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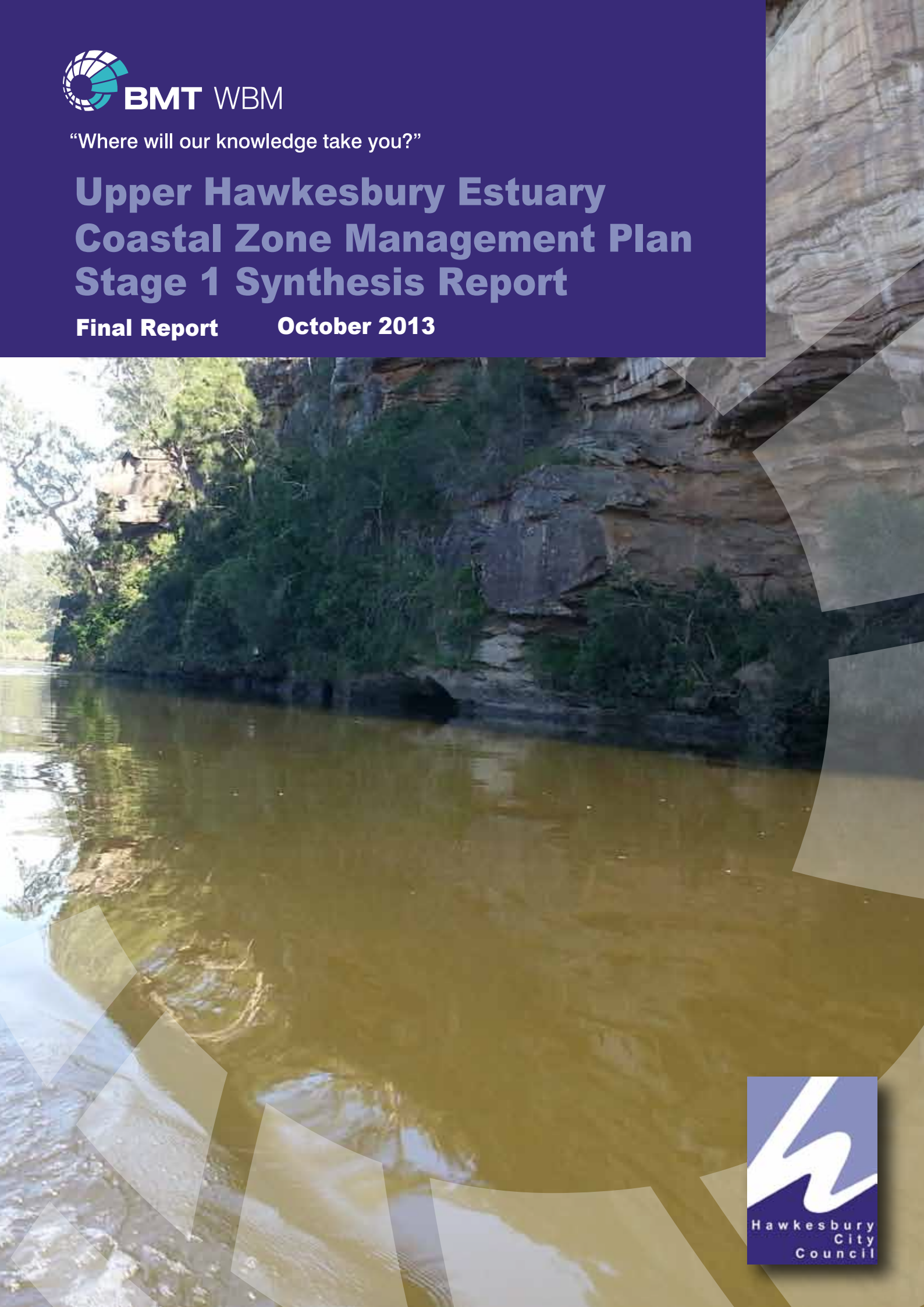
Upper Hawkesbury Estuary Coastal Zone Management Plan Stage 1 Synthesis Report

Final Report **October 2013**



Hawkesbury City Council

Upper Hawkesbury River Estuary Information Synthesis Report

Prepared For:	Hawkesbury City Council
Prepared By:	BMT WBM Pty Ltd (Member of the BMT group of companies)

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BMT WBM Pty Ltd 126 Belford Street BROADMEADOW NSW 2292 Australia PO Box 266 Broadmeadow NSW 2292 Tel: +61 2 4940 8882 Fax: +61 2 4940 8887 ABN 54 010 830 421 www.bmtwbm.com.au	***Document :*** R.N2357.001.00.Synthesis Report ***Project Manager :*** Michelle Fletcher ***Client :*** Hawkesbury City Council ***Client Contact:*** Suzanne Stuart ***Client Reference***

Title :	Upper Hawkesbury River Estuary Information Synthesis Report
Author :	Michelle Fletcher and Kate Byrnes (SKM)
Synopsis :	This report collates and reviews the background information regarding the Upper Hawkesbury River Estuary and its existing governance framework and management initiatives. This report will be used in stakeholder consultation throughout the preparation of the Upper Hawkesbury River Estuary Coastal Zone Management Plan.

REVISION/CHECKING HISTORY

REVISION NUMBER	DATE OF ISSUE	CHECKED BY		ISSUED BY	
0	May 2013	PEH		MF	
1	May 14 2013	MF		MF	
2	October 2013	MF		MF	

DISTRIBUTION

DESTINATION	REVISION			
	0	1	2	3
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1 INTRODUCTION

This report represents the first stage in the development of a Coastal Zone Management Plan (CZMP) for the Upper Hawkesbury River Estuary. It reviews the available information on the present condition of the Upper Hawkesbury River Estuary and describes the results from a preliminary round of stakeholder consultation regarding the waterway. The information contained within this report will be used as a starting point for discussions with a wider group of stakeholders.

The Upper Hawkesbury River Estuary CZMP will provide a list of actions and related implementation details to be carried out by Hawkesbury City Council (Council), other public authorities and potentially the community to address priority management issues affecting the Upper Hawkesbury River Estuary over a defined implementation period. As the CZMP will guide the investment of resources in the estuary, it needs to be based on the best possible information.

The project has been divided into three distinct stages as shown in Table 1-1.

Table 1-1 Stages involved in the Preparation of the Upper Hawkesbury River Estuary CZMP

Stage 1	Stage 2	Stage 3
Outcome: Synthesis Report	**Outcome: Short-list of Management Options**	**Outcome: CZMP Action Plan**
Involves: collation and detailed review of existing background information and stakeholder consultation regarding the Hawkesbury River and its existing governance framework and management initiatives	Involves: community involvement to identify values, community uses and pressures/threats to the river. It will then involve a detailed risk assessment to prioritise goals and objectives for management before formulating and assessing potential management options	Involves: development of the CZMP document, including implementation schedules. This stage also involves further consultation with agencies regarding co-operation for implementation as well as potential funding for works and measures

1.1 Study Area

The study area covers the Upper Hawkesbury River between Wisemans Ferry and Yarramundi (the tidal limit of the river). From a management perspective, the study will need to include the waterway of the Upper Hawkesbury River along with its tributaries, immediate riparian areas and its broader

catchment area insofar as catchment development has an impact on the receiving waters of the river. In this regard, the relevant catchment therefore incorporates the catchments of the Colo and Grose Rivers, as well as the entire Nepean River catchment that extends as far south as Goulburn and as far west as Lithgow.

Also to be included in this Plan are the Nationally Important Wetlands of Pitt Town Lagoon and Longneck Lagoon. Whilst these lagoons are subject to the local Scheyville National Park and Pitt Town Nature Reserve Plan of Management (NPWS, 2000), their intermittent connection to the estuary is important, and thus their values are intrinsically linked to those of the broader estuary.

It is not intended that the Coastal Zone Management Plan be a mechanism for broad catchment management planning across this vast area, although, it is important that the issues within the catchment are taken into account in the context of the river, and that there is strong linkages between this Plan and other existing strategic documents that have a more detailed focus on catchment initiatives, including the Hawkesbury-Nepean Catchment Action Plan (2007) and the accompanying Hawkesbury Nepean River Health Strategy (2007).

Most regular users of the Upper Hawkesbury River Estuary appreciate it is a tidal system, however, the long distance (some 143km) of the tidal limit from the ocean makes it quite different to many of the other estuaries that are managed through the NSW Government Coastal Zone Management Program. A discussion of the rationale for preparing a Coastal Zone Management Pan is given in Section 1.3.

The Yarramundi to Windsor Reach is wide and shallow with moderate freshwater tidal influence. It receives tributary inflows from the Grose River (at Yarramundi) and the Nepean River (upstream of Yarramundi) (Gruber *et al* 2010). The tidal limit of the Hawkesbury River occurs at Yarramundi, approximately 140km upstream of the river mouth (Krogh *et al* 2009). The channel form and bank stability of the upper estuary are largely influenced by the recurring low flows in the main stream of the Hawkesbury River (Kimmerikong 2005). The altered flow regimes impact on sediment and bank dynamics, particularly in this reach of the system.

1.2 Local Management Context

In 2005, a Scoping Study for Estuary Management covering the whole Hawkesbury River was prepared (Kimmerikong, 2005). Given the difference in environmental characteristics and major pressures, the Hawkesbury River was divided into Upper and Lower Sections. The Lower Hawkesbury River Estuary Management Plan was completed by BMT WBM in 2008. This present project now involves completing a commensurate Plan for the upper reaches of the Hawkesbury River.

Kimmerikong (2005) undertook a background review of existing environmental data and existing management frameworks through detailed consultation with a wide range of stakeholders of the river. One of the key outcomes from this review was that the estuary needed to be managed in a 'whole-of-estuary approach'. Whilst estuary issues have been flagged and considered as part of the holistic Catchment Action Plan and River Health Strategy, there are expected to be a number of more local issues and threats facing the Upper Hawkesbury River that to date have 'fallen through the cracks' of strategic environmental planning and management efforts.

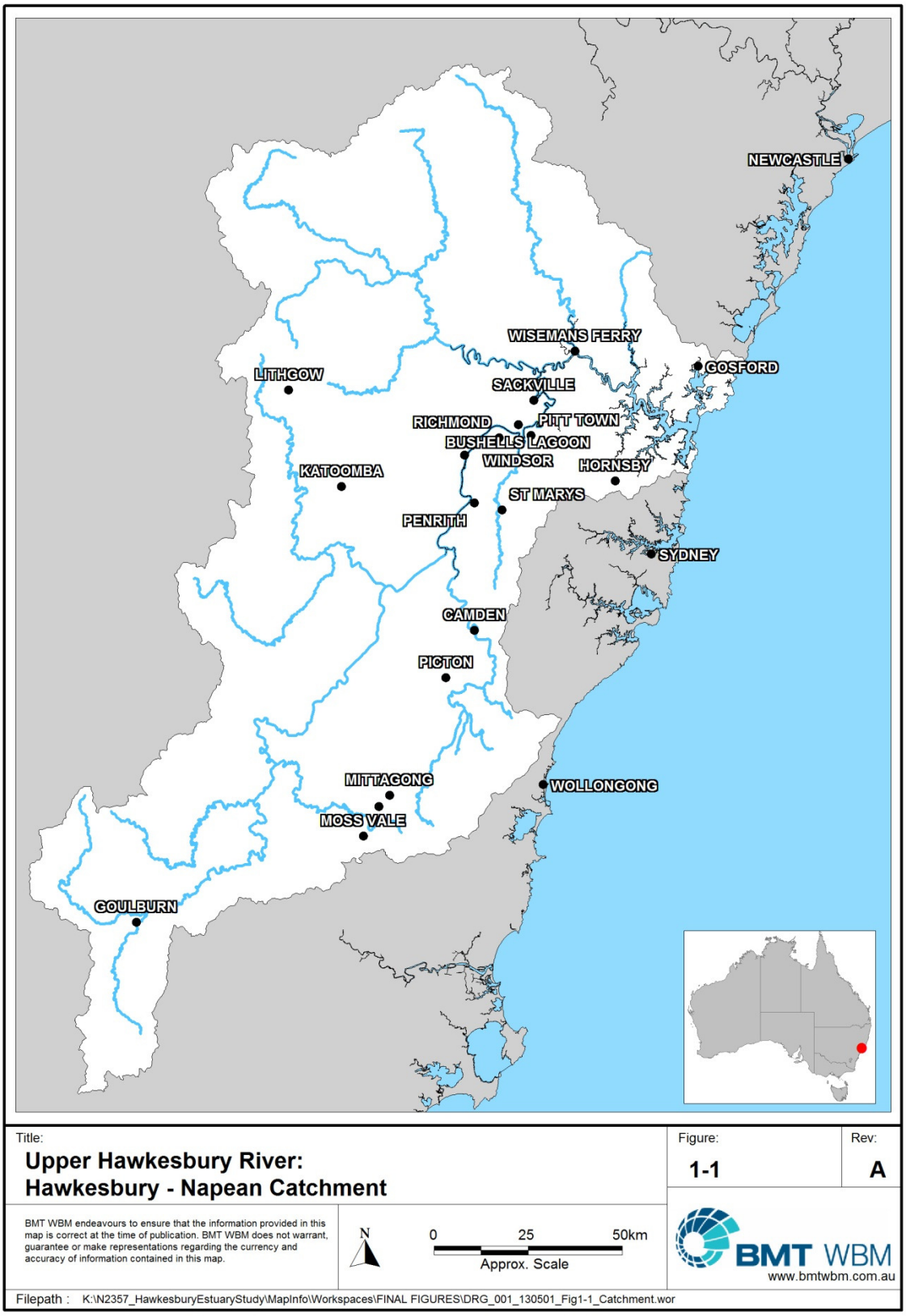

Figure 1-1 Upper Hawkesbury River Estuary Catchment

1.3 Why Prepare a Coastal Zone Management Plan for the Upper Hawkesbury River Estuary?

The Hawkesbury River is included in the NSW Coastal Zone up as far as Yarramundi due to the tidal influence. It is therefore eligible to receive funding through the NSW Coastal Zone Management Program. The process of preparing a Coastal Zone Management Plan is staged, to ensure the broad range of considerations are addressed in a holistic manner and to allow the range of stakeholders with knowledge of and interest in the estuary to contribute.

Coastal management in New South Wales is guided by the NSW Coastal Protection Act 1979, State Environment Planning Policy No. 71 Coastal Protection, and the NSW Coastal Policy (1997). The NSW Government Coastal Design Guidelines (2003) and the Standard Instrument: Local Environment Plan (DP, 2006) also provide additional guidance on land use planning in the coastal zone.

The Coastal Zone Management Plan that will be prepared for the Upper Hawkesbury River Estuary will help attract resources for a range of actions including on ground works, education programs, strategic planning and monitoring that can contribute to improvements in environmental condition. Under the Coastal Zone Management Program, the NSW Government provides grants to support local government improve the health of NSW estuaries. To be eligible for funding, actions generally need to be recommended in a site specific Coastal Zone Management Plan, prepared according to the Guidelines for Preparing Coastal Zone Management Plans (DECCW, 2010) ('the CZMP Guidelines') the guidelines, which ensure that the minimum requirements of the *Coastal Protection Act 1979* regarding coastal and estuary management are met.

1.4 How does this relate to the Hawkesbury Nepean River Health Strategy?

The Hawkesbury Nepean River Health Strategy (2007) was prepared by the CMA to guide rehabilitation works across the Hawkesbury Nepean Catchment. Considerable work has gone into the development of the strategy including data collection and analysis, community and stakeholder consultation, assessment of river reaches and detailed planning and prioritisation for future works. The intention now is not to repeat this work but to build on it and move forward. The present report will concentrate on the area defined in Section 1.1 and will address more local issues that are mostly within the management control of Council.

The Hawkesbury Nepean River Health Strategy focuses on the following key areas of river health:

- Improving the management of riparian lands;
- Managing severe immediate threats and severe downstream impacts;
- Managing important wetlands;
- Improving aquatic habitat condition and connectivity;
- Aquatic weeds management;
- Improving management of public recreation on riverbanks;
- Supporting the community to take action; and

- Managing habitat for flagship species.

Each of these areas will be within the scope of the Upper Hawkesbury River Estuary CZMP. In particular, the River Health Strategy has a focus on rehabilitating riparian areas, through partnerships with private land holders, with a priority on tributaries with high recovery potential (such as the Colo River).

The River Health Strategy has four key management objectives:

- Maintain the condition of reaches in natural or near natural condition;
- Maintain and improve reaches in good condition;
- Improve the environmental condition in the remaining reaches; and
- Achieve the highest environmental and community gain for the resources.

The established priorities relate to the River Reach Assessment undertaken in preparation of the Strategy. The study categorised waterways into river channel types (River Category), condition (River Condition) and the potential for them to recover following disturbance (Recovery Potential). Most of the reaches within the study area were the subject of a full assessment by a panel including representatives from state government agencies. Some side tributaries such as Cattai Creek and South Creek were the subject of a partial creek assessment. Intact reaches such as the upper Colo were identified early and not subject to further assessment. The River Reach Assessment mapping will contribute to the prioritisation of works for the Upper Hawkesbury CZMP. River Reach Assessment mapping for the entire Hawkesbury Nepean is shown in Figure 1-2

1.5 How does this relate to the Catchment Action Plan?

The Catchment Action Plan (CAP) is a strategic plan prepared by Local Land Services (formerly the Catchment Management Authority). It guides management of the environment through partnerships between community and government. The CAP recognises aquatic habitat values of the study area including the Nationally listed wetlands of Pitt Town and Long Neck Lagoons and wild rivers status of the Colo and Grose Rivers. The preparation and implementation of the Upper Hawkesbury River CZMP is a step towards achieving Catchment Management Targets across the Biodiversity, Water, Land and Community Issues that are central to the CAP. The CAP refers to the preparation of CZMPs as a means of meeting targets. The CAP strategies that the CZMP has the potential to contribute are shown in Table 1-2

Table 1-2Relevant Strategies from the Catchment Action Plan

Reference	CAP Strategies
C1	Support people to work together to maintain and improve environments that are significant to them
C4	Support groups with limited resources to allow them to manage their local environment
C5	Promote appreciation of natural environments for people from diverse cultural backgrounds
P3	Understand and maintain the flow of ecosystem services
P5	Restore ecosystem function to degraded areas
B1	Maintain diversity and health of natural systems
B3	Make connections across the landscape including the aquatic ecosystem
UL2	Create a more liveable and water sensitive city by implementing WSUD
UL4	Improve aquatic and terrestrial habitat condition, connectivity and recreational value in urban areas
UL6	Use demonstration sites to show best practice and influence future actions
RL5	Monitor outcomes and risks to support adaptive managment

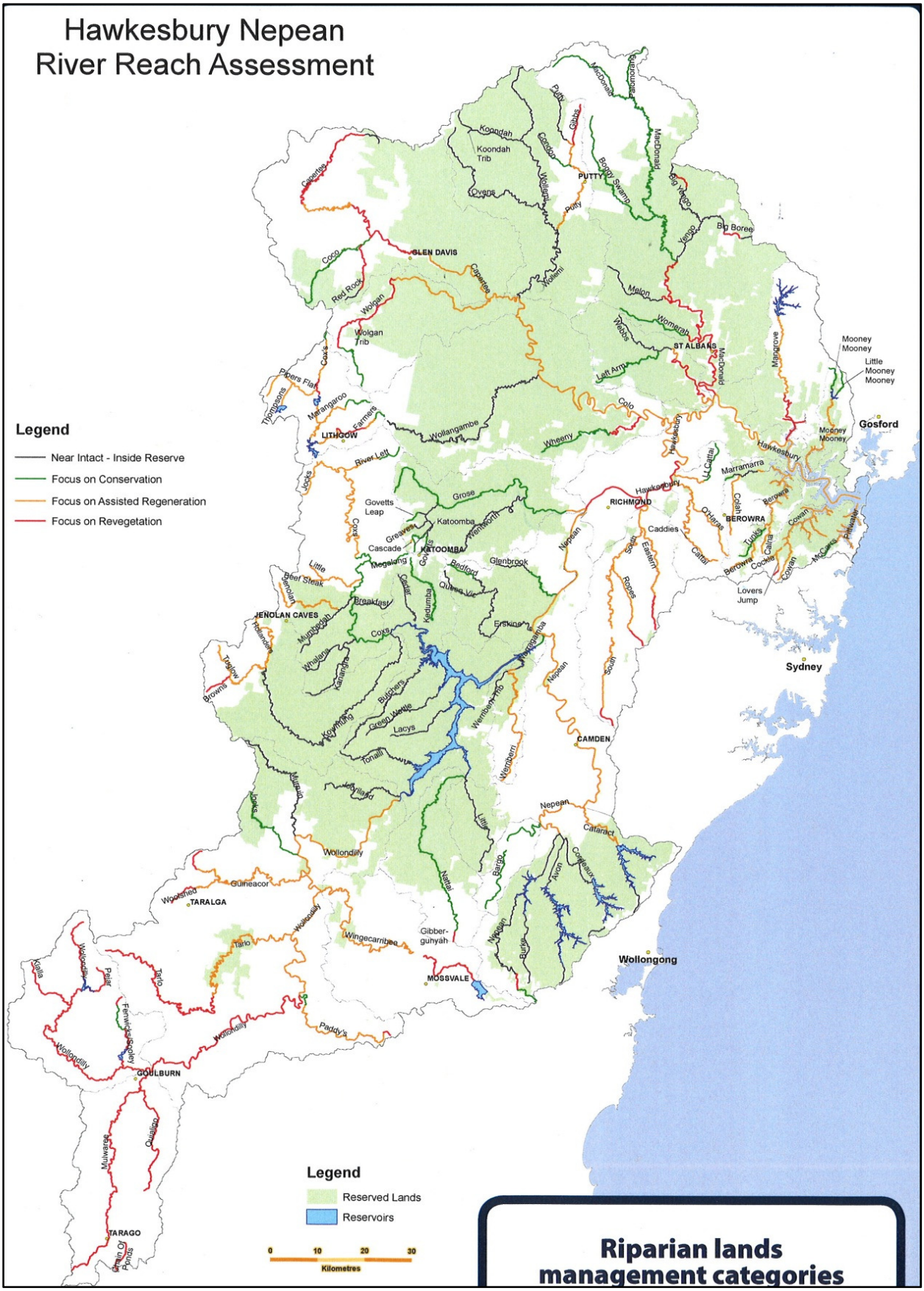

Figure 1-2 Hawkesbury Nepean Catchment River Reach Assessment

1.6 Community and Stakeholder Consultation

Community and stakeholder consultation will be an important component of developing a Coastal Zone Management Plan for the Upper Hawkesbury River Estuary. This Synthesis report is intended to be used as a background document to facilitate engagement and discussions regarding the estuary and further planning. In preparing this document, stakeholders likely to possess information were contacted via letters and follow up phone calls. The next round of consultation will include the wider community and targeted stakeholders who will be involved in a risk-based management assessment of threats to the Hawkesbury River Estuary. Stakeholders contacted in the preparation of the present report are listed in Table 1-3.

Table 1-3 Organisations contacted during the preparation of the present report

Organisations contacted in the preparation of this report	
Hawkesbury Nepean Catchment Management Authority	Local Government Advisory Group
Windsor Canoe Club	Hawkesbury River Uses Group
Hawkesbury Water Uses Group	Hawkesbury Environment Network
Willow Warriors	Eco Fishing Tours
Lower Hawkesbury Nepean Water Users Association	Hawkesbury Recreational Group,
Hornsby Shire Council	OEH, Sydney Unit
OEH, Sydney Unit Waters, Wetlands and Coast Division	Hawkesbury Nepean Catchment Management Authority Penrith Office
Department of Primary Industries Office of Water Penrith	Western Sydney Regional Organisation of Councils
University of Western Sydney-Hawkesbury, Office of Sustainability	Office of Environment and Heritage National Parks & Wildlife Service
Department of Planning and Infrastructure Sydney West Region	Transport Roads Maritime Services
Hawkesbury River County Council	Sydney Water
Hills Shire Council	Hawkesbury River Commercial Fishing Association Inc
Hawkesbury Environment Network	

1.6.1 Management Philosophy

It is unrealistic to try to manage the Upper Hawkesbury River Estuary with the intent of returning it to a completely natural system with original natural values. The purpose of the future CZMP is therefore to recognise and accommodate as best as possible impacts of external pressures and threats to the environment and the resulting modifications to its natural values, including overall estuary health. Where the current modified values of the estuary are beyond the limit of acceptable change, and therefore unduly compromise the way in which the estuary is used (from an environmental and an anthropocentric perspective), then the Plan should aim to:

1. Modify the external pressures so that they become less of a threat to the estuary values (i.e. intervention type measures); and /or

2. Modify the uses of the estuary to be more compatible with the new modified values (i.e. adaptive type measures).

An example of the former would be the construction of an artificial wetland to reduce nutrient runoff from an urban development, and thus reduce the occurrence of algae within the river (which compromises both its environmental and community use). An example of the latter would be the repositioning of navigation markers so that recreational use avoids an area that has become too shallow for that particular use. It is expected that a successful CZMP will encompass a combination of both intervention and adaptation options, to be implemented through a range of strategic planning, on-ground works, education and compliance based management approaches.

2 SUMMARY OF ESTUARY PROCESSES

2.1 Snapshot

This chapter is divided into two parts. The first is an overview of the key processes operating in the study area. It gives a snapshot description of geomorphology, tides, freshwater flows, ecology and water quality. The second section describes the interactions between these processes and how they come together to form the complex ecosystem of the Upper Hawkesbury River Estuary.

2.1.1 Geomorphology

The underlying valley of the Hawkesbury River was formed during the Pleistocene when sea levels were lower. Present sea level now 'drowns' much of the paleo valley. Sediment infilling has occurred as sea levels have risen, notably over the past 18000 years. The Hawkesbury Estuary is characterised by confining sandstone gorges, and relatively low erosion rates within the catchment.

The upper Hawkesbury geomorphology is described in two separate reaches by Kimmerikong (2005). From the Grose River junction to Lower Portland is a tidal channel with predominantly sandy benches and higher more cohesive alluvium. Near Windsor the channel has large meanders and the floodplain has widths of up to 6km that have high storage capacity for overbank flows. This section is also characterised by lagoons and floodplain swamp wetlands with low elevations as a result of more rapid sedimentation in the main channel compared to the smaller tributaries. The main channel on this reach has been dredged from time to time.

Between Windsor and Wisemans Ferry, the influence of geology on conservation is striking. The wide flat banks around Windsor are cleared, cultivated, usually weed infested and often eroding, whereas further downstream, where the imposing sandstone cliffs occur, the vegetation is predominantly native, and probably not dissimilar to conditions 200 years ago. The control that geomorphology has on vegetation condition is demonstrated through Figure 2-2 and Figure 2-3.

From Lower Portland to Wisemans Ferry the river runs through partially submerged gorges, and is characterised by bedrock and alluvial banks. Bedrock typically occurs on the outside of meander bends. There are a number of deep holes near steeper cliff sections that are up to 30m below sea level (Kimmerikong, 2005).

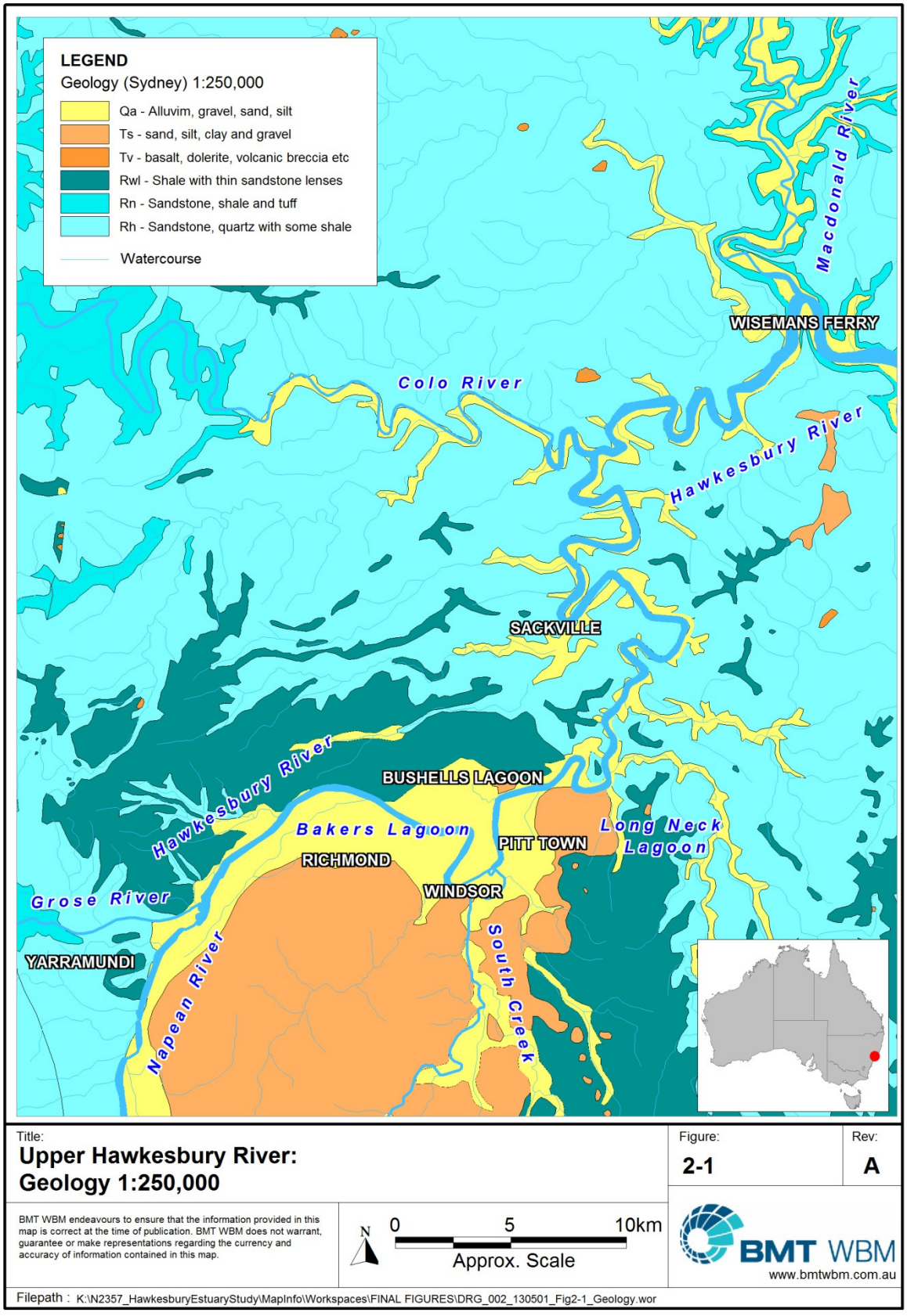

Figure 2-1 Geology in the study area

Figure 2-2 Typical bank in the Windsor area characterised by alluvial geomorphology

Figure 2-3 Typical vegetation coverage for sandstone cliff banks in the Upper Hawkesbury River Estuary

2.1.2 Hydrodynamics

The Upper Hawkesbury River Estuary received freshwater inflows from the catchment and is also tidal. Natural freshwater inflows are disrupted by the major metropolitan water supply dams in the Hawkesbury-Nepean system, including Warragamba dam. Kimmerikong (2005), report that about 80% of the freshwater flowing into the system is being extracted for metropolitan water supply.

The tributaries of the Upper Hawkesbury River Estuary include the Grose River, Red Bank Creek, Rickabys Creek, the Colo River, Webbs Creek, South Creek, Cattai Creek, Currency Creek and the Macdonald River.

At the downstream extent of the present study area (Wisemans Ferry), high tide is 2 hours and 15 minutes after the recorded high tide at fort Denison. With distance along the estuary from its entrance at Broken Bay, the tide continues to lag behind the ocean, low tides are increased slightly and high tides are amplified. At Windsor, high and low tide are 5 hours and 15 minutes and 5 hours and 30 minutes behind Fort Denison, respectively.

Salinity/conductivity data illustrates that oceanic exchange is largely limited to those reaches downstream of Wiseman's Ferry. Salinity at Wiseman's Ferry has generally increased over time due to reduced flows from upstream. Under natural conditions, salinity of 5 ppt would be exceeded about 12% of the time. Currently, this level is exceeded 35% of the time, illustrating a greater degree of salt intrusion to upstream sections of the estuary (Kimmerikong, 2005).

2.1.3 Water Quality

Water quality is a broad term that describes a water body's suitability for ecological or recreational uses. It is measured and reported in terms of biological, chemical and physical parameters. Assessing and describing the water quality of Australian rivers and estuaries is challenging due to the significant natural variability within and between seasons and years. Understanding the water quality for the Upper Hawkesbury River Estuary is further complicated by river regulation for water extraction. A comprehensive program of water quality monitoring has been undertaken for the Hawkesbury and this data set has been analysed in detail.

The water quality of the Hawkesbury River is influenced by diffuse and point source flows from local catchments, flows from treated effluent, spills and environmental releases from storages. Flow in the river is also influenced by licenced extractors for agricultural and industrial use (SCA 2012). Natural river flows have been affected by dams and weirs and continued low flow, primarily caused by the extraction of water (80% of freshwater flows into the system) for metropolitan water supply which has severely disrupted the ecology of the estuary. Low flow has resulted in longer residence times, which coupled with high nutrient loads, have created conditions conducive to algal blooms and allowed aquatic weeds to outcompete native species (Kimmerikong 2005). This in turn has impacted on the populations of invertebrates and fish stocks both upstream and in the lower estuary. The formation of stratification may also occur under these conditions, resulting in changes to water quality conditions that favour nutrient release from sediments (DECCW 2010).

Some general statements can be made based upon the data set:

- Improved water quality has been demonstrated in many parts of the study site and upper catchment since 2000;

- The water quality of the Hawkesbury River generally declines with distance downstream of the tidal limit at Yarramundi to Sackville, however the water column is generally well mixed throughout all reaches (Gruber *et al* 2010);
- Increases in conductivity have been measured throughout the study area;
- The water quality of the Hawkesbury River generally declines with distance downstream of the tidal limit at Yarramundi to Sackville;
- Tributary discharges are the main source of nutrients, with land uses widely varied but reflective of significant nitrogen and phosphorus loads. Generally water quality in South Creek and Cattai Creek is poor; and
- The Colo River supplies water of a very high quality to the estuary.

The implications of water quality for river health, and in particular the interaction between water quality and estuarine ecology, is discussed in Section 2.3.10.

2.1.4 Estuarine Ecology

Aquatic vegetation growing in the study area includes reeds (such as *Phragmites australis*), sedges and macrophytes. These provide habitat and food for aquatic fauna and also contribute to overall estuary health as a nutrient sink and protect banks from boat wake (particularly reeds).

Native and exotic macrophytes have been recorded in the Upper Hawkesbury River Estuary. Thiebaud and Williams (2007) recorded the distribution of taxa within various reaches. Between Richmond and Windsor, ten native and six exotic species were recorded. Exotic species dominate the floating macrophytes namely *Eichhornia crassipes*, although limited amounts of the native *Ludwigia peploides spp. Montevidensis* has also been recorded (Krogh *et al* 2009). Emergent macrophytes are generally dominated by native species, particularly the native species *Typha orientalis*, *Phragmites australis* and *Schoenoplectus validus*.

Many sources of information on the study area raise concerns about the species *Egeria densa* and its increasing dominance over the native macrophyte *Vallisneria gigantean.* This becomes less of an issue moving downstream as *Egeria* is less salt tolerant than the native *Vallisneria.* The presence of the exotic macrophyte *Egeria densa* is described as an indicator of river stress (Sainty *et al*., 2012)

Estuary plant composition may give some insight into estuary health. A detailed study by Gruber *et al* (2010) identified several submerged macrophyte species, namely the native ribbon weed *Vallisneria americana* and *Egeria densa*. The dominance of the submerged invasive species has noticeably increased over the past 15 years. Additionally, Krogh *et al*, reported the native plants *Ceratophyllum demersum* also in large numbers.

Aquatic habitat connectivity for the Hawkesbury Nepean River has been mapped for the Hawkesbury Nepean River Health Strategy. The HNCMA and DPI Fisheries have been working together to improve the condition of aquatic habitat in priority zones.

Riparian vegetation is an important (and noticeably largely absent) component of the Upper Hawkesbury River estuarine ecology due to its role in bank stabilisation, provision of habitat (including in stream snags) and contribution to productivity through leaf and insect drop (Kimmerikong, 2005). Riparian vegetation is particularly poor throughout the study area. Ongoing

threats include clearing, grazing, flow regulation, erosion from boat wake and weed invasion. Some tributaries retain riparian vegetation of a higher quality such as Webbs Creek and the Colo River. Riparian vegetation in Webbs Creek is in comparatively good condition and shows natural succession from phragmites to mangroves (*Avicennia marina*) to casuarina swamp forest. The Hawkesbury Nepean River Health Strategy has a focus on these areas in relatively good condition.

Large freshwater back-swamps and lagoons occur on the floodplain. This includes Pitt Town Lagoon and Long Neck Lagoon. Both provide significant bird habitat and are listed on the register of the National Estate. Further downstream of Sackville the steep sandstone cliffs prevent wetland formation.

Important indigenous freshwater fish species including Macquarie perch (*Macquaria australasica*), and the Australian grayling (*Prototroctes maraena*) have been recorded in the Hawkesbury-Nepean catchment, with pressures such as habitat degradation, competition, and predation from introduced fish species affecting their populations. Three threatened species were also recorded in the catchment: Silver perch (*Bidyanus bidyanus*), Murray cod (*Maccullochella peelii peelii*), and Trout cod (*Maccullochella macquariensis*) are found in the Hawkesbury-Nepean catchment as a result of stocking. Key threatened estuarine species, including the Black Cod (*Epinephelus daemelii*) and the Green sawfish (*Pristis zijsron*), are also likely to occur in the Hawkesbury estuary - both of these species have been affected by commercial and recreational fishing impacts, and the degradation of critical estuarine habitats (DPI Fisheries 2006). Kimmerikong (2005) reports that figures available from recreational bass fishing events suggest that catches of Australian Bass per unit effort have declined.

DPI Fisheries (2006) also report that the estuary has an array of aquatic macroinvertebrates including insects, prawns, crayfish and freshwater mussels. Both the threatened Adams emerald dragonfly (*Archaeophya adamsi*) and Sydney Hawk dragonfly (*Austrocordulia leonardi*) have an expected distribution within the Hawkesbury-Nepean catchment, with records indicating their presence in the lower subregion of the catchment. These rare dragonflies have only been recorded on limited occasions, with activities such as habitat degradation and water pollution significantly affecting their populations. Over 60 species of frogs are also found in the region including several threatened species such as the Giant burrowing frog, the Green and golden bell frog, the Giant barred frog, the Red-crowned toadlet, the Stuttering frog, Littlejohn's tree frog and the Booroolong frog. This indicates how important water levels are for estuary health.

2.1.5 Human Influences, Past and Present

The Upper Hawkesbury River Estuary and its upstream tributaries have been crucial to human settlements for a very long time. The first known inhabitants of the Hawkesbury Nepean River were the Darug people. The Hawkesbury River was known as Deerubbin by the Darug people and would have been an important source of water, fish, eels, mussels, water birds and as a method of transportation. Aboriginal occupation of the Hawkesbury River region is believed to have begun at least 30,000 years ago, becoming most intense from 4,000 years ago (WRL, 2003).

There are likely to be many of sites with Aboriginal Heritage value remaining within the study area. A plan of management for Holmes Drive Reserve is currently in draft. This area has an obelisk sandstone memorial dedicated to '"the Aborigines of the Hawkesbury for whom this area was originally reserved'' (unveiled in 1952).

The Hawkesbury region was explored early in the settlement of the continent by Europeans, with Governor Phillip himself leading an expedition up the river, and the Hawkesbury was opened for settlement in 1794 (WRL, 2003). In 1789, the first exploration party to the Hawkesbury area found extensive evidence of Aboriginal occupation along the banks of the river including "hunting huts", bark canoes, marks on trees, possum traps and bird decoys (Land Arc, in draft).

By 1810, there were 2,389 settlers in the Hawkesbury district. Development and agriculture in the Hawkesbury-Nepean catchment continued steadily throughout the 19th century (WRL, 2003).

Railway links to these towns, known as the Main Northern Railway, followed shortly after their settlement, beginning with a station to Penrith in 1863 and reaching Brooklyn in 1887. Between 1826 and 1836, the Great North Road to the Hunter Valley was built, to connect Sydney with the Hunter River valley and Newcastle. The road was constructed using convict labour, and spanned 264 km, crossing the river at Wiseman's Ferry. Unfortunately, even as it was completed, the route was unpopular as it had no permanent watercourses and bypassed many settlements. A 43km long section of the Old Great North Road remains relatively intact, and preserved within Dharug National Park (NPWS, 2004).

Today, the fresh water of the Hawkesbury Nepean catchment provides most of the drinking water for Sydney's population of almost 5 million people and irrigates the agricultural industries that supply the majority of their fresh food (DECC, 2009). The wider river also supports numerous extracting, manufacturing and processing industries.

The Upper Hawkesbury River Estuary is utilised extensively for a range of different activities. Water skiing and wakeboarding are very dominant waterway uses between Windsor and Wisemans Ferry. Kayaking is popular in the more natural areas such as the Colo River and Webbs Creek. The Willow Warriors combine conservation with adventure, paddling the Hawkesbury and removing weed species. Prawn trawlers operate downstream of Sackville. This involves the harvesting of prawns, squid and fish (Kimmerikong, 2005). The prawn trawl fishery is restricted to waters downstream of the vehicular ferry crossing at Lower Portland (upstream of Wisemans Ferry) to the entrance of the South Pacific Ocean (Kimmerikong, 2005). Commercial fishers in the Hawkesbury River numbered 80 in 1999-2000, and commercially licenced fishers from other areas may also work in the River (WRL, 2003). There are three ferry operations at Sackville, Lower Portland and Wisemans Ferry. Due to the predominantly private ownership of riparian areas, public recreation along the Hawkesbury Estuary is very limited. The Hawkesbury Nepean River Health Strategy considers this issue and has prioritised actions to rehabilitate publically owned lands to increase their viability. Further, in areas where the riverbank is publically owned, adjacent private landholders have encroached onto public land with, for example, buildings, barbeques, access ways and gardens.

Publically owned reserves for the study area are limited and are shown in Figure 2-5 and Figure 2-6.

A key pressure on the Upper Hawkesbury Nepean Estuary is riparian land uses. Riparian land uses directly impact on the waterway by changing bank morphology, contributing pollutants (both directly and through removing vegetation filters) and introducing exotic species. The next stage of this project will be assessing the threats to the Estuary and developing management strategies to minimise their impact. Some of the riparian land uses that have a significant impact on the waterway that will be considered in this assessment include:

- private caravan parks, many of which have individual water access for each site;
- Turf farms
- Golf courses
- Horse farms
- Private residences with mown lawns to the water's edge.

Section 4.4, and specifically Table 4-3 lists the pressures and issues identified to date. This list is expected to be expanded through community and stakeholder consultation.

The wider catchment has an extensive array of land uses, all of which have some impact on the quality and quantity of water that reaches the Upper Hawkesbury River Estuary. These will also be considered in the threat assessment.

2.1.6 Climate Change Considerations

The Upper Hawkesbury River Estuary is already subject to a variable climate. Climate change is predicted to have some impacts on rainfall and hydrology, however underlying trends are likely to continue. Trends in water quality and hydrology in the wider Hawkesbury Nepean River and Catchment have been shown to be influenced by longer term cycles such as the El Nino Southern Oscillation (ENSO) and Interdecadal Pacific Oscillation (IPO) and human induced changes such as river regulation (further discussed in Section 2.3.3). Analysis of the available rainfall data through the Hawkesbury Nepean Environmental Monitoring Program show the cyclic periods of higher and lower rainfall and flow over the last 100 years (DECC, 2009). The implications of climate change remain uncertain, however underlying trends in rainfall and hydrology are likely to continue (DECC, 2009).

2.1.6.1 Sea Level Rise

The former NSW Government's Sea Level Rise Policy Statement recommended that an increase in mean sea level above 1990 levels of 0.4 m by 2050 and 0.9 m by 2100 be used in all coastal assessments in NSW. The NSW Government has since repealed this policy, and recommended that local councils "have the flexibility determine their own sea level rise projections to suit their local conditions" (NSW Environment and Heritage, 2012). The Office of Environment and Heritage (OEH) has recommended that councils consider sea level rise projections that are 'widely accepted by competent scientific opinion', or indeed consider a range of probable projections (OEH, 2012).

The NSW Government's former sea level rise policy benchmarks were based upon IPCC (2007) and CSIRO (2007) reports (see DECCW, 2009), both of which provide the most current projections that are 'widely accepted by competent scientific opinion'. The former sea level rise benchmarks were calculated as the addition of the upper range of projections from:

- the most recent IPCC (2007) projections for sea level rise (ranging from 0.18 – 0.59 m by 2090-99),
- the IPCC's (2007) assumed linear trend in global ice melt (that was recommended to cause 0.1-0.2 m sea level rise by 2100); plus
- the CSIRO (2007) projections for regional sea level rise by 2100 associated with the East Australian Current on the NSW Coast (of 0.08 to 0.14 m).

The projections for 2100 were compared with the sea level rise trend projections to derive a 2050 sea level rise estimate of 0.4 m (DECCW, 2009).

The rate sea level rise measured over the last century was 1.7 mm/year (Church *et al.*, 2010). The rate of global sea level rise since 1992 is around 3.1 ± 0.4 mm/year (CSIRO/ARECRC, 2012). Figure 2-4 provides a summary of the global measurements and projections for sea level rise since 1990. Figure 2-4 shows that global sea level rise measurements are tracking with the highest sea level rise projections (i.e. 90th percentile projection plus poorly defined ice-sheet contribution). That is, the rate of sea level rise is projected to increase above the 3.1 mm/year that has been measured from 1992 to date. This also indicates that the upper range levels that were used to derive the former NSW sea level rise policy benchmarks are likely to occur by 2100 and are the best estimate projection to adopt for coastal assessment.

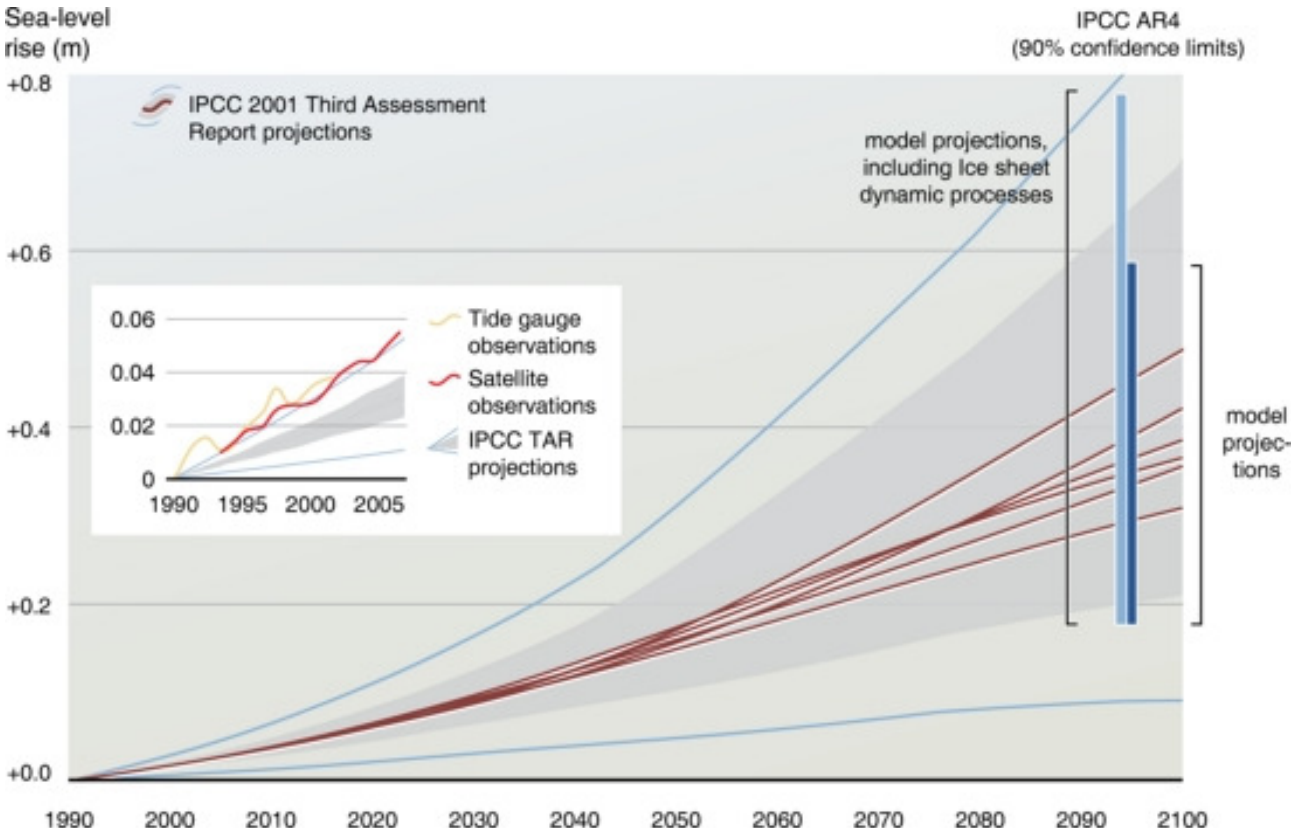

Figure 2-4 Projected and Measured Sea Level Rise to 2100 (source: UNEP/GRID-Arendal*, 2012)

**UNEP/GRID-Arendal (2012) explain for this figure: "the projected range of global averaged sea-level rise from the IPCC 2001 Assessment Report for the period 1990 to 2100 is shown by the lines and shading [grey]. The updated AR4 IPCC [2007] projections made are shown by the bars plotted at 2095, the dark blue bar is the range of model projections (90% confidence limits) and the light blue bar has the upper range extended to allow for the potential but poorly quantified additional contribution from a dynamic response of the Greenland and Antarctic ice sheets to global warming".*

Indeed, there is also a chance that sea level rise may exceed the current projections, and higher sea level rise projections need also to be investigated, albeit as a worst case or rare scenario. Evidence

from the previous interglacial period (some 125,000 years ago during the Pleistocene) indicates that sea levels were some 4-6 m higher than present, and global temperatures were about 3-5 ℃ higher than present (Church *et al*., 2010). It is thought that the higher sea levels at that time were due to contributions from the Greenland Ice Sheet and the Antarctic Ice Sheet to a lesser degree (Church *et al*., 2010 citing Otto-Bliesner *et al*., 2006).

Over the next century, sea level rise of 1.4 m by 2100 (i.e. a 0.5 m higher or 50% faster rate of rise than the upper level projections for 2100), equating to 0.7 m by 2050 (assuming a linear rate of increase to 2100) are a reasonable scenario to adopt as a worst case. The higher than projected sea level rise also provides for investigation of impacts where sea level rise occurs faster than projected.

Detailed modelling of how this sea level rise might translate and influence water levels and salinity as far upstream as the study area have not been undertaken, but a number of general trends are likely to occur.. In response to projected sea level rise, and in the absence of increased environmental flows, the salt wedge will migrate further upstream. This has the potential to impact on riparian vegetation and wetland areas such as freshwater back swamps. Mangroves and other estuarine species are also likely to migrate further upstream. Aquatic fauna will also shift in response to the new salinity distribution. An increase in the frequency of no pump days would be experienced as salinity levels of 5ppt would be exceeded on a more regular basis. Sea level rise is likely to have significant impacts on water quality, estuarine ecology and human uses of the study area.

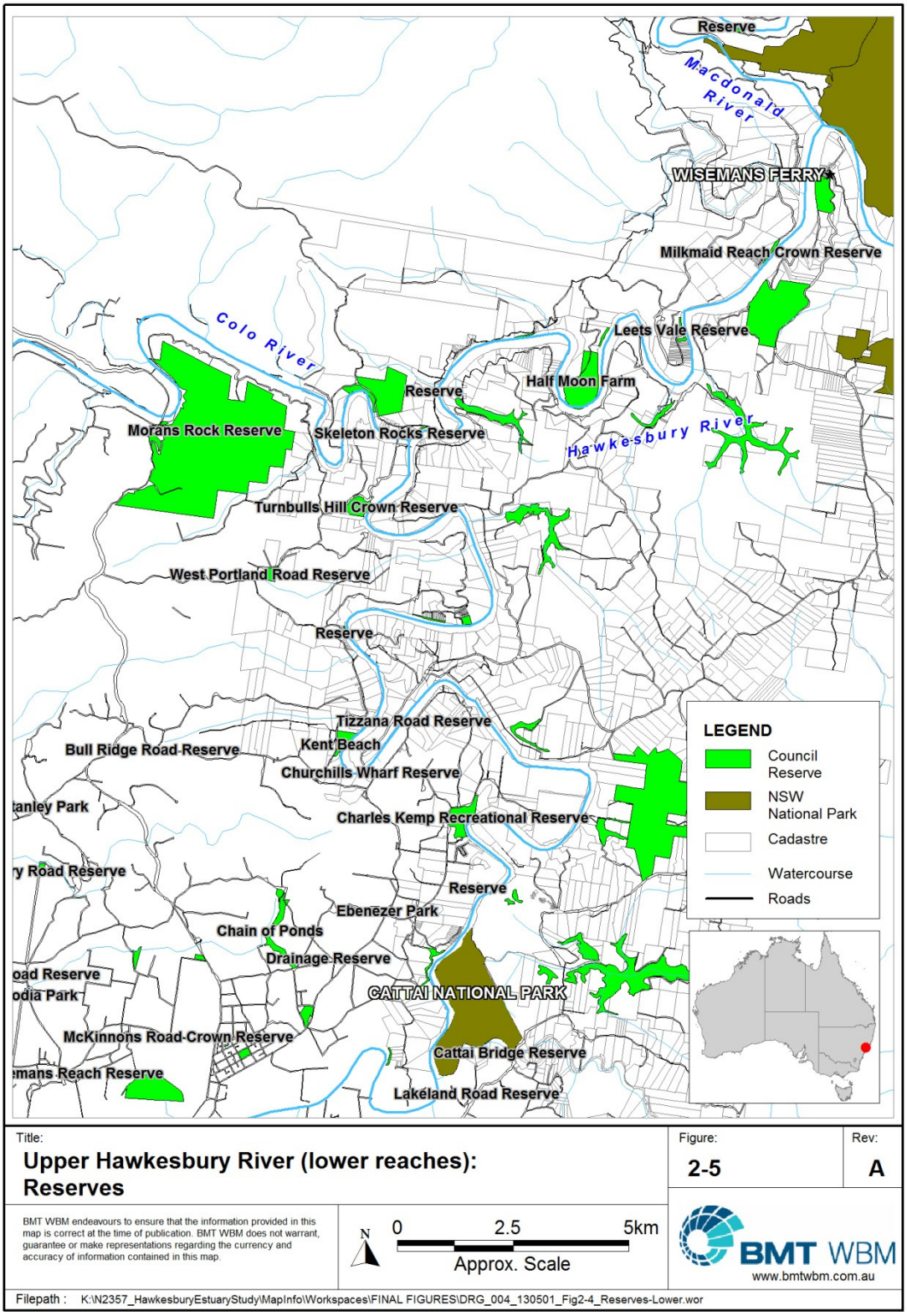

Figure 2-5 Reserves in the lower reaches of the Study area

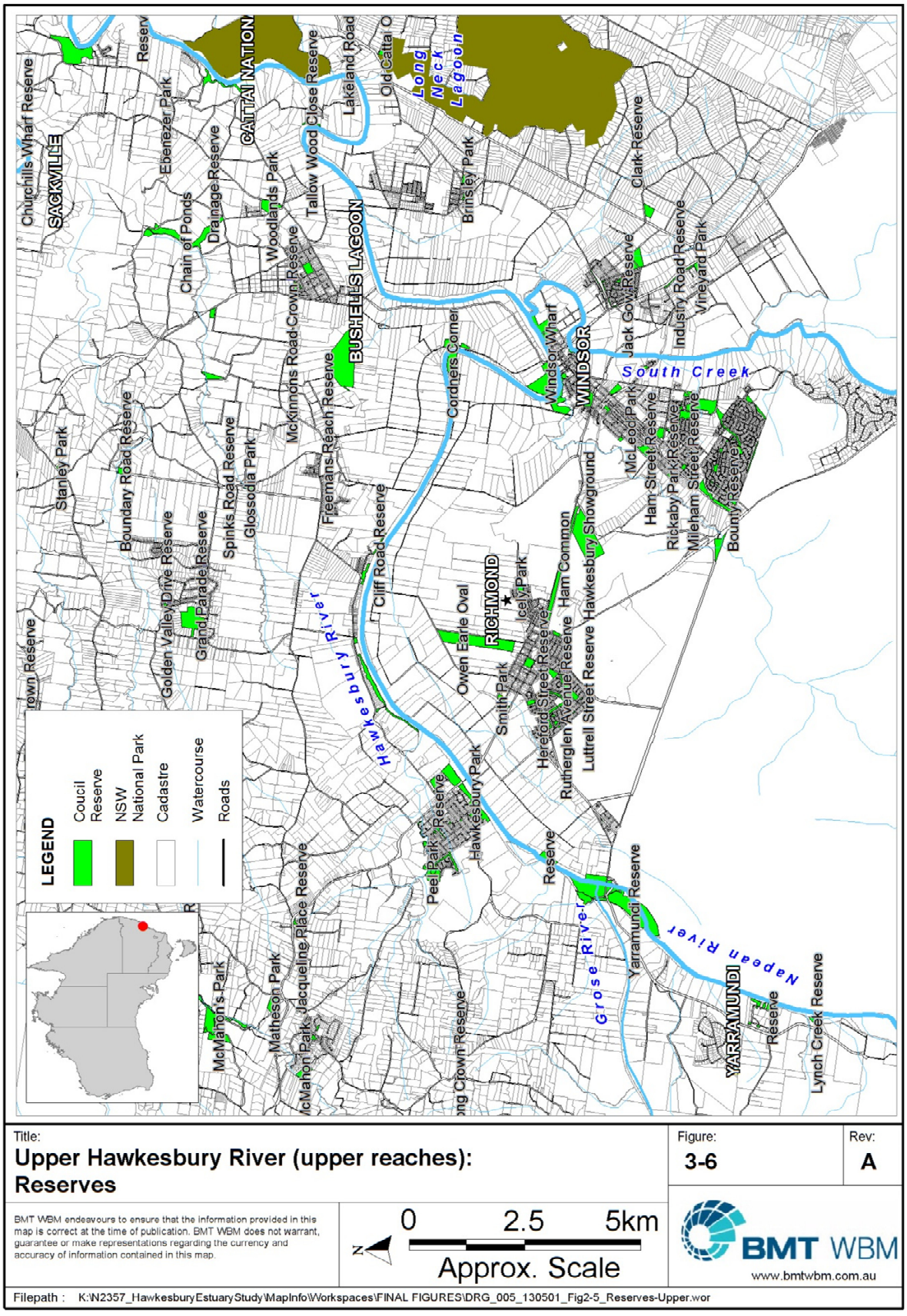

Figure 2-6 Reserves in the upper reaches of the study area

2.2 Estuary Health

The CZMP Guidelines (DECCW, 2010), require an assessment of estuary health. Estuaries are highly dynamic, complicated ecosystems and the conditions that define a "healthy" status can vary greatly between locations. Estuaries are an ecotone between tidal and fresh water. There is a broad range of chemical, biological and hydrodynamic conditions that may exist within the Upper Hawkesbury River, which makes it very difficult to apply a single applicable definition or scale for measuring estuary health.

Estuary health has a different meaning to different people. In particular, Pinto *et al*. (2012) explored the meaning of river health of the Hawkesbury Nepean with community members. This exercise showed that many of those included related river health to its ecological integrity, visual appeal, hydrologic balance and ability to meet community needs. The NSW Coastal Zone Guidelines do not give a specific definition for estuary health, however the manual requires a CZMP to include, amongst other things:

- A description of the pressures affecting estuary health status and their relative magnitude,
- An estuarine monitoring program, consistent with the NSW Natural Resources Monitoring, Evaluation and Reporting (MER) strategy.

Complicating this issue of defining estuary health is the availability of data to assess health status. Our understanding of these complex systems and their variability continues to improve, and with it, our definition of those parameters that best describe estuary health. In addition to the availability or lack thereof of data, the types of parameters recorded in the past may not necessarily provide a useful indicator of estuary health.

The Hawkesbury Nepean River Health Strategy adopts a definition of river health which has evolved through earlier projects carried out in the study area. This definition is:

"A healthy, productive and diverse catchment and river system, which recognises the need to balance environmental, economic and social values, including:

- Clean, healthy surface and groundwater - suitable for continued productivity and for people to use and enjoy
- Diverse native plants and animals with productive and protective vegetation and soil in ecological balance
- The cultural heritage values within the catchment are acknowledged, respected, maintained and enhanced
- The beauty and natural processes of the catchment are protected while providing for social and economic needs
- Everyone is working together – individuals, community groups, business and government"

2.3 Interactions between processes

The Upper Hawkesbury River Estuary is a dynamic environment that fluctuates according to the relative input of key factors including catchment inputs, morphology and tidal influence. Key defining factors are water quality, ecology and sediments.

The key processes operating in the Upper Hawkesbury River Estuary have been simplified into Figure 2-7. Also indicated on this figure are the interactions between processes. These interactions are the focus of the information review provided in the following sections.

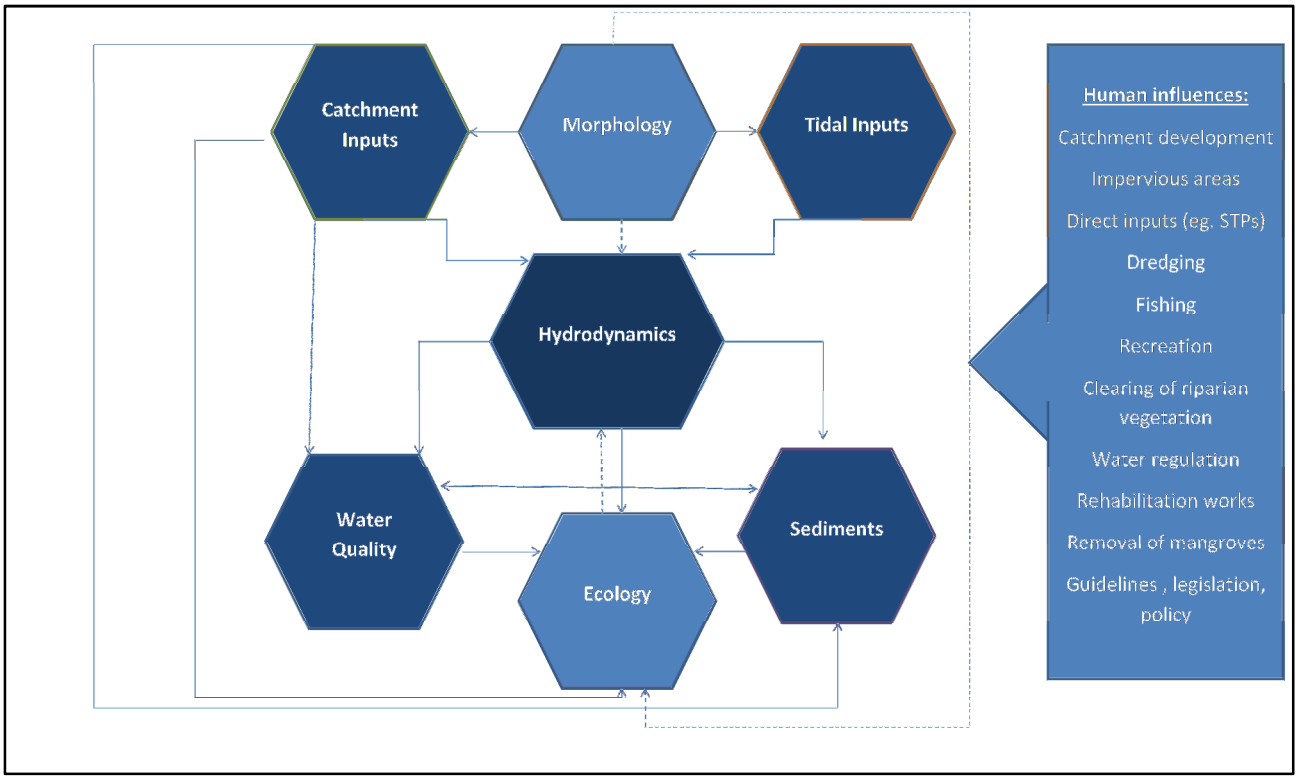

Figure 2-7 Simplified diagram of processes and interaction operating in the Upper Hawkesbury River Estuary

To help navigate the estuary with the detailed descriptions included in this section, the following Figures of four discrete reaches have been included.

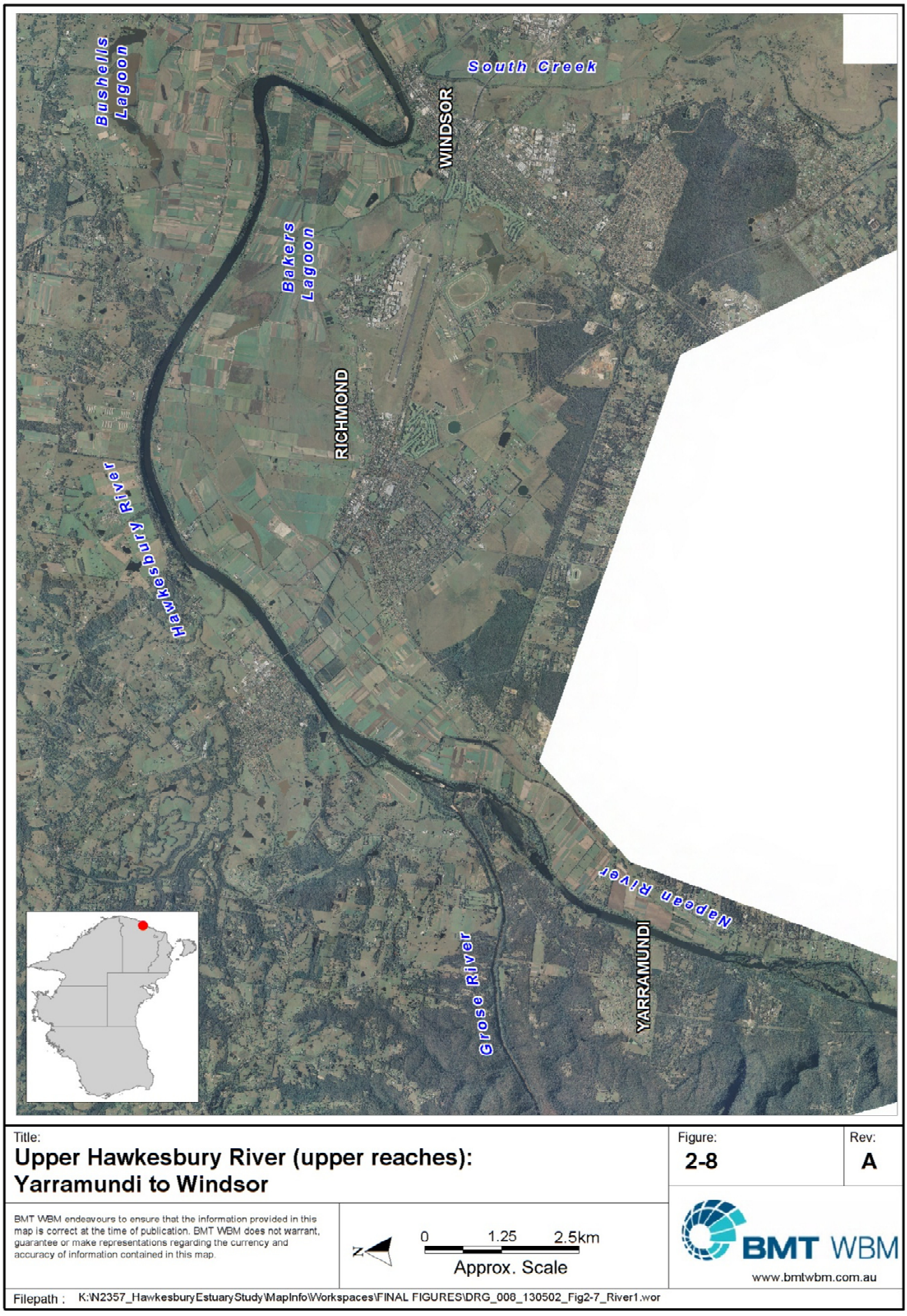

Figure 2-8 The study area from Yarramundi to Windsor

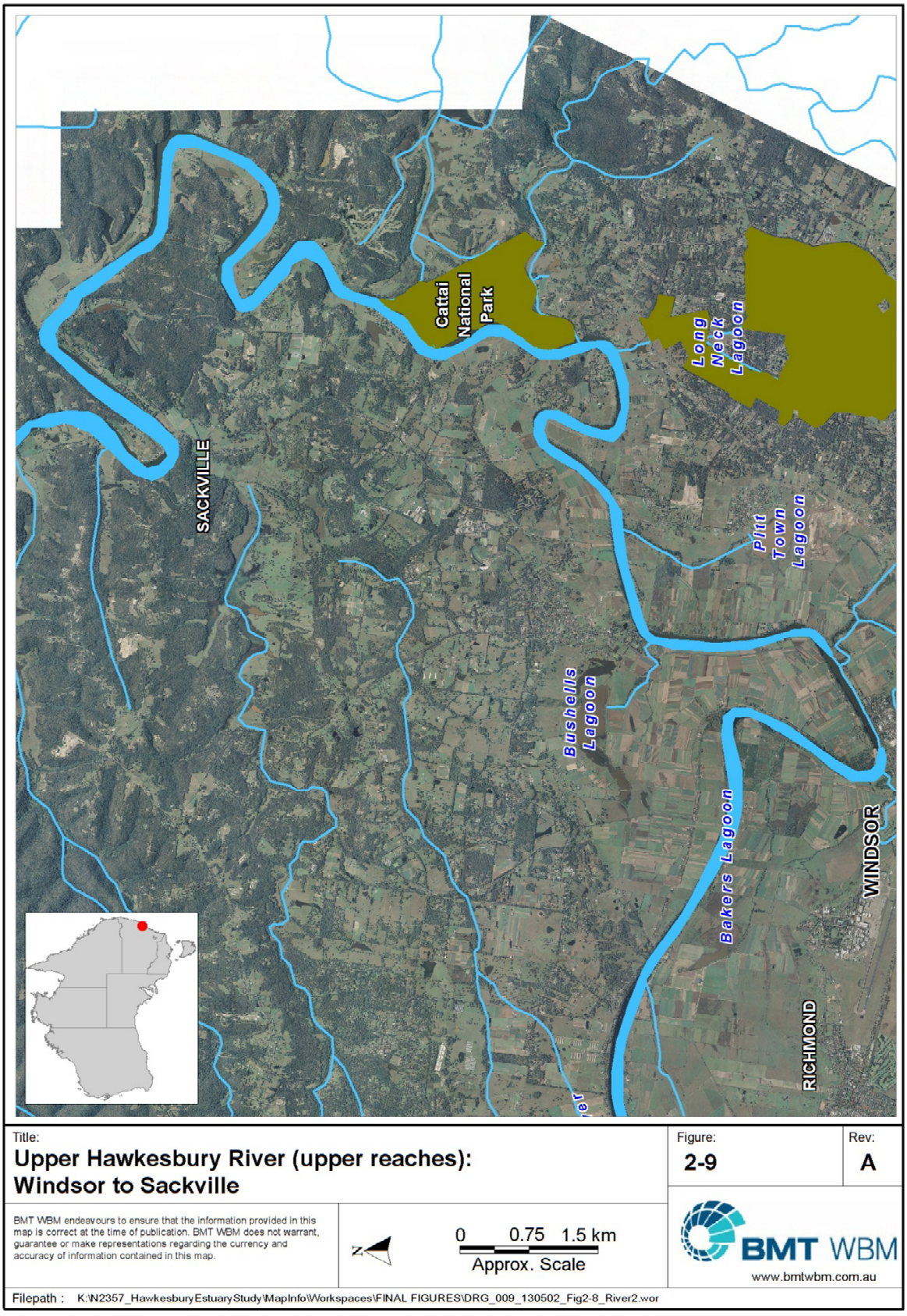

Figure 2-9 Windsor to Cattai National Parks

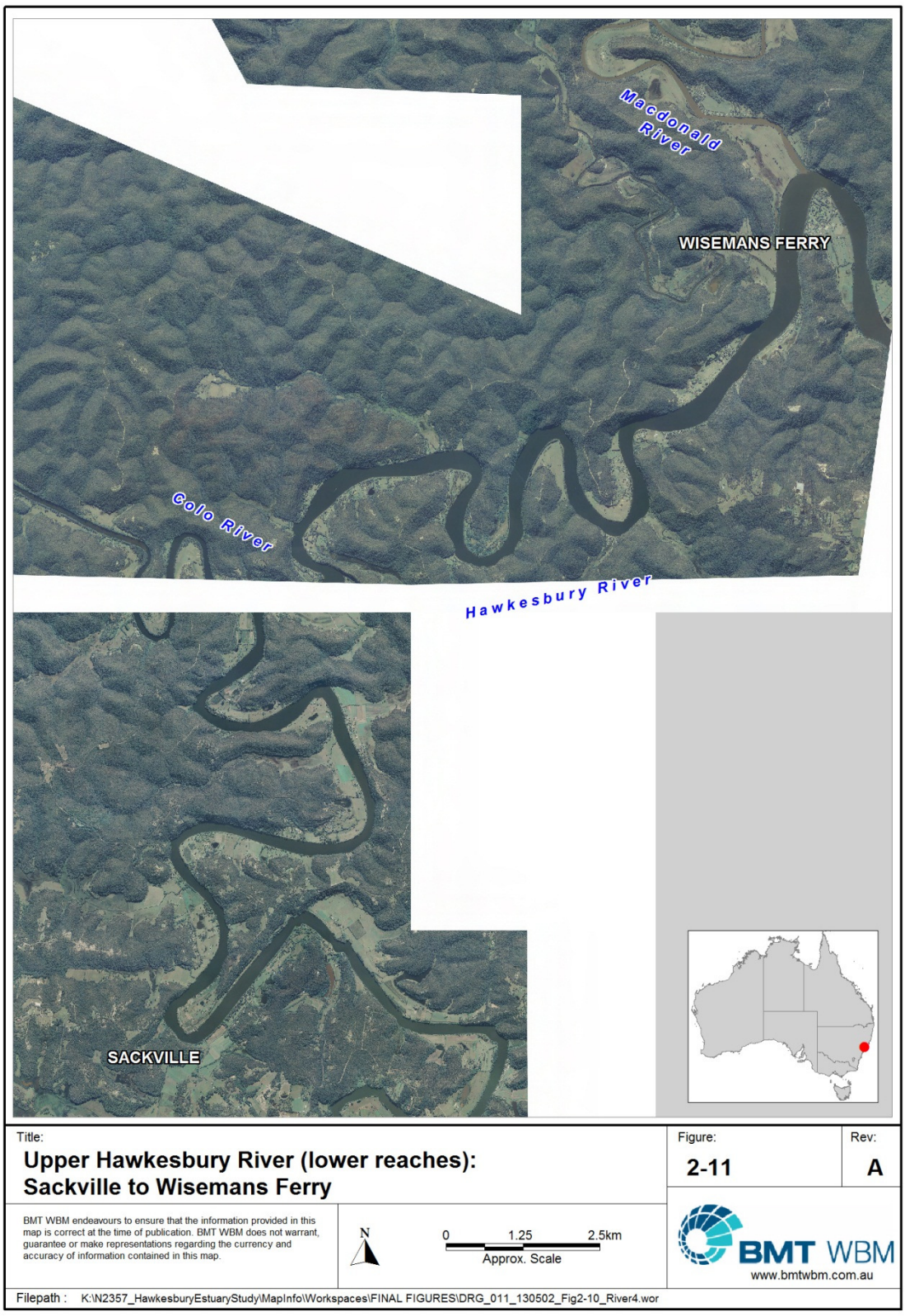

Figure 2-10 The study area from Wisemans Ferry to Sackville

2.3.1 Estuary Morphology and Tidal Processes

The long length, narrowing width and relatively large depth of the Hawkesbury River between the ocean and Yarramundi affects the propagation of tides through the Upper Hawkesbury River Estuary. As the river narrows from the ocean entrance, tidal range is amplified.

Tidal amplification occurs over most of the length of the Hawkesbury River, the tidal range at Wisemans Ferry, is 16% greater than the ocean range. The tidal range at Windsor, which is 123 km upstream from the estuary mouth, is slightly less than ocean range. Upstream of Windsor, the presence of coarse shallow sand shoals abruptly reduces tidal range to 26% of the ocean value (OEH, 2013).

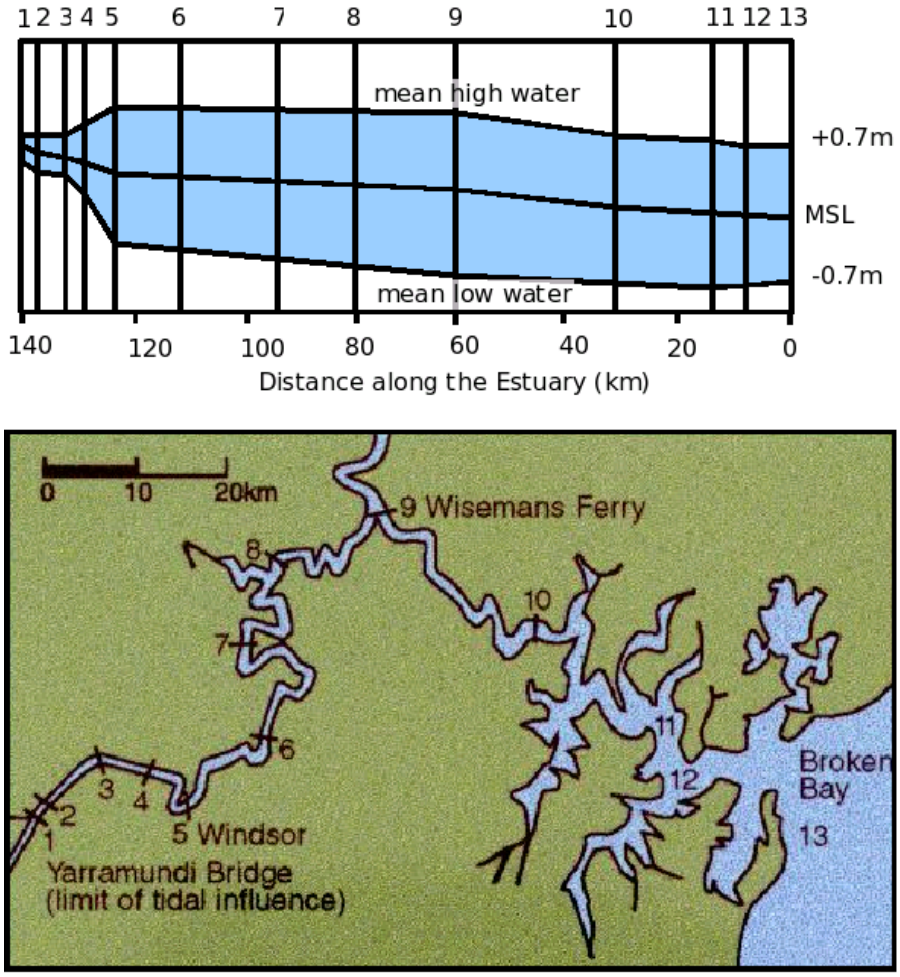

Figure 2-11 Tidal characteristics of the Hawkesbury River Estuary

Source (OEH, 2013)

2.3.2 Tidal Processes and Estuary Hydrodynamics

Tidal water enters the Hawkesbury River and acts as a restricting force to downstream fresh water flow. As the fresh seawater moves up the estuary, the tidal range is amplified due to narrowing geomorphology. Although freshwater flows have been highly restricted, the net movement of water remains the downstream direction.

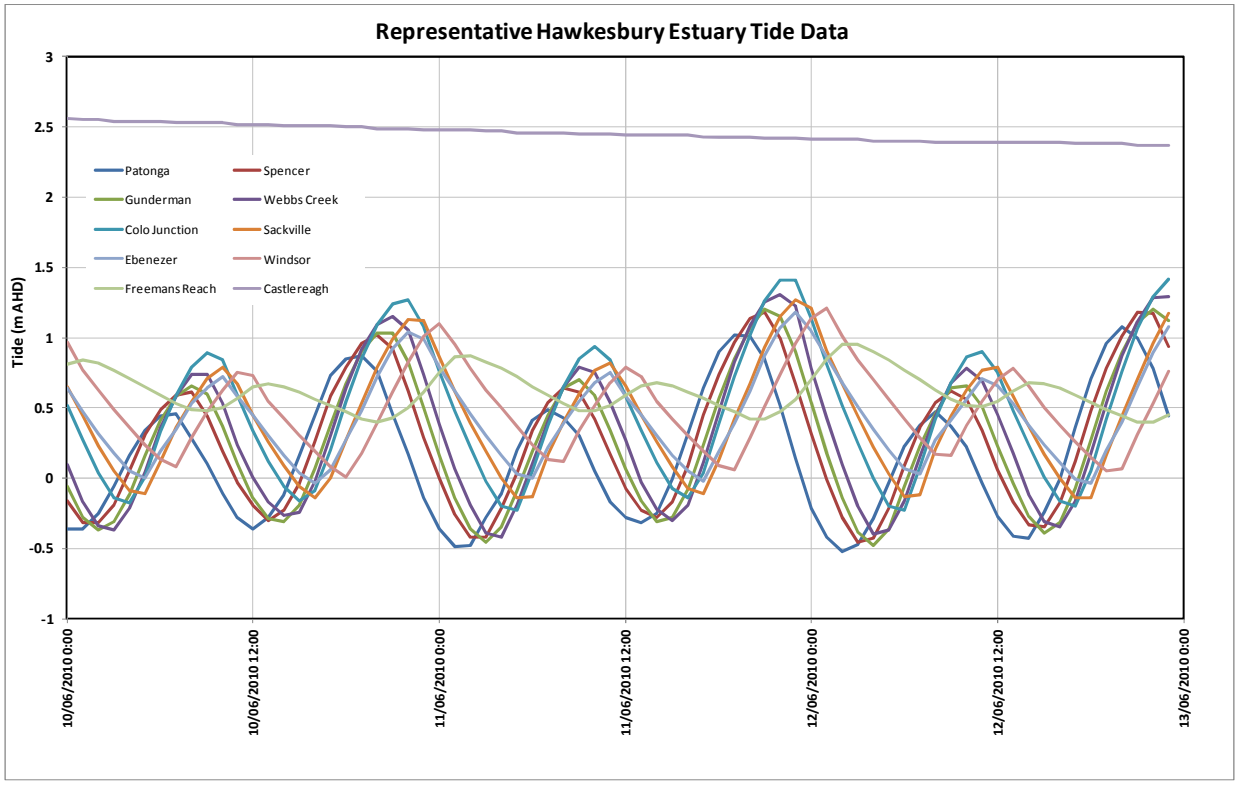

Figure 2-12 Representative Hawkesbury Tide Data

2.3.3 Catchment & Direct Inputs and Estuary Hydrodynamics

During high flows generated from the whole Hawkesbury-Nepean River catchment, there is a significant flow of freshwater, which provides a net downstream flow through the study area.

The assessment of available river gauge and water level monitoring for the Hawkesbury shows that there have been cyclic periods of higher and lower rainfall and flow (DECC 2009). Some of these variations can be attributed to the El Nino Southern Oscillation (ENSO) and Interdecadal Pacific Oscillation (IPO) and some to human induced changes.

There is more than 100 years of flow data available for Penrith Weir. Observations of this data set, along with comparisons for the unregulated Colo River (which also has a significantly long data set) as well as the SOI over the period gives an insight into the results of drought and government policy on flows. While the present day river flow levels are much less than the long term average, river regulation is not the sole factor involved as this decline is also observed in the Colo River. This is shown in Figure 2-13, which is taken directly from DECC (2009).

Consistent low flows have altered the salinity of the river. Salinity levels are highly variable from the tidal limit at Yarramundi downstream, more so than would be expected naturally. Overall the intrusion of saline water upstream has increased due to river regulation and water abstraction (Kimmerikong 2005).

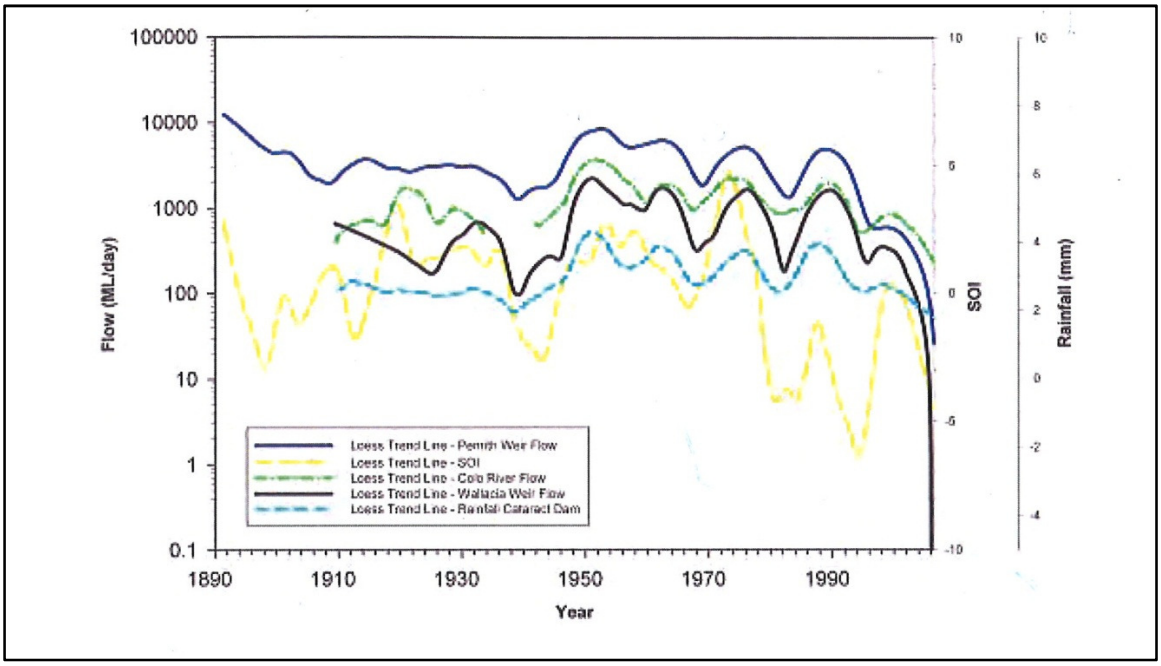

Figure 2-13 Smoothed trend lines for flow at Penrith Weir, Wallacia Weir and Colo River; rainfall (Cataract Dam); and the Southern Oscillation Index (SOI)

2.3.4 Estuary Hydrodynamics and Water Quality

Variations in flow over the period of available data show that there have been cyclic periods of higher and lower rainfall and flow (DECC 2009). Many water quality variables are significantly affected by flow so assessments of changes and or trends in water quality need to take this into account.

The water quality of the Hawkesbury River is influenced by flows from local catchments, flows from treated effluent, spills and environmental releases from storages and highly treated water from Sydney Water. Low flow has resulted in longer residence times, which coupled with high nutrient loads has created conditions conducive to algal blooms and allowed aquatic weeds to outcompete native species (Kimmerikong 2005). This in turn has impacted on the populations of invertebrates and fish stocks throughout the estuary. The formation of stratification may also occur under these conditions, resulting in changes to water quality conditions that favour nutrient release from sediments (DECCW 2010).

Windsor to Cattai National Park is a channel dominated reach of moderate depth with strong tidal influences. It receives inflows from major tributaries South and Cattai Creeks whose water quality is largely influenced by wastewater treatment plant (WWTP) inputs and diverse landuses. As such, South Creek (and its tributary Eastern Creek) together with Cattai Creek provide a major source of nutrients into the Hawkesbury River (Krogh *et al* 2009).

The Cattai National Park to Cumberland Reach is also dominated by a channel of moderate depth with strong tidal influences. It receives inflows from the smaller tributaries of Little Cattai and Currency Creeks.

The Cumberland Reach to Wisemans Ferry is notably deeper than the upstream reaches. The reach is influenced by strong tidal currents and the saltwater interface is located in this reach. This reach of the river receives inflow from the Colo River.

Flows influence water quality. Generally the Yarramundi to Windsor and the Cumberland to Wisemans Ferry reaches receive the greatest tributary inputs, with smaller contributions in the Windsor to Cattai National Park reach. Algae and cyanobacteria are also a common feature in these reaches (particularly between Windsor and Wisemans Ferry) because of prolonged low flows (due to river regulation) coupled with point and diffuse source nutrient discharges with point source discharges dominating water quality during periods of prolonged low flows, as well as water temperature and associated light regimes, which all interact together to give favourable conditions for the development of blue-green algal blooms (Krogh *et al* 2009). These blooms impact on the ecology of the river system by competing for light and other limiting resources, causing fluctuations in dissolved oxygen concentrations and pH, and producing toxins (Kimmerikong 2005). The lower reaches have a notably larger volume of water with smaller inflows, therefore water residence times tend to increase with distance downstream.

2.3.5 Catchment and Direct Inputs and Water Quality

Pollutant loads derived from the catchment and/or direct inputs will contribute to the water quality of the estuary. Resulting water quality is a function of the quantity and quality of the pollutant input and the tidal flushing capacity of the location of the input. Areas closest to the discharge location will be most degraded. In areas of poor tidal flushing, pollutant gradients away from the source will be relatively shallow, particularly when compared to pollutant gradients for inputs in well-flushed sections of the study area.

Catchment inputs will mostly tend to occur during wet weather events, while direct inputs could occur during either wet or dry weather conditions. During flood conditions in the river, the water quality of the study area will be dominated by catchment runoff from the upstream areas, which may include high concentrations of suspended sediment, nutrients and possibly algae.

Consideration of the long term water quality monitoring data by DECC (2009), has shown improved water quality in many areas throughout the Hawkesbury-Nepean River (specifically decreases in filterable and total phosphorus).

<u>Yarramundi to Windsor</u>

Monthly water quality monitoring undertaken by Sydney Catchment Authority since 2000 indicates that the water quality is generally good with low turbidity and metal concentrations. pH is generally within guideline limits and whilst total phosphorus concentrations vary, they are largely compliant with relevant guidelines. Dissolved oxygen levels were compliant for approximately 50% of the time, falling outside both the lower and upper recommended guideline limits (SCA 2012). All species of nitrogen frequently exceed the recommended guideline limits. Long term water quality was near 100% compliance for pH, turbidity, total and filterable phosphorus concentrations (Krogh *et al* 2009).

Krogh *et al* (2009) compared long term water quality at sites with the ANZECC/ARMCANZ (2000) guidelines. During 2003-2007, nutrient concentrations were more compliant at North Richmond (monitoring site N42) with total nitrogen concentrations exceeding the relevant guidelines

approximately 50% of the time, compared to Yarramundi and downstream at Windsor where concentrations exceeded the guidelines more than 75% of the time. Recent monitoring by the SCA during 2009-10 and 2010-11 also indicate that North Richmond (N42) generally had lower median concentrations of both TN (0.46mg/L in 2009-10 and 0.68mg/L in 2010-11) and TP (0.007mg/L in 2009-10 and 0.011mg/L in 2010-11), than Yarramundi, (monitoring site N44).

Overall the Yarramundi to Windsor reach of the Hawkesbury-Nepean River which largely receives nutrient loads from the Nepean River and has the lowest concentrations of dissolved inorganic nutrients (N and P). N and P appear to be assimilated into the system largely due to the presence of the exotic macrophyte *Egeria densa*. This same reach also shows low concentrations of chlorophyll-*a* and total suspended solids, compared with downstream reaches (Gruber *et al.,* 2010).

Whilst long term median conductivity levels remain low, overall they appear to be increasing although the magnitude is not large, and levels remain within the ANZECC/ARMCANZ guidelines (Krogh *et al.,* 2009). Conductivity results from the SCA monitoring program (2010-11) have recorded median conductivities ranging between 0.163 and 0.318ms/cm at Yarramundi (N44) and 0.073 and 0.282ms/cm at North Richmond (N42) (SCA 2012).

Windsor to Cattai National Park

The poorest water quality in the Hawkesbury River occurs in this reach particularly between the inflows of South Creek and Cattai Creek due to high nutrient concentrations. These have historically resulted in infestations of aquatic weeds (*Salvinia molesta* and *Egeria densa*) and persistent algal blooms (Kimmerikong 2005). Bacterial contamination also contributes to poor water quality. The poor water quality is largely due to effluent from WWTPs that discharge into South Creek and Cattai Creek, and the intensive agricultural areas that contribute high nutrient loads to the river, particularly during wet weather (Kimmerikong 2005).

Discharges from tribuatries are the main source of nutrients, with landuses widely varied but reflective of significant nitrogen and phosphorus loads. In particular water quality in South Creek and Cattai Creek is poor.

The Windsor to Cattai National Park reach receives inflows from tributaries (South, Eastern and Cattai Creeks). South Creek has a WWTP located a short distance upstream of the confluence with the Hawkesbury River. These tributaries have the highest total nitrogen and total phosphorus concentrations and the largest proportions of particulate nitrogen and phosphorus compared to other tributaries and the mainstream, although over the years nutrient contributions have decreased as upgrades in the nitrogen and phosphorus removal capacity at WWTPs has occurred (Gruber *et al* 2010). Water quality in this reach is routinely measured at the Hawkesbury River at Wilberforce (monitoring site N35) which is downstream of the South Creek inflow. Median total nitrogen concentrations of 0.85mg/L and 0.565mg/L and median total phosphorus concentrations of 0.021mg/L and 0.025mg/L were recorded in 2009-10 and 2010-11 respectively (SCA 2012, SCA 2011). Median concentrations appear to have increased at this site during 2011-12 with total nitrogen concentrations of 0.745mg/L and total phosphorus of 0.0565mg/L recorded (SCA 2013).

Water quality data collated between 2008 and 2010 shows trends both spatially and temporally. Dissolved inorganic nutrients increased dramatically in the Windsor to Cattai National Park reach compared to upstream. Dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP)

varied seasonally and spatially. Concentrations of DIN were highest throughout winter months, which is also when concentrations varied spatially (Gruber *et al* 2010).

Chlorophyll-*a* concentrations are at least three to five times higher in this reach than upstream with more frequently occurring potentially toxic cyanobacteria (Krogh *et al.,* 2009). Krogh *et al*., (2009) also found that chlorophyll-*a* concentrations were higher at Wilberforce (including during spring), with more than 75% of samples exceeding 5µg/L compared with 50% of samples at the two upstream sites. Similarly to chlorophyll-*a*, TSS concentrations were highest in this reach.

Conductivity was generally higher in this reach at Wilberforce (median 0.119ms/cm, 0.507ms/cm and 0.29mS/cm) (SCA 2011, SCA 2012 and SCA 2013) compared to upstream possibly due to runoff and wastewater discharges than tidal influences as conductivity decreases further downstream (e.g. at Lower Portland). Freshwater input from the Colo River is significant.

Overall the Hawkesbury River at Wilberforce portrays poor water quality due to a variety of landuses including contribution of nutrients from runoff of fertilised grasses and WWTP inputs.

Cattai National Park to Cumberland Reach (including Sackville)

Water quality in this reach is often poor due to bacterial contamination and in particular, algal blooms. Water quality of the Hawkesbury River at Sackville is known to have high dissolved oxygen concentrations, most likely due to the algal activity prevalent in this reach. pH levels are slightly higher than other sites, and turbidity is generally low.

Trend analysis undertaken by Sydney Water under the replacement flows project, has shown that nutrient concentrations have decreased over time (1994-2011). The results show that total nitrogen concentrations have decreased by 48% and dissolved inorganic nitrogen by 86%. Concentrations of phosphorus (total and filterable) have also decreased by 40% and 42% respectively (Sydney Water 2012). Despite the decreased trends in nutrients, levels are still elevated and exceed respective ANZECC/ARMCANZ (2000) guidelines values. Whist decreasing concentrations of nutrients have been recorded over the long term, annual temporal variations are the most variable in this reach, particularly for concentrations of dissolved organic nitrogen and dissolved organic phosphorus during autumn (Gruber *et al* 2010).

Similarly, chlorophyll-*a* concentrations have decreased over time, but remain elevated, with a median concentration of 23.6ug/L recorded in 2010-2011, the highset among all reaches of the Hawkesbury River (Sydney Water 2012). Krogh *et al* (2009) reported long term median chlorophyll-*a* concentrations to be the highest in this reach (most notably in spring).

Cumberland Reach to Wisemans Ferry (including Lower Portland and Colo River inflow)

The water quality of this reach is measured at Lower Portland and Wisemans Ferry, and is influenced by inflows from the Colo River which portrays good water quality which generally complies with the ANZECC/ARMCANZ (2000) guidelines. Monitoring by the SCA over the past few years has generally shown that water quality is similar between the sites, although turbidity tends to be slightly higher and dissolved oxygen and pH lower at Wisemans Ferry. Total suspended solids are lowest in this reach.

Median nutrient concentrations are similar within this reach with total nitrogen concentrations of 0.485mg/L and 0.44mg/L recorded in 2011-2012 at Lower Portland and Wisemans Ferry respectively, although these are higher when compared to previous years. In 2009/10 and 2010/11 median total nitrogen concentrations of 0.36mg/L and 0.39mg/L were recorded at Lower Portland and 0.39mg/L at Wisemans Ferry (SCA 2011, SCA 2012 and SCA 2013). Median total phosphorus concentrations were also higher over the last 12 months with concentrations of 0.024mg/L and 0.0295mg/L recorded at Lower Portland and Wisemans Ferry respectively (SCA 2013). These concentrations were approximately 1.5 times higher than median concentrations recorded in 2009/10 and 2010/11.

Nutrient transformation continues to occur in this reach as it enters the system upstream as DIN or DON, with DIN generally the largest fraction, but leaves the system with DON representing the largest fraction. The greatest degree of nitrogen transformation occurred during the months of spring, whilst autumn showed the least transformation (Gruber *et al* 2010). With respect to phosphorus, the largest fractions were recorded in spring and autumn when the greatest transformation also occurred with DIP and DOP transforming to particulate phosphorus when leaving the system. Overall the nutrient transformation in this reach appears to be dominated by bacteria (Gruber *et al* 2010). The lowest concentrations of dissolved inorganic nutrients were recorded in this reach (Gruber *et al* 2010). Despite the reduced nutrient concentrations, algal blooms can still be prevalent although less frequent as far down as Wisemans Ferry (Kimmerikong 2005).

2.3.6 Estuary Hydrodynamics and Sediments

The characteristics of bed sediments within the estuary are linked to the hydrodynamic processes. Estuarine hydrodynamics are responsible for transportation of sediments through the estuary. Areas of typically low velocities tend to accumulate sediments, while areas of high velocities would keep sediment in motion (either as suspended load or bed load) or may even erode sediments from the bed and banks.

The mobilisation and transportation of sediment is also related to the characteristics of individual sediment particles. Fine sediment can be mobilised and transported by relatively low velocities, whereas coarser sediment required much larger velocities to initiate and maintain particle motion. Therefore, estuarine hydrodynamics also defines the sediment facies within the study area. That is, it defines which areas of the bed will be dominated by fine silts and muds, and which areas will be dominated by coarser sands. The drowned river morphology of the estuary means that most of the Upper Hawkesbury River is a depositionary environment.

Causes of bank erosion in the upper reaches include wind, wind waves, boat wash, uncontrolled access for farm animals, sediment starvation and slumping (Kimmerikong 2005). This is exacerbated by the lack of riparian vegetation.

There has been some concern amongst the wider community about a perceived reduction in navigability related to sediment accumulation within the estuary. A recent hydrosurvey and navigability assessment undertaken by WorleyParsons (2012) indicates that the river bed dynamic and the channel thalweg is changing, but at a slow rate. Limited accretion was observed in some locations, and was attributed to sediment supply from local stream bank erosion. Shoals on the inside of some bends have formed from locally sourced sediment.

The hydrosurvey and navigability assessment concluded that, based on available data and assumptions for navigation requirements of a 50 m to 100 m fairway, with an acceptable channel bed level of -1.9 m to -2.1 m AHD and below (i.e. a minimum functional water depth of 1.8 m), Ben's Point represents the only location that does not comply with navigation requirements (WorleyParsons, 2012). A navigable channel of as narrow as 25 m occurs at this location. However, this area is located within an existing reduced speed zone (4 knot limit) and as such is not used for water-skiing or wake-boarding

2.3.7 Catchment and Direct Inputs and Sediments

Catchment runoff provides the primary source of sediment to the study area. Coarser grained sediment will tend to be deposited as alluvial deltas at the outlets of creeks and drainage lines, while finer grained sediments will remain suspended in the water column and slowly settle throughout the estuary.

Rates of sediment accretion within the estuary are a function of the rates of sediment runoff from the catchment, which in term is a function of catchment characteristics, including vegetation cover, soil type, catchment slope and the extent of development / soil disturbance.

The consistent and low flow regime has had a direct impact on sediment and bank dynamics. Defining the impacts is difficult due to the cumulative impacts from the removal of riparian vegetation, ad hoc bank works, bank erosion from power boats and trapping of sediment by upstream weirs.

The water storage dams on the Nepean and Warragamba Rivers restrict downstream flows and concurrently cut off supplies of sediment, thereby restricting sediments available to the lower river (Kimmerikong 2005).

The effect of these sediment deficient flows are reported to have resulted in a wider and deeper channel from the Grose River (near Yarramundi), to Sackville (Kimmerikong 2005). It is also suggested that flood mitigation works are keeping smaller floods in the channel and thereby further increasing energy for erosion. This material is then probably deposited further downstream (Kimmerikong 2005).

2.3.8 Water Quality and Sediments

Within estuaries, nutrients (particularly nitrogen, phosphorus and carbon) can migrate from the water column to the sediments (as organic matter settles), and from the sediments to the water column (as the organic matter remineralises). Some pollutants, such as trace metals, when discharged in a dissolved form, have the ability to attach to fine grained sediment particles. These contaminated sediments settle to the bed and accumulate with little or no avenue for release of the adsorbed metals. Therefore, areas where water quality is contaminated by pollutants such as metals, would generally also contain contaminated sediments.

The sediments throughout the study area are relatively high in total organic carbon and nutrients, indicating that the area is a natural deposition environment for catchment organic loads delivered from upstream (Kimmerikong 2005). It is estimated that more than 4,900 tonnes of nitrogen and 670 tonnes of phosphorus enter the river each year however only about 5.7% of nitrogen and 3.6% of phosphorus reach the lower boundary of Wisemans Ferry (Gruber *et al.*, 2010).

In the Windsor to Cattai National Park Reach, sediment samples generally had greater total organic carbon, total nitrogen and total phosphorus concentrations, particularly in the upstream section and downstream of the South Creek inflow (Cook and Johnstone, 2011). Concentrations of these parameters in sediments did not increase again until the Cumberland to Wisemans Ferry reach, most notably downstream of Lower Portland (Cook and Johnstone, 2011).

2.3.9 Estuary Hydrodynamics and Estuarine Ecology

The structure of the estuarine ecology is based on a number of factors including the hydrodynamics. The simple motion of tides provides a unique element of the environment where land is sometimes wet and sometimes dry. Many estuarine species are reliant upon regular water level variation, including mangroves and various invertebrates. However, the drowned river valley morphology of the Upper Hawkesbury River means that slopes adjacent to the waterway are steep, and the actual intertidal area is very narrow.

Estuary hydrodynamics also has an influence on weed dispersal through the estuary. The movement of water up and down the estuary provides transport for seeds and plant fragments. Aquatic weeds travel downstream with freshwater flows and tidal inflows also redistribute weed species.

Additionally, ecology may influence hydrodynamics, where in stream vegetation such as mangroves have been removed or have proliferated. The river also acts as a vector for seeds and other debris influencing the proliferation of weeds downstream.

When flow rates are substantially reduced the river is more exposed to phenomena like algal blooms. A minimum flow rate of $2m^3$ per second appears to be important to reduce the risk of blooms (Bill Pierson presentation, river summit).

Changes to hydrodynamics have had considerable impacts on fish passage through the Hawkesbury-Nepean River. Mapping of barriers to fish passage has been undertaken by the NSW Department of Primary Industries Fisheries (Conservation and Aquaculture) and funded by the NSW Environmental Trust Program. A high proportion of the highest priority structures are located within Hawkesbury LGA. It is not known how many of these have been rehabilitated. Most of the barriers affecting fish passage are upstream of the Upper Hawkesbury River Estuary waterway.

DPI Fisheries (2006) report that the macroinvertebrate communities of the Hawkesbury-Nepean catchment are moderately to significantly impaired, predominantly due to the pressures associated with river regulation and water extraction.

Water depths (~10m) without appropriate flow regimes and consequential inadequate mixing can lead to micro organisms depleting the deep sections of the water column of oxygen (Allen Management Solutions, undated, River Summit presentation summary by Professor Wayne Erskine from the University of Newcastle).

2.3.10 Water Quality and Estuarine Ecology

Water quality is also a factor in the structure of estuarine ecology. As water quality can change rapidly (due to advection and dilution by tides and floods), highly responsive elements of the ecology, such as algae, are the most affected by water quality. High nutrient concentrations in the water can

lead to rapid growth of pelagic (suspended) algae (i.e. eutrophication). More sustained nutrient loadings tend to result in increased epiphytic (attached) algae and macroalgae.

If water quality is changed for an extended period of time, then particular ecological species may become stressed. This may, for example, be the result of extended freshwater flows within a predominantly saline environment, or may be related to the introduction of a new pollutant discharge.

Aquatic ecology in the Hawkesbury River system is affected by flow and water quality, changes due to catchment disturbance and runoff, the discharge of treated effluent and flow regulation and modification (Krogh *et al*., 2009).

2.3.10.1 Macroalgae and phytoplankton

Macro algae and phytoplankton which cause algal blooms require sunlight, temperature, nutrients, and a relatively long residence time for stable conditions to allow algae to reach bloom proportions (WMA, 2002). Waters from the Hawkesbury River itself, which may flow into the tributaries under tidal flows, have been measured to be nutrient rich (WMA, 2002), as have sediments from the river. The high nutrient waters and sediments are likely to assist the continuation of blooms once they are initiated (Bourges *et al*., 1998).

It has been reported through stakeholder consultation that during floods, macrophytes break off and are washed downstream, the fragments reportedly die off as they reach saline areas causing water quality issues in that vicinity.

Despite the availability of long term water quality monitoring data as described in DECC (2009), long term monitoring programs for many biological indicators does not exist (for example, fish, macrophytes and periphytic algae).

Proliferation of the aquatic weeds *Savinia molesta* and *Egeria densa* is assisted by increased nutrient levels and changes to the flow regime (Kimmerikong, 2005). This proliferation further impacts on the already stressed ecosystem.

A significant finding of the Hawkesbury Nepean River Environmental Monitoring Program was that the algal community composition in the Hawkesbury Nepean River has changed dramatically in the recent past with Cyanobacterial blooms previously dominated by *Anabeena* and *Microcystis* being replaced by Cyanobacterial blooms dominated by *Aphanocapsa*.

Downstream of the confluence with South Creek, high nutrient concentrations together with prolonged low flows result in Cyanobacterial blooms (Kimmerikong, 2005). The water in this area is, as a result, unsuitable for domestic use, livestock, irrigation, recreational purposes and is uninhabitable by many species (Kimmerikong, 2005). This effectively acts as a barrier to the passage of many species migrating along the river (Kimmerikong, 2005).

The amount of algal data available is directly related to chlorophyll-a concentrations, whereby levels generally need to be greater than 10µg/L for algae and cyanobacteria counts to be undertaken. As such, much of the existing data are representative of high algal conditions including blooms. This presents difficulties when attempting to discern any relationship between observed populations and water quality (collected at different times and at different spatial scales) (Krogh *et al* 2009).

Overall algal blooms are a common occurrence in the Hawkesbury River, and whilst chlorophyll-a levels have mostly declined, blue-green algal counts have largely remained stable, although a shift in species from toxic blue-green algae to non-toxic species has been observed over recent times (Krogh *et al* 2009).

Trends in algae and cyanobacteria were investigated at Hawkesbury River at North Richmond (N42) between 1970 and 2007 indicating that there have been changes in the genus-level composition of algae over a number of decades (Krogh *et al* 2009). There was no clearly dominant genus in the 1970s, however above average abundance of *Cyclotella* were recorded.

The 1980s and 1990s had higher than average abundances of *Chroomonas*, *Melosira* and *Microcystis* compared to other decades. *Skeletonema* and *Merismopedia* had much higher than average abundances in the 1980s compared to the 1990s, and were very low in the 2000s. *Anabaena* also had much higher than average abundances in the 1980s than in any other decade. Over the 1980s, 1990s and the 2000s *Scenedesmus* has been recorded in similar abundance but was much lower in the 1970s. *Cyclotella* was also recorded in similar abundance in the 1970s, 1980s and 1990s but in low abundance in the 2000s (Krogh *et al* 2009).

Currently the most dominant genus is *Aphanocapsa*, which prior to 1999 had only been identified once. Other dominant genera include *Dictyosphaerium* (low abundance in the 1970s, 1980s and 1990s) and an unidentified unicellular green algae that prior to 2000 had not been recorded as a category (Krogh *et al* 2009).

Seasonal differences in algal types and abundances have also been recorded whereby dominant summer algae include *Merismopedia, Aphanocapsa* and *Anabaena*. *Microcystis* is abundant in both summer and spring, and *Scenedesmus*, *Dictyosphaerium*, *Achnanthes* and *Phormidium* are more abundant in spring. *Skeletonema* are more abundant in winter and spring while *Chroomonas* are more abundant in summer, autumn and winter (Krogh *et al* 2009).

Whilst the dominant species today are *Aphanocapsa*, they pose a much lower threat than some of the dominant species of the previous decades such as *Microcystis* and *Anabaena* which are largely toxin producing algae. To date, *Aphanocapsa* which are very small blue-green algae are not known to produce neurotoxins or hepatotoxins under Australian conditions. The change in species composition may be related to the change observed in the nutrient regime during this time including an overall reduction in nitrogen and phosphorus loads but also possible changes in nutrient stoichiometry.

Over time, there have been differences in algal genera in the Sackville reach. Most recent times (post 2000) have seen the increase in occurrence and density of *Aphanocapsa*, which was not recorded prior to 1999. *Cyanodictyon* was also recorded in high numbers since 2000, yet it was never recorded at Sackville in the 1970s, 1980s and 1990s (Krogh *et al* 2009). Prior to 2000, *Microcystis*, *Aphanothece* and *Anabaena* were the abundant genus, however these are now recorded in significantly lower numbers. Seasonal differences in algal species have also been recorded. Generally *Microcystis* and *Anabaena* are most abundant in summer, *Aphanothece* is also abundant in summer and to a lesser extent winter, whereas *Aphanocapsa* is more abundant in summer, autumn and winter (Krogh *et al* 2009).

Recent data shows similarities in the algal communities between the Yarramundi to Windsor reach and the Sackville reach with *Aphanocapsa* the dominant genus at both sites, however cell counts are much higher in the Sackville reach. In the past, blooms in the different reaches have involved different genera, with *Merismopedia* and *Phormidium* more prevalent at in the Yarramundi to Windsor Reach (at North Richmond) compared to *Aphanothece* at Sackville (Krogh *et al* 2009).

2.3.10.2 Macrophytes

Aquatic vegetation provides essential habitat for a variety of freshwater and estuarine aquatic fauna at different phases of their life cycle. It can also be a source of food for some species. Aquatic vegetation which includes reeds and sedges, macrophytes and seagrasses are important for the ecological health of the system, particularly as they provide a nutrient sink. However excessive growth, whether native or exotic can be detrimental (Kimmerikong 2005). Freshwater macrophytes are found along the entire length of the mainstream Hawkesbury River from Yarramundi to Wisemans Ferry. Shallower areas contain reeds and sedges, including *Phragmites.* The most dominant submerged species are the native *Vallisneria gigantea* and the exotic species *Egeria densa* which are interspersed and abundant between Yarramundi and Windsor. *Salvinia molesta* has had excessive growth in the upper 'freshwater' reaches, where it has formed temporary dense surface mats and impacted on water quality due to decreasing pH (Kimmerikong 2005).

Yarramundi to Windsor

Native and exotic macrophytes have been recorded in this reach. Between Richmond and Windsor, 10 native and 6 exotic species were recorded (Thiebaud and Williams 2007). Exotic species dominate the floating macrophytes namely *Eichhornia crassipes*, although limited amounts of the native *Ludwigia peploides spp. Montevidensis* has also been recorded (Krogh *et al* 2009). Emergent macrophytes are generally dominated by native species, particularly the native species *Typha orientalis*, *Phragmites australis* and *Schoenoplectus validus*. A detailed study by Gruber *et al* (2010) identified several submerged macrophyte species, namely the native ribbon weed *Vallisneria americana* and the invasive *Egeria densa*. The dominance of the submerged invasive species has noticeably increased over the past 15 years. Additionally, Krogh *et al* (2009) reported the native plants *Ceratophyllum demersum* also in large numbers. Of the recorded exotic species, the one of most concern is the submerged species *Egeria* and to a lesser extent *Elodea* (which has been recorded less frequently just upstream of Richmond). These species are found in nutrient rich environments and are readily dispersed during medium to high flows (Thiebaud and Williams 2007).

Windsor to Cattai National Park and Cattai National Park to Cumberland

Native and exotic submerged and emergent macrophytes have been recorded in this reach. The most dominant native submerged species include *Ceratophyllum demersum* and *Vallisneria gigantia* whereas the most dominant submerged exotic species was *Egeria densa* particularly on the South Bank (as initiated at Wisemans Ferry). Of the emergent macrophytes, the most dominant native species were *Phragmites australis* and *Schoenoplectus validus*, followed by *Bolboschoenus fluviatilis* and *Typha orientalis* on the South Bank (as initiated at Wisemans Ferry). *Juncus usitatus* was also recorded in this reach. The native submerged species *Hydrilla verticillata* was also recorded in this reach but had not been recorded upstream (Thiebaud and Williams 2007).

Tributaries within this zone, such as South Creek, Cattai Creek and Currency Creek have been reportedly dominated by the exotic floating macrophyte *Salvinia molesta* (HNAWSC 2006).

Cumberland to Wisemans Ferry

Similarly between the Cattai National Park and Cumberland reach, there were no native or exotic floating macrophytes recorded, nor were there any exotic emergent macrophytes recorded. There were native emergent macrophytes recorded, and they were the same five species recorded in the reach upstream (Thiebaud and Williams 2007).

There were three native submerged macrophytes species recorded, *Ceratophyllum demersum*, *Vallisneria gigantea* and *Hydrilla verticillata* however, no exotic species were recorded in this reach (Thiebaud and Williams 2007).

2.3.10.3 Macroinvertebrates

Sampling undertaken by Sydney Water has found that there are significant taxonomic differences in macroinvertebrates among habitats (edge and riffle) in the main channel of the Hawkesbury River. Potential influences contributing to these differences, may be the effect of the Grose River inflow and/or differences in microhabitat created by tidal influences, river geomorphology and other factors (Krogh *et al* 2009).

There are differences in community structure downstream of Yarramundi (compared to upstream), most likely due to the tidal influences in the river. Generally there were fewer macroinvertebrate communities (and abundances of individuals) at edge sites downstream of Yarramundi compared to upstream. Despite differences upstream and downstream of Yarramundi, there is no significant difference in macroinvertebrate communities within the different reaches between Yarramundi and Wisemans Ferry (Krogh *et al* 2009).

2.3.11 Sediments and Estuarine Ecology

The fauna ecology of the bed sediments (i.e. benthos) can differ depending on the structure of the sediments. Fine muds benthos is notably different to coarse sands benthos. Aquatic vegetation (seagrass) can also differ depending on the type of sediment.

Sediment quality can also have an impact on benthos. Contaminants within the sediments, such as metals and anthropogenic organic compounds, can bioaccumulate within the benthos, particularly filter feeders.

High suspended sediment within the water column can suppress biological productivity within the estuary, through restricting light penetration to the water, and particularly to the benthic environment.

2.3.12 Drowned River Valley Estuary Morphology and Estuarine Ecology

The estuarine ecology of the study area will also be influenced by the fact that the estuary is a drowned river valley. Being a drowned river valley, most of the estuary is actually quite deep. This depth affects the benthic environment, as only benthos adapted to low light conditions can be

supported. Benthos typically includes invertebrates as well as the microscopic benthic microalgae present amongst the sediment grains in the top 5 – 10 mm of the bed.

The drowned river valley nature of the estuary also means that there is unrestricted passage of demersal fauna between the study area and the ocean, as well as recruitment of juveniles from the ocean to the estuary.

Benthic nutrient remineralisation is a significant source and sink for nutrients in coastal water bodies. Benthic nutrient fluxes may influence the primary production of the water column either as a source of dissolved nutrients or as a channel for the removal of limiting nutrients (Cook and Johnstone, 2011). In the lower reaches, it is thought that sediments are potentially significant for the maintenance of algal blooms in the associated waters (Cook and Johnstone, 2011). Phytoplankton and benthic microalgae have been identified as key drivers of nutrient transformation (Gruber *et al* 2010).

Benthic ammonium fluxes vary throughout the system. Greatest effluxes were recorded in the Windsor to Cattai National Park reach, which was predominantly freshwater and had minimal tidal influence (Cook and Johnstone, 2011). Benthic fluxes of ammonium then decreased with distance downstream along the estuary gradient. It appears that effluxes are influenced by a range of physico-chemical parameters, such as tidal currents, flow, salinity, pH and proximity to particulate organic matter sources (Cook and Johnstone, 2011).

Silica fluxes varied with salinity and distance downstream, most notably in the Cumberland to Wisemans Ferry reach, downstream of Lower Portland, where the rate was more than double anywhere else. Other locations for high silica fluxes were in the Cattai National Park to Cumberland Reach at Sackville and the Hawkesbury River near Cattai Creek (Cook and Johnstone, 2011).

2.3.13 Human Influences on Estuary Processes

Human activities have modified virtually every process operating in and around the Upper Hawkesbury River Estuary. The extent to which the catchment and waterway has changed from natural conditions renders these influences irreversible. In a limited number of circumstances, the modified values may even be preferred over natural values as they better suit human uses.

The difference between the natural state and the modified states that are considered acceptable to the environment and the community is regarded as the acceptable limit of change to the ecosystem processes.

Human influences can have positive benefits for the estuary and in recent years, a number of individuals and organisations have participated in rehabilitation works. This includes the CMA, Local Aboriginal Land Council Green Teams, Willow Warriors and Bush Care Groups. Improvements have also been made in nutrient management and retention on rural land through programs such as the Hawkesbury Nepean Smart Farms project.

As indicated earlier in Table 1-1, Stage 2 of this project will involve an assessment of the pressures acting on the estuary.

Table 2-1 is a matrix of some potential human influences on estuary processes. Chapter 4.4 further considers the pressures that can be managed through the Coastal Zone Management process.

Table 2-1Human influences on estuary processes

Human Influence	Process			
	Hydrodynamics	Geomorphology	Water Quality	Ecology
Riparian Land Uses (stock access, vegetation removal)	Increased volume and velocity of diffuse runoff	Increased erosion Steepness	Increased sediment and nutrient inputs	Reduced connectivity Reduced aquatic habitat (dropping branches/ insects etc) Decreased water quality impacting on species composition
Water Based Development (jetties, stairs, bank protection works etc.)	Redirecting flows	Increased erosion End effect erosion	Gross pollutants as components of poorly designed structures break off Increased sediment runoff	Barrier to fish passage Reduced connectivity
Catchment Development	Increased runoff (e.g. from urban lands, turf farms and market gardens)	Increased sediment supply	Increased quantity of water Decreased quality of runoff	Declining water quality impacting aquatic organisms
Riverbank revegetation and restoration		Improves bank stability	Reduces sediment and nutrient inputs	Increases habitat potential Improves biodiversity
Weed introduction to riparian areas	Aquatic weeds influencing flows	Reduced bank stability	DO depletion Nutrient uptake Toxin production	Impacting on species composition Reduced biodiversity
Introduced fauna		Access causing bank erosion	Faeces depleting water quality	Loss of biodiversity
Climate change / sea level rise	Increased frequency of extreme events (drought / flood) Increased tidal excursion and range	Change to intertidal area	Increased salinity	Changes to species composition Changes to breeding cycles
Illegal	Redirecting flows	End effect erosion	Decreased water	Impacts of plastics

Human Influence	Process			
	Hydrodynamics	Geomorphology	Water Quality	Ecology
dumping of waste along the estuary			quality Sediments	on water birds
STP discharges	Change to flow regime (peak discharges at distinct times)		Increased nutrients Human health issues for primary contact	Impacts of reduced water quality on aquatic organisms Impacts of hormones on fish / prawns
Boat based activities (includes commercial, agricultural and recreational)	Waves of a different nature (e.g. period)	Bank erosion	Decreased water quality	Reduced fish stocks Disruption of breeding / feeding for waterbirds Erosion reducing riparian vegetation
Water extraction and dams	Changes to environmental flow	Sediment starving	Declining water quality from reduced flushing Anoxic deep water and reduced flows Increased salinity	Changed hydrological regime favours introduced species Impacts on breeding cycles / germination
Agricultural inputs	Increased volumes of runoff	Increased sediment supply	Increased nutrients and sediments	Pesticides and reduced water quality impacting on aquatic ecology

3 MANAGEMENT CONTEXT

Management of the Hawkesbury River is divided amongst local Councils, and a number of state government agencies and organisations. The size of the Hawkesbury Nepean River and its use in providing drinking water to Sydney has resulted in a complex management approach that is unique to this river. The complexity of the management structure will be an important consideration in identifying and assessing management options for inclusion in the Upper Hawkesbury River Estuary Coastal Zone Management Plan.

Table 3-1 Organisations and their responsibilities and contributions to the management of the Upper Hawkesbury River Estuary

Organisation	Role
Hawkesbury Nepean Catchment Management Authority (HN CMA) (to be replaced by Local Land Services from January 2014)	Co-ordinates natural resource management in the catchment by involving local communities and directing funding from NSW and federal governments. Development and implementation of the Hawkesbury Nepean Catchment Action Plan (CAP). Limited to works in the riparian zone or the catchment (i.e. not able to undertake works within the river). Currently Restructuring
Local Councils (Hawkesbury City Council, The Hills Shire Council)	Strategic and land use planning, development assessment and control, floodplain management, stormwater management, provision of waterway access and related infrastructure, sewage management (outside the Sydney Water serviced areas) and riparian and waterway monitoring and rehabilitation projects. Preparation of CZMP
Sydney Water	Centralised management of sewage treatment via 41 STPs discharging into the Hawkesbury Nepean River Estuary. Provision of drinking water to greater Sydney.
Hawkesbury River County Council	A special (single) purpose authority formed to administer, control and eradicate declared noxious weeds
NSW Office of Water	Administers extraction of water from the river and groundwater systems through water licensing, and is responsible for the development of Water Sharing Plan.
Roads and Maritime Services (RMS)	Regulates commercial and recreational boating activities to ensure safety and efficiency in the use of navigable waters.
NSW Department of Planning and	Determining Authority for large scale developments under the

Organisation	Role
Infrastructure	*Environmental Planning and Assessment Act 1979*. Makes recommendations to the Minister regarding the approval of LEPs. SEPP Hawkesbury Nepean River.
Independent Pricing and Regulatory Tribunal	Issues and administers operating licences to SCA and SWC. Regulates prices for metropolitan water sewerage and stormwater services and for water supplied by SCA. Regulates private sector access to water and wastewater systems to encourage competition and reuse.
Department of Primary Industries (DPI)	Management of aquatic weeds through the *Noxious Weeds Act 1993* Regulates development potentially impacting on fish habitat under the *Fisheries Management Act 1994*.
Crown Land	Management of Crown land and submerged Crown lands by: • leasing (subject to reserve revocation) or licensed under the *Crown Lands Act 1989*; or • leasing and/or licensed for aquaculture and fishing purposes by NSW Fisheries
Sydney Catchment Authority (SCA)	Catchment management activities including on ground works, managing 'special areas' surrounding the water storages and working with local councils to improve planning activities within the drinking water catchments. Dam operation, infrastructure development and maintenance.
Office of Environment and Heritage (OEH)	Develops and implements policies and programs for environmental protection. Implementation of the Estuary Management Program. Environmental protection licensing and compliance under the *National Parks and Wildlife Act 1974*, *Protection of the Environment Operations Act 1997* and the *Threatened Species Conservation Act 1997*. Environmental water acquisition under *Water Management Act 2000.* Concurrence role if triggered via development process.

Organisation	Role
Local Land Services	From January 2014 this organisation will replace the present HN CMA. Local Land Services brings together Livestock Health and Pest Authorities, Catchment Management Authorities and Agriculture NSW advisory services.
Hawkesbury Prawn Trawl Association	Environmental Management of Prawn Trawl industry activities

*Some extracts from this table come from the website of the former Office of the Hawkesbury Nepean (www.ohn.nsw.gov.au/River-managment).

3.1 Existing Initiatives

As there are a number of organisations responsible for management in the Hawkesbury Nepean River Catchment, there are a range of initiatives underway and one of the challenges for this project is to build on these initiatives and avoid duplication. Table3-2 lists key initiatives, however as this is a starting point for consultation and discussions, it is expected that the list will expand through the course of this project.

Table3-2 Initiatives underway in the study area

Organisation	Initiative	Relationship to present project
Sydney Water (with consultants SKM and BMT WBM)	Development of a complete hydrodynamic and WQ model of the estuarine and freshwater sections of the Hawkesbury Nepean system, linked to catchment model.	Model still in preparation - Subject to gaining appropriate approval may be used for: Assessing development scenarios and impacts Assessing potential of management options
Sydney Water and HCC	Hawkesbury-Nepean River Recovery Program – Upgrade of South Windsor STP	Awareness that water quality in South Creek should improve
Sydney Water	Hawkesbury-Nepean River Recovery Program – buy-back of water access licences, improved water efficiency for irrigators and other users and nutrients reduction campaigns	Identify opportunities to enhance the outcomes of this initiative

Organisation	Initiative	Relationship to present project
	from agricultural enterprises.	
Hawkesbury Nepean CMA (Local Land Services from January 2014)	Hawkesbury Nepean River Health strategy	Defines a vision for river health; contributes to understanding of economic, social and environmental values of the river across the whole of the catchment, and assesses the threats to those values; and Provides a consistent analysis of river reaches and provides priorities and a guide to implementation and management actions.
Hawkesbury City Council	Holmes Drive Reserve POM	Landscape master plan for Holmes Drive Reserve
OEH (form NPWS)	Scheyville National Park and Pitt Town Reserve Plan of Management	Protection of wetland values and migratory bird habitat provided by Pitt Town Lagoon and Longneck lagoon to be an important consideration
Greening Australia's River Recovery program (partnership with CMA)	Rehabilitation of riparian vegetation and re-introduction of woody debris and other components of in-stream habitat for the benefit of native fish	Identify priority sites, ensure management options are consistent with this priority.
OEH (formerly NPWS and DECC)	Scheyville National Park Conservation Management Plan	Heritage Conservation
The former Healthy Rivers Commission	Independent Inquiry into the Hawkesbury Nepean River System Final Report 1998	Recommendations to be revisited
Sydney Catchment Authority	On ground works to improve riparian corridors in upper catchment	Works would contribute to an improvement in estuary health
OEH (formerly DECCW)	Draft Lower Hawkesbury	Identifies priority nutrient

Organisation	Initiative	Relationship to present project
	Nepean River Nutrient Management Strategy	sources and actions to reduce loads
NSW Department of Primary Industries	Hawkesbury Nepean Catchment Weed Management Strategy 2007-2011	Support the integrated management of weeds between local councils, state government agencies and industry and the community.
OEH (formerly DECC)	Hawkesbury Nepean Environmental Monitoring Program (HN-EMP)	Long term monitoring to understand underlying natural cycles and the impacts of human induced changes
Ocean watch (and others)	Tide to Table	Involves rehabilitation works that would benefit overall estuary health

3.2 Local Government Role

Part 4 of the EPA Act lays out the legislative regime for the standard process for lodgement and consideration of development applications. Part 4 processes essentially apply where the local authority (Council) is the consent authority. The majority of land based development within the study area will fall within Part 4 of the EPA Act (see Appendix A)..

The controls and permissibility for development of particular sites and / or uses are found in the Local Environment Plan (LEP) and Development Control Plan (DCP) that cover Council's Local Government Area (LGA).

LEPs divide the area they cover into "zones", such as rural, residential, industrial, public recreational, environmental conservation, and business zones.

For each zone, a LEP will give a list of "objectives" that indicate the principal intended use for that zone. Each zone also lists the types of development within that zone that are:

- Permissible without development consent,
- Permissible with development consent, and
- Prohibited.

DCPs deal with particular aspects of LEPs in more detail than the LEP. For example, a DCP can specify additional criteria that a council must consider when assessing a development application. DCPs are not legally binding. However, a consent authority must take a DCP into account when considering a development application.

Development control along the banks of the Upper Hawkesbury Nepean Estuary and for much of the catchment is divided amongst Hawkesbury City Council and The Hills Shire Council. The zoning of

the study area through the Hawkesbury Local Environment Plan 2012 and The Hills LEP 2012 is shown in Figure 3.1 and Figure 3-2.

There are seven other local Councils with some control over zoning within the wider catchment. The diversity of landuses within the catchment therefore include virtually every category.

The discussion below focuses on the Hawkesbury City Council and The Hills Shire Council and permissible landuses along the riparian areas.

3.2.1 Hawkesbury Local Environmental Plan

The Hawkesbury Local Environment Plan commenced in 2012. Much of the land along the river is zoned RU2 Rural landscape. While the objectives of this zone include consideration of the estuary, the uses permitted with consent would have considerable impact on the waterway. The specific objective regarding the estuary is:

"To ensure that development occurs in a way that does not have a significant adverse effect on water catchments, including surface and groundwater quality and flows, land surface conditions and important ecosystems such as waterways."

Uses permitted without consent include extensive agriculture, which has considerable impact for the waterway. Another activity permitted without consent is environmental protection works. Appropriate rehabilitation of banks would be very beneficial for the waterway. This activity may however sometimes be misinterpreted by landholders to include hard bank protection works. Distribution of information on environmentally friendly seawalls will be one of the options considered when options are assessed during stage 2 of the present project.

Uses permitted with consent do not include caravan parks, therefore by default this is a prohibited development.

3.2.2 Hawkesbury Development Control Plan 2002

Development controls are outlined in the Hawkesbury Developmental Control Plan 2002. Part C of the DCP gives guidelines for development related to a number of areas, including the following areas of relevance to the estuary:

- Landscaping
- Soil Erosion
- Tree Removal

The DCP needs updating and there are some opportunities to improve wording and information for benefit of the Upper Hawkesbury River Estuary. For example, Section 4.5 of the DCP refers to the former DLWC and Section 4.6 on appropriate vegetation does not include recommendations specifically for riparian areas.

It is recommended that the DCP is revised to include specific recommendations for river bank development. The reference to DLWC refers to the provisions of the now repealed *Rivers and Foreshores Improvement Act 1948*, which has been replaced by the *Water Management Act 2000*. Please refer to Appendix A for details

There is also a Draft Heritage Chapter for the DCP on public exhibition at the time of writing that mentions the significance role the river played in Aboriginal daily life and culture.

3.2.3 The Hills Local Environmental Plan

As with the Hawkesbury Local Environmental Plan, much of the riverside land zoned within The Hills Shore Council is zoned RU2 Rural Landscape. While there is now a standard LEP template used, zones can have slightly different lists of permissible and prohibited uses for the same zones. A key difference (from the perspective of waterway impacts) between the zone RU2 in the Hawkesbury LEP and Hills Council LEP appears to be that for the Hills LGA caravan parks are permitted, with consent.

Urbanisation of rural lands within this LGA has the potential to impact on the waterway.

3.2.4 The Hills DCP 2012

Development controls for The Hills LGA are outlined in the Hills Development Control Plan 2012.

Appendix B outlines the Water Sensitive Urban Design components. These are important for the Upper Hawkesbury River Estuary as they reduce the potential impact of increased urban development within the catchment.

3.2.5 A new planning system for NSW

The NSW Government recently released the White Paper – *A New Planning System for NSW* and is currently requesting public feedback. The White Paper outlines sweeping changes to the environmental assessment process, including the establishment of expert independent panels to determine development applications, to enable elected councillors to concentrate on making key strategic decisions about their areas. This particular initiative is flagged as a tool to depoliticise the development assessment process. It is not yet clear how these proposed changes will influence decision making for the riparian areas and catchment of the upper Hawkesbury River Estuary, however, as new information becomes available, it will be included in the following stages of the project.

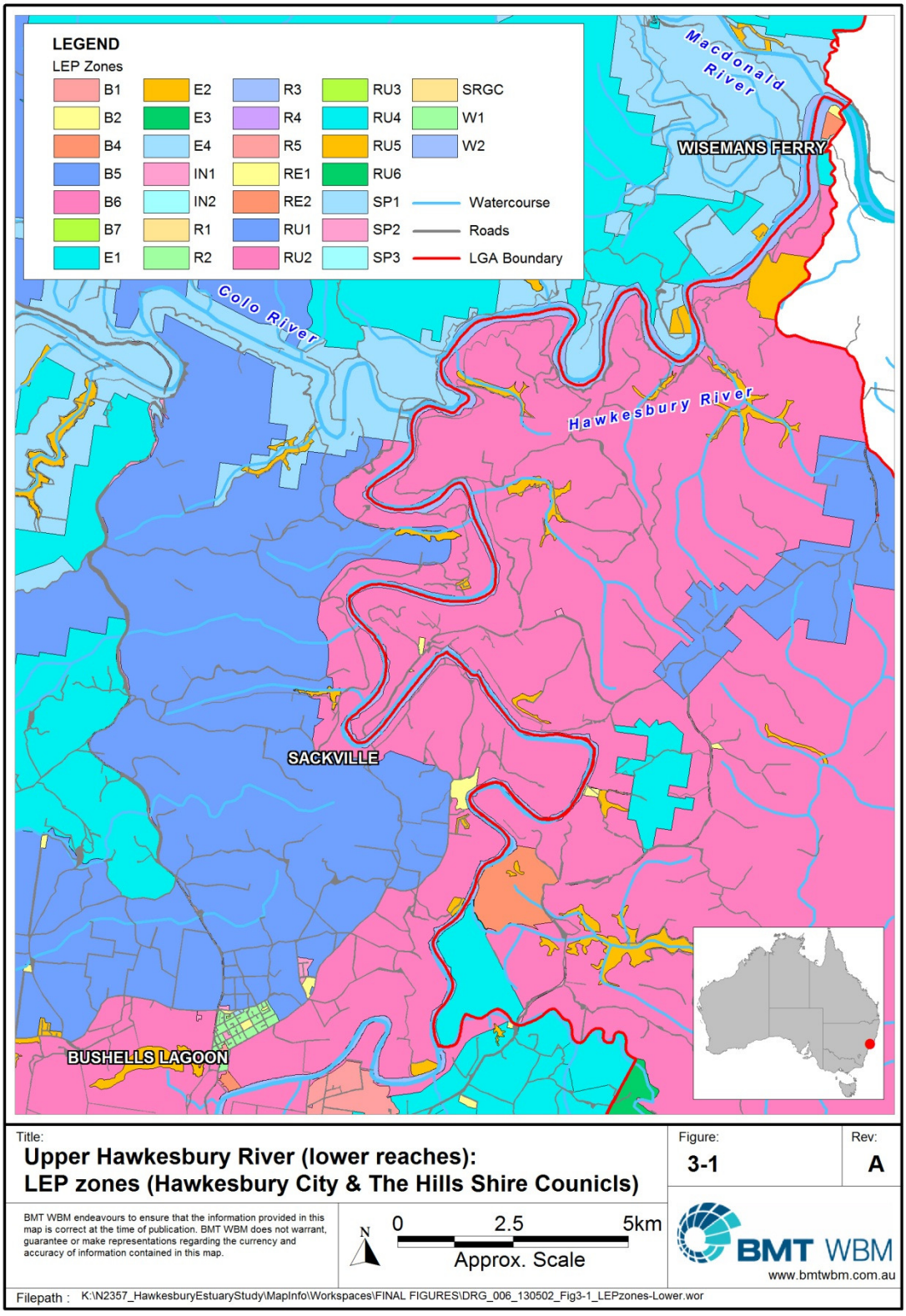

Figure 3-1 LEP zoning in the lower reaches of the study area

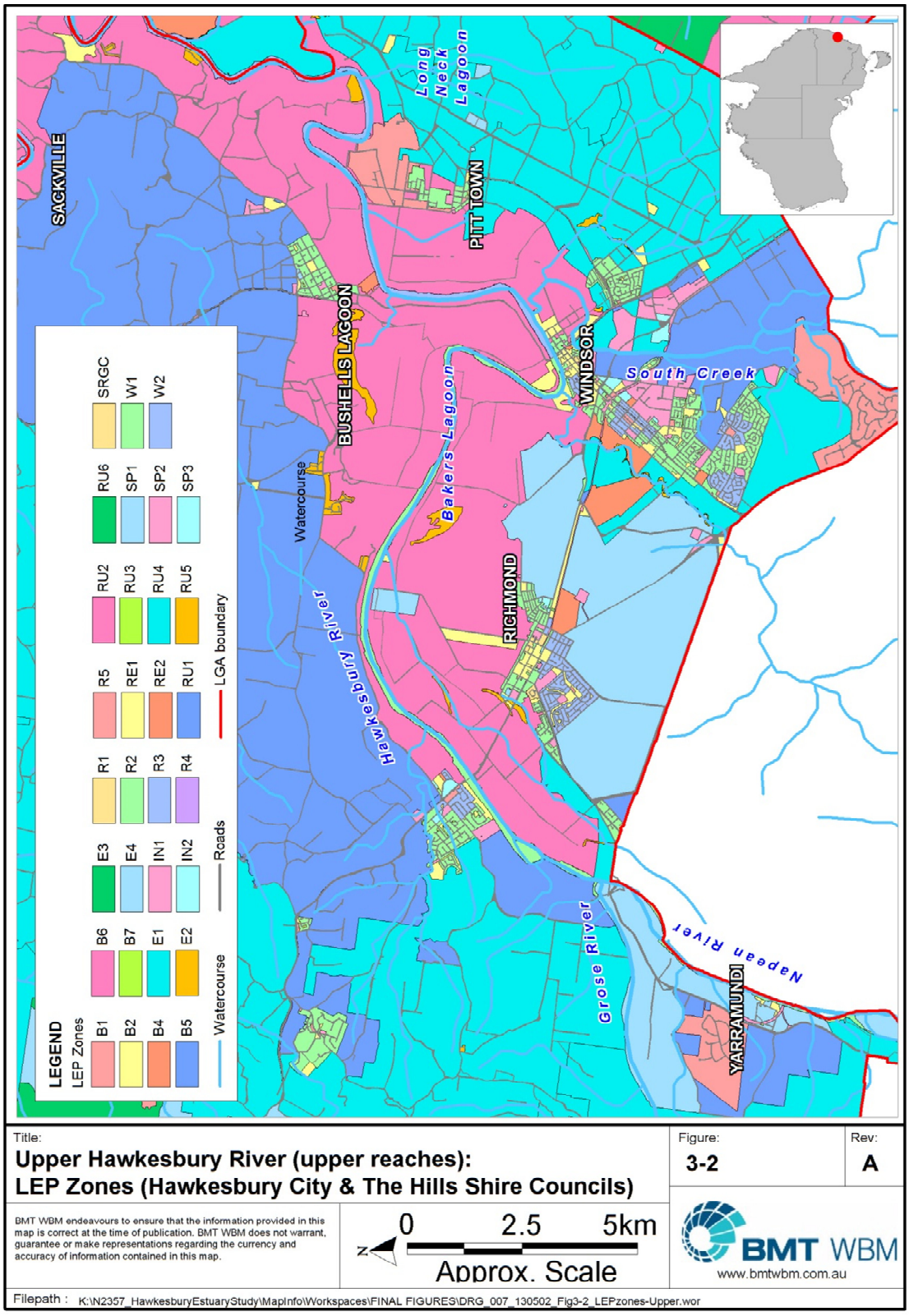

Figure 3-2 LEP zoning in the upper reaches of the catchment

4 VALUES AND ISSUES

4.1 Values

Considerable effort has been expended by the Hawkesbury Nepean Catchment Management Authority to identify and document environmental, social and economic values. Their approach used a 'rapid assessment model' involving a review of catchment wide data and an expert panel. A key priority for the present Coastal Zone Management Plan process is to avoid repeating works that have already been undertaken and to focus energy on tangible benefits for the estuary. The list given in Table 4-1 is a starting point for values of the Upper Hawkesbury River Estuary. It is envisaged that this list will be expanded upon during the subsequent stage of this project.

Table 4-1 Values of the Hawkesbury Nepean River health identified by HNCMA

Environmental Values	Social Values	Economic Values
Riparian vegetation	Recreational fishing	Irrigation water supply
Wetlands of significance	Motor boating	Riparian infrastructure
Rare or threatened river categories	Non-motor boating	Land use value
Riverbank condition	Swimming	Tourism
Geomorphic recovery potential	Scenic quality	Commercial fishing
Fish	Public recreation access	Town drinking water
Macroinvertebrates	Flagship species	
Sites of environmental significance	Heritage – European	
Significant vegetation communities	Heritage - Indigenous	

4.2 Issues

DECC (2009) and other background documents contain literally hundreds of issues for the Upper Hawkesbury River Estuary. In an attempt to condense these into a manageable list, the issues have been categorised according to the key driver. Each of the information sources looks at the Hawkesbury River Estuary as a whole and it is important to focus this list to the study area during the gap analyses. The information sources used to compile this list include the River Summit (2008), Healthy Rivers Commission (1998), Kimmerikong (2005), stakeholder submissions for the preparation of the present report and observations from field inspection.

For a detailed list of issues arising from each of the pressures, please refer to Table 4-3.

The list of identified pressures incorporates:

- Riparian land uses
- Water based development (jetties, stairs, bank protection works etc.)
- Catchment development
- Weed invasion in riparian areas
- Introduced fauna
- Climate change / sea level rise
- Illegal dumping of waste along the estuary
- STP discharges
- Private ownership of foreshore lands
- Boat based activities (includes commercial and recreational)
- Water extraction and dams
- Agricultural inputs
- Fishing
- Siltation
- Management approach

Each of these pressures is further broken down into issues in Table 4-3.

4.3 Gap Analysis and recommendations for further data collection

At this stage in the project program, there is the opportunity for further data collection to contribute to the development of a more complete and holistic plan. The review of background data and consultation undertaken to date shows that there is some frustration regarding a lack of action on the many obvious issues on the Hawkesbury Estuary. Recommendations made here for additional data collection are therefore aimed at information that could be collected rapidly and assist the immediate management of the estuary for maximum environmental benefit. Addressing data gaps where possible at this stage can also avoid the need for further research or data collection in the future CZMP. The focus of this assessment has been to identify any opportunities to collect information now that can immediately translate into more targeted practical actions.

The list of key identified data gaps shown in Table 4-2 illustrates the extent of unknowns in regard to this complex ecosystem. The many variables that influence the estuary such as inter and intra seasonal variability in hydrology, tidal variability, river regulation and weather patterns means that many data sets need to be collected over the long term to allow meaningful interpretation.

Table 4-2 Analyses of identified data gaps

Identified Data Gap	*Measureable in short term?*	*Translate to immediate benefit?*	*Consider for inclusion in CZMP?*
Implications of climate change for hydrodynamics	No	No	Yes
Additional sources of nutrients (groundwater, small tributaries, atmospheric deposition)	No	No	Yes
Role of DON/DIN, DIP/DOP in algal production and growth limiting concentrations	No	No	Yes
Macrophyte – rates of uptake and loss in submerged macrophytes, key nutrient species, relationship between flow and the occurrence of exotic macrophytes	No	No	Yes
Nutrient budgets / Nutrient assimilation and attenuation in (particularly right bank) tributaries	No	No	Yes
Sediment transport and deposition	No	No	Yes
Weed Mapping	Yes	Yes	Yes
An understanding of what a desired environmental flow regime would be (rate, duration, frequency, seasonality) and how this can be achieved.	No	No	Yes
No ongoing/and or consistent ecological monitoring programs	No	No	Yes
Lack of consistently monitored sites (spatially and temporally) for macroinvertebrates by same organisation. Therefore patterns for macroinvertebrate community composition and water quality are difficult to determine and further work needs to be undertaken.	No	No	Yes
Sampling of fish in the Hawkesbury Nepean has been inconsistent over the past 15 years.	Yes	No	Yes
Krogh (2009) mentions that further analysis is still required to investigate the potential relationship between	No	No	Yes

Identified Data Gap	*Measureable in short term?*	*Translate to immediate benefit?*	*Consider for inclusion in CZMP?*
changes in algal communities and changes in water quality.			
No recent studies of large scale distribution of all three macrophyte categories (submerged, floating and emergent) within the river have been reported.	No	No	Yes
Lack of accurate and comprehensive measurements of benthic sediments	No	No	Yes
Mapping of the location of caravan parks	Yes	No	Yes
Up to date mapping of structures and erosion zones (Waterways review)	Yes	Yes	Yes
Capability of publically owned land for rehabilitation and public access	Yes	Yes	Yes

4.3.1 Weed mapping

Weed management initiatives are presently being undertaken by Council through the Bushcare Program, community groups such as Willow Warriors and Landcare. Noxious weed control spraying is being undertaken by the Hawkesbury River County Council. Comprehensive weed mapping of the study site is not available. There is an opportunity to make the most of efforts in weed management by coordinating the effort through centrally available weed maps. This issue was initially raised by the Willow Warriors through the consultation program and its significance was apparent during the site visit / ground truthing exercise. Community groups have put maps together, where possible given their limited volunteer resources available.

It is understood that the Hawkesbury River County Council is currently implementing a web based management system that allows the weed officer in the field to show real time where they are working, what they are working on and when they need to go back to protect the communities investment in weed control (Weed Map Pro). It also serves weed notices to non-compliant landowners and prompts the weed officer when to return to do inspections.

A mapping exercise that brings together these sources of information on weeds in the study area and ground truths them would fill an important data gap that would immediately assist in tangible on ground works.

An emerging issue for the study area is the introduction and spread of the giant reed (*Arundo donax*). A coordinated approach will maximise the potential of managing this for the study area. *A. donax* responds strongly to fertiliser, prefers well-drained soils above the mean water level in freshwater streams, and it is generally most abundant and dominant in open sites (full sun) where the original native vegetation has been recently damaged or removed (Queensland Primary Industries, 2009). A rapid targeted and coordinated approach will be required if the introduction of this weed to the study area is to be managed.

Together with the River Reach Assessment presented in the Hawkesbury Nepean River Health strategy (HNCMA, 2007), up to date weed mapping will assist in the prioritisation and targeting of rehabilitation efforts.

4.3.2 Erosion and structure mapping

Bank erosion and foreshore structures (particularly walls) are a significant issue throughout much of the Upper Hawkesbury River Estuary. Foreshore structures above mean water level is an issue that is within Councils jurisdiction to manage. Water-based structure mapping was undertaken in 2007 by the former Waterways Authority, this mapping has not yet been located. An updated map of foreshore structures and erosion would serve as a baseline to measure the success of the future Upper Hawkesbury River Estuary Coastal Zone Management Plan, which is likely to include actions to reduce the construction of inappropriate foreshore structures. It would also be an important consideration in making recommendations regarding recreational zones and changes to boat speeds and wash.

An up to date map of erosion areas could also be used as a baseline and to inform priorities for rehabilitation works. Through the nest stage it will be important to work with RMS to ensure current recreational speed zones are appropriate. For example, research related to the impact of waves

generated by power boats in low energy environments such as the Upper Hawkesbury River Estuary have indicated that the most erosive waves from wake boarding boats (for example) are not at operating conditions but at slower velocities (e.g. Glamore, 2007). This is because it is not just wave height that influences a waves erosion potential. It is a function of both height and period, which combined give the complete wave energy. A map of erosion areas and recreational zones would be informative.

4.4 Identifying Controllable Pressures and Issues

The Hawkesbury Nepean Catchment is an almost overwhelmingly large system and as discussed there are several agencies involved in its management. There are many aspects of the management of Upper Hawkesbury River Estuary that can be targeted through the estuary management program and there are some aspects that are beyond the reach of this process. At this early stage of the project it is important to establish this context. Given the diversity of agencies and individuals involved in managing the Hawkesbury River and its ongoing role as the provider of water for Sydney and as the vector of wastewater for a large population, a Coastal Zone Management Plan will need to focus efforts on "controlling the controllable". It is essential that the plan be targeted, focussed, realistic and achievable. For example, while blue green algae blooms are a significant issue for the study area (Kimmerikong , 2005), the nature of the catchment means that there is not the potential for reducing the loads of trigger nutrients to the point where they limit plant growth through this process.

The key pressures and issues identified through the background data review have been summarised in Table 4-3. The agencies with responsibility for managing these issues have also been identified. The final column of the Table gives some examples of initiatives that could be facilitated through the Estuary Management Program. It should be noted that this list is a starting point. It is not considered comprehensive as it is based on a review of background information, limited consultation and a site visit. The contents are expected to be expanded during consultation in the second stage of the project.

Table 4-3 Pressures and Issues identified for consideration in the Upper Hawkesbury Coastal Zone Management Plan

Pressure	Issues	Responsible agencies	Examples of opportunities to contribute through the CZMP process
Riparian Land Uses	Lack of appropriate riparian vegetation (and deliberate clearing to increase views). Vegetation clearing is happening in some areas despite the Native Vegetation Act and Threatened Speces Conservation Act Approx. 27 Caravan Parks, associated works and Impacts Adhoc Bank Works Use of fertilisers and pesticides Clearing in Riparian areas despite SEPP (previously SREP 20), LEP and Tree Preservation Orders Encroachment of private development onto public land (e.g. Holmes Drive Reserve).	Hawkesbury City Council The Hills Shire Council HNCMA	Map caravan park locations- Clearly defining regulations regarding caravan parks and identifying opportunities to reduce impacts / prevent further proliferation Understand barriers to rehabilitation of privately owned banks and contribute to managing these Prepare a site specific guideline for environmentally friendly seawalls Work from priorities determined by the HNCMA through the River Health Strategy Providing additional resources for compliance Consider employing a Riverkeeper Council led program to identify when riparian land changes ownership and to contact new owners making them aware of opportunities for grants to improve the condition of riparian lands Pilot projects to showcase best practice riparian revegetation
Water Based Development (jetties, stairs, bank protection works etc.)	Contribution to bank degradation and loss of riparian vegetation Visual Impacts Barriers to fish passage Sometimes without consent under the Water Management Act.	DPI Fisheries Hawkesbury City Council The Hills Shire Council Office of Environment and Heritage	Repeat audit undertaken by Steve Black to assess increase and to establish a baseline for this plan Prepare a site specific guideline for environmentally friendly seawalls Clearly outline the relevant planning framework and identify opportunities to improve this to ensure appropriateness of future development Providing additional resources for compliance Resource rehabilitation of barriers to fish passage Consider employing a Riverkeeper
Catchment Development	Urbanisation Loss of market gardens Mining within the catchment	Hawkesbury City Council The Hills Shire Council Department of Planning and Infrastructure	Recommendations for planning initiatives to ensure best practice water sensitive urban design Identifying riparian and biodiversity corridors Looking for opportunities to return riparian land to public ownership Providing additional resources for compliance
Weed invasion in riparian areas	Destabilised banks Erosion Clearing of native vegetation and planting inappropriate species Recent appearance of *Arundo donax* Lack of central mapping Private ownership Impacts of dam overflows for weed proliferation	HNCMA (or Local Land Services from January) Hawkesbury River County Council Hawkesbury City Council The Hills Shire	Coordinating efforts between the County Council, Bushcare and Landcare (including Willow Warriors) to maximise benefits for the estuary. Provide centralised up to date weed mapping Support implementation of the priorities outlined in the River Health Strategy Education and engagement programs with landholders Communication between Council and Local Land Services when priority land changes ownership as a new opportunity for rehabilitation works.

Pressure	Issues	Responsible agencies	Examples of opportunities to contribute through the CZMP process
		Council	Consider employing a Riverkeeper
Introduced fauna	Changed hydrological regime favours introduced fish species (e.g. carp)	DPI Fisheries	
Climate change / sea level rise	Further propagation of tide / impacts on ecology Impacts to mangroves and casuarina forests in Webbs Creek Increased frequency of extreme events Exacerbating impacts from reduced environmental flows	Hawkesbury City Council Office of Environment and Heritage The Hills Shire Council	Mapping estuarine vegetation and identifying vulnerabilities
Illegal dumping of waste along the estuary	Fill, crushed rock and other ad hoc waste materials etc. along riparian zone Rubbish from recreational users	Hawkesbury City council The Hills Shire Council	Education programs Providing additional resources for compliance Consider employing a Riverkeeper
STP discharges	South Creek with major STP inputs Contribution to proliferation of algae blooms / aquatic weeds Impacts on aquatic ecology Impacts of medication derived chemicals in human waste on aquatic organisms Impacts to recreational users	Sydney Water Sydney Catchment Authority Office of Environment and Heritage	Utilise hydrodynamic and WQ modelling insights coming out of present study for Sydney water to understand processes and impacts Subject to permission being granted utilise model to assess impacts of Climate Change, changes to water sharing plan and potential impact of options Communicate appropriateness of water for recreational uses Opportunities for improvement to Council management of onsite systems
Private ownership of foreshore lands	Limited access Poor condition of riparian lands Interruption to riparian corridors Encroachment of private development onto the limited areas of public land (e.g. Holmes Drive Reserve).	Hawkesbury City Council The Hills Shire Council Office of Environment and Heritage	Develop educational materials and program to encourage best practice riparian land management Maximise potential of limited publically owned land for recreational opportunities Demonstrate best practice land management on publically owned land Lantana and other weed removal and subsequent rehabilitation of the cemetery site for public use
Boat based activities (includes commercial, agricultural and recreational)	Wake boarding and water skiing contributing to bank erosion Carrying capacity of estuary Increased number of boats Shift to wake boarding Appropriateness of recreational zones Effluent disposal	Roads and Maritime Services	Ensure latest research on boat wake, speed limits, boat type and erosion are considered in recreational zoning of the estuary Appropriate waste facilities Compliance Consider employing a Riverkeeper
Water extraction and	Abstraction licences	Office of Environment	Resource improved compliance activities

Pressure	Issues	Responsible agencies	Examples of opportunities to contribute through the CZMP process
dams	Domestic water Pumps as a barrier to fish passage Impacts to flow regime Stormwater not included in environmental flows considerations (role of freshwater in flushing nutrients not considered) Impacts on stratification Extractor not paying true environmental cost	and Heritage Office of Water	Continue to work with WRL and others to understand relationship between environmental flow regime and estuary health Water efficiency practices for individual extractors Know the Flow
Agricultural inputs	Contribution to algal proliferation Water demand Use of fertilisers, manure etc. Impact of farm dams	HN CMA Local Land Services (after January 2014)	Assistance to River Health Strategy implementation of actions to benefit the estuary (fencing, riparian revegetation etc)
Fishing	Impacts of prawn trawling Impacts of eel catchers Unknown catch from recreational fishers	DPI Fisheries Hawkesbury Trawl Association	Resource and make recommendations for research, zoning and compliance activities Consider Riverkeeper
Siltation	Impacts on navigation Dredging considerations Smothering of vegetation Proliferation of mangroves	Roads and Maritime Services Hawkesbury City Council	Communicate natural tendency for a depositional environment and actual siltation rates Communicate results of cross section and navigability study
Management approach	Lack of action on obvious issues Fragmentation of authority and approach Impact of government cycle (funding and policy changes) Need for consistent objectives and integrated panning to meet these No single authority looking at cumulative impacts Lack of compliance activities	All agencies listed in Table 3-1	Strong focus on tangible action early in project

5 WHERE TO FROM HERE?

The next step in this project is to undertake a detailed risk assessment to prioritise goals and objectives for management before formulating and assessing potential management options. The assessment of management options will include consideration of environmental, social and economic constraints. The focus of the options assessment will be to identify the options that can be practically implemented in short time frames, with the best chance of improving estuary health into the future. This second stage will involve engaging the local community through community drop in sessions and a web presence.

As significant work has been undertaken already through previous initiatives to document pressures, issues and values, the focus now is to ground truth the existing information (as presented in this Synthesis report) and to move forward with prioritising the issues and values and developing targeted, specific and achievable options.

6 REFERENCES

ANZECC/ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. Canberra, Australia.

Church, J. A., Aarup, T., Woodworth, P. L., Wilson, W. S., Nicholls, R. J., Rayner, R., Lambeck, K., Mitchum, G. T., Steffan, K., Cazenave, A., Blewitt, G., Mitrovica, J. X. and J. A. Lowe (2010), Sea-Level Rise and Variability: Synthesis and Outlook for the Future in *Understanding Sea-Level Rise and Variability*, 1st Edition, Eds. John A. Church, Philip L. Woodworth, Thorkild Aarup and W. Stanley Wilson, Blackwell Publishing Ltd, 2010, p 402-419.

CSIRO (2007), *Climate Change in Australia Technical Report 2007*. CSIRO Marine and Atmospheric Research and Bureau of Meteorology, Melbourne, VIC, Australia.

CSIRO/ACECRC (2012), *Sea Level Rise Understanding the past – Improving projections for the future*, webpage http://www.cmar.csiro.au/sealevel/sl_hist_last_15.html accessed on 26/11/2012

Department of Environment and Climate Change (2009) Hawkesbury – Nepean River Environmental Monitoring Program

Department of Environment and Climate Change Draft Lower Hawkesbury Nepean River nutrient management strategy

Department of Environment Krogh. M., Wright. A. and Miller.J. (2009). Hawkesbury-Nepean River Environmental Monitoring Program. Final Technical Report. NSW Department of Environment and Climate Change.

DECCW (2009), *Derivation of the NSW Government's sea level rise planning benchmarks*, Technical Note, October 2009

DPI Fisheries (2006) Reducing the impact of road crossings on environmental flows, water quality and fish passage in coastal NSW

Glamore, W (2007) A Decision Support Tool for Assessing the Impact of Boat Wake Waves on Inland Waterways

Gruber, R., Ferguson, A. and Haine, B. (2010) Final Report. Nutrient Transformation and Attenuation within Tidal Rivers. Research Project 2007/RD/0018 (July 2008 – July 2010). NSW Department of Environment Climate Change and Water.

Kimmerikong 2005 Scoping Study Hawkesbury Nepean River Estuary Management Final Report

Land Arc (in draft) Holmes Drive Reserve Cumberland Reach Draft Plan Of Management Draft Issue B: 8 April 2013

NSW NPWS (2000) Scheyville National Park and Pitt Town Nature Reserve Plan of Management

NSW NPWS and DECC (2009) Schaeyville National Park Conservation Management Plan Volume 1

NSW Environment and Heritage (2012) Sea Level Rise web-page available at http://www.environment.nsw.gov.au/climatechange/sealevel.htm. Accessed 1/11/12.

OEH 2013, Estuaries of NSW Website - Factsheets http://test.dnr.nsw.gov.au/estuaries/factsheets/physical/figures/b18.shtml (viewed in February 2013)

Pinto, U., Maheshwar, B.L., Shrestha, S., and Morris, C. (2012) Understanding the meaning of river health for a community: perspectives from the peri-urban region of the Hawkesbury-Nepean catchment, Australia Water Policy 14 (2012) 766-783

Thiebaud, I. and Williams, R.J. (2007) Distribution of freshwater macrophytes in the Hawkesbury-Nepean River from Warragamba Dam to Wisemans Ferry 2007. NSW Department of Primary Industries, Nelson Bay, NSW

Sydney Catchment Authority (2011) Annual Water Quality Monitoring Report 2009-10.

Sydney Catchment Authority (2012) Annual Water Quality Monitoring Report 2010-11.

Cook, C and Johnstone, R (2011). The Significance of Benthic Nutrient Cycling and Metabolism in the Hawkesbury-Nepean River System (Draft Report). Prepared for Sydney Water, June 2011.

Queensland Primary Industries (2009) Weed Risk Assessment Giant Reed *Arundo donax*

WRL, 2003, "Brooklyn Estuary Processes Study", Eds B M Miller, D C van Senden (Water Research Laboratory)

APPENDIX A: LEGISLATIVE FRAMEWORK

Environmental Planning and Assessment Act 1979 (EPA Act)

The *Environmental Planning and Assessment Act 1979* (EPA Act) is the key NSW legislation for planning and land use. The Act provides a system of environmental planning and assessment for NSW, and involves developing plans to regulate competing land uses, through 'environmental planning instruments'.

The Act establishes three types of environment planning instruments (EPI):

- Local Environmental Plans;
- Regional Environmental Plans (now deemed as SEPPs); and
- State Environmental Planning Policies.

The objectives of the EPA Act are to encourage:

- proper management, development and conservation of natural and artificial resources, including agricultural land, natural areas, forests, minerals, water, cities, towns and villages for the purpose of promoting the social and economic welfare of the community and a better environment;
- promotion and co-ordination of the orderly and economic use and development of land;
- protection, provision and co-ordination of communication and utility services;
- provision of land for public purposes;
- provision and co-ordination of community services and facilities;
- protection of the environment, including the protection and conservation of native animals and plants, including threatened species, populations and ecological communities, and their habitats;
- ecologically sustainable development;
- the provision and maintenance of affordable housing;
- promotion of the sharing of the responsibility for environmental planning between the different levels of government in the State;
- provision of increased opportunity for public involvement and participation in environmental planning and assessment.

Approval processes for "development" and "works" in NSW are provided for in Part 4, Part 5 and Part 5A of the EPA Act. Key provisions are outlined briefly below.

Part 4 – Development Assessment

Part 4 of the EPA Act lays out the legislative regime for the standard process for lodgement and consideration of development applications. Part 4 processes essentially apply where the local authority (Council) is the consent authority. The majority of land based development within the study area will fall within Part 4 of the EPA Act.

The controls and permissibility for development of particular sites and / or uses are found in the Local Environment Plan (LEP) and Development Control Plan (DCP) that cover Council's Local Government Area (LGA).

Section 79C under Part 4 of the *Environmental Planning and Assessment Act 1979* outlines matters for consideration for a consent authority (typically Council) in determining a development application to include the provisions of any coastal zone management plan (within the meaning of the *Coastal Protection Act 1979*) that apply to the land to which the development application relates.

Part 5 – Environmental Assessment

Part 5 outlines the requirements for determining authorities to consider the environmental impact of activities, through an environmental assessment for the proposed activity. The environmental assessment shall outline the effect of the activity on critical habitat, endangered fauna, vulnerable species, conservation agreements (under the *National Parks and Wildlife Act 1974*), plans of management, wilderness areas (under the *Wilderness Act 1987*) and joint management agreements and bio-banking agreements under the *Threatened Species Act, 1995*, and any other legislation pertaining to the proposed activity.

Part 5 of the Act applies to proposed activities that are permissible without development consent under Part 4 of the EPA Act but require approval from a Minister or Public Authority, or is proposed to be carried out by a Minister or Public Authority (and Council is classified as a Public Authority).

Part 5 obliges the "determining authority" for the proposal to consider the environmental impact of any activity. A determining authority is the public authority which is required to approve an activity, and can also be the public authority proposing to carry out the activity. For example, Council is permitted to undertake certain environmental management activities under SEPP (Infrastructure) 2007 without development consent, however will still need to complete an environmental assessment (typically, a Review of Environmental Factors) under Part 5 of the EPA Act. In certain cases where an activity is considered to be "designated development", an Environmental Impact Statement (EIS) is required.

Part 5A (Development by the Crown) essentially provides a legislative regime for consideration of Development Applications made by, or for and on behalf of, the Crown.

The remaining parts of the EPA Act relate to: Part 6 – Implementation and Enforcement; Part 7 – Finance and Part 8 – Miscellaneous.

State Environmental Planning Policies

SEPP No. 71 – Coastal Protection

State Environmental Planning Policy No. 71 – Coastal Protection (SEPP 71) aims to protect and manage the natural, cultural, recreational and economic attributes of the New South Wales coast. SEPP 71 aims for development in the NSW coastal zone to be appropriate and suitably located, in accordance with the principles of the Ecologically Sustainable Development (ESD). The policy provides for: the protection of and improvement to public access compatible with the natural attributes coastal foreshores; and protects and preserves Aboriginal cultural heritage, visual amenities of the coast, the beach environment and amenity, native coastal vegetation, marine environment of New South Wales, and rocky platforms.

SEPP 71 applies to all lands within the coastal zone of NSW, which is defined on gazetted maps under the SEPP. Therefore, SEPP 71 applies all of the land in the study area for this CZMP. SEPP 71 provides matters for consideration in clause 8 that are to be taken into account: by a council when preparing its LEP for land within the coastal zone; and by a consent authority (e.g. council) when determining a development application on land within the coastal zone.

SEPP 71 also outlines the conditions for which the Minister for Planning becomes the consent authority for 'significant coastal development', that is, development on land within 100 metres of and below mean high water mark of the sea, a bay or an estuary. Development applications received by Council on such lands must be sent to the Director-General of Planning, and Council is required to take any additional matters specified by the Director-General into account when determining the application (in addition to the 'matters for consideration' given in Clause 8).

SEPP 71 also outlines development controls in Part 4 for which consent cannot be granted to applications that, in the opinion of the consent authority:

- will or is likely to impede or diminish to any extent the physical, land based right of access of the public to or along the coastal foreshore;
- where effluent is proposed to be disposed of by means of a non-reticulated system, will or is likely to have a negative effect on the water of the sea or any nearby beach, or an estuary, a coastal lake, a coastal creek or other similar body of water, or a rock platform; or
- will or is likely to, discharge untreated stormwater into the sea, a beach, or an estuary, a coastal lake, a coastal creek or other similar body of water, or onto a rock platform.

A master plan is to be adopted by Minister for Planning (or otherwise waived by the Minister as per Clause 18), prior to Council granting consent for subdivision of land:

- within a residential zone or rural residential zone if part or all of the land is in a 'sensitive coastal location'; or
- within a residential zone that is not within a 'sensitive coastal location' into more than 25 lots, or 25 lots or less, if the land proposed to be subdivided and any adjoining or neighbouring land in the same ownership could be subdivided into more than 25 lots; or
- within a rural residential zone that is not identified as a 'sensitive coastal location' into more than 5 lots.

SEPP71 defines 'sensitive coastal location' to mean land within:

- 100 metres above mean high water mark of the sea, a bay or an estuary;
- a coastal lake, or within 100 m of the water's edge of a coastal lake;
- a declared Ramsar Wetland, or within 100 m of a declared Ramsar Wetland;
- a declared World Heritage Property, or within 100 m of a declared World Heritage Property;
- a declared aquatic reserves under the *Fisheries Management Act 1994*, or within 100 m of such;
- a declared marine park under the *Marine Parks Act 1997*, or within 100 m of a marine park;
- coastal lakes, Ramsar wetlands and World Heritage areas;

- marine parks and aquatic reserves under the *Fisheries Management Act*; land within 100 metres of any of the above;
- within 100 m of land reserved under the *National Parks and Wildlife Act 1974*;
- within 100 m of SEPP 14 Coastal Wetlands; and
- residential land within 100 metres of SEPP 26 Littoral Rainforests.

SEPP No. 14 – Coastal Wetlands

Information regarding SEPP 14 is included below for information only.

State Environmental Planning Policy (SEPP) 14 – Coastal Wetlands (SEPP14) was designed to protect and preserve coastal wetlands for the environmental and economic interests of the State. The policy provides protection to specific wetland areas that have been mapped and gazetted by Department of Planning. Development that involves the following activities is not allowed to be carried out unless consent (as 'designated development') is provided by local council or the Director General of Planning: clearing of land, construction of levees, draining of land, and filling of land. If this development is to be carried out, an Environmental Impact Statement first needs to be prepared.

The Director General of Planning must consider a number of matters prior to agreeing to the proposed development including:

- The environmental effect of the proposed development;
- Whether adequate safeguard and rehabilitation methods are proposed;
- Whether the development is consistent with the aims of the policy; and
- Whether any feasible alternatives have been considered and if so, the reason for choosing the proposed development.

SEPP (Infrastructure) 2007

SEPP (Infrastructure) 2007 provides a consistent planning regime for infrastructure and the provision of services across NSW, including consultation with relevant public authorities during the assessment process. The intent of the SEPP is to support greater flexibility in the location of infrastructure and service facilities along with improved regulatory certainty and efficiency for the State.

Division 25 of the SEPP outlines development permitted with and without consent for the purpose of 'waterway or foreshore management activities', which are defined as:

'(a) riparian corridor and bank management, including erosion control, bank stabilisation, resnagging, weed management, revegetation and the creation of foreshore access ways, and

(b) instream management or dredging to rehabilitate aquatic habitat or to maintain or restore environmental flows or tidal flows for ecological purposes, and

(c) coastal management and beach nourishment, including erosion control, dune or foreshore stabilisation works, headland management, weed management, revegetation activities and foreshore access ways, and

(d) coastal protection works, and

(e) salt interception schemes to improve water quality in surface freshwater systems, and

(f) installation or upgrade of waterway gauging stations for water accounting purposes.

Development for the purpose of waterway or foreshore management activities may be carried out by or on behalf of a public authority (i.e. Council) without consent on any land, which may include:

- construction works;
- routine maintenance works;
- emergency works, including works required as a result of flooding, storms or coastal erosion (noting that this excludes emergency coastal protection works within the meaning of the Coastal Protection Act 1979);
- environmental management works.
- new coastal protection works on the open coast or entrance to a coastal lake (despite Clause 129A, see below), provided the public authority considers the provisions of any adopted CZMP relating to the land on which the works are proposed, or if there is no CZMP, notify the NSW Coastal Panel and take into consideration any response received from them within 21 days of notification. The 'new coastal protection works' excludes beach nourishment or sand placement, presumably so that councils can undertake beach nourishment without requiring such action to be a stated action in the CZMP or gaining approval from the Coastal Panel.

Under Clause 129A, development for the purposes of a sea wall or beach nourishment may be carried out by any person with consent on the open coast or entrance to a coastal lake. In determining the application, the consent authority (e.g. Council) must consider the provisions of any CZMP relating to the land on which the works are proposed, the matters stated in Clause 8 of SEPP 71, and any guidelines for assessing and managing the impacts of the works issued by the Director-General (noting that preconditions for granting consent for coastal protection works are stated in Section 55M of *the Coastal Protection Act*). Where there is no CZMP, the NSW Coastal Panel shall determine such applications.

SEPP (Infrastructure) 2007 formally repeals SEPP 35 – Maintenance Dredging of Tidal Waterways (among others). As noted above, Council and other public authorities may undertake dredging for environmental purposes (i.e. aquatic rehabilitation). In addition, Under Division 13 (Clause 68) development for the purpose of wharf or boating facilities may be carried out by or on behalf of a public authority without consent on any land, except for land reserved under the *National Parks and Wildlife Act 1974* such development may be carried out if it is authorised by or under that Act. Such development in connection wharf or boating facilities permitted without consent includes:

a) construction works (including dredging and land reclamation, if it is required for the construction of facilities), or

(b) routine maintenance works (including dredging, or bed profile levelling, of existing navigation channels if it is for safety reasons or in connection with existing facilities).

Thus, dredging for the purpose of safe navigation may also be undertaken without consent by Council under SEPP (Infrastructure) 2007.

Council may undertake waterway or foreshore management activities or activities for wharf and boating facilities without consent, provided they undertake a Review of Environmental Factors (REF) (under Part 5 of the EPA Act) and gain any approvals / licences required under other relevant Acts (e.g. *Crown Lands Act 1989*, *Fisheries Management Act 1994*, *Water Management Act 2000* etc). Dredging proposing the removal of greater than 1,000 cubic metres is 'designated development' under Clause 77A of the EPA Act and therefore requires the preparation of an Environmental Impact Statement (EIS).

Coastal Protection Act 1979

The NSW *Coastal Protection Act 1979* (the CP Act) provides guidance on the use, occupation and development of the coastal zone in NSW. The CP Act was amended in 1998 to extend the coastal zone to include estuaries, coastal lakes and lagoons, islands and rivers in recognition of the strong connection between estuaries and the open coast. The CP Act was again amended in 2002 to better reflect the purpose of the NSW Coastal Policy (1997) and to incorporate the principles of ecologically sustainable development.

The CP Act allows the Minister for the Environment to direct a council with land within the coastal zone to prepare a Coastal Zone Management Plan, and gives directions as to how such Plans shall be prepared, approved, gazetted and amended where necessary. This Coastal Zone Management Plan is being prepared in accordance with the *Coastal Protection Act 1979*, including the objectives of the Act as below. The CP Act also requires Coastal Zone Management Plans to provide for the unobstructed access to the coastline by the public (beaches, headlands, waterways, including lakes and lagoons).

The objects of the CP Act are to provide for the protection of the coastal environment of the State for the benefit of both present and future generations and, in particular:

- to protect, enhance, maintain and restore the environment of the coastal region, its associated ecosystems, ecological processes and biological diversity, and its water quality;
- to encourage, promote and secure the orderly and balanced utilisation and conservation of the coastal region and its natural and man-made resources, having regard to the principles of ecologically sustainable development;
- to recognise and foster the significant social and economic benefits to the State that result from a sustainable coastal environment, including
- benefits to the environment, and
- benefits to urban communities, fisheries, industry and recreation, and
- benefits to culture and heritage, and
- benefits to the Aboriginal people in relation to their spiritual, social, customary and economic use of land and water;
- to promote public pedestrian access to the coastal region and recognise the public's right to access;

- to provide for the acquisition of land in the coastal region to promote the protection, enhancement, maintenance and restoration of the environment of the coastal region;
- to recognise the role of the community, as a partner with government, in resolving issues relating to the protection of the coastal environment; and
- to ensure co-ordination of the policies and activities of the Government and public authorities relating to the coastal region and to facilitate the proper integration of their management activities.

Amendments to the CP Act 1979 were recently implemented as part of the *Coastal Protection and Other Legislation Amendment Act 2010* (now repealed). Of relevance to this estuary-based CZMP are:

- amendments to Part 2A of the CP Act establishing a joint state-local body called the NSW Coastal Panel, which shall act as a consent authority for coastal protection development applications where a council does not have a certified CZMP and / or requires further technical assistance in assessing such development applications, and the Panel shall also assist the Minister when requested, such as for reviewing CZMPs; and
- amendments to Section 55M of the CP Act and SEPP (Infrastructure) 2007 (refer above) that enable Council to construct coastal protection works without consent or any person to construct protection works with consent at the entrances to coastal lakes, provided such works are consistent with the adopted CZMP, or otherwise approved by the NSW Coastal Panel; and
- amendments to the *Local Government Act 1993* (Section 553B) to allow local councils to levy a Coastal Protection Service Charge to maintain and repair coastal protection works or to manage the impacts of coastal protection works.

Threatened Species Act 1995

The *Threatened Species Conservation Act 1995* (the TSC Act) aims to conserve biological diversity and promote ecologically sustainable development, by providing for the identification, protection and recovery of threatened species, populations, endangered ecological communities and their critical habitats. The TSC Act also aims to eliminate or manage processes that may threaten the survival of threatened species, populations or ecological communities.

Within the TSC Act:

- Schedule 1 lists endangered species, endangered populations, endangered ecological communities, species presumed to be extinct and critically endangered species and ecological communities (Schedule 1A);
- Schedule 2 lists vulnerable species and vulnerable ecological communities; and
- Schedule 3 lists key threatening processes.

The TSC Act has established a committee that is responsible for determining species, populations, ecological communities or threatening processes that should be included in Schedules 1, 2 or 3, or such can be listed upon request by the Minister (for the Environment, Climate Change and Water who administers this act).

The TSC Act does not include fish or marine vegetation as defined within Part 7A of the FM Act, i.e., such threatened species are covered by the FM Act. However, there is some overlap between the acts, and where a plant or animal may inhabit a terrestrial environment at some stage during its biological development, in concurrence with the Minister administering the FM Act, it may be listed in the TSC Act.

It is an offence under the TSC Act (and the *National Parks and Wildlife Act 1974* (NPW Act)) to harm, damage or pick an animal or plant that is, is part of, is critical habitat for, or is habitat for a threatened species, population or ecological community, unless a licence has been obtained under the TSC Act or NPW Act.

National Parks and Wildlife Act 1974

The objectives of the *National Parks and Wildlife Act 1974* (NPW Act) are:

- the conservation of nature, including habitats, ecosystems, ecosystem processes, biological diversity at the community, species and genetic levels, landforms of significance including geological features and processes, and landscapes and natural features of significance including wilderness and wild rivers;
- the conservation of objects, places or features (including biological diversity) of cultural value within the landscape, including of Aboriginal significance, of social value to the people of NSW and of historic, architectural or scientific significance;
- fostering public appreciation, understanding and enjoyment of nature and cultural heritage and their conservation; and
- providing for the management of land reserved under the NPW Act.

The objectives of the NPW Act are to be achieved by applying the principles of ecologically sustainable development (ESD).

The NPW Act was responsible for the establishment of the NSW National Parks and Wildlife Services (NPWS) which is now part of OEH. The officers are responsible for administering the NPW Act including national parks and other lands under this act, and also administration of the *Wilderness Act 1987* and the TSC Act 1995.

It is an offence under the NPW Act to damage, deface or destroy items of Aboriginal heritage (places, objects) without approval from the Director-General for OEH.

Fisheries Management Act 1994

The aim of the *Fisheries Management Act 1994* and *Fisheries Management Amendment Act 1994* (the FM Act) is to conserve, develop and share the fishery resources for the state's benefit for present and future generations. The FM Act applies specifically to aquatic flora and fauna, primarily fish, invertebrates and some algae. The FM Act promotes ecologically sustainable development, including conservation of biological diversity.

The FM Acts protects marine vegetation, including mangroves, saltmarsh and seagrass. Under the FM Acts, a permit is required to destroy or damage marine vegetation such as mangroves, seagrass, and saltmarsh. The Act also includes schedules of endangered aquatic species, populations and

ecological communities, which must be considered in the same manner as species listed under the *Threatened Species Conservation Act 1995*.

All developments under the EPA Act must also be consistent with the objectives and permissible uses of aquatic reserves as contained within the FM Act and any management plans where they exist for the aquatic reserve.

Dredging and reclamation activities also fall under the FM Act. Reclamation of land in the waterway shall be managed so as to conserve the biodiversity of fish, aquatic vegetation and fish habitat and be consistent with the principles of ecologically sustainable development. Persons (i.e., not a public or local authority) must have a permit issued by the Minister for Fisheries before they may proceed with reclamation or dredging activities.

Under the FM Act it is an offence to harm or cause damage to (by an act or an omission) any fish, marine vegetation or habitat of a threatened species, population or ecological community, or critical habitat. This includes damage caused in the act of carrying out a development or as a failure to comply with a development consent or approval. Licences to cause harm or damage will only be granted for: scientific purposes; the welfare of fish or marine vegetation; or where there is threat to life or property.

The FM Act also includes and allows for the preparation of Habitat Protection Plans. Those plans relevant to the study area include:

Habitat Protection Plan No. 1 General

This is an advisory document summarising various protective measures in relation to dredging and reclamation activities, fish passage requirements, and the protection of mangroves, other marine vegetation and snags.

Habitat Protection Plan No. 2 Seagrasses

The Plan deals specifically with the protection of seagrasses across NSW, and discusses activities which impact on seagrasses, including the construction of jetties, wharves, and bridges, dredging and reclamation, and the collection of seagrasses.

Local Government Act 1993

The *Local Government Act 1993* (the LG Act) creates local governments and grants them the power to perform their functions, which involve management, development, protection, restoration, enhancement and conservation of the environment for the local government area. The functions of the local government are to be performed in a manner that is consistent with and promote the principles of ecologically sustainable development.

The service functions of local councils (defined in Chapter 6 of the Act) includes the classification, use and management of public land, including the objectives for management of the Community Land owned by Council (i.e. that is not Crown Land).

Plans of Management for Community Land need also to be prepared under Section 35 of the Act. Section 35 of the act provides that community land only be used in accordance with the plan of

management applying to the parcel of community land; any law permitting the use of the land for a specified purpose or otherwise regulating the use of the land; and the provisions of Division 2 Chapter 6 of the Act.

Community land can be categorised into a range of categories under Section 36 of the Act, and each of these categories have their own core objectives specified under the Act. The categorisation of community lands is important as the Act requires Council to only grant a lease, licence or another estate (other than in respect of public utilities) for a purpose consistent with the core objectives of the category of that community land.

Section 733 of the LG Act offers exemption of liability to Council with respect to coastal and floodplain lands providing that Council acts in 'good faith' and manages the lands in accordance with Government guidelines and manuals. In respect to coastal lands, the relevant Government manual is the CZMP Guidelines. Consequently, the development of this CZMS and subsequent CZMP is considered to be acting in good faith and in accordance with the appropriate guidelines, and as such, when the CZMP is gazetted, Council can assume the liability exemption.

Crown Lands Act 1989

The *Crown Lands Act 1989* (the CL Act) provides for the administration and management of Crown land for the benefit of the people of NSW. The CL Act provides principles for the proper assessment, development, reservation or dedication and conservation of Crown Lands.

Waterbodies such as beaches and foreshores and estuaries / creeks / lagoons below the mean high water mark are designated as Crown Land and managed by the Department of Primary Industries Crown Lands Division (CLD).

The principles of Crown Land management as defined in Section 11 of the Act are: environmental protection principles be observed in relation to the management and administration of Crown land; natural resources of Crown Land (including water, soil, flora, fauna and scenic quality) be conserved wherever possible; public use and enjoyment of Crown lands be encouraged; where appropriate, multiple uses of Crown land be encouraged; and where appropriate, Crown Land be used and managed in such a manner that the land and its resources are sustained in perpetuity.

In addition to these principles, the objectives of the Coastal Crown Lands Policy 1991 apply to Crown lands within the coastal zone. The policy sets specific objectives for conserving the environmental and cultural qualities of coastal Crown Land, retaining in public ownership coastal lands that are environmentally sensitive and / or required for public purpose, and providing use of coastal crown lands for recreation, tourism, residential and commercial development with due regard to the nature and consequences of coastal processes.

For all Crown land reserves, a Plan of Management (POM) is required to be prepared and adopted (in accordance with Division 6 of the *Crown Lands Act 1989*). The POM shall identify the key attributes and values of the area, general physical improvements to enhance the values and specify the permissible uses for the reserve.

The CL Act requires a land assessment to be undertaken prior to the reservation, dedication, exchange, vesting or sale of Crown land, or the granting of easements, leases or licences in respect

of such land. The process for land assessment is specified by the Act and the *Crown Lands Regulation 2000*. It requires the physical characteristics of the land to be identified, the land's capabilities to be assessed and suitable uses identified. A draft land assessment is publicly exhibited for 28 days for comment. The exhibited draft may indicate a preferred use or uses.

Under the CL Act Crown lands may be:

- Held under tenure (lease or licence) for public purposes;
- Community managed reserves;
- Reserved for environmental purposes;
- Crown public roads; or
- Managed reserved lands.

Where an individual or organisation proposes to undertake an activity, build a structure or use Crown land, they are required to apply for tenure from CLD. This includes the issue of domestic waterfront licences for the use of submerged and tidal Crown land where there is direct access to Crown land. This type of licence would cover facilities such as jetties, boatsheds or boat ramps. There are three general types of arrangements under which Crown land may be held under tenure:

- Lease – form of tenure generally for exclusive occupation and use of Crown land for a specific term and under specific conditions as outlined under the provisions of the CL Act. Leases are designed with terms to suit the purpose of the lease. A lease may be forfeited for non-compliance of conditions, or may expire because the term has lapsed. A lease is also transferrable with the consent of the Minister. Generally, leases will require land assessments.
- Licence – provides the right to occupy or use Crown land under the provisions of the CL Act. A licence may not necessarily confer exclusive use by a licensee. It is not transferrable and may be revoked at the will of the Minister without compensation.
- Permissive Occupancy (PO) – PO agreements with the Minister are pursuant to the CL (Continued Tenures) Act 1989. Under the CL Act, only leases or licences will be issued in the future and permissive occupancies will be progressively terminated in favour of a licence or lease.

Water Management Act 2000

The *Water Management Act 2000* (the WM Act) seeks to promote the integrated and sustainable management of the States waters for the benefit of both present and future generations. Of key relevance to the Study area, the Act aims in particular "to protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity and their water quality". The Water Management Act 2000 replaced the Rivers and Foreshores Improvement Act 1948 (RFI Act 1948) in February 2008.

The WM Act outlines those activities for which a 'controlled activities approval' is required for works on waterfront land. The WM Act defines waterfront land as all land between the bed of a watercourse and a distance of 40 m from: the top the highest bank of a river (including creeks); shores of a lake; or, mean high water mark of an estuary or coastal waters (including lakes and lagoons). Therefore,

controlled activities approval is required for the following activities on all foreshores of the Study area within 40 m of the mean high water mark:

'(a) the erection of a building or the carrying out of a work (within the meaning of the EPA Act), or

(b) the removal of material (whether or not extractive material) or vegetation from land, whether by way of excavation or otherwise, or

(c) the deposition of material (whether or not extractive material) on land, whether by way of landfill operations or otherwise, or

(d) the carrying out of any other activity that affects the quantity or flow of water in a water source.'

Exemptions from the WM Act are defined in Clause 39A of the Water Management (General) Regulation 2004 and include exemptions for government authorities, with the exception of Landcom.

Protection of the Environment Operation Act 1997

The Protection of the Environment Operations Act regulates water pollution, air pollution and noise pollution in New South Wales. The Act enables the Environment Protection Authority, an agency within the OEH, to issue pollution license and notices, to take legal action to enforce the law and to create a range of pollution offences and penalties. The Act also enables members of the public to take legal action to enforce laws.

Under the PEO Act it is considered an offence to pollute water without an environmental protection licence. Water pollution is the placement of any matter in a position where pollution enters or is likely to enter the water. Pollution of a waterway is allowed if an environmental protection license is held, however, there are conditions of a licence.

Other activities that require a licence under the Act are dredging or extractive activities where more than 30,000 m^3 per year is being removed, for re-use or resale (refer Schedule 1).

Catchment Management Act 2003

The purpose of the *Catchment Management Act 2003* is to establish catchment management authorities that would carry out certain natural resource management functions in their regions. These are currently undergoing reorganisation. The Act repealed the Catchment Management Act 1989 and amends various other Acts.

The objectives of the Act are:

- To provide natural resource planning on a catchment level;
- To ensure that the decisions about natural resources take into account appropriate catchment issues;
- To ensure that catchment level decisions take into account state standards and involve the Natural Resource Commission in catchment planning;
- To make use of the communities' knowledge and expertise and to involved them in decision making;

- To ensure proper management of natural resources from the social, economic and environmental issues; and
- To provide financial assistance and incentives to landholders in connection with natural resource management.

Under the Act each catchment management authority prepared a Catchment Action Plan (CAP).The Hawkesbury Nepean Catchment Management Authority has also prepared the Hawkebury Nepean River Health Strategy.

Natural Resource Management Act 2003

The *Natural Resource Management Act 2003* is responsible for the creation of the Natural Resources Commission. The objectives of the Act are:

- To establish a sound scientific basis for the informed management of natural resources in regards to the social, economic and environment interests of the State;
- To enable the adoption of State-wide standards and targets for natural resource management issues; and
- To advise in the circumstance where broad-scale clearing is regarded to be an improvement or maintenance of environmental outcomes for the purpose of the *Native Vegetation Act 2003*.

The Natural Resource Commission consists of a full time Commissioner and Assistant Commissioner. The role of the Commission is to provide the government with independent advice on natural resource management, in addition to recommending state-wide targets for natural resource management, approval of catchment action plans, and commenting on the effectiveness of these plans. The commission would also undertake natural resource management assessments, and would control investigations and inquires into natural resource management issues and research of the issues.

Environment Protection and Biodiversity Conservation Act

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the main Commonwealth Law responsible for the protection of flora and fauna. The Act applies to:

- Flora and fauna within areas controlled or owned by the Commonwealth;
- Flora or fauna that may be harmed by the actions of a Commonwealth agency; and
- Actions that may have a significant effect on species on the national threatened species list.

The EPBC Act requires approval by the Commonwealth Minister for the Environment for actions that may have a significant impact on matters of national environmental significance. The EPBC Act defines matters of national environmental significance as: Ramsar wetlands, listed threatened species and communities, World Heritage properties, listed migratory species, the Commonwealth marine environment and nuclear actions (including uranium mining). The EPBC Act was amended in 2003 to include protection of National Heritage. This amendment involved, including 'national heritage' as new matter of national environment significance, and the establishment of a national heritage list.

The EPBC Act also requires Commonwealth approval for certain actions on Commonwealth land.

Estuary Management Policy 1992

The NSW Estuary Management Policy was one of a suite of policies under the former NSW State Rivers and Estuaries Policy. The Estuary Management Policy was developed in response to the State Government's recognition of the social and economic importance of estuaries. The specified general goal of the policy is "to achieve an integrated balance responsible and ecologically sustainable use of the State estuaries which form a key component of coastal catchments".

The Estuary Management Manual (1992) was replaced by the *Guidelines for Preparing Coastal Zone Management Plans* (DECCW, 2010), in which the coastal and estuary management processes were combined. This Scoping study has taken consideration of the objectives and relevant guidance for estuaries given in the former Manual.

NSW Coastal Policy 1997

The aim of the New South Wales Coastal Policy 1997 is to promote the ecologically sustainable development of the New South Wales coastline. To achieve this, the policy sets out various goals, objective and actions. This policy applies the coastal zone, as defined by the area that extends to:

- three nautical miles seaward of the mainland and offshore islands;
- one kilometre inland of the 'open coast' High Water Mark;
- one kilometre around all the bays, estuaries, coastal lakes, lagoons and island; and
- in relation to tidal rivers, one kilometre around the tidal waters of the river to the limit of mangroves or the tidal limit (whichever is closer to the sea).

The Upper Hawkesbury River Estuary and its foreshores are within the defined coastal zone; therefore the Coastal Policy has been considered in the preparation of this study.

The relevance of the Policy to future development is that the council is required to implement the policy when making local environment plans applying to land within the coastal zone and to take the provisions of the policy into consideration when determining development applications in the coastal zone.

As the NSW Coastal Policy 1997 applies to the Upper Hawkesbury River Estuary, Council is required to reflect the principles of ecologically sustainable development in planning and management decisions. Also, Council is committed to the principles of ecologically sustainable development through the *Local Government Act 1993* (amended 1997), which are embodied within Council's Environmental Policy 2002.

The Coastal Policy has nine goals, each underpinned by objectives that are to be achieved by strategic actions. Responsibilities for these actions have been assigned to appropriate agencies, councils and other bodies. OEH is wholly or partly responsible for nearly half of the strategic actions in the Coastal Policy, with many of these involving a partnership with local councils.

The nine goals of the NSW Coastal Policy 1997 are:

1. To protect, rehabilitate and improve the natural environment;

2. To recognise and accommodate natural processes and climate change;
3. To protect and enhance the aesthetic qualities;
4. To protect and conserve cultural heritage;
5. To promote Ecologically Sustainable Development;
6. To provide for ecologically sustainable human settlement;
7. To provide for appropriate public access and use;
8. To provide information to enable effective management; and
9. To provide for integrated planning and management.

Ecologically Sustainable Development

The four principles of Ecologically Sustainable Development (ESD) are:

1. The precautionary principle: The lack of full scientific evidence should not be used as a justification for the postponement of the introduction of measures to prevent or mitigate environmental degradation. This principle is fundamental to adaptive management. Monitoring and prevention are central to the precautionary principle – monitoring to measure progress, and prevention to minimise costs and risks. Decisions can and should be refined as ongoing monitoring and research provides better understanding.

2. Intergenerational equity: Each generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for future generations. This principle points to institutional and community responsibilities for integrated management, to ensure quality of life is maintained and enhanced.

3. Conservation of biological diversity and ecological integrity: Measures should be taken to prevent and protect against the extinction or loss of viability of plant and animal species due to human activities.

4. Improved valuation and pricing of environmental resources: The quality and value of environmental resources should be maintained and enhanced through appropriate management and pricing, preventing degradation and damage.

Regional Environmental Plans

SEPP – Hawkesbury/Nepean River (formerly SREP 20)

This SEPP applies to the whole Study Area and has the aim to protect the environment of the Hawkesbury Nepean River system by ensuring the impacts of future land uses are considered in a regional context.

The SEPP does not contain all the controls that may apply to a development proposal. Local planning controls (if they are in place) apply, as do licensing and approval requirements of other agencies.

Clause 6 of the SREP provides planning policies and recommended strategies. These are broad-brush strategies for consideration in planning and future development. They include:

- total catchment management;
- environmentally sensitive areas – which includes the river; waterway;
- water quality;
- water quantity;
- cultural heritage;
- flora and fauna;
- riverine scenic quality;
- agriculture/aquaculture and fishing;
- rural/residential development; and
- recreation and tourism.

Part 3 of the SEPP includes development controls relating to certain uses and works, both on land and in the waterway. Some of these have particular relevance to the Study, such as maintenance dredging and extractive operations, and filling of land (including submerged aquatic land), marinas and all land uses in or near the waterway. The SEPP confirms that all of these uses and works require development consent, as well as relevant concurrence provisions and specific matters for consideration. These matters address environmental impact and protection of aquatic flora and fauna.

The SEPP does not contain any additional detailed development or design controls for matters requiring development consent. Pursuant to clause 12(4), it also does not permit development which is prohibited by another environmental planning instrument or remove or reduce restrictions/standards imposed by another instrument.

Drinking Water Catchments Regional Environmental Plan No. 1

The Drinking Water Catchments REP No. 1 commenced on 1 January 2007

The REP aims:

(a) to create healthy water catchments that will deliver high quality water while sustaining diverse and prosperous communities, and

(b) to provide the statutory components in Sustaining the Catchments that, together with the non-statutory components in Sustaining the Catchments, will achieve the aim set out in paragraph (a), and

(c) to achieve the water quality management goals of:

(i) improving water quality in degraded areas and critical locations where water quality is not suitable for the relevant environmental values, and

(ii) maintaining or improving water quality where it is currently suitable for the relevant environmental values.

APPENDIX B: FIELD PHOTO LOG

BMT WBM Brisbane
Level 8, 200 Creek Street Brisbane 4000
PO Box 203 Spring Hill QLD 4004
Tel +61 7 3831 6744 Fax +61 7 3832 3627
Email bmtwbm@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Denver
8200 S. Akron Street, Unit 120
Centennial Denver Colorado 80112 USA
Tel +1 303 792 9814 Fax +1 303 792 9742
Email denver@bmtwbm.com
Web www.bmtwbm.com.au

BMT WBM Mackay
Suite 1, 138 Wood Street Mackay 4740
PO Box 4447 Mackay QLD 4740
Tel +61 7 4953 5144 Fax +61 7 4953 5132
Email mackay@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Melbourne
Level 5, 99 King Street Melbourne 3000
PO Box 604 Collins Street West VIC 8007
Tel +61 3 8620 6100 Fax +61 3 8620 6105
Email melbourne@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Newcastle
126 Belford Street Broadmeadow 2292
PO Box 266 Broadmeadow NSW 2292
Tel +61 2 4940 8882 Fax +61 2 4940 8887
Email newcastle@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Perth
Suite 6, 29 Hood Street Subiaco 6008
Tel +61 8 9328 2029 Fax +61 8 9484 7588
Email perth@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Sydney
Level 1, 256-258 Norton Street Leichhardt 2040
PO Box 194 Leichhardt NSW 2040
Tel +61 2 9713 4836 Fax +61 2 9713 4890
Email sydney@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Vancouver
401 611 Alexander Street Vancouver
British Columbia V6A 1E1 Canada
Tel +1 604 683 5777 Fax +1 604 608 3232
Email vancouver@bmtwbm.com
Web www.bmtwbm.com.au