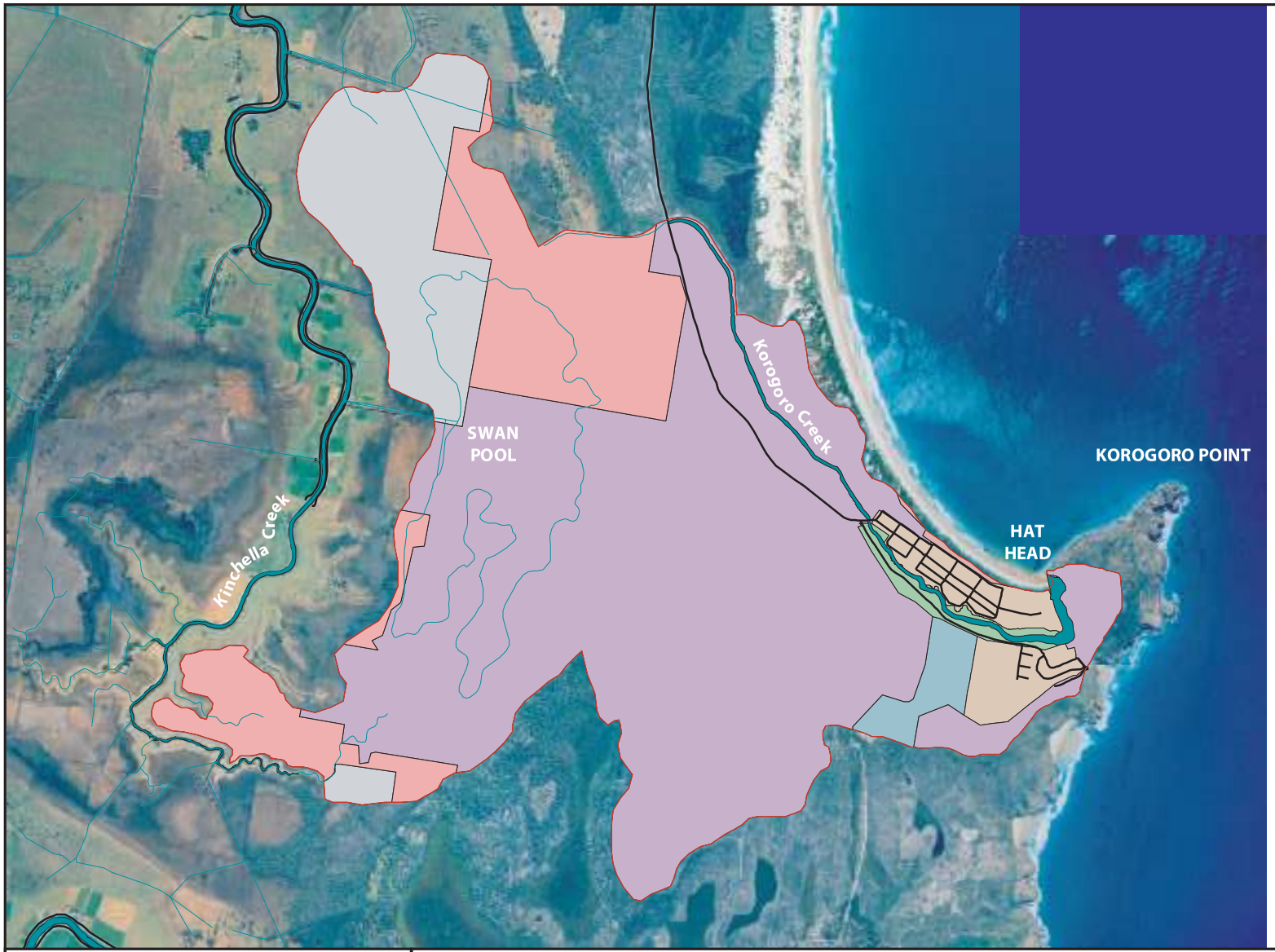


Figure 2-C

Southern Oscillation Index (SOI) 1990 - 2007

Source:
Bureau of Meterology

Refer http://www.bom.gov.au/climate/current/soihtm1.shtml



LEGEND

- Approximate Catchment Boundary
- Roads
- Creeks and drains
- Waterways

KEMPSEY COUNCIL LEP ZONINGS

- 1(a1) Rural
- 1(d) Rural Investigation
- 2(v) Residential Village or Township
- 6(a) Open Space
- 7(f1) Coastal Lands Protection
- 8(a) Existing National Parks, Nature Reserves, Recreation Areas
- 8(b) Proposed National Parks Extension

Approximate Scale 1:30,000

500 0 500 1000 1500 m

Figure 2-D

Created by:
Damon Telfer
GECO Environmental,
Grassy Head, NSW 2441

Korogoro Creek Catchment - Kempsey Shire LEP Zonings

Sources: Base orthophoto images: created from 1997 1:25,000 aerial photography LPI, Dept Lands, Bathurst
Cultural (Roads) and Drainage coverage: Resource Information Unit, Dept Environment and Climate Change, Grafton
LEP Coverage: Kempsey Shire Council.

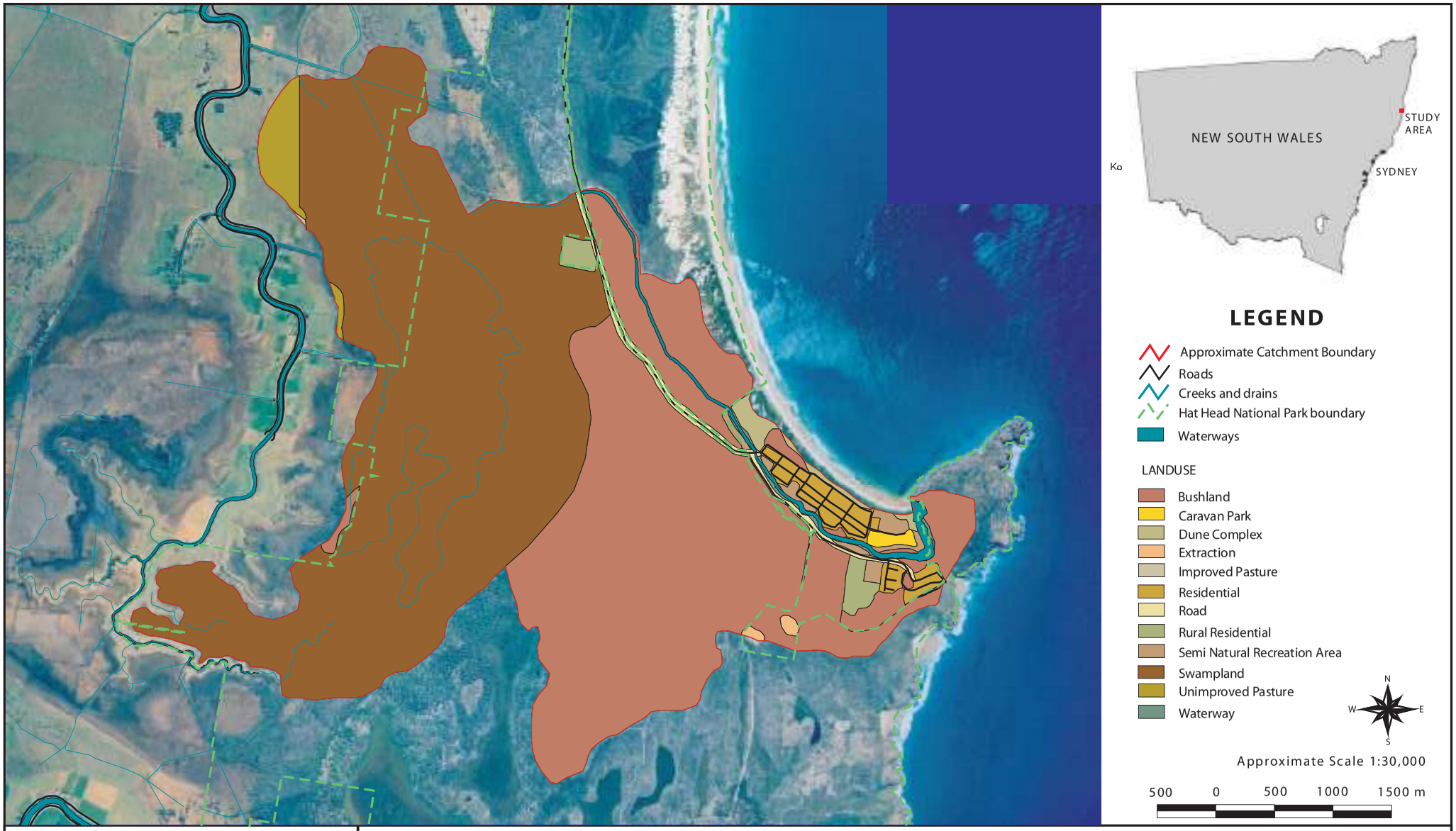
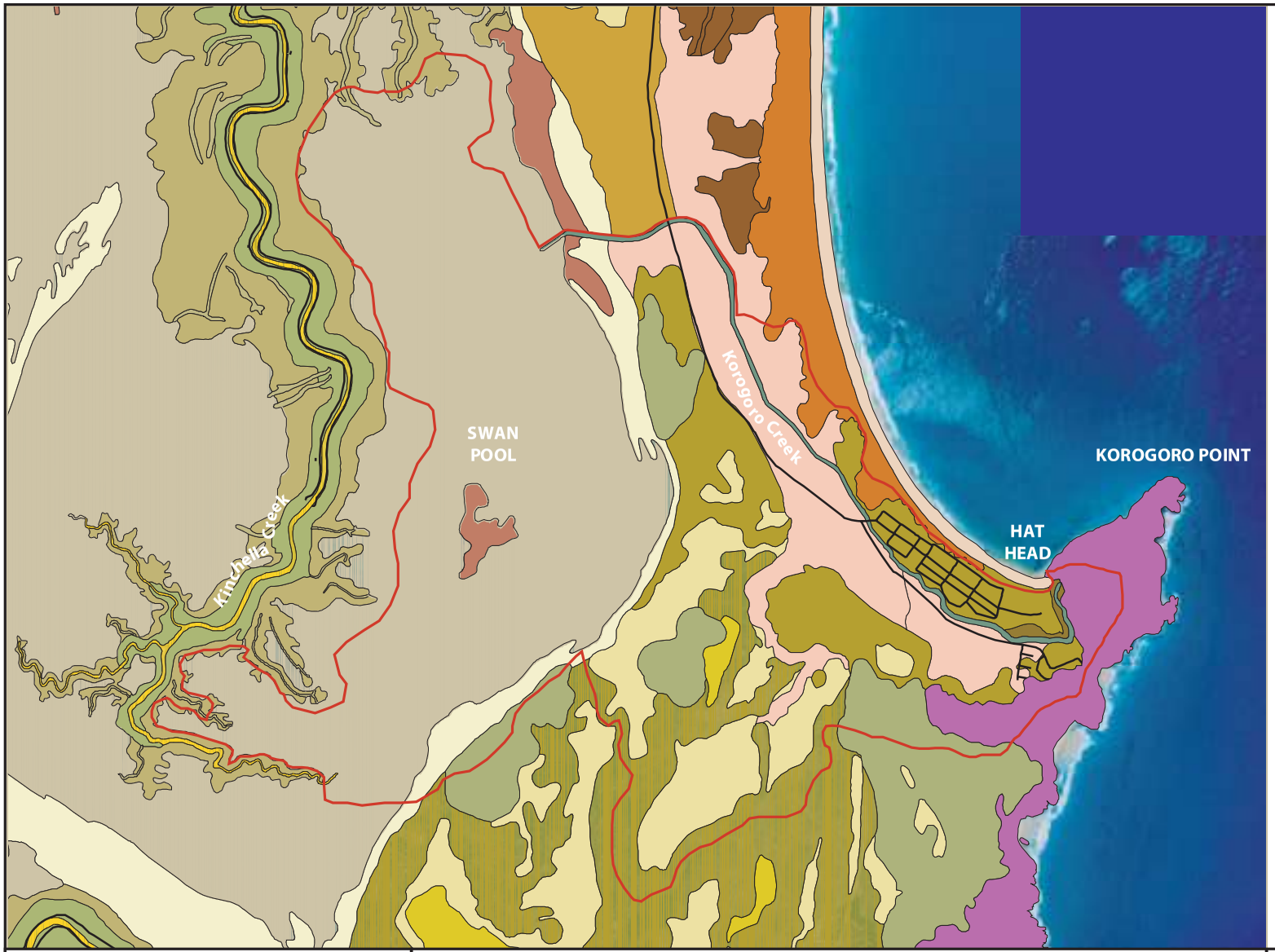


Figure 2-E

Created by:
Damon Telfer
GECO Environmental,
Grassy Head, NSW 2441

Korogoro Creek Catchment - Distribution of Landuse Types

Sources: Base orthophoto images: created from 1997 1:25,000 aerial photography LPI, Dept Lands, Bathurst
Landuse Types based on DNR MUltiattribute Mapping 1999.
National Park boundary, Cultural (Roads), Creeks and Drainage coverages: Resource Information Unit, Dept Environment and Climate Change, Grafton



LEGEND

- Approximate Catchment Boundary
- Roads

Bedrock Units

- Bedrock - Kempsey Bed Conglomerate

Quaternary Geology - Units

- Alluvial and colluvial fan
- Alluvial channel (subaqueous)
- Alluvial palaeochannel fill and inter-levee swale
- Backbarrier flat
- Backswamp
- Beach ridge and associated strandplain
- Beach-ridge swale and dune-deflation hollow
- Bedrock-mantling dune
- Breakwaters, embankments and artificial levees
- Coastal lagoon
- Dune
- Estuarine channel (subaqueous)
- Estuarine inchannel bar and beach
- Estuarine palaeochannel fill
- Estuarine shoreline ridge and dune
- Floodplain
- Freshwater swamp
- In-channel bar
- Interbarrier creek deposits
- Levee
- Mobile dune
- Saline swamp
- Sandy beach
- Stored water, pondage, reservoirs, canals
- Terrace
- Tidal-delta flat
- Undifferentiated
- Valley fill

Figure 2-F

Created by:
Damon Telfer
GECO Environmental,
Grassy Head, NSW 2441

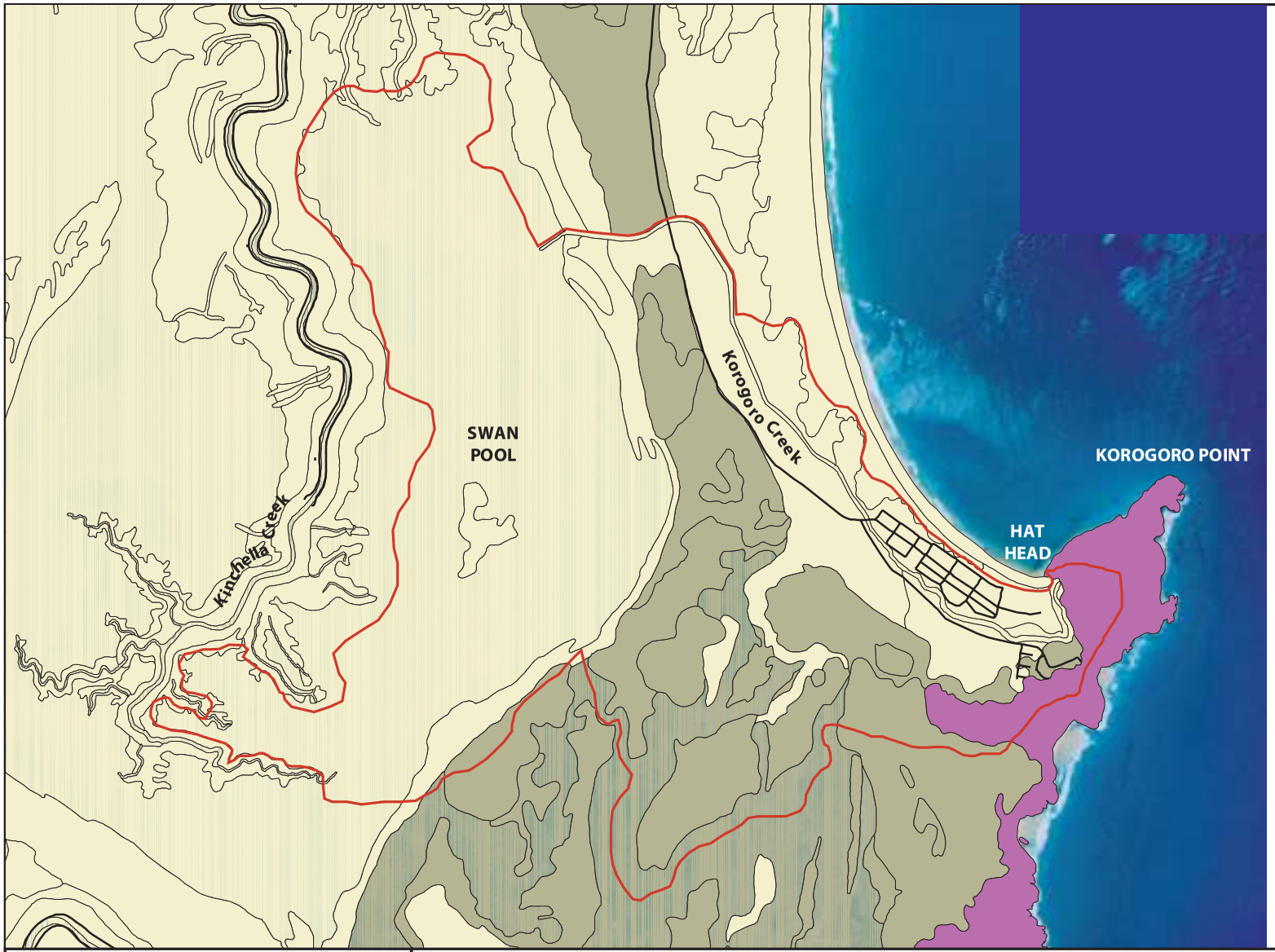
Korogoro Creek Catchment - Quaternary Geological Units

Sources: Quaternary Geological Units: Geological Survey of NSW, DPI.
Cultural (Roads), Creeks and Drainage coverages: Resource Information Unit, Dept Environment and Climate Change, Grafton

N
W E
S

Approximate Scale 1:30,000

500 0 500 1000 1500 m



LEGEND

- Approximate Catchment Boundary
- Roads
- Creeks and drains
- Permian Conglomerates (255-280 million years)
- Pleistocene Deposit (120,000-350,000 years old)
- Holocene Deposits (<10,000 years old)

Approximate Scale 1:30,000

500 0 500 1000 1500 m

Figure 2-G

Created by:
Damon Telfer
GECO Environmental,
Grassy Head, NSW 2441

Korogoro Creek Catchment - Geological Age

Sources: Quaternary Geology: Geological Survey of NSW, DPI.
Cultural (Roads), Creeks and Drainage coverages: Resource Information Unit, Dept Environment and Climate Change, Grafton

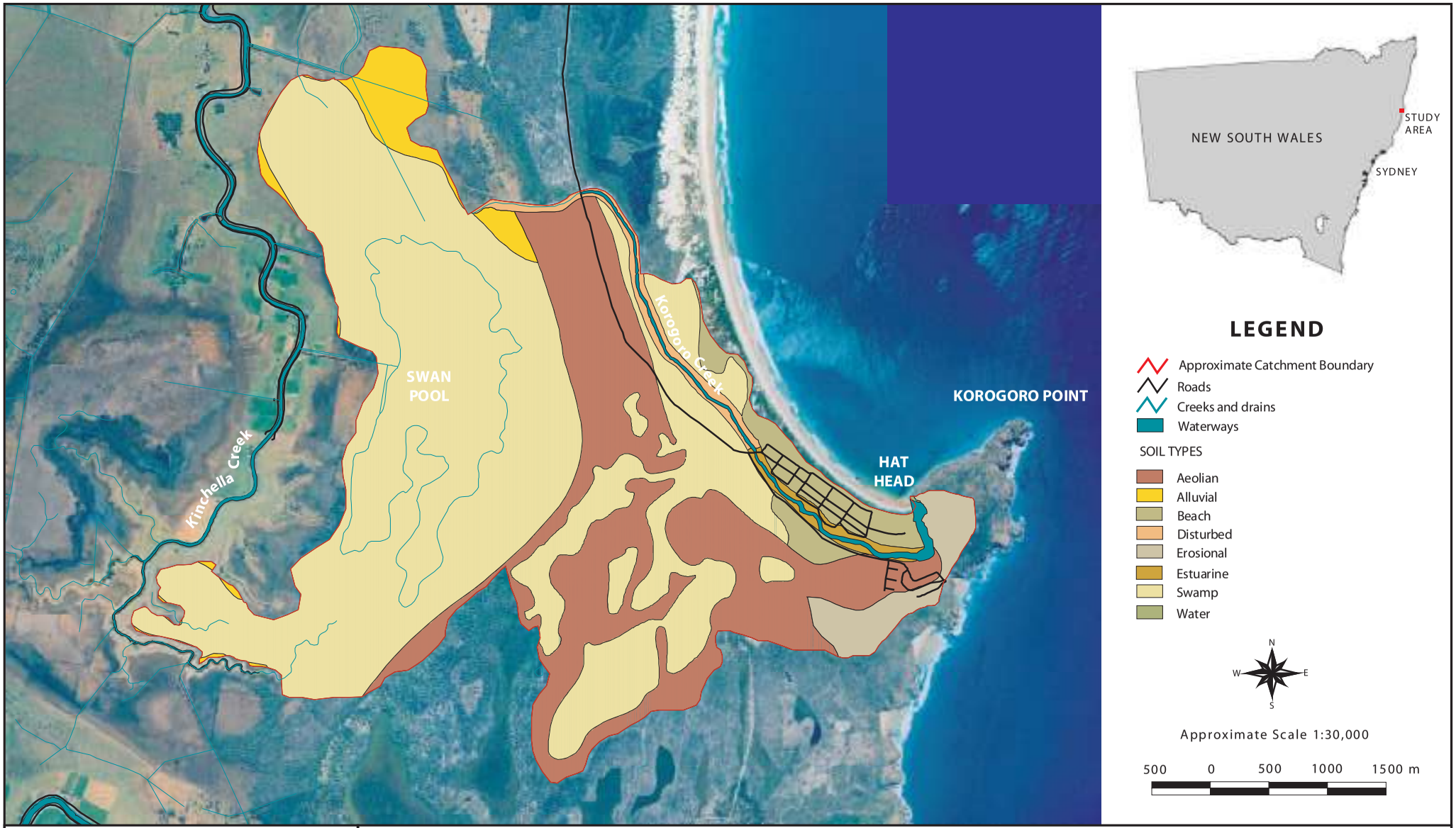


Figure 2-H

Korogoro Creek Catchment - Soil Landscape Processes

Created by:
Damon Telfer
GECO Environmental,
Grassy Head, NSW 2441

Sources: Base orthophoto images: created from 1997 1:25,000 aerial photography LPI, Dept Lands, Bathurst
Cultural (Roads) and Drainage coverage: Resource Information Unit, Dept Environment and Climate Change, Grafton
Soil Landscapes coverage: as per Atkinson, G.(1999), Resource Information Unit, Dept Environment and Climate Change, Grafton

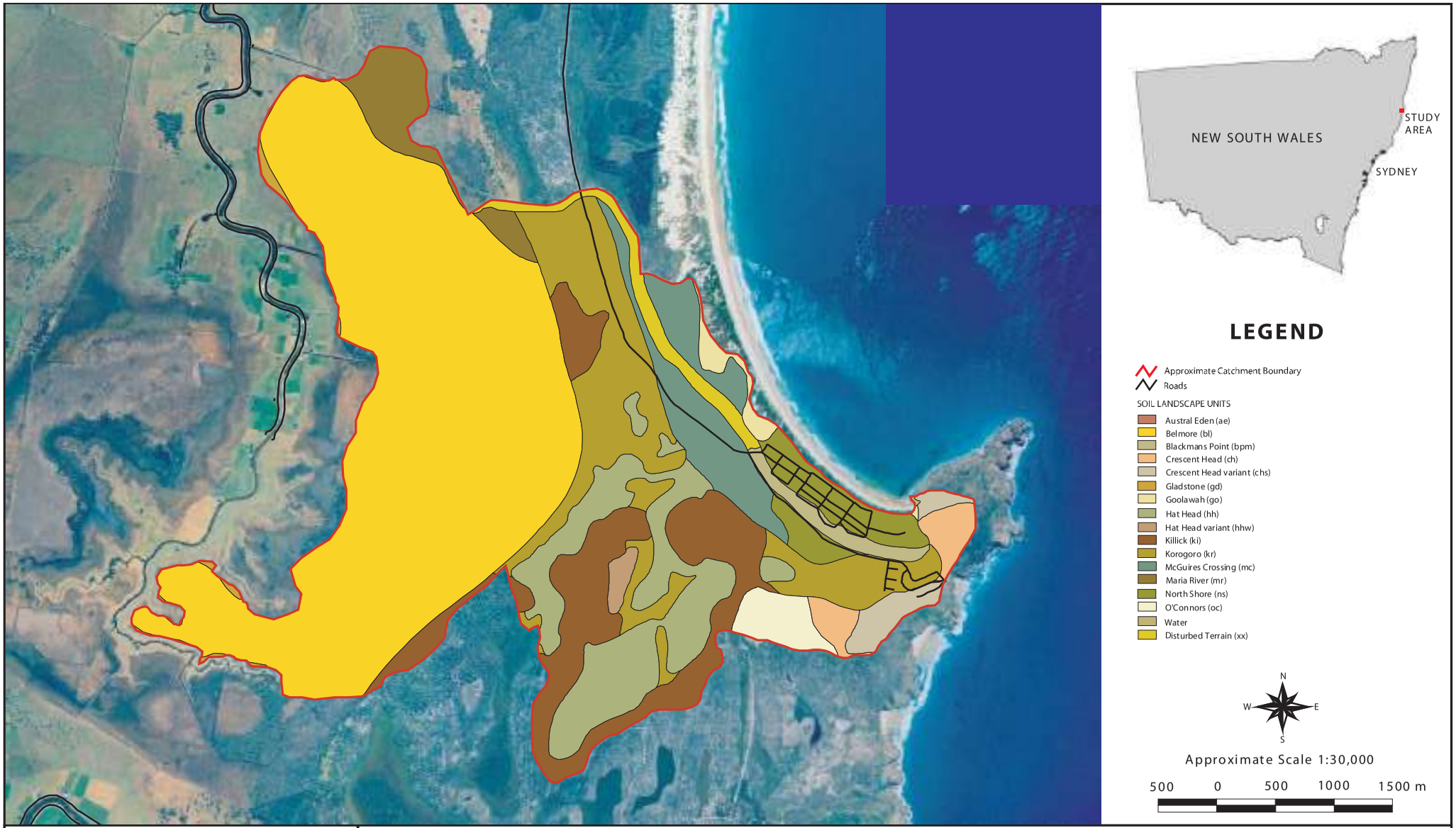
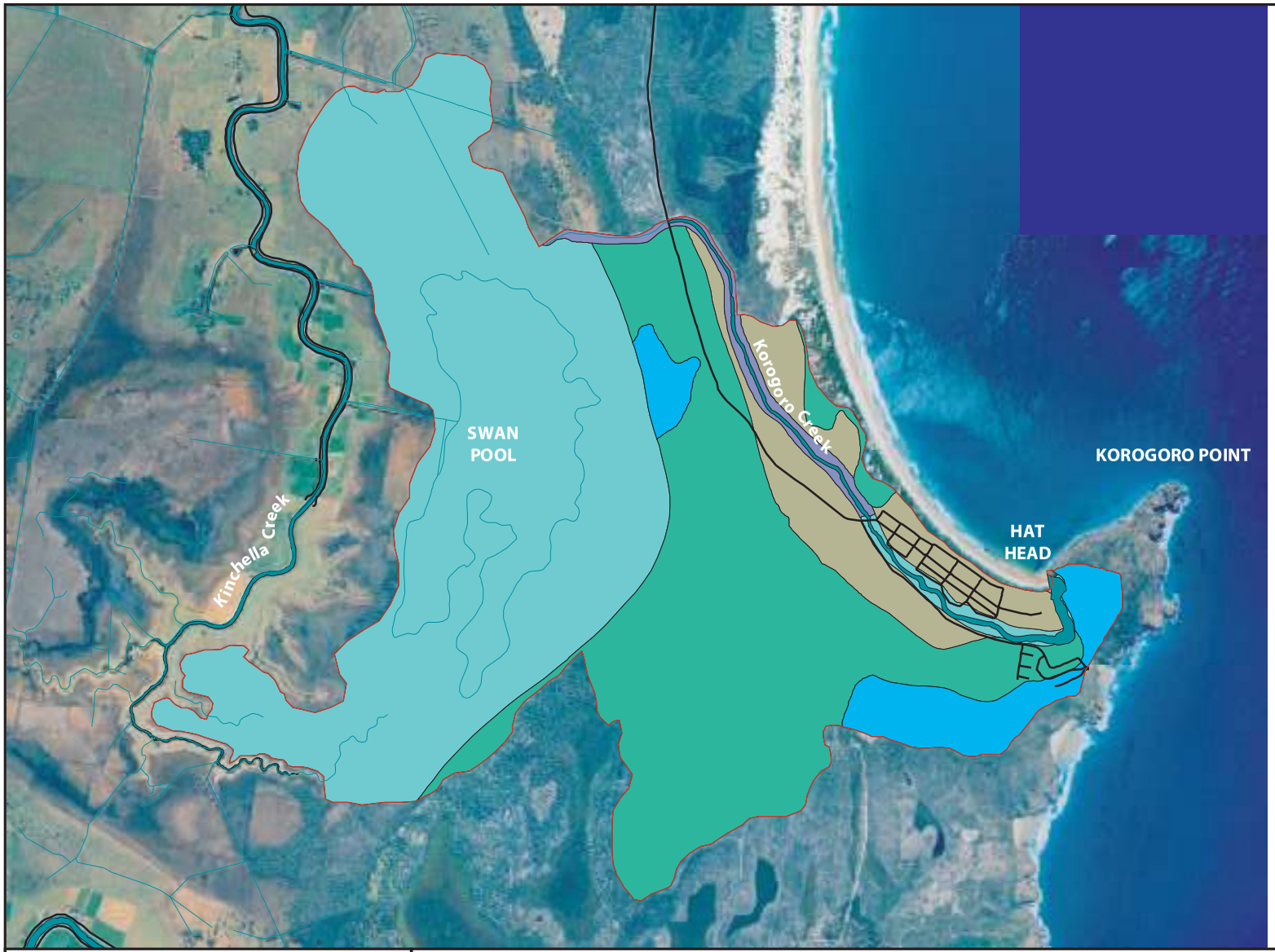


Figure 2-I

Korogoro Creek Catchment - Soil Landscape Units

Created by:
Damon Telfer
GECO Environmental,
Grassy Head, NSW 2441

Sources: Base orthophoto images: created from 1997 1:25,000 aerial photography LPI, Dept Lands, Bathurst
Cultural (Roads): Resource Information Unit, Dept Environment and Climate Change, Grafton
Soil Landscapes coverage: as per Atkinson, G.(1999), Resource Information Unit, Dept Environment and Climate Change, Grafton



LEGEND

- Approximate Catchment Boundary
- Roads
- Creeks and drains
- Waterways

Acid Sulfate Soil Risk

- Beach
- High Risk
- Low Risk
- Not known to occur
- Assessed, not ASS
- Disturbed, potential ASS

Approximate Scale 1:30,000

500 0 500 1000 1500 m

Figure 2-K

Korogoro Creek Catchment - Acid Sulfate Soil Risk

Created by:
Damon Telfer
GECO Environmental,
Grassy Head, NSW 2441

Sources: Base orthophoto images: created from 1997 1:25,000 aerial photography LPI, Dept Lands, Bathurst
Cultural (Roads) and Drainage coverage: Resource Information Unit, Dept Environment and Climate Change, Grafton
ASS Risk coverage: Resource Information Unit, Dept Environment and Climate Change, Grafton

LEGEND

Roads
Creeks and drains

ESTUARY PROCESS ZONES

Marine Tidal Delta
Modified Estuarine Basin

Approximate Scale 1:15,000

Figure 2-M

Created by:
Damon Telfer
GECO Environmental,
Grassy Head, NSW 2441

Korogoro Creek Estuary - Geomorphological Process Zones

Sources: Base orthophoto images: created from 1997 1:25,000 aerial photography LPI, Dept Lands, Bathurst
Cultural (Roads) and Drainage coverage: Resource Information Unit, Dept Environment and Climate Change, Grafton

Figure 2-N

Korogoro Creek Catchment - Estuarine Aquatic Vegetation

Created by:
Damon Telfer
GECO Environmental,
Grassy Head, NSW 2441

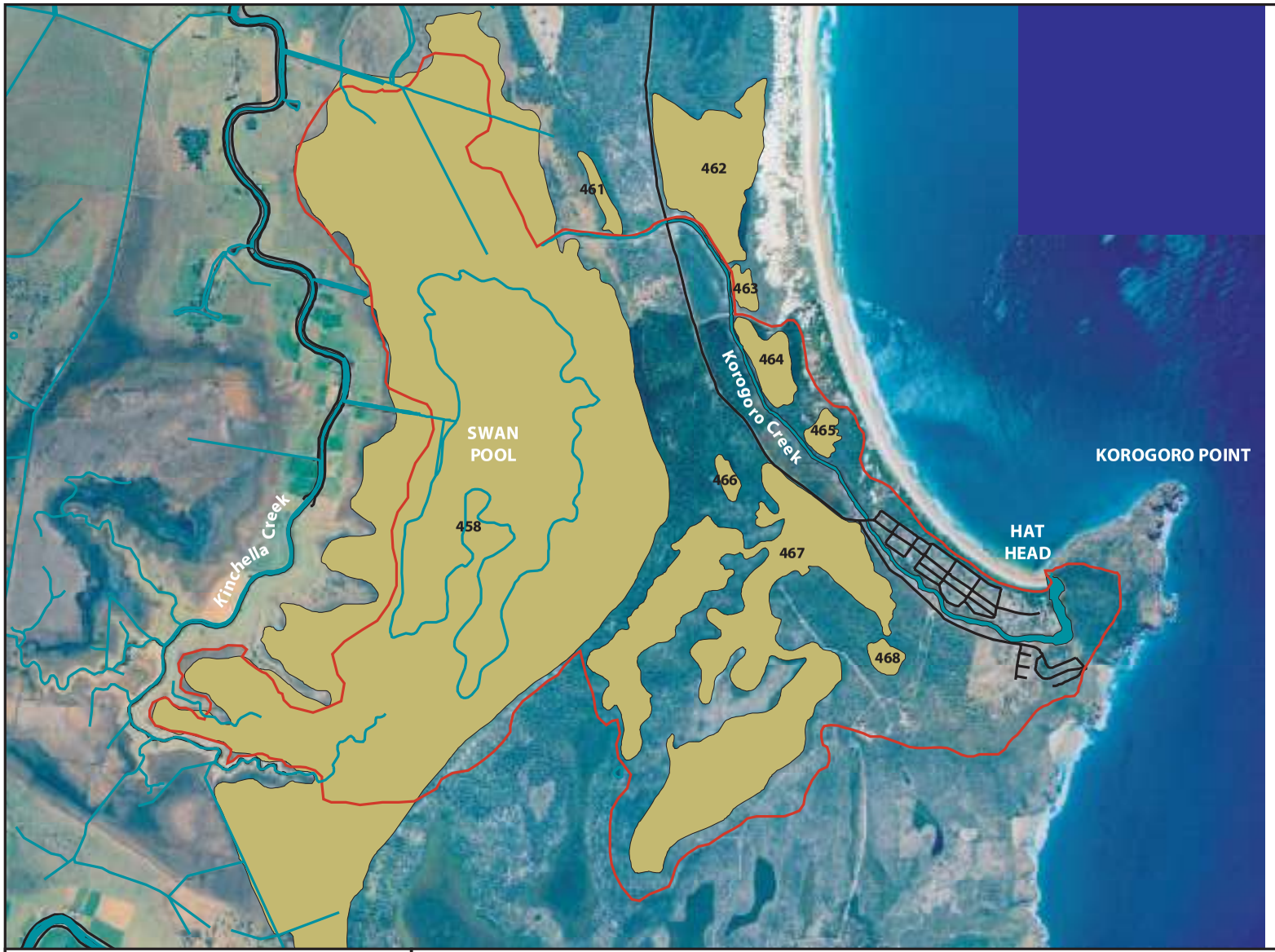
Data Source:
Aquatic Macrophytes - Dept Primary Industries Fisheries
Orthophotos - derived from LIP NSW images (2003,2004)
Roads - Dept Environment and Climate Change

LEGEND

- Approximate Catchment Boundary
- Roads

ESTUARINE VEGETATION

- Mangrove
- Seagrass
- Saltmarsh



LEGEND

- Approximate Catchment Boundary
- Roads
- Creeks and drains
- Waterways
- SEPP14 Wetlands
- 461 SEPP14 identification number

Approximate Scale 1:30,000

500 0 500 1000 1500 m

Figure 2-O

Korogoro Creek Catchment - SEPP14 Wetlands

Created by:
Damon Telfer
GECO Environmental,
Grassy Head, NSW 2441

Sources: Base orthophoto images: created from 1997 1:25,000 aerial photography LPI, Dept Lands, Bathurst
Cultural (Roads) and Drainage coverage: Resource Information Unit, Dept Environment and Climate Change, Grafton
SEPP14 Wetlands coverage: Dept Planning, Parramatta

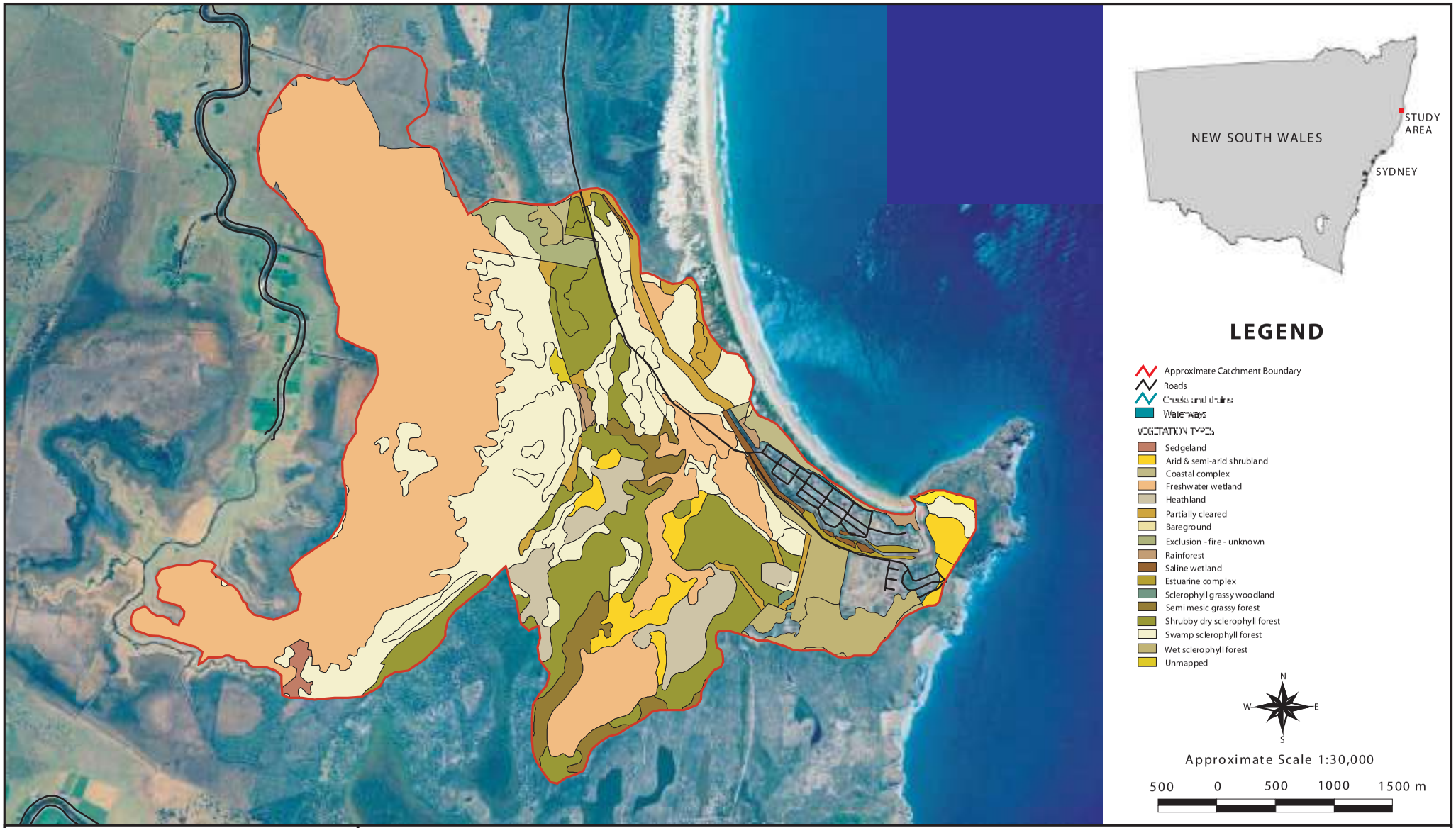


Figure 2-P

Korogoro Creek Catchment - Vegetation Communities

Created by:
Damon Telfer
GECO Environmental,
Grassy Head, NSW 2441

Sources: Base orthophoto images: created from 1997 1:25,000 aerial photography LPI, Dept Lands, Bathurst
Cultural (Roads) and Drainage coverage: Resource Information Unit, Dept Environment and Climate Change, Grafton
Vegetation Communities: Kempsey Shire Council East - Native Vegetation Communities mapping (Telfer & Kendall, 2006)