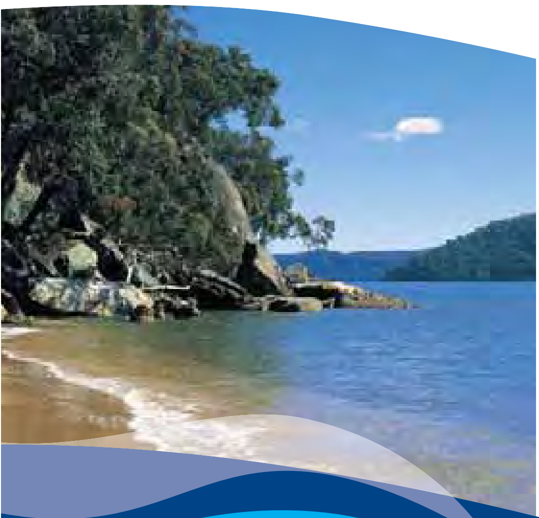
Hawkesbury
estuary
program

Lower Hawkesbury Estuary Management Plan



November 2008

www.estuary.hornsby.nsw.gov.au

HORNSBY
SHIRE COUNCIL

Hornsby Shire Council
Hawkesbury Estuary Program

Hornsby Shire Council's Lower Hawkesbury Estuary Management Plan and Program provides an integrated and strategic approach to the management of estuarine assets. These assets are protected through the implementation of strategies which incorporate:

- Planning – ensuring planning instruments include best practice and provisions for sustainable development
- Research – undertaking programs to monitor estuarine health and prepare for climate change
- Education – engaging local communities and schools through estuary awareness activities
- Compliance – encouraging riverside settlements to implement sustainable practices
- On-ground works – installing infrastructure and undertaking regeneration programs to protect estuarine assets

For more information visit Council's estuary website at www.estuary.hornsby.nsw.gov.au or call (02) 9847 6766.




Lower Hawkesbury Estuary Management Plan

Offices

Brisbane
Denver
Karratha
Melbourne
Morwell
Newcastle
Perth
Sydney
Vancouver

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

DOCUMENT CONTROL SHEET

BMT WBM Pty Ltd 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 54 010 830 421 003 www.wbmpl.com.au	***Document :*** R.N1252.003.03.doc ***Project Manager :*** Philip Haines ***Client :*** Hornsby Shire Council ***Client Contact:*** Peter Coad ***Client Reference***

Title :	Lower Hawkesbury Estuary Management Plan
Author :	Philip Haines, Michelle Fletcher, Verity Rollason, Peter Coad (HSC)
Synopsis :	This document is an Estuary Management Plan for the Lower Hawkesbury Estuary prepared under the provisions of the NSW Government's Estuary Management Program. It outlines a series of management strategies aimed at reducing identified risks to estuary assets.

REVISION/CHECKING HISTORY

REVISION NUMBER	DATE OF ISSUE	CHECKED BY		ISSUED BY	
1	26 March 2008	PH		MF	
2	20 June 2008	PH		MF	
3	13 November 2008	PH		PH	

DISTRIBUTION

DESTINATION	REVISION			
	1	2	3	4
HSC	elec	elec	elec	
BMT WBM File			1	
BMT WBM Library			1	

ACKNOWLEDGEMENTS

This report brings together the efforts of a wide range of individuals and organisations. The authors sincerely appreciate the time taken by everyone that attended the participatory workshops. The diversity of attendees strengthened the risk assessment methodology and resulting recommendations. Katherine Daniell contributed significantly to the detailed community and stakeholder consultation. SJB Planning undertook Town Planning tasks, including the review of relevant planning instruments and legislation. Hornsby Councils' Water Catchments Team, particularly Peter Coad, Ross McPherson, and Kristy Guise have also been crucial to the development of the strategies and direction and functionality of this document.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 ABOUT THE PLAN

1.1 Title

This document should be referred to as the "Lower Hawkesbury Estuary Management Plan" (BMT WBM, 2008). Copies of the plan and supporting information can be obtained from Council or through the project web-site www.estuary.hornsby.nsw.gov.au.

1.2 Management Area

The Management Area relevant to this Estuary Management Plan includes the estuarine areas of the Lower Hawkesbury River (below Wisemans Ferry), Berowra Creek, Cowan Creek and Mangrove Creek. The Management Area is shown in Figure 1-5.

1.3 Purpose of the Plan

Management of the Lower Hawkesbury Estuary to date has been disparate, with no lead organisation having the sole authority or responsibility for managing all issues required for effective management of estuarine assets. This situation is recognised within the NSW Government Estuary Management Manual (1992) which provides the direction for a coordinated approach for estuary management by providing the necessary framework for establishing Estuary Management Plans for discrete sections of the estuary. Currently, the Berowra Creek estuary and Brooklyn estuarine areas are managed through separate Estuary Management Plans, while separate Plans are also currently being prepared for Pittwater and Brisbane Waters.

In 2005 the Hawkesbury Nepean Catchment Management Authority finalised the "Kimmerikong Report" (Kimmerikong 2005), which identified the following problems with the current segmented management approach;

- narrowly defined programs which focus on a single issue or local issue with an inability to address wider implications on the estuarine system;
- problems being treated in isolation rather than on a "whole of estuary" approach;
- limited resources not being used to maximum effect;
- highly sectoral management systems with inherent rigidity resulting in gaps in responsibilities and no management;
- insufficient coordination between and within organisations leading to inconsistencies in management regimes and outcomes;
- failure to understand complex estuarine dynamics;
- inability to effectively identify impacts from up-stream development or cumulative impacts and advocate for remedial action;
- duplication of effort and expenditure by organisations sharing responsibility for the same issue; and
- an inability to identify funding within organisations that support work on estuary wide issues.

In response to these issues, Hornsby Shire Council took the initiative to develop the Lower Hawkesbury Estuary Management Plan (LHEMP) to provide an integrated whole of estuary approach. This Plan provides the strategic direction for future management of the estuary and its associated assets.

The LHEMP recognises that the risks influencing the sustainability of estuarine assets are a direct consequence of the health of the catchments within which it lies. Treatment of risks to the estuarine assets is to be facilitated through the action plan detailed in Section 4. By treating risks at this scale, through implementation of the LHEMP, benefits to the Lower Hawkesbury are anticipated to include:

- All risks to estuarine assets will be considered and not limited to local areas;
- Institutional and commercial goals and aspirations for preservation of estuarine assets will be coordinated and integrated;
- Improved strategic goals and objectives which are based on a system wide understanding of the estuary;
- More efficient and effective use of government resources in reducing risks;
- Increased opportunities to access and integrate funding and research opportunities;
- Better use of local and regional knowledge; and
- Creation of opportunities for projects and community groups to address similar problems in different parts of the estuary.

The LHEMP has therefore adopted a risk management approach to developing and prioritising potential future management actions and strategies. Details of this risk management approach are provided in Section 3.1.

1.4 Status of the Plan

This is an Estuary Management Plan prepared in accordance with the Estuary Management Manual (NSW Govt. 1992). It has also been prepared giving consideration to the Draft Coastal Zone Management Manual, and as such should satisfy the objectives for a Coastal Zone Management Plan under Part 4A of the Coastal Protection Act 1979. It is intended that once this plan is adopted by Hornsby Shire Council that it will be presented to the NSW Government for Gazettal.

1.5 Values and Goals

Values and goals for the Lower Hawkesbury Estuary Management Plan were defined during an initial community workshop (Workshop 1) and then discussed further and agreed at a stakeholder workshop (Workshop 2).

1.5.1 Values

Through the community and stakeholder consultation (refer to Section 1.10.2), the following values for the Lower Hawkesbury Estuary were identified:

1. Functional and sustainable ecosystems
2. High scenic amenity

3. Largely undeveloped surrounding lands
4. Recreational opportunities
5. Sustainable economic industries
6. Culture and heritage
7. Water quality to support user demands
8. Community character
9. Effective governance

1.5.2 Goals

During Workshop 1 (refer to Section 1.10.2), a number of overarching goals for the LHEMP were identified. These goals were further discussed during Workshop 2 (refer to Section 1.10.2.2) and a refined list of goals generated, which sets the strategic direction for this Plan.

1. **Preserve and enhance the unique and diverse scenic and natural environment of the estuary through the integrated and holistic management of human and environmental interests**

2. **Conserve, protect and enhance sustainable economic, recreational and social issues without compromising the high quality and functional estuarine ecosystems upon which they rely**

3. **Preserve and foster the sense of belonging, culture and respect for the estuary amongst users and managers**

1.6 Duration of the Plan

It is intended that the Lower Hawkesbury Estuary Management Plan will be implemented within a period of ten (10) years. During this period, the Plan will be reviewed on an annual basis and updated as necessary every 3 years. For more information on the review schedule, please refer to Section 5.10.

1.7 Management Agencies

1.7.1 Agency Roles and Governance

Government agencies have different roles in managing the estuary that are determined from implementing legislative requirements and obligations; these roles have been summarised as (SJB, 2005):

- Owner
- Consent authority
- Licenser
- Enforcement/regulator

- Policy development and implementation

Common to all of these roles is that of educator, whereby agencies need to inform people who are unfamiliar with government processes or legislation requirements.

A number of agencies have been assigned responsibilities for the implementation of actions within this Estuary Management Plan. Table 1-1 lists each of the management agencies that have either statutory or governance responsibilities that are required to implement the LHEMP. Former agency names are included to assist the reader. The agencies' wider roles in the management of the Lower Hawkesbury Estuary are also noted.

Table 1-1 Agencies with Implementation Responsibilities (adapted from HNCMA, 2007)

Agency	Previous names	Role
Local Councils		Assess development under Part 4 of the Environmental Planning and Assessment Act 1979 (NSW) (EP&A Act) and provide essential local services including local infrastructure, rubbish removal, stormwater management and natural resource management.
NSW Food Authority		Provides the regulation framework for industry to produce safe and correctly labelled food and educates consumers on food safety
Department of Lands		Manages state owned lands
NSW Maritime	NSW Waterways Authority	Responsible for boating safety, licensing and mapping.
NSW Department of Primary Industries – Fisheries	NSW Fisheries	Fosters profitable and sustainable development of NSW fisheries including aquaculture.
Hawkesbury Nepean Catchment Management Authority	Hawkesbury Nepean Catchment Management Trust	The HNCMA is a statutory body, established under the Catchment Management Authorities Act 2003 (NSW) (CMA Act), to coordinate natural resource management (NRM) in the Hawkesbury–Nepean catchment. It is responsible for involving regional communities in management of the NRM issues facing the region, and is the primary means for the delivery of funding from the NSW and Australian governments to help land managers improve and restore the natural resources of the state.
NSW Department of Environment and Climate Change – Natural Resources	Department of Natural Resources, Department of Infrastructure, Planning and Natural Resources.	Water management, soil and vegetation management, and coastal and floodplain management.
NSW Department of Environment and Climate Change – Parks and Wildlife	NSW National Parks and Wildlife Service	Conserving the states biodiversity and aboriginal cultural heritage

Agency	Previous names	Role
NSW Department of Environment and Climate Change – Environment Protection	NSW Environmental Protection Authority	Regulation of potentially polluting activities
Sydney Water		Licensed polluter to the estuary. Provides drinking water, recycled water, wastewater services and some stormwater services to the catchment.

1.8 Relationship to other Plans

The Lower Hawkesbury Estuary is subject to a wide range of existing plans and policies that have been prepared by both State Government agencies and local government. These Plans frame the planning and policy context that has been incorporated into the development of this Estuary Management Plan. To facilitate this, a detailed review of existing plans and policy documents was undertaken by SJB Planning (refer to Appendix C).

At a regional level, there are policies and plans prepared by the various State Government agencies. The most significant of these is the Hawkesbury Nepean Catchment Action Plan, which is discussed in Section 1.8.1. At the local level there are also local management plans prepared by each of the local councils. Existing Estuary Management Plans have also previously been prepared for Brooklyn and Berowra Creeks, while Estuary Management plans are currently underway for Brisbane Water and Pittwater.

Finally, there are management plans prepared by the owners of adjoining land. Such as National Parks Plans of Management.

1.8.1 Hawkesbury – Nepean Catchment Action Plan 2006-2015

The Hawkesbury-Nepean Draft Catchment Action Plan (HNCAP) is the mechanism to direct and produce natural resource investment by the Hawkesbury-Nepean Catchment Management Authority (CMA). It provides a 10 year strategic direction, identifying priorities for incentives programs to better target activities to improve environmental outcomes and investment return.

The HNCAP will direct partnerships and collaborations with government, industry, community groups and individuals. The document prioritises natural resource issues in the whole Hawkesbury Nepean region, and guides rehabilitation effort where it is considered most essential. The HNCAP has a term of ten years, but may be modified over time as new information becomes available or priorities change.

The CMA is expected to be an important funding mechanism for strategies included in the Lower Hawkesbury Estuary Management Plan.

1.8.2 Brooklyn Estuary Management Plan

The Brooklyn Estuary Management Plan was adopted by Council in December 2006. The Brooklyn Estuary comprises the Hawkesbury River waterway between Croppy Point and the F3 Freeway Bridge, Sandbrook Inlet, Brooklyn Harbour, Parsley Bay, Mooney Mooney and Mullet Creeks to their tidal limits. The Brooklyn Estuary Management Plan contains a list of recommended strategies that have been designed and prioritised according to the goals and objectives for the future of the Brooklyn Estuary, as agreed to by the Brooklyn Estuary Management Committee.

All strategies included in the Brooklyn Estuary Management Plan were considered in the risk assessment carried out in preparing the present LHEMP.

Table 1-2 Relationship between strategies in the Brooklyn Estuary Management Plan (BEMP) and the present document (LHEMP)

BEMP Strategy Number	Description	LHEMP Strategy Reference
2	Liaise further with HNCMA to ensure integration with the Catchment Action Plan and associated strategies	9a
3	Initiate a program for the removal of rubbish (including derelict boats) from riparian areas. The clean up program should focus on larger items such as derelict boats and dumped construction materials, with input and assistance from industry groups. Volunteers from the general public could also be encouraged to assist in the clean up of dumped tyres, plastics, food wrappings and other dumped materials.	2s
4	Liaise with the Metropolitan LALC and other indigenous groups to assess if the current level of protection of aboriginal sites is appropriate and to develop opportunities for educational programs	2g, 15e
5	Promote the EPIC framework for use by Council Planners when assessing development applications by converting the requirements of the EPIC framework into a new or existing DCP. The Estuary Processes and Issues Checklist (EPIC) is a tool prepared as a part of this Estuary Management Study, which has been designed to assist the Brooklyn Estuary Management Committee (BEMC) and Council planning staff assess the likely impacts of future proposals on the natural processes and existing values of the Brooklyn Estuary	1f
6	Review effectiveness of existing planning frameworks such as Hornsby and Gosford LEPs and DCPs to protect the estuary values. This strategy would include an audit of the types of developments that are being approved for these areas and an assessment of the existing planning documents in ensuring such development fits with the goals for the area described in Sydney Regional Environmental Plan 20 and does not impact significantly on the natural processes of the Brooklyn Estuary.	2a
7	Enhance current program of auditing and enforcing sediment and erosion controls at all development sites, including rail	6c

BEMP Strategy Number	Description	LHEMP Strategy Reference
	and road projects.	
9	Develop a numerical catchment and receiving water model, to identify areas where ecological health may be vulnerable. The model will be used to inform data collection and monitoring programs then be used for future model calibration and verification. Once calibrated, the model could be used to assess future strategic landuse management options.	16b
20	Monitor recreational fishing in the Brooklyn Estuary. Data should be collected over the entire Hawkesbury River Estuary and combined with information from commercial fishing returns to identify impacts on fish stocks.	16d
21	Prepare and implement creek rehabilitation plans for tributaries to the Brooklyn Estuary	14c
23	Identify significant seagrass beds on boating charts and by using navigation markers and undertake an education program to promote the protection of these areas	2m, 2w
25	Investigate opportunities for allowing some flushing under the causeway	12ii
27	Determine sources of sediment contamination and impacts of contaminants on estuarine health, through a program of targeted sediment and water quality monitoring. Results could be compared to other locations where metals contamination is much more significant than within the study area (such as the southern end of Pittwater).	12jj, 12kk
28	Upgrade public jetties, wharves and waste facilities at Mc Kell Park, Brooklyn Park, Parsley Bay, Kangaroo Point and Saltpan Reserve	1e
30	Redesign Brooklyn Harbour. Brooklyn Harbour is highly congested during busy times such as weekends and public holidays. The harbour could benefit from a redesign, within the existing land based footprint. A design should be prepared in consultation with existing users and businesses and implemented through a place based DCP.	1e
31	Periodic maintenance dredging of Sandbrook Inlet and Brooklyn Harbour.	7h

1.8.3 Berowra Estuary Management Plan

Berowra Creek and its catchment are located within the Hornsby Shire Council (HSC) Local Government Area. Berowra Creek connects to the Hawkesbury River 25 km upstream of the ocean at Broken Bay. The estuary extends south for 23 km to Rocky Rapid Falls, and 7km to the east along Marramarra Creek. Preparation of the Berowra Creek Estuary Management Plan (BCEMP) commenced in 1996, and was finalised in 2002. The Plan commenced implementation as soon as a draft document was prepared (1997), and has continued since then.

Of the 139 actions outlined in the Plan, an impressive 112 have been implemented fully (and of which, 61 were implemented for the entire Hornsby Shire LGA). Only 13 actions were not implemented, of which a few are no longer relevant. In some cases the implementation of the action has resolved the problem, and no further work is required. More often, however, the actions require on-going commitment and maintenance.

Despite close to 100% implementation of proposed actions, some issues still pose a threat to the health and sustainability of Berowra Creek. Further, new aspects to some issues have become apparent. Thus, ostensibly it would appear that the EMP has not been effective in redressing the issues. However, there are no defined methods to determine the effectiveness of the BCEMP in actually meeting its objectives (ie preserving the values of Berowra Creek and redressing the major issues facing the creek) using existing datasets. Even though issues have not been resolved, it is possible that the BCEMP has assisted in reducing the rate of degradation of the estuary over the past 5 – 10 years. Furthermore, the BCEMP has been the catalyst for improved environmental management of all waterways in Hornsby LGA. Many of the proposed planning, compliance and education activities were performed cover the entire LGA, not just land within the Berowra Creek catchment.

There are many issues identified within Berowra Creek that are relevant to the entire Lower Hawkesbury River. Strategies considered in the present study include those listed in the original Berowra Creek Estuary Management Plan and those recommended as part of the review of the plans implementation (undertaken as a part of the present study) (refer Table 1-3).

1.8.4 Pittwater Estuary Management Plan

The Pittwater Estuary Management Study (PEMS) was finalised in August, 2006. Following on from this work as per the NSW Governments Estuary Management Manual (1992), the Pittwater Estuary Management Plan is currently being prepared by BMT WBM on behalf of Pittwater Council. The Plan will describe the goals and objectives for future management of the estuary, and the actions required to achieve these goals. The estuary management plan will be designed to integrate and compliment the present Lower Hawkesbury Estuary Management Plan.

Pittwater is an estuary of approximately 10 km in length and 18 km^2 in waterway area, close to the mouth of the Hawkesbury River. It is located entirely within the Pittwater LGA in the northern part of Sydney. Pittwater is a drowned river valley, with relatively steep sided slopes, and drains a largely urbanised catchment of 51 km^2. The catchment extends between the suburbs of Mona Vale and Warriewood in the south, then east along the Barrenjoey Peninsula, and also west along Lambert Peninsula to West Head. The western edge of the estuary is managed within the Ku-ring-gai Chase National Park, while the remainder of the catchment is predominantly urbanised.

Table 1-3 Relationship between strategies in the Berowra Creek Estuary Management Plan (BCEMP) and the LHEMP

BCEMP Strategy Reference	LHEMP Strategy Reference	BCEMP Strategy Reference	LHEMP Strategy Reference
M1 & M2	1b, 3a	BSP2, RSP4	12e
CSP7, RSP3, RSP 10, RSP11, SN2, FI5, FI7	1g	OS2	12g
BSP6	1j	RSP2, RSP3, RSP5, RSP6	12i
ERF14	1d, 5a, 16d	HHS3	12k
SN3	2d	HMA1, HAM2	12m
S3	2m	OS2	12n
NW1, SN11	2p	CSP13, RSP7	12o
SN10	2r	HHS4	12p
HP1	2t	CSP15	12q
S3	2w	RSP9	12s
BioM1, M2, M4	2o	RSP1	12v
ERF10	3c	FI6	12aa
BSP5	4a	CSP8	12y
BioM1, M2	5c	CSP4	12z
BioM1, M2, M4	5d	CSP9, CSP10, CSP16	12w
CSP2, CSP3	5e	CSP16, HMA3	12bb
SN10	6a	CSP16, HMA3	12x
CSP7	6c	HMA7	12ff
HMA7	6h	CSP5	12gg
M3	7a	HHS2	12hh
BM2	7f	BEMP 27	12jj
SN13	7h	HMA 10	12kk
BM4, BSP1	7i	CSP6	12ll
BSP7	7k	NW2	13a
DCC4	8b	NW1	14c
DCC3, DCC5	8e	BSP7, ERF11	15d
BioM2	9d	ERF12	15g
EM1	9e	NW6	15h
CSP1	11b	ETF7	15i
FI3	11e	ERF8	15j
FI1, F12	11f	BioM3	16a
BSP 9	12b	ERF14	16c
BSP3	12d	DCC2	16g

1.8.5 Brisbane Water Estuary Management Plan

In 2001, Gosford City Council commenced the estuary management process with the formation of Gosford City Council's CEMC. The CEMC is made up of representatives from relevant government agencies, stakeholder groups and community representatives. Ongoing engagement with this group will be crucial to the development of a representative and effectual management plan that is ultimately implemented.

The draft Brisbane Water Estuary Processes Study, has recently been completed (Cardno 2007). Additionally, two separate Coastal Lagoon Assessment and Management tools (CLAMs), have been developed in a pilot study to assess the feasibility of dredging. The CLAM models consider a range of environmental, social, recreational, safety and economic impacts associated with maintaining navigable waterways.

Gosford City Council recently commissioned Cardno to prepare and estuary management study and plan for Brisbane Water. The study area comprises the tidal waterway, foreshore and adjacent land of Brisbane Water, including the entrance area and tidal tributaries covering the whole region of Brisbane Water from the channel connecting to Broken Bay at the eastern end of Ocean Beach in the south to Gosford in the north. The area includes various embayments such as Woy Woy Bay and Cockle Broadwater. In addition, the study area will extend as far inland, into Broken Bay and the marine zone as necessary to encompass all the processes that significantly impact upon the quality and amenity of the Brisbane Water Estuary.

1.8.6 Future planning integration

Holistic management of the entire Hawkesbury Estuary will require integration of these discreet Plans. Given the size of the system, this may require leadership and coordination from a state agency.

1.9 Definitions

Please refer to the Glossary of Terms presented in Part 6 of this document.

1.10 Supporting Information

1.10.1 Documentation

A number of key reference documents have been collated and reviewed in order to provide the summary of estuary processes presented in Section 1. Key documents include

- Kimmerikong (2005) Hawkesbury-Nepean River Estuary Management – Scoping Study – Final Report, Hawkesbury Nepean Catchment Action Authority
- DLWC (1997) Berowra Catchment Economic Scoping Study
- WMA (2002) Berowra Creek Estuary Management Study and Management Plan
- WRL (2003) Brooklyn Estuary Processes Study

- ACUN (2003) Biological Monitoring Program for Berowra Creek Estuary: Preliminary Study and Design
- Taylor C, Hincks R (2005) Economic Evaluation of Lower Hawkesbury River Boat Pump-out Options
- WBM (2004) Brooklyn Estuary Management Study and Plan: Review and Consideration of Estuary Processes Information
- SJB (2005) Hornsby Shire Waterways Review

A prioritised list of available documents pertaining to the Lower Hawkesbury was provided by HSC, (refer Appendix A). Due to time and funding constraints, it was only possible to review those documents that were given top ("1") priority for this estuary processes summary.

1.10.2 Community and Stakeholder Consultation

Three workshops were organised to engage the community and relevant stakeholders. The workshops also formed part of a PhD project for Ms Katherine Daniell of the Australian National University. Two detailed reports have been prepared on this aspect and (Daniell 2007a and Daniell 2007b). An overview of the workshops is present in Table 1-4.

Table 1-4 Overview of Stakeholder and Community Workshops (Source: Modified from Daniell 2007a)

Workshop	Activities
Workshop No. 1 *Management Situation*	Identify stakeholders values (assets) and issues related to the estuary - How and by whom are these currently being managed? - Are the resources to manage these sufficient?
	Identify overall goals, vision and objectives for the estuary
Workshop No. 2 *Risk Analysis*	Assess estuarine risks (related to defined issues) for their consequences on the assets and the associated likelihood of these impacts - Determine risk level - Classify uncertainty of this prediction
	Evaluate and prioritise risks - Classification as" Acceptable, Tolerable or Intolerable"
Workshop No. 3 *Strategy Formulation*	Define strategies and their associated actions to treat priority risks - Which stakeholders and resources are required?
	Determine target states of risk reduction the actions are to achieve - Select indicators, monitoring needs and information dissemination strategies to evaluate and improve management

1.10.2.1 Workshop 1 November 2006

The first workshop attracted 30 attendees including representatives from State Government Departments, Local Governments, industry groups and the wider community (including representatives of industry and residential groups). During the workshop a variety of individual and group activities were used to develop an agreed list of values for the estuary as well as a list of issues that need to be managed in the future. In keeping with the risk management approach that was adopted in preparing this LHEMP (refer to Section 3.1) the values are termed "assets" and the issues are termed "risks". Details of the methodology used and an evaluation of the workshop process are outlined in Daniell (2007a).

1.10.2.2 Workshop 2 February 2007

The second stakeholder workshop was attended by 19 representatives from State Government Departments, Local Governments and industry groups. A risk assessment process based on the Australian Standard for Risk Management (AS/NZS 4360:2004) was used during the workshops to help assess and prioritise risks. For each risk (issue) identified in the previous workshop, the "consequences" and "likelihoods" of the risk impacting on the nine previously defined estuarine assets (values) were identified by participants. The resulting "risk level" also considered the uncertainties related to these classifications, and the level of current management effectiveness of the risk related to each asset. From this information, the priority of the risks (acceptable, tolerable, or intolerable) was consolidated and the results discussed. For more detail on this process, please refer to Daniell (2007a and 2007b). The following photos taken during the workshops are taken from Daniell (2007a and 2007b).

1.10.2.3 Workshop 3 March 2007

The third stakeholder workshop focussed on developing strategies and actions for the treatment of the risks, as well as identifying monitoring needs and stakeholder responsibilities. There were 18 representatives from State and Local government, industry, agencies, associations and local residents present.

Figure 1-1 A Small Group Sorting Estuary Assets and Risks on Colour Coded Cards During Workshop 1

Figure 1-2 A Small Group Undertaking Spatial Mapping and Development of an Assets and Risks Matrix During Workshop 1

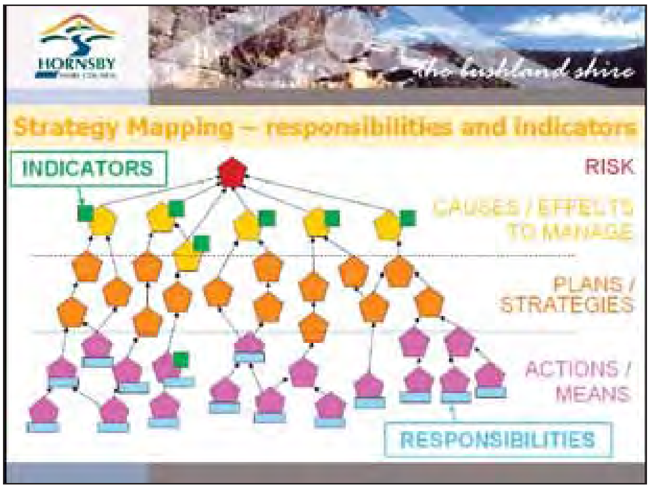


Figure 1-3 Outline of Strategy Mapping Methodology for Workshop 3

Figure 1-4 Small Group Structuring of Strategy Maps during workshop 3

1.10.3 Review of Relevant Planning and Legislation Documentation

A detailed review of the relevant planning instruments and legislation was undertaken by specialist planning consultants, SJB Planning. The review covered all environmental planning and management instruments relevant to the estuary. This included formal local government, state government and federal government instruments, as well as informal strategic responses and initiatives.

This information assisted in establishing the constraints applying to future management of the estuary and to identify opportunities to meet study objectives through planning initiatives. Where appropriate, recommendations to be incorporated into Councils new LEPs prepared under the new LEP template guidelines have been made.

This review is presented in Appendix C.

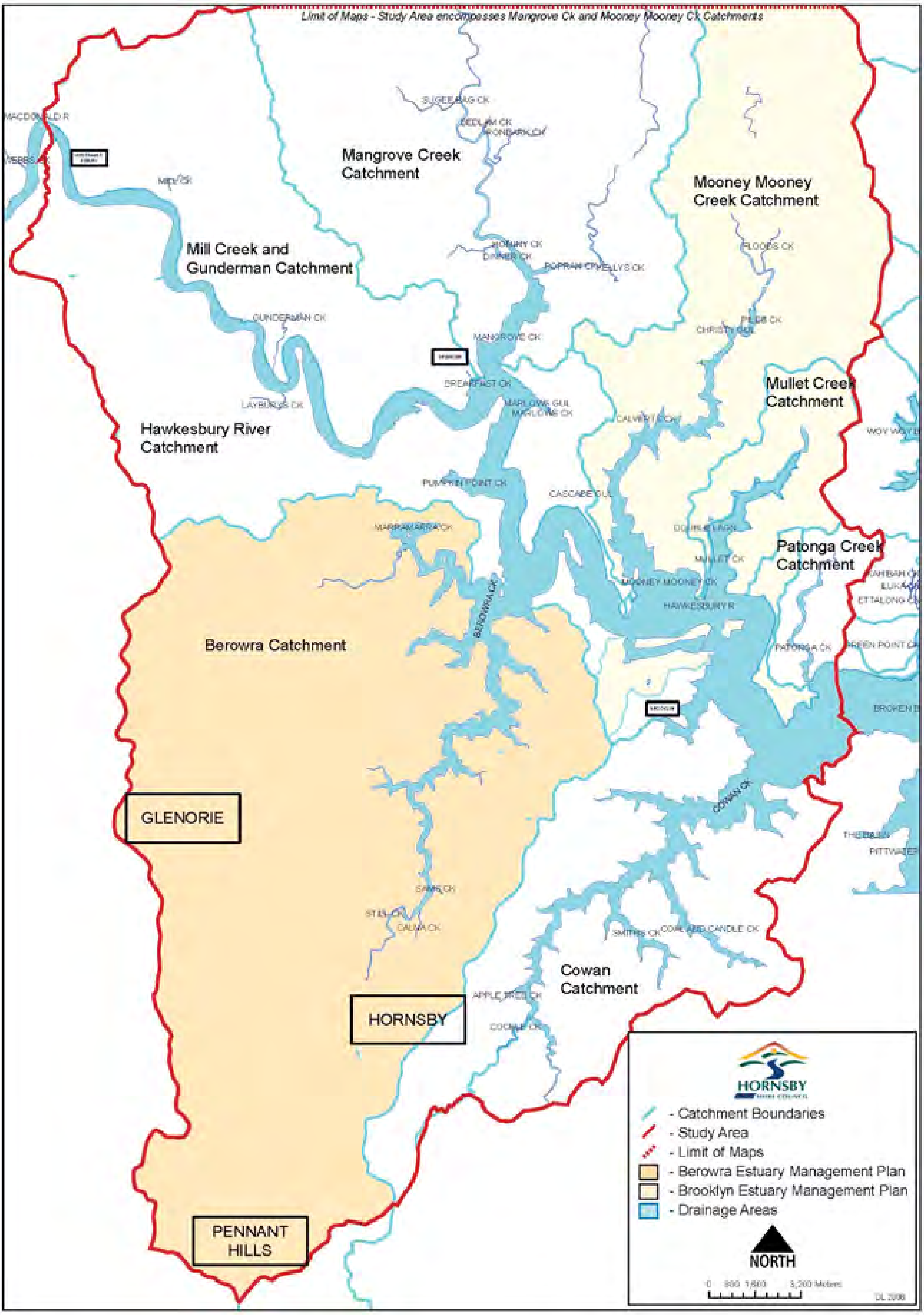


Figure 1-5 The Lower Hawkesbury Estuary Study Area

2 LOWER HAWKESBURY ESTUARY

The Lower Hawkesbury River Estuary is a drowned river valley, which was incised into Hawkesbury sandstone bedrock during the historical ice ages, when ocean levels were much lower than present. The greater Hawkesbury-Nepean River catchment has a total area of approximately 22,000km^2. Consideration has also been given to the upper catchment influences from land being managed within the jurisdiction of Hornsby Shire Council, Gosford City Council (excluding Brisbane Waters), Department of Environment and Conservation (Ku-ring-gai Chase National Park) and Warringah Council.

A review of the environmental processes relevant to the Lower Hawkesbury River, akin to a formal Estuary Processes Study, as outlined in the Estuary Management Manual (NSW Government 1992), has been incorporated into LHEMP document. This review, based primarily on existing literature (refer chapter sub-sections and Appendix A for details of literature reviewed and further reading references), is described within this chapter of the LHEMP.

2.1 Location Description

The management area of the Lower Hawkesbury Estuary Management Plan extends from the ocean entrance at Broken Bay upstream to Wisemans Ferry. There are a number of major tributaries to the Lower Hawkesbury Estuary, including Berowra, Mangrove, Mooney Mooney, Mullet, and Cowan Creeks. With its tall, highly weathered vertical sandstone cliffs and gorges, open waterways, secluded bays and expanse of natural vegetation, the Lower Hawkesbury Estuary is one of the most visually spectacular waterways in New South Wales.

The Lower Hawkesbury catchment is unique in that is the foreshore areas contain significant forested areas and with relatively little foreshore development. The majority of the foreshore and adjacent land is national park (Kimmerikong, 2005). The drowned river valley morphology, with steep sandstone slopes and incised gorges has meant foreshore areas are largely only accessible by boat. Those foreshores that are relatively flat are mostly occupied by private development or natural mangrove barriers. The large extents of national park and the steep topography which has limited access and development on the foreshore have preserved the natural character and beauty of the estuary.

The Lower Hawkesbury supports the 2nd largest estuary fishery and the 2nd largest oyster farming industry in NSW (although in recent years an outbreak of QX disease has greatly affected local oyster production) (pers. comm. DPI). Dams on Mooney and Mangrove Creeks supply part of the water to the Gosford/Wyong area on the Central Coast of NSW (HNCMA, 2005). The Hornsby Plateau to the south of Berowra Creek is where much of the residential, industrial and commercial development of Hornsby and surrounding suburbs is located (WMA, 2002).

The area's accessibility to the population of Sydney and the Central Coast, the open waterway with sheltered bays and harbours, and its scenic quality make it a very popular destination for a large number of recreational visitors (WBM, 2006b). The region boasts imposing sandstone headlands such as West Head, distinctive landforms such as Lion Island, naturally vegetated hillslopes and small secluded beaches, all of which provide a natural and scenic backdrop to the waterway (NPWS, 2002).

National parks and reserves in the catchment include Ku-ring-gai Chase National Park (NP), Marramarra NP, Muogamarra Nature Reserve (NR), Berowra Valley Regional Park, Brisbane Waters NP, Bouddi NP, Dharug NP, Popran NP, Long Island NR, and Lion Island NR.

The undeveloped nature and large amount of national park in the Lower Hawkesbury estuary has allowed for a wealth of Aboriginal heritage to be preserved in the area. This is particularly valuable due to the heavily developed nature of much of the remainder of the Sydney Basin and hence general lack of information about Aboriginal occupation and practices prior to European settlement (NPWS, 2002).

Upstream processes and activities in the Hawkesbury-Nepean catchment impact strongly upon conditions in the Lower Hawkesbury Estuary (WRL, 2003). The entire Hawkesbury-Nepean River catchment covers an area of 21,400 km^2, of which an estimated 68% is forested, 25% is agricultural and 7% is urbanised (HNCMA, 2005; WRL, 2003). The upper Hawkesbury-Nepean River is vital to the Sydney Region as the major (97%) drinking water supply to Sydney, via Warragamba Dam (HNCMA, 2005), and supporting valuable agriculture, particularly market gardens, in the region.

The Australian estuaries database has classified the Hawkesbury River as having 'high' conservation value, with a 'real' conservation threat. The fisheries value was rated 'high' and the ecological status was 'moderately affected' (Breen et al., 2005).

2.1.1 Tributaries

The entrance to Pittwater lies in Broken Bay, between Barrenjoey Head and West Head. Cowan Creek is the next tributary to the west of Pittwater. The entrance to the Creek lies between Challenger Head and Eleanor Bluffs (to the west). Porto Bay lies between Cowan Creek and Brooklyn, with its entrance between Green Point and Dead Horse Bay (just south of Parsley Bay and Brooklyn). Both Cowan Creek and Porto Bay are almost completely surrounded by Ku-ring-gai NP.

Sandbrook Inlet was formed by the construction of a causeway for the Main Northern Railway line, between Brooklyn and Long Island built in the 1880’s. The inlet extends south and east from Kangaroo Point, and lies between Long Island and Brooklyn. Seymours Creek flows into Sandbrook Inlet (WRL, 2003).

The entrance to Mullet Creek lies between Alice and Cogra Points (on the opposite side of the River to tributaries discussed above). The creek extends approximately 6 km to the tidal limit (WRL, 2003).

The entrance to Mooney Mooney Creek, also on the northern side of the River, lies between Cogra Point and Peats Ferry Bridge. The creek extends 35 km upstream, fed by Little Mooney Mooney, Floods, Piles and Calverts Creeks, and is mostly surrounded by bushland. Spectacle and Snake Island is located within the creek (WRL, 2003).

The entrance to Berowra Creek is approximately 25 km upstream from the river’s ocean entrance and located upstream of the F3 crossing (WRL, 2003). From the entrance, the estuary extends a further 23 km upstream to Rocky Fall Rapids, its tidal limit (WRL, 2003). Berowra Creek has several tributaries including: Marramarra Creek, Coba Creek, Calabash Creek, Charltans Creek, Waitara Creek and Calna Creek (NSWFA, 2004a).

Berowra Creek is shallow (< 1 m) in the upper reaches, while most of the lower estuary zone is greater than 5m deep, except at the entrance bar to the Hawkesbury River which is around 3 m deep. The creek contains a number of deep holes, particularly around Calabash Point, which reach 17 m in depth. Marramarra Creek, which begins a short distance from the confluence of Berowra with the Hawkesbury, is 7 km in length and is mostly 2 m or less in depth (WRL, 2003).

Mangrove Creek entrance lies between Wendoree Park and Spencer, on the northern side of the River. Land adjacent to the Creek is zoned for development, however, many areas are still undeveloped, and both Dharug and Popran NPs lie a short distance to the west and east of the creek, respectively.

2.1.2 References

A number of key reference documents have been collated and reviewed in order to provide the summary of estuary processes presented in this chapter. Key documents include DLWC (1997), WMA (2002), WRL (2003), NPWS (2002), ACUN (2003), NSWFA (2004a), NSWFA (2004c), WBM (2004), Taylor and Hincks (2005), HSC (2005), SJB (2005), NSTOC (2005), Kimmerikong (2005), WBM (2006a), Breen *et al* (2005), WBM (2006b), HNCMA (2005) and Williams and Thiebaud (2006).

A prioritised list of available documents pertaining to the Lower Hawkesbury was provided by HSC, and is given in Appendix A. Due to time and funding constraints, it was only possible to review those documents which were given top (“1”) priority for this estuary processes summary.

2.2 Climate

The climate for the Lower Hawkesbury, as taken from information for the Berowra and Brooklyn catchments, is warm temperate, and so experiences cool to cold winters and warm to hot summers (WRL, 2003). The wettest months are January to April, the driest are July to November (WRL, 2003). The average rainfall for the Berowra region is 1000 – 1150 mm/year with an average maximum temperature of 27 °C in summer and 17 °C in winter (NSWFA, 2004a; WMA, 2002).

2.3 Geology and Geomorphology

2.3.1 Overview

The Lower Hawkesbury River is part of the Sydney Basin, of Permian and Triassic age (200-250 ma), which consists almost entirely of horizontally bedded sedimentary rocks. At this time, the basin was a large lake filling with sediment, before being uplifted at the end of the Triassic. Following this, the uplifted sandstone bedrock was eroded over millions of years to form deep V-shaped valleys and cliffs. These valleys were then drowned during the last sea level rise (c. 20,000 to 7,000 years ago) to form the morphology of the region seen today.

The Hawkesbury River is the largest drowned river valley in the Hawkesbury Shelf bioregion (SJB, 2005). This drowned river morphology typically comprises river foreshores that are steep sided forested sandstone ridges, and steep incised sandstone gorges (WMA, 2002), which preclude development. The western part of catchment has generally gentler landforms that are suitable for rural use (DLWC, 1997). Channel widths vary from just over 100 m in the upper reaches to nearly 1 km at Brooklyn (Kimmerikong, 2005). Downstream from the Brooklyn Bridge the water depths are 8 to 9 m (Kimmerikong, 2005).

Many islands were created by the drowning of old ridge lines, such as Bar, Milson, Triangle, Peat, Long and Spectacle islands (Kimmerikong, 2005). Between the sandstone, broad rock benches with shale deposits are permanently wet and have formed peat soils that support important hanging swamps and associated plant communities (for example, at Lambert Peninsula) (NPWS, 2002).

The tributaries of the Lower Hawkesbury estuary are also deeply incised gorges characterised by riverine and marine sediment bars at or near the confluence with the main channel (Kimmerikong, 2005). The shallow nature of the upper reaches of tributary creeks has led to the formation of extensive shoals with deep scour holes around the outside of bends or against extruding rock edges (WMA, 2002). The drowned tributary valleys tend to form backwater areas to the main channel, for example, Mooney Mooney Creek and Mullet Creek (WBM, 2006b).

2.3.2 Soils

Hawkesbury sandstone is the dominant bedrock unit, forming many of the plateaus and hillslopes (NPWS, 2002). The unit erodes to coarse grained soils, which form shallow sandy soils on the ridges and deeper yellow earths in the valleys and fine sandy clay loams (NPWS, 2002; WMA, 2002). The steep slopes have a high potential for soil loss and disturbance and are highly erodible, infertile and have poor water holding capacity (NPWS, 2002; WMA, 2002). This limits their potential for recreational use in the parks (NPWS, 2002), and development in other areas.

Narrabeen Group shales and sandstones outcrop below the Hawkesbury sandstone (typically 20 – 40 m elevation) at the western shores of Pittwater and the shores of Cowan Waters, Cottage Point and Barrenjoey Head. Narrabeen Shales erode to form relatively rich red clay soils (NPWS, 2002).

A few remnants of Wianamatta Shale exist in the region, such as in Duffy's Forest (in and adjacent to Ku-ring-gai NP) (NPWS, 2002). Most of the remnants of Wianamatta Shale outside the park have been cleared for development (NPWS, 2002). Hard setting red brown clay loams derived from Wianamatta Shale are more fertile, have higher water holding capacity, although they may become water logged (WMA, 2002). Immediately overlying the Wianamatta Shale along ridge tops such as Terrey Hills and Ingleside, small areas of laterite or iron stone soils exist (NPWS, 2002).

Intrusions of igneous dykes and diatremes occurred 65 to 40 million years ago. The igneous intrusions weather to form deep red soils of higher nutrient content than surrounding rocks in the region. The deeply weathered breccia filled diatremes have weathered to form amphitheatre shaped valleys at Campbells Crater (near Cowan) and Smiths Crater (near Cowan Water) (NPWS, 2002).

In mangrove and saltmarsh areas, the dark brown organic silty loams have a high wave erosion hazard, high acid sulfate soil (ASS) potential, very low fertility and low permeability (WMA, 2002).

The Hawkesbury River has 6049 ha of land that fall into the category of a high probability of the occurrence acid sulphate soils. There is also 3968 ha of land with low probability of the occurrence of acid sulphate soils (HNCMA, 2005).

2.3.3 Further Reading

For further reading regarding the geology and geomorphology of the estuary, please refer to DLWC (1997), WMA (2002), WRL (2003), NPWS (2002), Kimmerikong (2005) and HNCMA (2005).

2.4 Hydrodynamics

2.4.1 Tidal Behaviour

The Lower Hawkesbury River is tidally dominated, with the tidal influence extending some 120 km from Broken Bay to York Reach, near Wilberforce (NSWFA, 2004a).

The drowned river valley morphology and subsequently deep, wide ocean entrance and main channel has meant that tidal amplitudes are approximately the same, albeit delayed, as the tides on the coast (WBM, 2006b). Some amplification of tides is reported upstream in the tributaries such as Mullet, Mooney Mooney and Berowra Creeks (WMA, 2002; WRL, 2003). The maximum tidal range at Berowra Point (ie HHWS to ISLW) is 1.97 m, the mean spring tide range is 1.37m and mean neap tide range is 0.88m (NSWFA, 2004a).

The large cross-sectional area of the river channel (due to its deep incised morphology) means that tidal velocities typically tend to be low (WBM, 2006b). Tidal velocities in some isolated sections of the main channel can still be high, however, with velocities adjacent to Dangar Island being measured up to a maximum of 1.2 m/s (WRL, 2003).

The tidal prism at Brooklyn has been estimated at 103 x 10^6 m^3. Around 75% of this continues to flow further upstream, while about 10% enters Mooney Mooney Creek, 4% Mullet Creek, 1.5% into Sandbrook Inlet and 12% remains in the section of the Hawkesbury main channel around Brooklyn (WRL, 2003). Tidal flushing times in the main channel adjacent to Dangar Island has been modelled at 3-5 days (WRL, 2003).

2.4.2 Freshwater Flows

Under typical low flow conditions, less than 300ML/day of freshwater runoff is received from the upstream reaches of the Hawkesbury River (Kimmerikong, 2005). The average annual discharges from the subcatchments are: 64,200 ML/year, from Mangrove Creek; 64,200 ML/year, from Mooney Mooney Creek; 111,200 ML/year from Berowra Creek; 60,500 ML/year from Cowan Creek; and 39,500 ML/year from Pittwater (Kimmerikong, 2005). In Berowra Creek, effluent discharge from the Hornsby Heights and West Hornsby STPs constitutes the greatest proportion of flow from the catchment during dry weather, at 15-20 ML/day (Sydney Water, 2008).

Infrequently, floods may dominate the hydrodynamics of the main channel. Large scale flooding in the Hawkesbury Nepean catchment results in a significant flow of freshwater and a net downstream flow through the Lower Hawkesbury. During a large flood, freshwater inputs of more than 1,000,000 ML/day may be discharged through the river.

During particularly large floods, velocities increase well above typical tidal velocities, both within the main river channel and within the side channel tributaries. During a 20 % AEP (1 in 5yr) flood, hydrodynamic modelling has indicated maximum velocities in the main river channel to be close to double that of maximum tidal velocities in dry weather, ie 2.2 m/s compared with 1.2 m/s (WRL, 2003).

Outside the study area, deep holes in the gorge sections of the main channel of the Hawkesbury River are characterised by high turbulence during floods. A series of such holes exist in the river bed between Lower Portland and Wiseman's Ferry, several of which exceed 30 m below AHD. These holes are said to increase the sub tidal capacity and lower the effectiveness of tidal flushing (Kimmerikong, 2005).

2.4.3 Wind Waves

Generally, the short fetch and the relative lack of long stretches of water unbroken by land is said to allow minimal generation of wind waves, or wind setup. However, wind effects are still important where certain wind directions allow wind funnelling along the creeks (especially in the vicinity of the road and rail bridges), causing wind waves which may be important for mixing in the upper creek reaches. Wind is also considered likely to have some impact on water circulation in shallow areas, especially in Sandbrook Inlet, causing mixing in the surface layer and stirring of sediments (WRL, 2003).

2.4.4 Groundwater

Groundwater in the area is said to flow at 0.4 to 0.5 L/s, is fresh to saline and sourced from the fractured Hawkesbury Sandstone aquifer. Groundwater information is relatively scarce, and is not considered to have a significant impact upon estuarine hydrodynamics (WRL, 2003).

2.4.5 Tributaries

The lower reaches of the tributary creeks in proximity to the main channel of the Hawkesbury River are also significantly tidally dominated. Tidal currents in the main river channel and downstream tributary reaches induce intense turbulent mixing that prevent stratification (WBM, 2006b), and allow swift removal of pollutants (WMA, 2002). During relatively high rainfall events, catchment input from local tributaries may reach the Hawkesbury River from where it is quickly flushed by the dominant tidal flow (WBM, 2006a).

The middle reaches of the tributary creeks are dominated by tidal flow, and have a greater volume than upper creek reaches due to greater width and depth. Smaller rainfall events typically produce catchment input volumes that are smaller than tidal or estuary volumes. During such events, freshwater inputs will flow over saline tidal flows, forming a salt water wedge. During large storms, the volume of catchment inputs may be sufficient to flush the middle reaches out to the Hawkesbury's main channel, and remove the vertical salt water stratification (WMA, 2002).

Berowra Creek is documented to experience vertical stratification with tides (WMA, 2002), however, only a weak vertical stratification in Mooney Mooney Creek has been measured (WRL, 2003). It has been suggested that strong tidal mixing and thus longitudinal movement prevents the development of vertical stratification and the potential for deep water stagnation in Mooney Mooney Creek (WRL, 2003).

Hydrodynamics in the upper reaches of the tributary creeks is often tidally dominated during dry weather, and catchment dominated during wet weather (WMA, 2002). Flushing times for Mooney Mooney Creek, Berowra Creek and Mullet Creek have been estimated to be 14 days, 5 days and 8 days, respectively (WMA, 2002; WRL, 2003). Catchment inputs from a 1 in 2 year storm are typically sufficient to dominate the hydrodynamics in the upper reaches, providing inputs greater than or equal to the volume of the creek (WMA, 2002).

As upper and middle reaches of the tributaries are less flushed, pollutants discharged may remain for longer periods, and this period may be further extended when vertical stratification occurs. In this case, residence times for pollutants in the middle (and upper estuary) can be quite high, and may impact upon mixing and dispersal of pollutants (WBM, 2006b).

Deep holes, which may be found in the middle reaches of tributaries such as Berowra Creek, are typically filled with saline water during tidally dominated dry weather flows. Freshwater from catchment rainfall typically passes over the deep holes, which remain saline. Very large flood events are required to flush the deep holes of saline water, and so the deep holes tend to provide a refuge for aquatic fauna from changes in salinity during floods. Flushing of the deep holes in Calabash Bay can take from 7 – 30 days (NSWFA, 2004a).

Sandbrook Inlet experiences modified tidal flushing and hydrodynamics compared with other tributaries in the estuary, based upon its altered morphology (due to the construction of the rail causeway between Long Island and the mainland at the eastern end of the inlet). Tidal flushing in Sandbrook Inlet takes approximately 6 – 9 days (WRL, 2003). Modelling has shown the velocities in the Inlet to range from 0.1 m/s at the western end to 0.0 at the eastern end during base flow (dry weather) conditions, and from 0.3 m/s at the western end to 0.0 at the Inlet's eastern end during 20 % AEP flow conditions (WRL, 2003). Furthermore, particle tracking indicates that during dry weather, pollutants discharged into Sandbrook Inlet are likely to remain within the inlet, and in wet weather, pollutants are able to be discharged from the inlet (WBM, 2004; WRL, 2003).

2.4.6 Water Extraction

Water extraction is viewed as a particular problem in the greater Hawkesbury River as it has changed the freshwater extent and flow regimes (HRC, 2003). Releases from dams are said to be less than 5% of natural flow and the river is also highly regulated for electricity generation (HNCMA, 2005). Approximately 80% of the freshwater flowing into the Hawkesbury-Nepean system is being diverted into Warragamba Dam to supply 97% of Sydney's drinking water (HNCMA, 2005; Kimmerikong, 2005).

In the Lower Hawkesbury, water extraction for industry has been estimated at 14.2 GL/year from the catchment between Wiseman's Ferry and Brooklyn and the Mangrove Creek catchment (Kimmerikong, 2005). In addition, approximately 11.3 GL/year of water is extracted from the catchments of Mullet and Mooney Mooney Creeks, and the greatest volume of this is drawn by the Gosford - Wyong Council's Water Authority (Kimmerikong, 2005). Extraction of water from the Kulnura Mangrove Mountain Groundwater Source may equal, but not exceed 28 % of the annual recharge (Kimmerikong, 2005). The 4,500 ML Mooney Mooney Dam and the dam on Mangrove Creek contributes to the Gosford-Wyong water supply (WRL, 2003).

As a result of water extraction and reduced flows, some of the channels of the Lower Hawkesbury have contracted over time, due to the inability of the river to flush sediment downstream. The extra sediment often forms in-channel bars and can be colonised by vegetation, such as near the mouth of Mangrove Creek (WRL, 2003).

One indication of the reduction of flows is from salinity measurements at Wiseman's Ferry. The variability of salinity at Wiseman's Ferry has increased due to reduced flows from upstream. Under natural conditions, salinity of 5 ppt is exceeded 12 % of the time. Currently, this level is exceeded 35% of the time, which illustrates a greater degree of salt intrusion to upstream sections of the estuary (Kimmerikong, 2005).

2.4.7 Further Reading

For further reading regarding the hydrodynamics of the estuary, please refer to WMA (2002), WRL (2003), ACUN (2003), NSWFA (2004a), NSWFA (2004b), NSWFA (2004c), WBM (2004), Kimmerikong (2005), WBM (2006b) and HNCMA (2005).

2.5 Sediments

2.5.1 Sedimentology

The Hawkesbury River is considered a depositional environment, and has been filling with sediment to varying extents during the last 18,000 years (Kimmerikong, 2005). Rates of erosion in the Hawkesbury Nepean catchment are said to be low and the resulting infilling of the estuary over its 152 km is very slow (HNCMA, 2005). Downstream from the Brooklyn Bridge the estimated rate of infill of sediments is 4.5 mm/yr or 0.5 m/century (Kimmerikong, 2005).

Sediment distribution is determined by estuarine hydrodynamics. High velocity areas tend to keep sediment in motion while low velocities allow sediment to accumulate. In addition, sediment particle size determines the ability of the sediment to be transported, with fine sediments being suspended more easily than coarser grained sediments. Thus coarser grained sediments will tend to be deposited as alluvial deltas at the outlets of creeks and drainage lines (eg the Seymours Creek delta), while finer grained sediments will remain suspended in the water column and slowly settle within the general mud basin of the Lower Hawkesbury River and quiescent backwaters and tributaries (eg Mooney Mooney Creek, Mullet Creek, Sandbrook Inlet). The main river channel contains sandy muds and sands (WBM, 2006b).

Sediments between the motorway bridge and the ocean consist largely of muds, with mostly coarse sandy sediments in the main channel extending to Patonga (Kimmerikong, 2005; WRL, 2003). The region between Wiseman's Ferry and the motorway bridge consists largely of discontinuous sandy alluvium (Kimmerikong, 2005). The tributaries contain muds and sandy muds, with the percentage of mud in sediments ranging from 31.3 to 99.7 % between sites at Dangar Island (in the main channel), Sandbrook Inlet, Mooney Mooney Creek and Mullet Creek (WRL, 2003). Sandbrook Inlet contains a mixture of silts and sands (WRL, 2003).

In the tributaries more specifically, the upper reaches are predominantly fluvial sands, with a higher proportion of mud towards their downstream ends. The middle reaches may contain sandy muds and are rich in organic material. These sediments are thought to be sourced from both the catchment and the Hawkesbury River, which transports sediments upstream. The lower tributary reaches contain mostly organic sandy muds, delivered during floods and freshes and tides from the Hawkesbury River (WMA, 2002).

During dry weather conditions, around 70 tonnes of fine suspended sediment passes through the study area in the main Hawkesbury River channel during each ebb tide. A very small proportion of this sediment would fall out of suspension, mostly in the less flushed, quiescent parts of the study area, forming a thin layer of fine mud, which would typically overly coarser material. During wet weather/flood conditions, the thin layer of mud would be quickly resuspended into the water column and transported downstream along with the very large quantity of sediment coming from upstream. Settlement of suspended sediment within the Lower Hawkesbury Estuary would mostly occur post-flood (WBM, 2006b).

2.5.2 Sediment Inputs

The amount of sediment runoff from an area is a function of catchment characteristics including vegetation cover, soil type, catchment slope and the extent of development / soil disturbance. Rates of sediment accretion within the estuary, both at the alluvial deltas and within the deeper mud basin, are a function of the rates of sediment runoff from the catchment (WBM, 2006b).

Alterations to the upper catchment of the Hawkesbury-Nepean River from agricultural and urban development since the early 1800s have markedly increased the delivery of sediment to the Lower Hawkesbury River. Clearing for agriculture has a lesser initial impact however sediment export is persistent over time, particularly as tilling and grazing maintain low vegetative cover (WRL, 2003).

While to some degree the large area of national park in the catchment and steep topography have limited the spread of agricultural and urban development in the Lower Hawkesbury, increased human disturbance in the catchment and urban development of waterfront and plateau areas is believed to have increased the loads of coarse grained sands, muddy sands, and charcoal to the tributaries and river (WMA, 2002). Urban development typically generates large sediment loads during construction, which may be exacerbated by inappropriate practices by builders and developers (WRL, 2003). Sediment runoff tends to decrease once paved (and grassed) areas are established (WRL, 2003).

Large development events, in particular, construction of the Pacific Highway, F3 freeway and Main Northern Railway, have caused temporarily high sediment delivery to the estuary, followed by lower but permanently altered sediment loads once the development is complete. The highway, F3 and railway, at approximately 10 m width each, can be estimated to have resulted in clearing of at least 90 ha of vegetation (within the study area) and excavation through bedrock, resulting in increased sediment loads during their construction. The 1992 aerial photographs indicate that vegetation has regrown in the areas cleared for these services (where possible), and sedimentation export from these areas has decreased. However, there are documented changes to sediment transport and deposition, surface and groundwater quality in relation to turbidity and suspended solids, and aquatic habitats due to siltation (WRL, 2003).

2.5.3 Sediment Accumulation

In Sandbrook Inlet the railway causeway has resulted in increased sedimentation due to reduced tidal flushing. Analysis suggests Sandbrook Inlet is accreting at 10 – 20 mm/year, with an increasing tendency towards the eastern end of the Inlet where velocities are a minimum (WRL, 2003).

For the upper reaches of Berowra Creek, radio isotope and volumetric analysis has indicated that urbanisation and clearing in the catchment has not caused an increase in the sedimentation rate. The estimated rate of delta advance over the past 460 years in Berowra Creek was 1.3 m/year, thus it would take hundreds of years for Berowra Ferry to be filled. Instead, it was suggested that time pressures where people are no longer waiting until high tide to travel by boat has generated a misconception that there has been a sudden increase in sedimentation causing navigational difficulty, rather than the tide level (WMA, 2002).

Between 2002 and 2003, the surface elevation decreased in the mangrove zone (2.02 mm/year), and increased in the salt marsh zone (3.49 mm/year), where as the vertical accretion of sediments in the mangrove zone was 5.05 mm/year. It is thought that the reduction of groundwater flow due to the drought at this time resulted in a greater amount of sinking, or subsidence, than the amount of vertical accretion of sediments and therefore a reduction in surface elevation in the mangrove zone. The rates of sedimentation are said to be low in mangroves in Berowra Creek when compared against other sites in SE Australia. (ACUN, 2003)

The sedimentation rate of Brooklyn Harbour is estimated to be between 30 and 130 mm/year, with an average of 80 mm/year, based on the dredging removal of 25,000 m^3 between 1968 and 1986. Analysis of hydrographic records from 1872 to 1980 indicated 0 to 5 m accretion for the majority of locations at and near Brooklyn. Rapid erosion between Long Island and Dangar Island, consistent with the high velocities in this area, and lesser erosion between Long Island and Spectacle Island was noted. Accretion occurred in Brooklyn Boat Harbour, likely from eroded material from between Long Island and Dangar Island being directed into the Harbour and settling due to the lower velocities (as a result of the construction of the rail causeway across Sandbrook Inlet). Large areas of accretion appear on the southern side of Spectacle Island and the eastern side of the channel (WRL, 2003).

Navigational channels that may be experiencing navigational difficulty as a result of sedimentation from the catchment include: the channel into Brooklyn Harbour; the channel around Spectacle Island; and the channel into Sandbrook Inlet (WRL, 2003). In the Hornsby Shire, dredging of the waterways is undertaken to maintain navigation channels and water depths under marinas, wharves or pontoons. Maintenance dredging has occurred twice in the last 30 years (SJB, 2005). Both the Hawkesbury Marina and HSC, for the channel adjacent to McKell Park, are licensed by the EPA to dredge between 30000 – 50000 m^3 of material with the use of water quality controls (mainly for turbidity) (WRL, 2003). Dredging of the Sandbrook Inlet has been proposed to re-establish the navigation channel (SJB, 2005).

2.5.4 Foreshore Erosion

In the reaches and tributaries downstream of Wisemans Ferry, erosion of beaches occurs due to boat wash, high velocity discharges associated with stormwater outlets, and uncontrolled access to some areas of the foreshore (Kimmerikong, 2005). Limited erosion has been noted in Berowra Creek in the area between Woolwash and Joe Crafts Bay on exposed silty shorelines as a result of wind waves, boat wake and foreshore changes (WMA, 2002).

2.5.5 Sediment Quality

2.5.5.1 Sediment Monitoring within the Estuary

An investigation of sediment quality in the Lower Hawkesbury Nepean River was undertaken by the consultants URS as part of Hornsby Shire Council Estuary Management Program to determine sources and the regional extent of sediment contamination and assist in the prioritisation of required remedial actions (URS, 2007) (refer Figure 2-1). Sediment grab samples from 52 locations in the Lower Hawkesbury Nepean River and tributaries were analysed for trace metals (As, Ba, Be, Cd, Cr, Co, Cu, Hg, Mn, Ni, Fe, Pb, Sr, V, Zn), major elements (Al, Ca, Mg), nutrients (Total Kjeldahl Nitrogen, nitrate and nitrite), TOC, organic contaminants (PCBs, OC and OP pesticides, PAHs, TPHs, BTEX) and grain size. During a second stage of the assessment, 16 locations were selected from the original 52 locations to determine concentrations of tributyltin (TBT) and organic contaminants in the sediments at ultra trace analytical detection limits. Organic booster biocides (diuron, chlorothalonil, irgarol and dichlofluanid), which augment Cu-based antifoulants since the banning of TBT in 1989, were analysed in sediments from four locations near marinas and a pristine reference location. Analysis for these compounds in sediments is rarely undertaken in Australia and this study represents the first of its kind for sediments in the Lower Hawkesbury Nepean River. Concentrations of diuron up to 40 µg/kg were detected in sediments near a marina compared to <1 µg/kg at the reference location, suggesting that there is an impact from booster biocides used in antifoulants on sediments in areas of high boating activity. Regionally, only few heavy metals and no organic contaminants exceed ANZECC/ARMCANZ (2000) sediment quality guideline values in sediments of the Lower Hawkesbury Nepean River. However, sediments near marinas and riverside settlements in upper Berowra and Cowan Creeks contain elevated concentrations of TBT and other heavy metals and may pose potential adverse effects on aquatic biota.

2.5.5.2 Nutrients and Organics

Sediments of the river have a relatively high total organic carbon (TOC) and nutrient content, which is derived from the catchment (Kimmerikong, 2005; WMA, 2002). Analysis of sediment cores taken from the estuarine mud basin in the main channel at Dangar Island, Sandbrook Inlet, Mooney Mooney Creek and Mullet Creek found TOC ranged from 1.36 to 4.12 % (WRL, 2003). Phosphorous levels were found to be highest in Mullet Creek and Sandbrook Inlet, with maximums of 842 mg/kg and 821 mg/kg respectively (WRL, 2003).

Relatively high TOC (and nutrients) content in the sediments, such as noted above in the Brooklyn segment of the main river channel, are indicators of a natural deposition environment for catchment organic loads delivered from upstream (particularly after floods). Organics within the water column settle to the bed, where they become buried within the sediments. Anaerobic bacteria within the sediments break down the organic material and re-mineralise it back into inorganic nutrients. If conditions allow the inorganic nutrients to then be effluxed back into the water column they will be converted to organic forms through uptake by algae (WBM, 2006b).

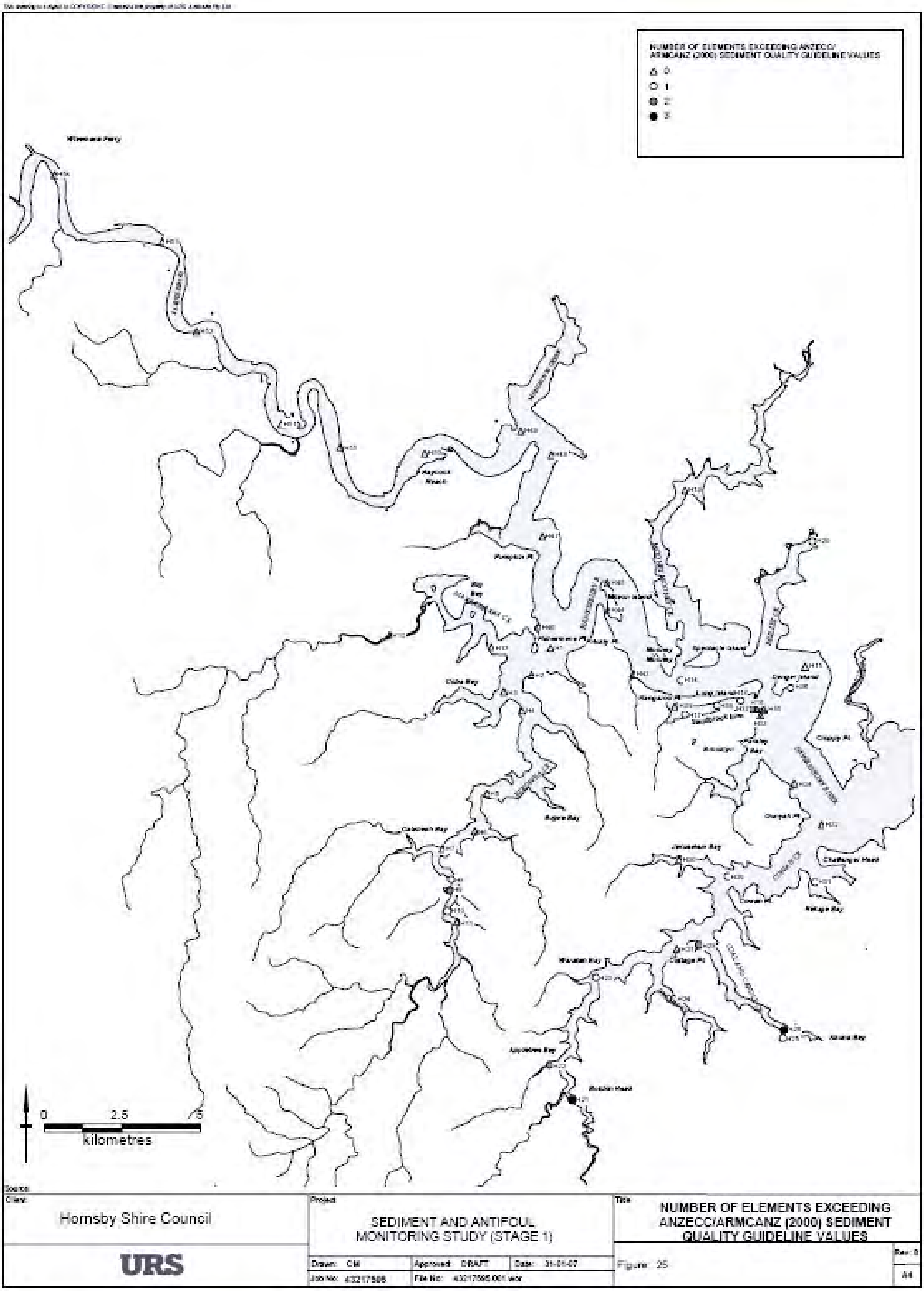


Figure 2-1 Results from the Sediment and Antifoul Monitoring Study (source: URS, 2007)

The release of ammonium, oxidised nitrogen (NO_x) and phosphorous from sediments from shallow and deep water and in the overlying water column was assessed in a study by Bourges et al. (1998) with the aim of potentially explaining the occurrence of algal blooms in Berowra Creek. The study found both deep and shallow sediments in Berowra Creek represent an important source of nutrients for primary production in the form of ammonium, which is the preferred dissolved inorganic form for phytoplankton (until concentrations fall below a threshold limit). The study involved three field trips, and sediments were tested in oxic and hypoxic to anoxic conditions. Conclusions from the study (Bourges et al., 1998) were:

- There was virtually no change in the amount of ammonium or phosphorous release, or NO_x uptake under oxic compared with anoxic/hypoxic conditions. As nutrient release is similar at all oxygen levels, algal blooms cannot be attributed to low dissolved oxygen (DO) levels which occurs occasionally in deep holes in the creek.
- Overall, the amount of benthic oxygen and the rate of flux of nutrients were found to be similar at either shallow or deep sites. Thus algal blooms originating above deep holes cannot be attributed to higher release of phosphorous or nitrogen from deep hole sediments.
- The sediments were a source of phosphorous however at all sites, phosphorous was minimal at depth and virtually undetectable at the surface (and as noted, no increase in phosphorous release was demonstrated under anoxic compared with oxic conditions).
- Irrespective of water oxygenation, the release of ammonia was far greater than the uptake of NO_x by the sediment, by a factor of 44 in oxic and 4 in anoxic conditions.
- NO_x was never depleted completely from the water column, and therefore was not a limiting factor for denitrification activity.
- Ammonia discharge rates were among the highest reported in the literature, thus creek sediments are said to provide a substantial source of nitrogen to the water column.
- While unlikely to initiate blooms solely, the high source of nutrients from sediments may assist in sustaining the blooms.

2.5.5.3 Heavy Metal and Chemical Contaminants

Contaminants within the sediments, such as metals and anthropogenic organic compounds, can bioaccumulate within the benthos, particularly filter feeders, such as pipis and oysters, making them unsuitable for consumption by humans, or other aquatic fauna (WBM, 2006b).

High levels of contaminants have been found in sediments at Bobbin Head, Akuna Bay, southern Pittwater (Kimmerikong, 2005), Berowra Creek (NSWFA, 2004c; WMA, 2002) Sandbrook Inlet and Dangar Island (WRL, 2003). Sediments contaminated with heavy metals are particularly found in proximity to marinas, boat servicing/cleaning areas and slipways, and moored vessels using anti-fouling paints (Kimmerikong, 2005; NSWFA, 2004c; WMA, 2002; WRL, 2003). Other potential sources include sewage discharges, urban runoff, vehicular emissions and dust (NSWFA, 2004c; WMA, 2002).

Sediment sampling conducted by the Hawkesbury-Nepean Catchment Trust in 1997 (cited in (NSWFA, 2004c) discovered high levels of copper and lead (of each 100 µg/kg) adjacent to Berowra Ferry. Adjacent to Berowra Waters, there were also high levels of zinc (100 µg/kg). Berowra Creek was found to contain high levels of dieldrin (maximum of 39 µg/kg) and organochlorine pesticides (OCPs), while copper, zinc and chromium levels exceeding sediment quality guidelines were found in Sams Creek, which drains an industrial area to Berowra Creek (NSWFA, 2004c).

Arsenic concentrations above the interim sediment quality guidelines (ISQG) and elevated concentrations of tin were found in surface sediments in the main channel at Dangar Island (WRL, 2003). Elevated levels of tin were also reported in surface sediments at Mooney Mooney Creek. Surface sediment contamination is suggested to represent a recent source such as marinas (WRL, 2003).

There was slight elevation of copper, lead and zinc levels in surface sediments in the eastern end of Sandbrook Inlet, while elevated tin levels were recorded at sites in Sandbrook Inlet (WRL, 2003).. This may indicate the long term trapping of contaminants during the railway causeway construction (WRL, 2003), or the heavy usage of the inlet by permanent and visiting boat traffic.

Nickel in concentrations above the ISQG and elevated levels of tin were found in subsurface sediments in Mullet Creek (WRL, 2003).

Polyaromatic hydrocarbon (PAH) sampling indicated individual compounds and total PAHs to be below the ISQG. However, total PAH concentrations ranged from <10 µg/kg in sandy sediments up to 2530 µg/kg in muddy sediments. Elevated PAH levels were found in Mooney Mooney Creek, but particularly in Sandbrook Inlet, suggesting future contamination issues may need to be addressed (WRL, 2003).

2.5.6 Further Reading

For further reading regarding the sediments of the estuary, please refer to Bourges *et al* (1998), WMA (2002), WRL (2003), ACUN (2003), NSWFA (2004a), NSWFA (2004c), SJB (2005) and Kimmerikong (2005).

2.6 Water Quality

Water quality in the Lower Hawkesbury is in part determined by the quantity of the pollutant input, and the degree of tidal flushing with oceanic waters to remove and dissipate these inputs. Areas with less tidal flushing are more likely to experience degradation, particularly where catchment inputs are high in pollutants. Pollutant concentrations have been measured to increase following rainfall runoff from the catchment (WMA, 2002), while point source inputs may occur in wet or dry conditions (WBM, 2006b). Good water quality is imperative to sustaining aquatic and related habitats, and aquatic based industries such as commercial fishing and oyster aquaculture, as well as supporting recreational activities. Figure 2-2 shows areas throughout the estuary where particular water quality standards are required to support aquatic ecosystem health and human contact.

Pollutants in the Lower Hawkesbury may include nutrients and sediments (typically associated with agricultural activities and fertiliser use, construction activities, urban runoff and the clearing of native vegetation), faecal pollutants (from STP overflows and bypassing, septic system failure, and boat discharges, as well as animal faeces in stormwater), chemicals such as hydrocarbons and pesticides (from agricultural use of pesticides, industrial activities, road runoff and fuel spills and exhaust from boats), heavy metals and gross pollutants (litter from stormwater, recreational areas and boats, and riverside houses in rainfall). Chemical and metal pollutants may also bioaccumulate, increasing their toxicity to humans or other aquatic organisms.

Catchment runoff and other catchment-based activities within the entire 22,000 km^2 Hawkesbury-Nepean River catchment are the major contributors to pollutant loadings in the lower sections of the Hawkesbury River (HNCMA, 2005; WBM, 2006b).

Within the Lower Hawkesbury catchment alone (ie, aside from pollutants sourced from upstream) STP discharges and plant bypassing, urban and industrial runoff, on-site sewage treatment failures and runoff, and runoff from disused and active landfill sites have all contributed to the water quality degradation, particularly within the tributary creeks where tidal flushing is less frequent.

There were known to be 19 EPA licensed discharges in 2002 (mostly sewage outlets) within the Berowra Creek catchment alone (WMA, 2002). Road and rail runoff is typically carried into stormwater systems then into waterways without treatment, although the installation of stormwater treatment measures is increasing (WRL, 2003). In 2001/02, 289m^3 of litter, sediment, and organic matter was removed from GPTs in the Hornsby LGA (WRL, 2003), 2006/07 this amount has increased to 1200m^3 (pers comm., Dr Ross McPherson, HSC). Treatment processes to improve the quality of leachates from disused waste disposal sites in the Hornsby Shire have been implemented (Kimmerikong, 2005).

Some of the sub-catchments drained by Marramarra Creek have significant agricultural activity including intensive market gardening (NSWFA, 2004c). Runoff from this area is known to be high in turbidity, oxidised nitrogen, TN and ammonia (NSWFA, 2004c).

A review of water quality issues by the former Hawkesbury Nepean Catchment Management Board found water quality to generally be good, however levels of total nitrogen (TN), total phosphorous (TP) and faecal coliforms (FC) have consistently failed to meet appropriate standards at various locations in the estuary (WRL, 2003). ANZECC guidelines have also been frequently exceeded in Berowra Creek, especially for nitrogen, suspended solids and industrial toxicants (DLWC, 1997).

2.6.1 Stormwater Treatment

The HSC Berowra Catchment Stormwater Management Plan details a number of activities to reduce stormwater pollution. This has included the installation of stormwater treatment devices (eg GPTs, litter racks/baskets) and proprietary stormwater treatment devices (filter systems, end of pipe pits and traps, and pollutant booms) of which there are currently over 350 devices in the LGA. The construction of wetlands, sediment basins, and community education has also been undertaken as part of this program (NSWFA, 2004c). A pollution control device has been installed adjacent to the boatramp at Dusthole Bay, Berowra Creek to stop sediment and oil contaminated runoff from the carpark entering the estuary (Kimmerikong, 2005).

A Stormwater Catchment Management Plan (SCMP) for the urban areas of Brooklyn and Glenorie has also been prepared for Hornsby Shire Council. Significant stormwater management issues in Brooklyn and Glenorie included: elevated suspended solids and turbidity and toxins and chemical pollutants; litter; degraded aquatic ecosystems; inappropriate streamflow regimes; and flooding in local areas. Modelling was used to identify problem areas with various streets and a total of 10 properties estimated to be subject to significant overland flows (WBM, 2004).

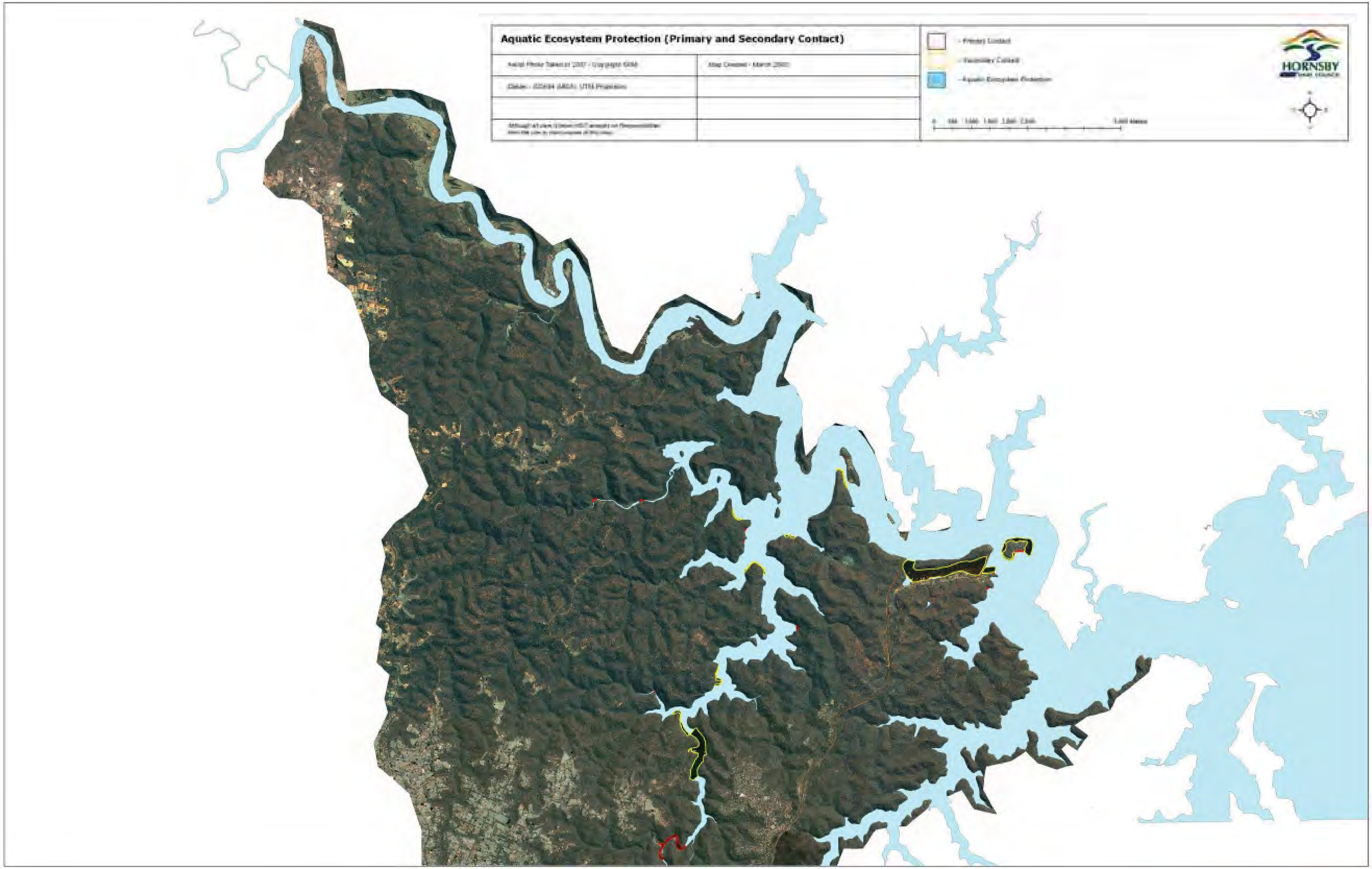


Figure 2-2 Areas within Lower Hawkesbury Estuary Requiring Particular Water Quality Standards

The SCMP recommended an extension of HSC's existing community education programs, particularly drain stencilling; capacity improvement of some specific sections of stormwater drain; upgrade or replacement of some pits, usually in conjunction with pipe amplification; the formalisation of overland flow paths, and kerb and gutter improvements to direct overland flows away from private properties (WBM, 2004).

Some of the stormwater quality control measures constructed at Brooklyn include a Rocla DD and swale at Dangar Road, a humeceptor and sand filter at Parsley Reserve and a wetland at Brooklyn Road (WBM, 2004). The humeceptor at Parsley Bay captures pollutants from boat washing and flushing, and fish cleaning waste, and has successfully reduced nutrient, biochemical oxygen demand (BOD), hydrocarbons, turbidity and TSS concentrations discharged to the estuary (WRL, 2003).

Stormwater infrastructure within the township of Brooklyn incorporates 219 pits, 3,692 metres of pipes, and 143 metres of open channel (WBM, 2004). The sediment basin in Brooklyn alone collected 1.5 tonnes of sediment in 2000/01 (WRL, 2003).

2.6.2 Licensed Discharges

The licenced discharges within Berowra Creek include: sewage treatment plants at Dural Caravan Park, Berowra Waters Marina, Vision Valley (Arcadia); non-sewage discharges from CSR Readymix Quarry (in Hornsby), the Hornsby and the Hills district public swimming pools and Summertime Chickens Farm; diffuse point source flows from the RSL Rowland retirement village and Northolm Grammar School; and current and disused tip sites at Mt Colah and Arcadia run by HSC and Western Earthmoving Landfill depot (DLWC, 1997).

Treatment processes to improve the quality of leachates from disused waste disposal sites in the Hornsby Shire have been implemented (Kimmerikong, 2005).

Licensed discharges are also permitted in the Brooklyn catchment, and include: Fenwick Marina, Brooklyn Rd (marina and boat repairs, runoff restrictions); Hawkesbury Marina, Dangar Rd (30000 m^3 dredging with controls); HSC, on Crown Land at Mckell Park (dredging 30000 – 50000 m^3, with WQ controls); Pioneer, Central Coast Sands (land based sand extraction with water discharge permitted with monitoring, and dust emission controls) (WRL, 2003).

2.6.3 Physico-Chemical Parameters

Water quality measurements taken between 1990 and 1996 in the upstream section of the Hawkesbury-Nepean River found surface and bottom measurements of pH, temperature, dissolved oxygen (DO) which indicated waters to be well mixed to a depth of 10m (WRL, 2003).

The majority of dissolved oxygen (DO) measurements in the channels in and around Brooklyn were found to be above aquatic protection guidelines, and 75 % of measurements were above recreation guidelines. Likewise for this area, the majority of pH measurements were within aquatic ecosystem, aquaculture and recreational guidelines. Water temperature at Brooklyn ranged from around 11 °C in winter to around 29 °C in summer (WRL, 2003).

At the Brooklyn section of the main channel, salinity concentrations were highly variable, between 12 and 41 ppt, reflecting the varying influence of freshwater from the catchment and ocean water from tides (WRL, 2003). The maximum variability in salinity occurs just upstream of Spencer and the confluence with Mangrove Creek (Kimmerikong, 2005).

Measurements of secci depth at sites in Mooney Mooney and Mullet Creeks were below recreational guidelines (of > 1.6 m depth visibility) suggesting issues of visibility at these locations (WRL, 2003).

2.6.4 Faecal Coliforms

Water quality measurements taken between 1990 and 1996 in the upstream section of the Hawkesbury-Nepean River has shown faecal coliform (FC) levels frequently exceeded recreational guidelines in the main stream and tributaries (WRL, 2003).

The impact of contaminant flows from on-site sewage systems, boat discharges and overflow points are quickly dispersed by tidal flushing across the wider region of the main channel and lower tributary reaches. However, the cumulative impacts of many boats, septics, stormwater and overflow points at an individual locality, especially during high usage holiday periods, has been shown to cause water quality deterioration at the locality (WRL, 2003).

Within Pittwater for example (although outside the LHEMP management area), high faecal coliform concentrations and a possible public health problem have been recorded for Scotland Island in both wet and dry conditions, as well as Careel Creek and McMahons Creek (Kimmerikong, 2005).

In the waterway in and around Brooklyn, the range of faecal coliform levels was variable, with median values of 1 – 4 cfu/100mL (WRL, 2003). Most measurements were below the 150 cfu/100mL recreational contact guideline, except for occasional samples from Spectacle Island and Mullet Creek (WRL, 2003). Water quality within stormwater drains at Brooklyn contains high concentrations of faecal coliforms, enterococci, and nutrients, with these pollutants most likely coming from leaking septic systems (WBM, 2006b).

On Dangar Island, sewage contamination was noted during dry weather in groundwater wells and during wet weather in surface water locations. However, contamination in the waterway adjacent to the island was considered negligible due to the frequent strong tidal flushing (WRL, 2003).

As part of the NSW Shellfish Program, the NSW Food Authority (NSWFA) (2004) reported upon detailed faecal coliform testing at Marramarra Creek, Kimmerikong Bay and Coba Bay oyster harvest areas in Berowra Creek. The results have been summarised below:

- In Marramarra Creek, one site exceeded the Adverse Pollution Condition Sampling (APCS) criteria for a Restricted harvest area (of less than 10 % of samples greater than 85 cfu/100mL), and four out of five sample locations did not comply with the APCS criteria for Approved harvest areas (of less than 10 % of samples greater than 21 cfu/100mL) (the APCS are used by the Australian Shellfish Quality Assurance Program (ASQAP)). At the site exceeding the Restricted area criteria, it was found that only one sample caused the exceedence and this sample coincided with salinity of less that 2 % and a high rainfall event, and subsequent pollution causing an "atypical" FC result (NSWFA, 2004c);
- The site at the mouth of Coba Bay did not comply with APCS criteria for a Restricted area (NSWFA, 2004a). All sample sites in Kimmerikong Bay failed to meet the APCS criteria for a

Restricted harvested area (NSWFA, 2004b). When samples with salinity less than 18% were removed, the sites met the requirements (NSWFA, 2004b);

- Data from 1990 to 2003 show that rainfall events of a magnitude to cause significant contamination in the Berowra Creek estuary are likely to occur on average 6 times a year, with a range from 2 to 10 times per year (NSWFA, 2004a);
- High FC levels were typically, but not always, associated with rainfall events in Marramarra Creek (NSWFA, 2004c). The eastern oyster harvesting area in Marramarra Creek is less affected in terms of frequency and magnitude of faecal contamination than the western end, likely due to better tidal flushing of the eastern end. The western end of the harvest area experiences lower salinities for longer periods after rain, as well as a greater impact from runoff entering the Creek (NSWFA, 2004c);
- In Coba Bay, bacteriological water quality is reasonable during dry weather with moderate to high contamination usually but not always associated with rainfall events. Occasional instances of contamination during dry weather are derived from sewage discharges from commercial and recreational boats that do not have holding tanks and from unsewered Coba Point properties (NSWFA, 2004a); and
- Kimmerikong Bay is subject to the occasional presence of known faecal pollution from documented sources which is not predictable and not always linked to rainfall, although E.coli. levels in shellfish flesh are linked with rainfall (and runoff) events (NSWFA, 2004b).

2.6.5 Sewage Treatment Plants

In 2002, West Hornsby STP and Hornsby Heights STP, combined, serviced around 76,000 people (DLWC, 1997; WMA, 2002). Hornsby Heights STP and West Hornsby STP are designed to discharge a maximum of 85 ML/d and 154 ML/d, respectively, of tertiary treated effluent into Berowra Creek (NSWFA, 2004a and EPA Public Register). Typically, Hornsby Heights STP discharges 5.4 ML/d into Canla Creek, and West Hornsby STP discharges 10.5 ML/d into Waitara Creek (Waitara Creek enters Berowra Creek upstream of Rocky Fall Rapids, and Canla Creek enters between Crossroads and Berowra Waters) (WMA, 2002).

West Hornsby STP and Hornsby Heights STP accounts for 7 % of effluent flow to the Hawkesbury River (DLWC, 1997). This discharge of treated effluent from the Hornsby Heights and West Hornsby STPs constitutes the major freshwater inflow into Berowra Creek during dry weather, taking about one day during a rain event and five days in dry weather, to reach oyster harvest areas in Berowra Creek (NSWFA, 2004a). During wet weather, there are overflows and designed bypassing of the sewage system that discharge untreated sewage to the waterway (DLWC, 1997; NSWFA, 2004c). There is also a small STP at Berowra Waters Marina discharging chlorinated effluent to the Creek (NSWFA, 2004c).

Upgrades of the Hornsby Heights STP and the West Hornsby STP were undertaken to reduce nutrient concentrations to 5 mg/L of nitrogen, change the disinfection method from chlorine to ultraviolet disinfection, and reduce bypassing events to 2.9 per year (Kimmerikong, 2005; WMA, 2002).

A new sewage scheme involving a treatment plant on the ‘Old Dairy’ site at Brooklyn to service up to 3,400 persons began construction in April 2006. Connections became available to Brooklyn residents in November 2007. Connections are progressively being made available to Dangar Island residents from April 2008.

The new STP discharges treated effluent into the river, via an outfall at the second pylon on the south side of the Peats Ferry Road Bridge (SydneyWATER, 2005). The maximum discharge allowed according to the licence on the EPA public register is 2.1 ML/d

Modelling has indicated around an 80 % reduction in nutrients and faecal coliforms (FC) loads discharged to the waterway compared with current loads by the replacement of currently sub-standard septic tanks with an STP (although this still equates to some input of nutrients and FC to the waterway) (WRL, 2003). For wet and dry weather combined, there is estimated to be: TP loads of 90 kg/year sewered compared with 554 kg/year unsewered; TN loads of 156 kg/year sewered compared with 1,330 kg/year unsewered; and FC loads of 16,249 x 10^9 cfu/100mL/year compared with 129,386 x 10^9 cfu/100mL/year unsewered.

2.6.6 On-Site Sewage Management

On site sewage treatment systems are potentially a source of faecal contaminants, nutrients, general household wastewater and gross pollutants, and may fail to meet health standards without proper maintenance, or where they are installed in inappropriate topography and soils. During rainfall, there may be runoff of effluent from soil absorption trenches and other on-site components to the waterway (WRL, 2003).

All riverside dwellings within the Hawkesbury estuary region, except for the eastern shore of Pittwater, are serviced by onsite sewage treatment (Kimmerikong, 2005). Semi-rural areas around Arcadia, Galston and Glenorie are also unsewered (WMA, 2002). In the Hornsby LGA there are 4077 on site residential sewage systems. Of these, 57 % have a low risk rating, 36 % have a medium risk rating and 7 % have a high risk rating (The Middle Way, 2005). Close to all of the Hornsby LGA drains to the Hawkesbury River.

The HSC audit of on-site sewage systems found: 16 % on Brooklyn and 36 % on Dangar Island were impacting water quality; 22 % on Brooklyn and 66 % on Dangar Island were impacting community amenity; and 40 % on Brooklyn and 74 % on Dangar Island posed a serious threat to public health. Most of the current on-site systems used at Mooney Mooney, Cheero Point and Little Wobby Beach are also considered to pose a public health risk, with wet weather overflows and ground and surface water contamination (WRL, 2003). Note that on-site systems in Brooklyn and Dangar Island are currently in the process of being progressively connected to the new Brooklyn and Dangar Island Sewerage Scheme.

Following the Berowra Creek Enhancement Options Study by HSC in 2001, one third of septic systems were replaced or upgraded. As a result, in 2004, 60 % of septics in Berowra Creek were deemed low risk, and 20 % medium risk. The remaining high risk sites are mainly due to topography and geology, which prevent adequate on-site sewage management. In spite of improvements to Berowra Creek septic systems, effluent contamination remains a threat to oyster harvest areas in the creek (NSWFA, 2004c).

2.6.7 Boat Discharges

Boat discharges refers to the discharge of faecal material, wastewater and gross pollutants (rubbish), from both commercial and recreational vessels, during day or overnight trips. Vessels on which people may spend an extended period (that is: Class 4 commercial vessels which may be hired for long periods/overnight, eg houseboats; and Class 1 commercial vessels, namely, charters) pose a risk of discharging of sewage waste into surrounding waters (WRL, 2003). There is said to be a lack of pumpout facilities and waste skips, and a lack of policing in the estuary (WMA, 2002). Waterways have noted existing legislation to be insufficient to effectively manage sewage discharges from vessels (WRL, 2003).

Within the Lower Hawkesbury (including Pittwater) there are at least 4,735 moorings and 789 private berths (DLWC, 1997; Kimmerikong, 2005; Taylor and Hincks, 2005). In addition, there is any number of "trailable" boats launched into the River at any time. Of the moored vessels in the waterway, an estimated 50% may have a toilet fitted (Taylor and Hincks, 2005). Of the 101 commercial hire boats registered to operate in the Lower Hawkesbury, 22 do not have holding tanks (but have or will be notified that they need to install one) (NSWFA, 2004a).

It is estimated that 137,150 L of wastewater was produced by recreational boaters on the Lower Hawkesbury in 2004/05 (Taylor and Hincks, 2005). Of the annual wastewater produced, 40% is collected at Kangaroo Point (of 280,714 L in 2003/4), 10-15% at private marinas, leaving another 45-50% not being collected and likely discharged to the river (Taylor and Hincks, 2005). The pump out facility at Kangaroo Point averages 1.5 uses per day (Kimmerikong, 2005).

Pumpout facilities for vessels on the Lower Hawkesbury are located at (Taylor and Hincks, 2005):

- Kangaroo Point (free to recreational users and at a fee for commercial vessels);
- Holidays Afloat Houseboats, Sandbrook Inlet (fee charged to all users);
- Ripples Marina, Sandbrook Inlet (private facility);
- Hawkesbury River Marina, Brooklyn (private facility only allows emergency use for other vessels);
- d'Albora Marina, Akuna Bay, Cowan Creek (private but free to all users);
- Quays Marina, Church Point, Pittwater (private but free to all users); and
- Halvorsen Boat Marina, Cowan Creek (private facility, fee charged to users).

In a report compiled by Taylor and Hincks (2005), the construction of a new pumpout facility on the eastern side of the Hawkesbury River railway bridge was proposed as the most environmental and economically sound option for providing adequate pumpout facilities in the Hawkesbury River.

2.6.8 Nutrients

Total nitrogen (TN) loads of 189.4 kg/day and total phosphorous (TP) loads of 7.4 kg/day from the Upper Hawkesbury-Nepean River flow into the Lower Hawkesbury (WRL, 2003). A summary of water quality measurements taken between 1990-1996 in the upstream reaches of the Hawkesbury-Nepean River indicated TN and TP levels to be above ANZECC 1992 for the majority of sites (WRL, 2003).

Catchment modelling has determined approximately 47,000 kg of TN and 8,200 kg of TP are generated from the Brooklyn estuary catchment per year, of which it is estimated that only 1.4 % of TN and 0.3 % of TP are in an inorganic bioavailable form (WBM, 2004).

Approximately 83 % of the total nitrogen load and 22 % of the total phosphorous load in Berowra Creek may be attributed to STP discharges (Kimmerikong, 2005). The three transport networks (the Main Northern Railway, F3 and Pacific Highway), combined, contribute an estimated nitrogen load of 864kg/year, phosphorous load of 45 kg/year and TSS load of 10368 kg/year to the estuary (WRL, 2003). Runoff from the road and rail transport corridors is considered to be insignificant in terms of the estuary's total nutrient loading. However, the relatively high inorganic forms of nutrients that runoff from these landuses means that the total dissolved inorganic nutrient loads (both nitrogen and phosphorus) are increased by about 50 % as a result of these corridors (WBM, 2006b).

Nitrogen (in various forms) was found to be high in and around Brooklyn however, it is likely that much of this is sourced from upstream. The majority of measurements showed concentrations of ammonia exceeding the recreational guidelines, and of oxidised nitrogen (NO_x) and TN exceeding aquatic ecosystem protection guidelines, with some sites also exceeding the saltwater aquaculture protection guideline for TN. TP concentrations were found to be below the saltwater aquaculture protection guidelines, with at least 50% of measurements below aquatic ecosystem protection guidelines (WRL, 2003).

Interestingly, it is thought that the Brooklyn segment of the waterway may be acting as a nitrogen sink. The TN load calculated for Bar Point is 189.4 kg/day (or. 0.64 mg/L) and by Flat Rock Point (just downstream of Brooklyn), the TN load is 106.3 kg/day or 0.35 mg/L. However, phosphorous loads are said to be advected through Brooklyn. At both Bar Point and Flat Rock point, TP loads are calculated to be 7.4 kg/day, or 0.025 mg/L (WRL, 2003).

2.6.9 Suspended Solids

The concentrations of total suspended solids (TSS) were found to be below aquaculture protection guidelines in and around Brooklyn, except in Sandbrook Inlet, which averaged 14mg/L, while turbidity measurements were commonly above guidelines. This is likely due to tidal and wind forces reworking fine sediments across the shallow tidal flats of the Inlet (WRL, 2003).

2.6.10 Algal Blooms

Algal blooms may have ecological and economic implications, including (Bourges et al., 1998):

- The toxins released by some types of algae may kill other aquatic organisms,
- Some types may also be toxic to humans either directly through recreational contact, or through edible shellfish, such as oysters; and
- Night time respiration and the decay of organisms at the crash of the bloom may significantly deplete oxygen in the water, resulting in the death of aquatic organisms.

Clearly, algal blooms, both toxic and non-toxic, may be detrimental to oyster aquaculture and commercial fishing, and also deteriorate recreational and tourism resources of the river and tributaries (DLWC, 1997).

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). Information from Berowra Creek suggests high levels of phytoplankton generally occur during extended sunshine following rainfall, particularly in summer (WMA, 2002). Blooms tend to persist for longer in dry years compared to wet years when the increased rainfall assists the dispersal and dilution of blooms (NSWFA, 2004a). Several potentially toxic species are seasonal (NSWFA, 2004a, b).

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 (refer Section 2.5.5.2). The high nutrient waters and sediments are likely to assist the continuation of blooms once they are initiated (Bourges et al., 1998).

Algal blooms have been reported in Berowra Creek by a number of authors (Bourges et al., 1998; Chapman and Underwood, 2005; DLWC, 1997; Ecology Lab, 1998; WMA, 2002). The blooms generally occur between Berowra Ferry and Oaky Point and particularly in the region of Calabash Bay (where water is up to 17m deep) (Bourges et al., 1998).

Both toxic and non-toxic algae are known to occur in Berowra Creek, with 33 species of phytoplankton collected during previous studies (DLWC, 1997), and also Marramarra Creek, and Coba Bay (NSWFA, 2004a, c). The dominant phytoplankton species in Berowra Creek are *Chaetoceros spp*. and *Pseudo-nitzschia spp.* with potentially toxic species also identified as *Pseudo-nitzschia* multiseries, *Alexandrium catenella* and *Gymnodinium catenatum*. DLWC (1997) noted four red algal forms, including one species of toxic dinoflagellates have been collected at Calabash Bay.

In Marramarra Creek, several species of potentially toxic algae were found. Two such species were found to exceed the shellfish testing levels on seven occasions, of which, one exceeded the closure levels for its genus (NSWFA, 2004c).

Blooms of blue-green algae are also known to occur at Wisemans Ferry (Kimmerikong, 2005), with signs at the ferry terminal indicating recreational water contact is not recommended.

The measurement of Chlorophyll-a in water is commonly used to indicate the presence of algae, although the measurement does not distinguish the type and hence toxicity of the algae. Measurements taken between 1990-1996 in the upstream section of the Hawkesbury-Nepean River indicated Chlorophyll-a often exceeded guidelines in sites between Penrith and Wisemans Ferry (WRL, 2003).

Chlorophyll-a has been measured between 40-80 µg/L in estuarine sections of Berowra Creek (DLWC, 1997), and ranged from 1.35 to 12.6 µg/L during August to November in 2001 at Dusthole Bay (in Berowra Creek) (Kimmerikong, 2005). Of the fish kills that occurred in Berowra Creek, two coincided with low DO (which may have been the end result of algal blooms), and with high Chlorophyll-a (Ecology Lab, 1998).

A remote chlorophyll monitoring probe was deployed at Calabash Bay by Manly Hydraulics Laboratory (MHL) in 2002, on behalf of Council. The probe collects real time chlorophyll, conductivity, salinity and temperature data from the estuary. Data is transmitted every 15 minutes via a data logger and is displayed on the internet. If chlorophyll levels exceed a pre-defined trigger level, a warning is sent via email to Council officers who then follow the appropriate algal bloom procedure stipulated by the Department of Environment and Climate Change.

Chlorophyll-a concentrations have exceeded the guidelines in Sandbrook Inlet, however, algal blooms have not been reported (WRL, 2003). This is probably due to higher turbidity concentrations (hence less light penetration) and relatively rapid evacuation of pollutants from the Inlet during wet weather conditions (as highlighted by particle tracking modelling) (WBM, 2006b). In the main channel around Brooklyn, Chlorophyll-a levels are below the relevant guidelines (WRL, 2003).

There have been relatively high concentrations of Chlorophyll-a measured in the upper reaches of Mullet and Mooney Mooney Creeks (Kimmerikong, 2005). WRL (2003) measured maximum values of 12 and 16 µg/L in the creeks, respectively, which suggests algal blooms may occur here given the right conditions (WRL, 2003).

High Chlorophyll-a levels were found to correlate with phosphorous values for samples taken in Sandbrook Inlet, Mooney Mooney Creek and Mullet Creek. This suggests phosphorous may be a limiting factor in algal growth, unlike nitrogen, which is known to be high in this region, and so unlikely to limit growth (WRL, 2003).

2.6.11 Oyster Flesh Monitoring

A farmed Sydney Rock Oyster will filter an estimated 0.25 ML of estuarine river water on average during its life. They remove suspended material, mainly phytoplankton (algae) from the water column. Silt can affect the feeding apparatus of oysters and can lead to infestation of mudworms. Increased turbidity may also reduce oyster primary production (DPI Fisheries, 2006).

Heavy metals were found in oyster flesh in all locations of the Hawkesbury, however, mercury was the only contaminant found in concentrations above guideline levels (WRL, 2003).

Wild oysters in Brooklyn Harbour and Sandbrook Inlet were found to contain significantly higher levels of zinc, copper, selenium, and arsenic. Concentrations of copper in oysters in Sandbrook Inlet and Brooklyn Harbour, and arsenic in oysters in Brooklyn Harbour were found to exceed the maximum values permitted by the ANZFA food standards. The elevated copper levels reported are likely the result of anti-fouling paints from the large number of boats in both areas (WRL, 2003).

Field and lab experiments on the Sydney Rock oyster in the Lower Hawkesbury river found Sandbrook Inlet had the highest rate of oyster mortality and shell deformation, likely due to the high concentration of tributyl tin (TBT) in the Inlet and the long residence time of contaminants in the Inlet compared with other locations (WRL, 2003).

Monitoring of shellfish flesh in Marramarra Creek, Coba Bay and Kimmerikong Bay harvest areas was conducted as part of the NSW Shellfish Program by the NSWFA (2004). The outcomes of shellfish flesh testing for E.coli and heavy metals are discussed below:

- In Coba Bay, the majority of shellfish examined in a survey, showed that the E.coli levels were either undetectable or less than 2.0 E. coli per gram (NSWFA, 2004a). Shellfish flesh testing in the eastern end of Marramarra Creek harvest area indicated all samples were;

- below the NSW pre-depuration limit for a Restricted area (of less than 10 E.coli/g). Testing at the western end of the creek exceeded this limit on three occasions, two of which coincided with high rainfall and low salinity (of 20 – 27 %) (NSWFA, 2004c);
- Contaminant testing of shellfish flesh between1999 and 2002 in Marramarra Creek found selenium at the Generally Expected Level (GEL), zinc and copper exceeding the GELs and minor levels of lead and cadmium (NSWFA, 2004c). Elevated levels of copper and zinc were also found in shellfish in Coba Bay and Kimmerikong Bay (NSWFA, 2004a); and
- Kimmerikong Bay is the most affected harvest area in Berowra Creek, in terms if frequency and magnitude of contamination events (NSWFA, 2004b). The exposure of Kimmerikong Bay to west to north west winds may resuspend contaminated silts particularly at times when these winds are most common (early spring to summer) (NSWFA, 2004b). Shellfish contamination in Coba Bay is most likely to occur either during the initial arrival of contamination in major rain events or when rainfall is minor but sufficient to induce runoff (NSWFA, 2004a).

2.6.12 Further Reading

For further reading regarding the water quality of the estuary, please refer to DLWC (1997), Ecology Lab (1998), WMA (2002), WRL (2003), NPWS (2002), NSWFA (2004a), NSWFA (2004b), NSWFA (2004c), Taylor and Hincks (2005), Kimmerikong (2005), WBM (2006b), HNCMA (2005) and (MHL, 2002).

2.7 Ecology

The Hawkesbury's floristic diversity has evolved in part due to the variety of bedrock, dominated by Hawkesbury Sandstone, as well as igneous intrusions (such as on West Head), outcrops of Narrabeen Group Shales and sandstones, and pockets of Wianamatta Shale, and in part due to the varied aspect, topography and drainage (DLWC, 1997; NPWS, 2002; WRL, 2003). The entire Hawkesbury-Nepean catchment is known to contain over 1,100 native vertebrates (including fish, amphibians, reptiles, birds and mammals) and 1,700 invertebrates (HNCMA, 2005).

Within Hornsby Shire there are over 1,000 native plant species and 338 native vertebrate animal species. In the Ku-ring-gai Shire there are over 800 native plant species and 170 fungi, 360 vertebrate animals, and more than 170 insect and invertebrate species (The Middle Way, 2005).

Sydney Regional Environment Plan (SREP) No.20 emphasises the importance of protecting the Hawkesbury's significant vegetation and habitat values, and scenic values, which are contained within the foreshores, hillslopes and skylines, from built elements which may detract from such values.

An assessment of aerial photographs from the 1940s, 50s, 80s, 90s and 2000s for changes in aquatic habitat and land use over time was conducted by Williams and Thiebaud (2006). The series of orthorectified air photos covered the region from Warragamba Dam to the Hawkesbury River entrance, from which, a total of 13 locations were assessed. Six sites at each location were examined for changes in vegetation, land use and estuarine habitat over the photographic period. The locations were chosen biased towards locations where large scale changes could be measured, and so the outcomes are to be used with caution, and may not be representative of the river as a whole.

2.7.1 Aquatic Habitats

2.7.1.1 Seagrass

Seagrass beds are highly valuable habitats as they support juveniles of fish, prawn and crabs, many species of which are also economically important and are targeted by commercial and recreational fishers (Ecology Lab, 1998). The impacts on seagrass may include: boat propellers and other human disturbance/damage; poor water quality, sedimentation, and storm flows which disturb/scour creek beds (WMA, 2002); and poor management practices (HNCMA, 2005).

Large areas of seagrass exist in the Hawkesbury Estuary (SJB, 2005). The amount of seagrass has declined over time except around Brooklyn and Dangar Island (Kimmerikong, 2005; Williams and Thiebaud, 2006; WMA, 2002). The extents of seagrass coverage within the Lower Hawkesbury Estuary are shown in Figure 2-3.

The review of aerial photos by Williams and Thiebaud (2006) suggests that across the eight locations in the Lower Hawkesbury as a whole there had been a 20% decrease in seagrass coverage. In detail, there was an 11.7 ha increase in seagrass at the study site in the river between Flat Rock Point and just north of Mangrove Creek (also noted by WRL (2003) and Kimmerikong (2005)). However this was vastly outweighed by declines at the remaining study sites, ranging from 62 ha at Pittwater to 2 ha at Cowan Creek.

In and around Brooklyn, beds may be found at Sandbrook Inlet east of the railway causeway, Brooklyn Harbour, east of Kangaroo Point, south of Dangar Island and the head of Mullet Creek (WBM, 2006b; WRL, 2003). The beds are generally healthy and are dominantly of *Zostera capricorni* which is a protected species under the NSW *Threatened Species and Conservation Act 1995* (the TSC Act) (WRL, 2003).

Williams and Thiebaud (2006) state the main driver for the reduction in seagrass habitat is a decrease in natural vegetation, which allows for an increase in stormwater discharge. The enhanced stormwater flows can erode and remove seagrass, deposit sediment which smothers aquatic vegetation, and deliver increased nutrients which encourages algal blooms which then shade seagrass.

2.7.1.2 Benthic Assemblages

Due to its drowned river morphology, most of the estuary is relatively deep, which affects the benthic environment, as only benthos adapted to low light conditions can be supported (WBM, 2006b). It may also limit the width of the subtidal and intertidal zone inhabited by many benthic species, as the foreshores are typically steep (WBM, 2006b). In spite of this there are many mud flat, subtidal and intertidal regions (found in the river and in lower reaches of tributaries) and expanding mangrove areas which support much biological activity and ecological diversity (WBM, 2006b; WMA, 2002).

Figure 2-3 Seagrass and saltmarsh extents in the Lower Hawkesbury Estuary

In some creek and tributary areas where the salinity regime and stratification may result in periodically low dissolved oxygen (DO) (typically in the upper reaches), the diversity and abundance of foreshore and aquatic fauna may likewise be low. Periods of low DO are likely to be exacerbated in areas where algal blooms also occur. The lower reaches of creeks are said to contain a more abundant and diverse foreshore and aquatic fauna and very rarely experiences algal blooms due to tidal flushing (WMA, 2002).

Across benthic habitats in Berowra Creek as a whole, Chapman and Underwood (2004) noted there to be no discernible difference in macrobenthos in sites affected by urban runoff compared with sites unaffected by urban runoff. In fact, benthos sampling in Brooklyn Harbour indicated the number of crustaceans at man-made marina sites to be far greater than from the natural sites (WRL, 2003). However, sampling at Sandbrook Inlet suggests anthropogenic influences are more likely to be detrimental.

Sandbrook Inlet contains lower benthic species diversity and abundance and the highest rate of Sydney Rock oyster mortality and shell deformation in the Lower Hawkesbury River. This is said to indicate a highly disturbed environment which may be the result of natural and anthropogenic influences, in particular, maintenance dredging, the railway causeway, and long contaminant residence times in the inlet. Sampling before and after maintenance dredging has showed a loss of benthic fauna, and a varied rate of recolonisation (WRL, 2003).

Berowra Creek is said to contain 55 species of benthic algae (DLWC, 1997), and seven phylum of macrobenthos (namely, Annelida, Crustacea, Echinodermata, Mollusca, Arthropoda, Nemertea and Platyhelminthes) (Chapman and Underwood, 2005).

Benthos in Mangrove Stands

From various mangrove stands along Berowra Creek, the epifauna assemblage included six snail species and over 1,000 individuals of infauna were collected, which were of varying species of snails, bivalve molluscs, and isopods. In both cases (epifauna and infauna) there appeared to be no relationship between the abundance and diversity and the location, with substantial variation between sites (Ecology Lab, 1998).

Mangrove sediments in Kimmerikong Bay contain 29 taxa of macrofauna and 44 taxa of macrofauna were found at Joe's Craft Bay (Chapman and Underwood, 2004).

Sampling in mangrove stands in Brooklyn and Sandbrook Inlet found 26 intertidal species and 475 individuals. Communities in Sandbrook Inlet varied between the eastern and western ends of the inlet (WRL, 2003).

In mangrove sediments in Berowra Creek there were more taxa, more species of amphipods and more species of molluscs in regions without catchment runoff compared with regions with runoff (interestingly, there were no differences in isopod numbers between regions) (Chapman and Underwood, 2004).

Benthos in Sediments

In muddy subtidal sediments of Berowra Creek over 1,800 invertebrates were collected, which were mainly polycheate worms, crustaceans (amphipods, isopods, crabs, shrimp) and molluscs. Deep hole locations differed in abundance from shallow holes and by their location along the creek. The deep holes contained a relatively diverse and abundant fauna overall, suggesting they may provide a refuge for macroinvertebrates (Ecology Lab, 1998).

Shallow (less than 2 m) sandy subtidal sediments between Canla and Marramarra Creek mouths most commonly contained molluscs, polycheate worms and crustacean amphipods. The dominance of a filter feeding bivalve near Calabash Bay was thought to be due to the generally higher phyto- and zoo plankton levels here which would provide food in the form of detritus (Ecology Lab, 1998).

Sampling of intertidal soft sediment organisms at Brooklyn Boat Harbour, Sandbrook Inlet and Mooney Mooney and Mullet Creeks found 51 taxa representing 5 phyla, of which 84% of individuals fell within 6 dominant taxa (WRL, 2003).

Benthos on rocky substratum

Intertidal rocks in the main channel of the Hawkesbury River are moderately to heavily encrusted with oysters and mussels, with scattered limpets, and periwinkles found in higher intertidal areas (WRL, 2003). Fauna of hard substrata were said to be of relatively few individuals and species compared to hard substrata fauna on the open coast, however this was said to be typical of estuarine environments (Ecology Lab, 1998).

Intertidal organisms on rocky substratum in Sandbrook Inlet and Brooklyn Harbour were typical of estuarine habitats, and were dominated by littorinid snails, Sydney Rock Oysters, honeycomb barnacles, small paletid limpits and purple periwinkles (WRL, 2003).

Intertidal communities in mangroves and on rocky shores of Sandbrook Inlet varied between the eastern and western ends of the inlet, and also differed to that of Mooney Mooney and Mullet Creeks. Typically, different taxa rather than lower abundance were found.

2.7.1.3 Fish and Mobile Invertebrates

Within the Hawkesbury-Nepean catchment as a whole there are 164 fish species (DLWC, 1997; WRL, 2003) with 90 species found near Broken Bay, to 15 species in the freshwater upstream reaches (WRL, 2003). During various studies, 31 fish species have been collected from Sandbrook Inlet, 29 from Cowan Creek (WRL, 2003), and 134 aquatic species and 14 species of zooplankton in Berowra Creek (DLWC, 1997). By-catch statistics from prawn trawling in three areas of the Hawkesbury found 75 species of fish, 13 species of crustaceans and 6 mollusc species, and of this, 42 species were economically valuable (WRL, 2003).

The Ecology Lab (1998) collected 29 fish species, 5 mobile crustacean species and 1 mobile mollusc species from Berowra Creek. The diversity and abundance of fish assemblages in seagrass beds were similar to that of such habitats in other estuarine systems. The fish and mobile invertebrate assemblage differed greatly between sites: flat-headed gudgeons, which prefer fresh to brackish waters were found in the upper reaches, where as large numbers of Tamar River gobies, which prefer saline water, inhabited the lower reaches of the creek (Ecology Lab, 1998).

Within the deep holes, 14 species were found, including large-tooth flounder, flat-tail mullet and silver biddy, however, the species types and abundance were found to be similar to that of the shallow creek sections. It was suggested that during floods, deep holes may become refuges for fish species to avoid the physical changes in water associated with rainfall, such as to remain in amply saline water or avoid fast surface currents (Ecology Lab, 1998).

Populations of demersal fish in Sandbrook Inlet and around Brooklyn were similar to that of other estuarine areas of the Lower Hawkesbury, with the most abundant fish group being gobies and the most abundant mobile invertebrate being shrimps (WRL, 2003). It was suggested that this similarity indicates that proximity to urban developments may not be the major/only factor impacting demersal fish and mobile invertebrate populations (WRL, 2003). Instead it is likely that the drowned river valley morphology of the estuary allows unrestricted passage of demersal fauna between the estuary and the ocean, as well as recruitment of juveniles from the ocean to the estuary (WBM, 2006b).

Contrary to findings by WRL (2003), Kimmerikong (2005) found there has been a reduction in Australian Bass populations in polluted areas of the Hawkesbury River estuary, and the typical size of Australian Bass caught in the Hawkesbury estuary (17.5cm long) is small compared to other coastal rivers.

2.7.2 Riparian Habitat

The riparian (meaning river bank) zone comprises that region between the land (terrestrial) habitat and a body of water. The riparian zone may contain wetlands as well as terrestrial plant species such as forest trees. The steep sided foreshores common along the Hawkesbury River limits the width of inter-tidal regions in which estuarine wetland species (particularly mangroves and saltmarsh) inhabit (WBM, 2006b). Thus, riparian vegetation on the foreshores of the Hawkesbury is dominated by tall open forest, and open forest and woodland formations (WBM, 2006b).

Estuarine wetlands are still commonly found throughout the Lower Hawkesbury. The transition from freshwater wetlands to estuarine wetlands occurs just downstream of Wiseman's Ferry. These estuarine wetlands support saltmarsh and mangrove communities backed by *Casuarina* and *Melaleuca* stands, and their size increases downstream. The largest estuarine wetlands are found at the confluence of Mangrove Creek and the Hawkesbury River, and along Marramarra Creek in Big Bay (Kimmerikong, 2005).

Communities of mixed saltmarsh and mangroves are also found in Coba Bay, Peats Bight, Mangrove Creek opposite the junction to Popran Creek and Piles Creek near the junction with Mooney Mooney Creek (ACUN, 2003).

Work has been carried out to restore foreshore vegetation in the upper catchment of McCarr's Creek, the upper catchment of Cowan Creek, the western catchment of Berowra Creek and Iron Bark and Popran Creeks (Kimmerikong, 2005).

2.7.2.1 Saltmarsh

Coastal saltmarsh is listed as an Endangered Ecological Community under the Threatened Species Conservation Act (1995). Significant losses to Saltmarsh communities have principally occurred as a result of clearing, filling and land reclamation and weed invasion (namely *Juncus acutus*). The study by Williams and Thiebaud (2006) calculated that for sites in the Lower Hawkesbury, there had been a 61.6% decrease in saltmarsh (a total loss of 293.5 ha). The extent of decrease in saltmarsh calculated ranged between 3.2 ha lost at Cowan Creek, to 114.5 ha lost in Mangrove Creek (Williams and Thiebaud, 2006). Losses of saltmarsh have also been estimated at 25 to 38% in Berowra Creek, 30% at Couranga Point and 92% in Careel Bay between 1941 and 1994 (ACUN, 2003). Other areas known to contain saltmarsh included isolated stands located around Brooklyn, Long Island (ie on both banks of Sandbrook Inlet), Spectacle Island, and at the heads of Mooney Mooney, Smiths and Cockle Creeks (NPWS, 2002; WBM, 2006b; WRL, 2003). Whilst the extent of saltmarsh across the Lower Hawkesbury Estuary is shown in Figure 2-3 further mapping is required to manage saltmarsh communities. Additional, mapping has been undertaken in 2008 by Smith and Smith and NSW Department of Primary Industries (Fisheries), but was not available at the time of this report production..

Much of this reduction in saltmarsh has been attributed to encroachment by mangroves, as these areas have all experienced similar or greater increases in mangroves (ACUN, 2003; WMA, 2002). However, Williams and Thiebaud (2006) stated there has been a decrease in natural vegetation and subsequent increase in stormwater discharge over recent decades, which may be adversely affecting saltmarsh. It is worth noting that saltmarsh and mangroves in fact occupy a slightly different tidal zone, and encroachment by development and increased sedimentation may potentially be reducing the area of appropriate habitat available to saltmarsh.

There are known to be several saltmarsh areas, namely along the Wiseman's Ferry Road, downstream of Wiseman's Ferry and along the lower reaches of Mangrove Creek, that have been drained and/or cut off by embankments and culverts (Kimmerikong, 2005).

Saltmarsh species in the Lower Hawkesbury variously include: samphire (*Sarcocornia quinqueflora*), rushes (especially *Juncas Krausii*), creeping brookweed (*Samolus repens*), salt couch (*Sporobolus virginicus*), and she-oak (C*asuarina glauca*) (ACUN, 2003; WRL, 2003).

2.7.2.2 Mangroves

Extensive areas of mangroves backed by saltmarsh and melaleuca swamps are found in Marramarra Creek, Coba Bay, Kimmerikong Creek and Calabash Bay all within the Berowra Creek estuary (Chapman and Underwood, 2005); on mudflats at Cowan, Smiths and Cockle Creeks, Porto Bay and the western end of Spectacle Island (NPWS 2002); and along both shores of Sandbrook Inlet, and at Mooney Mooney Point (WRL, 2003). The leaf biomass for common grey mangroves is 40 kg/m^2 in the Hawkesbury, the highest of any record for temperate forest communities (WRL, 2003).

Mangroves may support abundant aquatic life, as discussed in Section 2.7.1.2 above. In particular, the area known as Big Bay in Marramarra Creek is said to support an abundant epifaunal community, and represents a habitat of regional significance (Ecology Lab, 1998; WMA, 2002). The mud flats at Kimmerikong Bay and Big Bay are popular feeding grounds for some protected waterbird species, although Berowra Creek is not considered by NPWS to be of regional or local significance to waterbirds (Ecology Lab, 1998).

There is an estimated 11 km^2 of mangroves in the Hawkesbury River (SJB, 2005; WRL, 2003). The extent of mangrove area is generally observed to have increased over recent decades (Williams and Thiebaud, 2006; WMA, 2002; WRL, 2003). Williams and Thiebaud (2006) calculated a 49% increase in mangrove area between 1940s and 2000s across the eight locations assessed in the Lower Hawkesbury as a whole. This increase in mangroves ranged from 1.4 ha at Cowan Creek to 89.8 ha in the River between Flat Rock Point to just north of Mangrove Creek (Williams and Thiebaud, 2006).

Other authors have also estimated increases in mangroves of 30% each in Berowra Creek and Couranga Point, and 551% in Careel Bay (Pittwater) between 1941 and 1994 (ACUN, 2003).

Williams and Thiebaud (2006) stated the decrease in natural vegetation and subsequent increase in stormwater discharge is likely to have increased sedimentation and thus growth opportunities for mangroves.

Mangrove expansion in some areas (such as near Woolwash in Berowra Creek) is suggested to have been at the expense of some areas of seagrass and/or saltmarsh (WMA, 2002). However, as noted in Berowra Creek, mangrove encroachment is greatest in areas where the saltmarsh surface is subsiding, and the rate of sedimentation, even if high, is not translating into a net elevation increase (ACUN, 2003). That is, the area of available habitat for saltmarsh is decreasing, rather than mangroves invading the zone of saltmarsh.

Construction of the freeway bridge and land reclamation have also encouraged mangrove growth in the last two decades, such as along the western fringe of Spectacle Island and Mooney Mooney Point (both through linear expansion of single trees along the watercourses and trapping of sediment) (WRL, 2003).

Mangrove species in the region are dominantly grey mangroves (*Avicennia marina*) and river mangroves (*Aegiceras corniculatum*) (ACUN, 2003; WRL, 2003). The muddy sands rich in organics, which have tended to accumulate in embayments, forming muddy shores and shallow muddy bays, are a productive habitat for mangrove growth (WMA, 2002).

In Berowra Creek, the mean height of *Avicennia marina* is 10.13m, and of *Aegiceras corniculatum* is 1.82m. The mean density of mangroves in Berowra Creek is 5,489 individuals/ha. At Marramarra Creek the mean height of *Avicennia marina* is 12.81m, with a range of 30cm to greater than 25m, and the mean density is 978 individuals/ha (ACUN, 2003).

2.7.3 Terrestrial Habitat

The Lower Hawkesbury River catchment is heavily forested, containing a high diversity of plants and range of animals distinctive to Hawkesbury Sandstone regions (DLWC, 1997; NPWS, 2002; WRL, 2003). Within the Hornsby Shire, bushland covers approximately 65% of the land area (DLWC, 1997; HSC, 2005; The Middle Way, 2005). In the Ku-ring-gai Chase NP alone there are 24 vegetation communities and over 1,000 plant species, and over 28 native mammals, 160 birds, and close to 20 reptiles have been recorded (NPWS, 2002). Also, 207 bird species have been found within 5km of Brooklyn (WRL, 2003).

Vegetation in Berowra Creek catchment comprises dry sclerophyll forests (woodlands, scrublands, heathlands) typical of Hawkesbury sandstone, with remnants of blue gum high forest, turpentine forest and ironbark forest on the richer soil areas and rainforest remnants within some gullies (WMA, 2002). Similarly, the most extensive vegetation communities in the Brooklyn catchment are tall open forest, open forest, and woodland formations (WRL, 2003).

The broad vegetation communities described below for Ku-ring-gai NP are similar to the above description for the catchment areas, and so are likely to be indicative of the Lower Hawkesbury as a whole (NPWS, 2002):

- Dry heath vegetation, found on shallow sandy soils on the exposed outcrops of Hawkesbury Sandstone (eg along Lambert Peninsula);
- Wet heathland (also known as the 'hanging swamps'), found on rock platforms with poor drainage and where the thin clay soils retain water;
- Low eucalypt woodland, found on the gentler upper slopes and protected ridge tops;
- Open forest dominated by smooth-barked apple and Sydney peppermint, and also containing Red bloodwood and Christmas bush, found on the steeper, lower sandstone hillslopes;
- Taller open forests are found on Narrabeen shales along Pittwater and Cowan Water; and
- Warm temperate rainforest within the deeper protected gullies, (such as in Jerusalem Bay).

Vegetation surveys of Lion Island, Long Island and Spectacle Island indicate these areas support a similar range of vegetation communities as the mainland Ku-ring-gai NP. This diversity is remarkable due to the small size of these locations (NPWS, 2002).

Lion Island is a breeding site for the Little Penguin (300 breeding pairs). Foraging little penguins have also been recorded at West Head and other sites within the Hawkesbury River. Furthermore, sea bird breeding islands are found in the Hawkesbury River region (Breen et al., 2005).

The study by Williams and Thiebaud (2006) determined that overall across the entire Lower Hawkesbury catchment, the amount of natural vegetation cover has decreased by 2.7% (220.2 ha). Interestingly, while vegetative cover has decreased overall in sites in the Lower Hawkesbury, the cover has in fact increased compared to what was present in the 1950s, 1980s, and 1990s (Williams and Thiebaud, 2006). Within the Brooklyn catchment alone over the past 42 years bushland has decreased 13.3%, in spite of the vast majority of the catchment being contained in national parks (Ku-ring-gai Chase and Brisbane Waters NPs) (WBM, 2004, 2006b).

Pressures on native vegetation in the Hawkesbury-Nepean catchment include: urban development and subdivisions causing fragmentation; changes to the natural water balances leading to vegetation modification and habitat modification; and changes in nutrient levels causing modified vegetation (HNCMA, 2005). Further disturbances to vegetation have included introduced plants and animals, fire, fire suppression, hazard reduction works, water pollution from industrial and urban areas, recreational activities, and maintenance associated with transmission lines and services (NPWS, 2002). In areas such as Berowra Creek where water quality is known to be poor, there is little ecology monitoring in spite of the strong link with water quality (WMA, 2002).

2.7.4 Threatened Species and Regional Importance

Within the Berowra Creek catchment there are documented to be 21 species of rare plants and 13 threatened animal species listed on the TSC Act (DLWC, 1997). Berowra Valley Regional Park contains at least 10 fauna species listed on the *National Parks and Wildlife Act 1974* (the NPW Act) as rare or threatened (WMA, 2002). Across the entire Hornsby LGA there are 20 threatened species and 44 vulnerable species as listed on the TSC Act and 11 threatened species and 27 vulnerable species in the Ku-ring-gai LGA (Kimmerikong, 2005).

Ku-ring-gai NP and Lion, Spectacle and Long Island NRs support 14 plant species and 13 animal species and three endangered ecological communities (EECs) as listed on the TSC Act, as well as

24 regionally rare or uncommon species and two endangered populations. Another species listed as endangered that exists in the Hornsby LGA may extend into Ku-ring-gai Chase NP. Lion Island supports the largest population of Little Penguins in the Sydney area (NPWS, 2002).

Five bird species listed as endangered and 15 bird species listed as vulnerable under the TSC Act and three species covered by the migratory provisions of the *Environmental Protection and Biodiversity Conservation 1999* (the EPBC Act) have been recorded around the Lower Hawkesbury Estuary (WRL, 2003).

The EECs found in the parks include Duffys Forest Open Forest, Pittwater Spotted Gum Forest and Sydney Coastal Riverflat Forest. The other important vegetation community types in the parks are: low woodland at the start of Elvina Trail near Lambert Peninsula; diatreme vegetation communities at Campbells and Smiths Craters; dyke vegetation communities, particularly found at West Head; open forest on Wianamatta Shale upstream of Gibberagong Waterholes on Cockle Creek; vegetation communities containing rainforest; and hanging swamps and associated seepage zone vegetation communities (NPWS, 2002).

The Ku-ring-gai Chase NP, and Long, Lion and Spectacle Is NRs are listed on the Register of the National Estate. Ku-ring-gai Chase NP is listed for its scientific importance in preserving remnants of the natural environment of Sydney, and abundant Aboriginal heritage sites. Lion Island is a breeding habitat for shearwaters and little penguins. Long and Spectacle Islands are listed for their particularly diverse and distinctive vegetation (NPWS, 2002).

The Berowra Valley Regional Park has been listed as State significant in the Hornsby Shire Heritage Study (WMA, 2002), while Marramarra NP and Muogamarra NR have been listed as significant to natural heritage in the Heritage Study (WMA, 2002). Other EECs within the catchment include Turpertine Iron Bark Forest, Shale Sandstone Transition Forest, Shale Gravel Transition Forest and one critically endangered EEC Blue Gum High Forest.

2.7.4.1 Swamp Sclerophyll Forest

This endangered ecological community is known to occur in the region. The description below is modified from the Department of Environment and Climate Change Website.

The most widespread and abundant dominant trees include *Eucalyptus robusta* (swamp mahogany), *Melaleuca quinquenervia* (paperbark) and, south from Sydney, *Eucalyptus botryoides* (bangalay) and *Eucalyptus longifolia* (woollybut). Other trees may be scattered throughout at low abundance or may be locally common at few sites, including *Callistemon salignus* (sweet willow bottlebrush), Casuarina glauca (swamp oak) and *Eucalyptus resinifera* subsp. hemilampra (red mahogany), *Livistona australis* (cabbage palm) and *Lophostemon suaveolens* (swamp turpentine).

A layer of small trees may be present, including Acacia irrorata (green wattle), *Acmena smithii* (lilly pilly), *Elaeocarpus reticulatus* (blueberry ash), *Glochidion ferdinandi* (cheese tree), *Melaleuca linariifolia and M. styphelioides* (paperbarks).

Shrubs include *Acacia longifolia*, *Dodonaea triquetra*, *Ficus coronata*, *Leptospermum polygalifolium subsp. polygalifolium* and *Melaleuca spp.*. Occasional vines include *Parsonsia straminea, Morinda jasminoides* and *Stephania japonica var. discolor*.

The groundcover is composed of abundant sedges, ferns, forbs, and grasses including *Gahnia clarkei, Pteridium esculentum, Hypolepis muelleri, Calochlaena dubia, Dianella caerulea, Viola hederacea, Lomandra longifolia, Entolasia marginata* and *Imperata cylindrica*.

On sites downslope of lithic substrates or with soils of clay-loam texture, species such as *Allocasuarina littoralis, Banksia oblongifolia*, *B. spinulosa*, *Ptilothrix deusta* and *Themeda australis*, may also be present in the understorey.

2.7.4.2 Swamp Oak Floodplain Forest

This community is found on the coastal floodplains of NSW. It has is known to occur in the region of the Lower Hawkesbury Estuary. The description below is modified from the Department of Environment and Climate Change Website.

Other trees including *Acmena smithii* (lilly pilly), *Glochidion* spp. (cheese trees) and *Melaleuca* spp. (paperbarks) may be present as subordinate species, and are found most frequently in stands of the community northwards from Gosford. Tree diversity decreases with latitude, and *Melaleuca ericifolia* is the only abundant tree in this community south of Bermagui.

The understorey is characterised by frequent occurrences of vines, *Parsonsia straminea, Geitonoplesium cymosum* and *Stephania japonica* var. *discolor*, a sparse cover of shrubs, and a continuous groundcover of forbs, sedges, grasses and leaf litter.

The composition of the ground stratum varies depending on levels of salinity in the groundwater. Under less saline conditions prominent ground layer plants include forbs such *Centella asiatica, Commelina cyanea, Persicaria decipiens* and *Viola banksii*; graminoids such as *Carex appressa, Gahnia clarkei, Lomandra longifolia, Oplismenus imbecillis*; and the fern *Hypolepis muelleri*.

On the fringes of coastal estuaries, where soils are more saline, the ground layer may include the threatened grass species, *Alexfloydia repens*, as well as *Baumea juncea, Juncus kraussii, Phragmites australis, Selliera radicans* and other saltmarsh species.

2.7.4.3 River Flat Eucalyptus Forest

As the name suggests, this EEC is found on the river flats of the coastal floodplains and is known to occur in the region of the Lower Hawkesbury Estuary.

It has a tall open tree layer of eucalypts, which may exceed 40 m in height, but can be considerably shorter in regrowth stands or under conditions of lower site quality. While the composition of the tree stratum varies considerably, the most widespread and abundant dominant trees include *Eucalyptus tereticornis (forest red gum)*, *E. amplifolia* (cabbage gum), *Angophora floribunda* (rough-barked apple) and *A. subvelutina* (broad-leaved apple). *Eucalyptus baueriana* (blue box), *E. botryoides* (bangalay) and *E. elata* (river peppermint) may be common south from Sydney, *E. ovata* (swamp gum) occurs on the far south coast, *E. saligna* (Sydney blue gum) and *E. grandis* (flooded gum) may occur north of Sydney, while *E. benthamii* is restricted to the Hawkesbury floodplain.

A layer of small trees may be present, including *Melaleuca decora, M. styphelioides* (prickly-leaved teatree), *Backhousia myrtifolia* (grey myrtle), *Melia azaderach* (white cedar), *Casuarina cunninghamiana* (river oak) and *C. glauca* (swamp oak).

Scattered shrubs include *Bursaria spinosa* , *Solanum prinophyllum, Rubus parvifolius, Breynia oblongifolia, Ozothamnus diosmifolius, Hymenanthera dentata, Acacia floribunda* and *Phyllanthus gunnii* .

The groundcover is composed of abundant forbs, scramblers and grasses including *Microlaena stipoides, Dichondra repens, Glycine clandestina, Oplismenus aemulus, Desmodium gunnii, Pratia purpurascens, Entolasia marginata, Oxalis perennans* and *Veronica plebeia* . The composition and structure of the understorey is influenced by grazing and fire history, changes to hydrology and soil salinity and other disturbance, and may have a substantial component of exotic shrubs, grasses, vines and forbs.

The combination of features that distinguish River-Flat Eucalypt Forest on Coastal Floodplains from other endangered communities on the coastal floodplains include: its dominance by either a mixed eucalypt canopy or by a single species of eucalypt belonging to either the genus *Angophora* or the sections *Exsertaria* or *Transversaria* of the genus *Eucalyptus* ; the relatively low abundance or sub-dominance of *Casuarina* and *Melaleuca* species; the relatively low abundance of *Eucalyptus robusta* ; and the prominent groundcover of soft-leaved forbs and grasses.

2.7.5 Pest Species

Weeds are most prevalent along foreshores at various locations in the creeks and the river (NPWS, 2002; WMA, 2002). Weeds are also common in parkland near urbanised areas, high usage areas, and areas of past habitation (NPWS, 2002). Within Berowra catchment, 30-40% of riparian vegetation is suggested to be exotic (DLWC, 1997). Up to 236 exotic plant species are known to occur within the Ku-ring-gai Chase NP alone (NPWS, 2002). Invasion by bitou bush, boneseed and exotic perennial grasses is noted to be a threatening process, which is of significance to a number of threatened species in the Hawkesbury-Nepean Catchment.

The seeds of weed species are sourced from neighbouring bushland and properties, as well as dumped garden refuse. Catchment runoff and flow along the tributaries carries seeds to foreshore areas where they may establish. Weed growth is encouraged by soil disturbance and urban and semi-rural runoff from the catchment which is rich in nutrients and sediments (NPWS, 2002; WMA, 2002).

Introduced animals in the national parks include cats, dogs, foxes, black rats, mice, European honey-bees and rabbits. Introduced animals disturb native vegetation and soils causing increased erosion and potentially damaging threatened plants, affect natural pollination processes, and compete with or prey upon native animals for food. Foxes are noted as having the greatest impact (NPWS, 2002). Additional pest fauna noted in the catchment include goats, pigs and deer (HNCMA, 2005).

The estuarine portion of the Lower Hawkesbury River is noted to contain the aquatic weeds *Caulerpa taxifolia* and *Juncus acutus* (Spiky Rush) (Kimmerikong, 2005; Williams and Thiebaud, 2006). Outbreaks of *C. taxifolia* occurred in Careel Bay (Pittwater) in late 2000 and 2004, and to the north of Observation Point in the Palm Beach area (Kimmerikong, 2005). The total area of *C. taxifolia* in the lower Hawkesbury River estuary has increased from 0.23 ha in February 2002, to 0.27 ha in August 2003 before ballooning to 48.98 ha in March 2004 and finally 59.32 ha by August 2004 (Kimmerikong, 2005).

2.7.6 Further Reading

For further reading regarding the ecology of the estuary, please refer to DLWC (1997), Ecology Lab (1998), Bourges *et al* (1998), WMA (2002), WRL (2003), Williams and Thiebaud (2006), NPWS (2002), HRC (2003), ACUN (2003), NSWFA (2004a), NSWFA (2004b), Chapman and Underwood (2004), Chapman and Underwood (2005), Kimmerikong (2005), NSTOC (2005), WBM (2006b), Breen *et al* (2005), HNCMA (2005) and DPI Fisheries (2006).

In particular:

- Typical species for the vegetation communities in Ku-ring-gai Chase NP are listed in NPWS (2002), p15-16;
- A full list of threatened species is given on p19-20 of NPWS (2002) and a list of the remaining mammals, birds and reptiles in Ku-ring-gai Chase NP is listed on p20;
- A list of all the threatened species in the Hawkesbury-Nepean catchment can be found in Appendix 3 of HNCMA 2005; and
- The main weed species, and areas of greatest impact are listed on p28 of NPWS (2002), and the impact of foxes is discussed in detail on p31.

2.8 Heritage

2.8.1 Aboriginal Heritage

The Lower Hawkesbury area was originally inhabited by the Guringai Group, who occupied the area from Broken Bay to Port Jackson and west to the Lane Cove River (NPWS, 2002). Aboriginal occupation of the Hawkesbury River region is believed to have begun 30,000 years ago, becoming most intense from 4,000 years ago (WRL, 2003). Local Aboriginal groups include the Dharug, Darkinjung Dharawal and Kuringgais (DLWC, 1997) and within Ku-ring-gai Chase NP were the Garrigal people (who occupied the area around Lambert Peninsula), and Terramerragal (in the Turramurra area) (NPWS, 2002).

By 1790, over half of the Guringai population had been killed by smallpox and by the 1840s, nearly all had left Pittwater, as their land was taken over by white settlers (DLWC, 1997; NPWS, 2002). The development of Sydney city has destroyed most of the evidence of Aboriginal heritage. Those sites remaining (particularly where protected in national parks) provide evidence of the way of life of the local Guringai people, which was not recorded at the time of settlement and has been largely lost from metropolitan Sydney due to development.

The remaining sites are important to Aboriginal people as evidence of the traditional way of life and for educating children. The sites are also of interest to the wider community and for improving understanding of Aboriginal culture (NPWS, 2002).

There are likely to be thousands of Aboriginal heritage sites located across the Lower Hawkesbury catchment, with Ku-ring-gai Chase NP alone containing 350 sites (NPWS, 2002), and the Brooklyn Estuary containing some 1,076 Aboriginal sites with 1,316 site features (WRL, 2003). Aboriginal sites include (NPWS, 2002; WRL, 2003):

- Shell middens, found along most foreshores;

- Rock engravings, of which there are 170 within Ku-ring-gai Chase NP alone, and one at Kangaroo Point, a popular recreation spot; and
- Hand stencils, cave paintings, grinding grooves, stone arrangements, burials and occupation sites, such as a shelter at Kangaroo Point.

There are likely to be more as yet unidentified sites. Of those already found, only a small number are actively promoted for public viewing and understanding, although many may be visited due to their proximity to trails and roads (NPWS, 2002; WRL, 2003).

2.8.2 European Heritage

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 landing on Mullet (now Dangar) Island in 1788 (WRL, 2003). The Hawkesbury was opened for settlement in 1794 (WRL, 2003).

By 1810, there were 2,389 settlers in the Hawkesbury district. Development and agriculture in the Hawkesbury-Nepean catchment continued steadily throughout the 19^{th} century, with Windsor, Richmond, Pitt Town, Wilberforce and Castlereagh created in 1810, the settlement at Penrith in 1819 and the first official resident in Brooklyn (George Peat) settled in 1836. Peats Ferry was established in 1844, and the first house on Dangar Island was completed in 1847 (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. The causeway between Brooklyn and Long Island (forming Sandbrook Inlet) was constructed some time in 1880s, and the Hawkesbury railbridge in 1889. This railbridge was replaced in 1946 (WRL, 2003).

Between 1826 and 1836, the Great North Road to the Hunter Valley was built, to connect Sydney with the Hunter 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 NP (NPWS, 2004).

The construction of a road between Peats Ferry and Sydney commenced in the 1840s to link with Pennant Hills Road and to provide a more direct route to Gosford and to Wollombi. This road crossed the river at Peats Ferry (Kangaroo Point), with the completion of the Peats Ferry Bridge in 1945. This bridge is the current river crossing for the Pacific Highway (Kimmerikong, 2005; WRL, 2003).

The Sydney to Newcastle Freeway (F3), including a new bridge adjacent to the Peats Ferry Bridge, was constructed in 1973. The F3 replaced the Pacific Highway as the major transport route between Newcastle and Sydney.

The Upper Nepean water supply scheme was constructed between 1880 and 1935. The Upper Mooney Dam of 4,500ML was completed in 1982, replacing the lower Mooney Dam of 1,000ML. The reticulated city water supply reached Dangar Island in 1971 (WRL, 2003).

Ku-ring-gai Chase NP was created in 1894. It is the second oldest NP in Sydney, the second oldest continuous NP in Australia, and the first park established primarily for nature conservation. The park’s founder (Eccleston Du Faur) was concerned about the destruction of bush by wildflower and timber getters. Long Island and Spectacle Island reserves, which are managed jointly with Ku-ring-gai Chase NP, were dedicated in 1972 (NPWS, 2002).

In the initial days of the colony, the Ku-ring-gai area was mostly used for timber getting and boat building. Soda ash, salt and shell lime were also collected from the area. After 1901, around four quarries were created in Ku-ring-gai Chase NP to extract material for road and building construction. One quarry, which existed part way down Bobbin Head Road (used to construct the first road to Bobbin Head and other sandstone features in the park) has been retained in the park for its historic value (NPWS, 2002).

Brooklyn, Dangar Island, Berowra and other locations in the Lower Hawkesbury have a long history of European settlement. Brooklyn and Dangar Island provided a base for explorations up the river, and Australia's first steamer carried passengers between Brooklyn and Windsor until 1909. Brooklyn is said to have significant heritage value due to its history as a base for oyster farming and fishing, and railway and road constructions (WRL, 2003).

Heritage items within the study area are identified in planning instruments for both Hornsby and Gosford Councils, and a number of items are also on the State Heritage Register. Sites of State heritage significance include the railway tunnels and the 1889 railway bridge piers, pylon and plaque on Long Island, the road remains from the disused Old Peats Ferry Road, as well as a number of post offices, bridges, railway stations, roads, schools, police stations and ferries (Kimmerikong, 2005; WBM, 2006b).

Heritage sites and areas in the Berowra Creek region include: Berowra Waters vehicular cable ferry; Berowra Waters boatshed; Berowra Waters kiosk/teahouse; Berowra Waters toilet block (on eastern shore); a ballast heap at the junction of Berowra and Marramarra Creeks; "Tarcoonie" at Sunny Corner; the remains of George Peat's farmhouse at Peats Bight; and the old road at Peats Bight (WMA, 2002).

Historic sites in Ku-ring-gai Chase NP include: Beechwood cottage, built in 1882, a remnant of early recreational use; early 20th century roads to the recreational area of Bobbin Head; sandstone structures constructed by an unemployed labour scheme in the 1930s; Bobbin Head Inn, a restaurant and dance hall in 1930s; a sandstone sculpted war memorial (shaped like the Egyptian sphinx) constructed in 1920s; military observation posts and defence emplacements constructed around West Head during World War II; the lighthouse, keepers cottage and roadway at Barrenjoey Head, designed by James Barnett, a colonial architect, and the only remaining unpainted SS lighthouse in NSW (NPWS, 2002).

2.8.3 Further Reading

For further reading regarding the Aboriginal and European heritage of the estuary, please refer to DLWC (1997), WMA (2002), WRL (2003), NPWS (2002), Kimmerikong (2005), WBM (2006b) and DPI Fisheries (2006).

In particular, WRL (2003) provide a detailed list of the history of European Settlement of the Hawkesbury region in Table 7.4 p115.

2.9 Human Uses

2.9.1 Oyster Aquaculture

The establishment of commercial oyster cultivation in NSW occurred in the 1870's. In 2004, oyster farms in the Hawkesbury River (particularly Berowra Creek) produced 12% of the NSW rock oyster crop (7211 bags), making the Hawkesbury the second largest oyster production area in NSW (DPI Fisheries, 2006; HRC, 2003; Kimmerikong, 2005; NSWFA, 2004b,c). Oyster production in the Hawkesbury reached its peak in 1969/1970 financial year, of 21,252 bags. The entire NSW industry peak occurred in 1976/77 with an annual production approaching 150,000 bags (DPI Fisheries, 2006).

Immediately prior to the outbreak of *QX* disease, oyster farming production amounted to a value of \$3.66M (SJB, 2005). Sydney Rock Oyster production for the Hawkesbury River (in dozens) was 853,665 in 2000/01, 1,075,995 in 2001/02, 892,730 in 2002/03 and 846,261 in 2003/04 (Kimmerikong, 2005). The historic 10 yr moving average production in the Hawkesbury is 16,798 bags (DPI Fisheries, 2006).

The outbreak of *QX* disease occurred in 2004 causing high mortality rates in Sydney Rock Oysters (DPI Fisheries, 2006; NSWFA, 2004c). The disease is caused by the organism *Marteilia sydneyi* (NSWFA, 2004c).

Currently, oysters harvested in the Hawkesbury are the *QX* resistant strain of Sydney Rock Oyster (*Saccostrea glomerata*) and the triploid Pacific Oyster (*Crassostrea gigas*). The native flat oyster (*Ostrea angasi*) is also an edible species which may be farmed in NSW (DPI Fisheries, 2006).

The current area mapped as priority oyster aquaculture leases is 292.7 ha. The current lease area determined to be phased out is 70.7ha. Historically, the largest extent of area under lease was 447 ha (DPI Fisheries, 2006).

Current oyster harvest areas locations within the Lower Hawkesbury are shown in Figure 2-4 and include:

- The mouth of Mooney Mooney Creek from south of Two Dollar Bay to south of Spectacle Island (WRL, 2003);
- Marramarra Creek, extending from Bar Island in the east to 2.3km upstream to within 1.5km of Big Bay (NSWFA, 2004c);
- Kimmerikong Bay, lying 3 km upstream of the Berowra Creek confluence with the Hawkesbury River (NSWFA, 2004b);
- Coba Bay, Berowra Creek (NSWFA, 2004a);
- North of Little Wobby Beach (WRL, 2003);
- Sandbrook Inlet, with leases midway along the Brooklyn shore, at the eastern end of the inlet and on the southwest edge of Long Island, covering nearly 25% of the Inlet in 2002 (WRL, 2003);
- Outside the breakwater at Parsley Bay (WRL, 2003);

- a small area along the northern shore of Dangar Island (WRL, 2003); and
- In Mullet Creek, with leases extending south from Wondabyne station on both sides, to the largest area of leases at the mouth of the creek (where there is no development) (WRL, 2003).
- Berowra Creek harvest areas may be harvested in winter and summer (NSWFA, 2004a, b) and are important for the last stage of oyster development, with oysters spending the last 3-9 months here for fattening prior to harvesting (DLWC, 1997).
- The Coba Bay, Kimmerikong Bay and Marramarra Creek Harvest Areas have all been classified to be reliably managed as a Conditional Restricted harvest areas, with confidence in the shellfish harvested (NSWFA, 2005a, b, c). Those events (typically rainfall) in which each of the harvest areas will be closed are outlined in their respective management plans (refer NSWFA, 2005a, b, c).

Current management of the oyster industry is directed by the implementation of the NSW Oyster Industry Sustainable Aquaculture Industry Strategy (2007). This document has an overarching vision statement to "…. *achieve the sustainable production of 120,000 bags of premium NSW oyster products for domestic and export markets by 2013*". In summary, the document:

- Identifies those areas within NSW estuaries where oyster aquaculture is a sustainable and priority outcome
- Secures resource access rights for present and future oyster farmers in NSW
- Documents and promotes environmental, social and economic best practice for NSW oyster farming and ensures that the principles of ESD, community expectations and the needs of other user groups are integrated into the management and operation of the NSW oyster industry;
- Formalises industry's commitment to environmental sustainable practices and a duty of care for the environment in which the industry is located;
- Provides a framework for the operation and development of a viable and sustainable NSW oyster aquaculture industry with a clear approval regime and up-front certainty for existing industry participants, new industry entrants, the community and decision makers;
- Identifies the key water quality parameters necessary for sustainable oyster aquaculture and establishes a mechanism to maintain and where possible improve the environmental conditions required for oyster production and;
- Ensures that the water quality requirements for oyster growing are considered in the State's land and water management and strategic planning framework.

2.9.2 Commercial Fishing

Commercial fishing in the Hawkesbury River has the 6th largest estuarine production area and is the 4th largest fishery in NSW (Breen et al., 2005; SJB, 2005). The fishery is estimated to generate an annual catch with a monetary value greater than \$2.5M (SJB, 2005). In 1997/98 the commercial catch weighed approximately 450,000kg (Breen et al., 2005). In the 15 years to 2002, the commercial catch comprised of 66% finfish, 27% crustaceans and 6% molluscs (WRL, 2003).

The largest sector of commercial fishing in the Hawkesbury estuary is the prawn trawl fishery. This involves the harvesting of prawns, squid and fish (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).

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), with no hauling permitted in Sandbrook Inlet or between Croppy Point and the railway bridge (due to juvenile jewfish and heavy boat traffic) (WRL, 2003). Due to restrictions and closures, fishers get access to 44% of the river during weekdays and less than 16% during weekends for trawling (Kimmerikong, 2005).

Brooklyn is a centre for commercial fishing in the Lower Hawkesbury (SJB, 2005). Commercial fishing is permitted in many of the creeks, however, the upper reaches (such along Marramarra Creek) are somewhat inaccessible due to shallow depths (WMA, 2002). Tributary creeks (eg Berowra Creek) provide a nursery, and perhaps breeding, feeding, resting and holding grounds for fish (DLWC, 1997).

The 1997/98 commercial catch from the Hawkesbury River contained 80 - 90 species of fish and invertebrates (Breen et al., 2005). Economically important fish species in the river and estuaries include mullet, bream, whiting, tailor, flounder, leatherjacket, mulloway, and sandy sprat (WRL, 2003). Economically important invertebrate species include eastern king prawns, school prawns, greasyback prawns and king prawns (WRL, 2003).

2.9.3 Agriculture

Agricultural land use in the catchment includes market gardening, orchards, nurseries, poultry production, stud farms and low intensity grazing (DLWC, 1997; WBM, 2006b). Areas of grazing, orchards and vegetable growing exist in the upper reaches of Mooney Mooney Creek (WBM, 2004; WRL, 2003). Small farm enterprises between Glenhaven/Dural and Wiseman's Ferry are responsible for providing about 10% by value of Sydney's agriculture production (The Middle Way, 2005).

The study by Williams and Thiebaud (2006) showed agricultural land to have decreased by 24.5% (192.6 ha) overall in the Lower Hawkesbury. There was a complete removal of agricultural land at Pittwater, becoming more minor in locations in the middle stretch of the river and heading upstream (Williams and Thiebaud, 2006).

2.9.4 Industry

Areas at Somersby, Kariong and Peats Ridge are centres for industrial landuses (WBM, 2004; WRL, 2003). A large proportion of the Piles Creek catchment has been zoned for future industrial development (WRL, 2003), and there is potential for expansion at Somersby and Kariong (WBM, 2006b). Industrial activity is estimated to have increased in the upper reaches of the River over the past decades (Williams and Thiebaud, 2006).

The Mt Ku-ring-gai Industrial Zone in Berowra Catchment has been limited in its growth by sewage management. Currently it is proposed to sewer the zone, which would allow greater light industrial growth. It was suggested that sewering would reduce the area's impact upon surrounding waterways by removing onsite seepage (WMA, 2002).

Figure 2-4 Oyster Harvest Areas in the Lower Hawkesbury River

2.9.5 Recreation

Popular recreation activities in the tributary creeks and main channel of the Hawkesbury include boating, canoeing, recreational fishing, swimming, picnicking, sightseeing, bird watching, camping and bushwalking (DLWC, 1997; WMA, 2002).

Recreational fishing is extremely popular, with NSW Fisheries estimating there to be 150,000 recreational fishing outings in the Hawkesbury River per year. Of this, 82% are from boats and 18% from the shore. An estimated 580,000 fish are retained by fishers per year, and double this are returned to the water. The 10 most commonly caught species are whiting, flathead, bream, leatherjacket, flounder or sole, yellowtail, tailor, catfish, jewfish and trevally. Blue swimmer crabs are the most commonly caught crustaceans, and cockles the most commonly collected mollusc. Within the Brooklyn area, recreational fishing compliance rates are 90-95% for undersized fish, and more than 80% of recreational fishers have current licences (WRL, 2003).

In addition to fishing from boats, there are a variety of locations from which fishing is permitted from the shore, such as along Cowan Creek, McKell Park, Parsley Bay and many other accessible locations, particularly from the various foreshore parks (WRL, 2003).

There are a wealth of national parks and reserves in the Lower Hawkesbury which are used for recreation, including bushwalking, picnicking, scenic viewing, camping, boat launching, jogging and in some areas, cycling and horse riding. The parks' proximity to Sydney, especially Ku-ring-gai Chase and Brisbane Waters, makes them particularly attractive to visitors. The Great Northern Walk passes through Berowra Valley Regional Park and Ku-ring-gai Chase NP on its way from Sydney to Newcastle.

A survey of 1,181 visitors in 307 cars to Ku-ring-gai Chase NP in Easter 1997 found 35% went to West Head Lookout and 35% to Bobbin Head. Picnicking (27%) and barbequing (19%) were the main reasons for visiting Bobbin Head, and sightseeing (31%) and bushwalking (31%) were the main reasons for visiting West Head/Lambert Peninsula. Nearly half (48%) of visitors went walking in the park (NPWS, 2002).

Access to Long Island and Spectacle Island NRs is restricted to scientific, education or research purposes only, and there are no recreational facilities provided at these locations (NPWS, 2002; WRL, 2003).

2.9.6 Tourism

Tourism including recreational boating and fishing, is said to be growing rapidly, with estimated expenditure generated from visitors of approximately $126 M in 1996-97 (SJB, 2005). It is estimated that in the order of 10 million visitors visit the Hawkesbury River system each year, and Ku-ring-gai Chase NP receives about four million visits per year (Kimmerikong, 2005). Tourism activities are typically similar to and include the recreational activities described in Section 2.9.5 above.

For recreational fishing alone, an estimated 43,000 anglers across the Hawkesbury Nepean system spend approximately $3.5-5.2 million, landing 87 tonnes of fish each year. In 1993 there were approximately 40,000 boat licenses issued for use of the Hawkesbury-Nepean (Kimmerikong, 2005).

Brooklyn, particularly Sandbrook Inlet, is the centre for boating, with the largest marina complex in the Lower Hawkesbury (NSWFA, 2004a; SJB, 2005; WRL, 2003). There are at least seven boat hire companies and at least nine charter boat companies operating out of Sandbrook Inlet. Houseboat hire is popular from this location (WRL, 2003). Brooklyn is therefore the launching point for most of the tourist activity in the area (SJB, 2005).

There are 101 commercial hire boats registered and operate in the waterways extending from Akuna Bay to Wiseman's Ferry, including Berowra Creek (NSWFA, 2004a). 42 commercial vessels were registered to Berowra Creek in 1997 (DLWC, 1997).

The population of riverside settlements along Berowra Creek has been estimated to increase from 200 to 700 during holiday periods (NSWFA, 2004a).

2.9.7 Urban Development

2.9.7.1 Riverside Developments

Foreshore (riverside) development of the Lower Hawkesbury Estuary are limited and typically only accessible by boat. The southern and eastern foreshores of Pittwater are the most intensively developed on the Hawkesbury estuary (Kimmerikong, 2005), however, this area is outside of the study area for the EMP. The following is an outline of the locations and populations of riverside villages:

- In the Ku-ring-gai Chase NP, there are riverside settlements at Cottage Point (on Cowan Creek) and in Pittwater at Elvina, Lovetts and Morning Bays, Coaster's Retreat and Great Mackerel Beach;
- Brooklyn covers the entire southern shoreline of Sandbrook Inlet, and extends both sides of the causeway to Brooklyn Harbour and around to Parsley Bay. (The northern shoreline of Sandbrook Inlet comprises Long Island, a nature reserve which is not accessible by the public, and this shore only contains an electricity substation and railway infrastructure) (WRL, 2003). Brooklyn has a population of 677 (SJB, 2005; WRL, 2003);
- On the opposite side of the river from Brooklyn, settlements are found at Little Wobby Beach, Cogra Bay, Mooney Mooney Point, Cheero Point and Dangar Island. The entire foreshore of Dangar Island contains private hillside residences with jetties and moorings, and has a population of 259 (SJB, 2005; WRL, 2003). Mooney Mooney, Cheero Point and Little Wobby Point combined comprise 260 lots (WRL, 2003);
- A small number of developments are also scattered along Mooney Mooney Creek, accompanied by seawalls, wooden jetties, slipways with boatsheds and moorings (WRL, 2003);
- Less than a dozen private residences are found on Mullet Creek, with occasional sandstone seawalls, moorings and jetties, concentrated mainly around Wondabyne Station where there is a wharf. The Main Northern Railway line follows the western foreshore from Cogra Point to just past Wondabyne on artificial rock rubble seawalls (WRL, 2003).
- In the Berowra catchment, the majority of developments are at Berowra Waters, Calabash Bay, Neverfail Bay, Coba Point, between Woolwash and Berowra Ferry, and a small area at the entrance to Marramarra Creek (WMA, 2002). There were a total of 223 riverside allotments, with 169 residences in this Creek catchment in 2002 (WMA, 2002);

- Upstream towards Mangrove Creek, riverside developments can be found at Milson's Passage, Milson Island, Sunny Corner and Bar Point. In 2001 there were an estimated 54 people in the Milson's Passage/National Park settlements, and 10 houses in Sunny Corner (SJB, 2005);
- Along Mangrove Creek, riverside settlements are found at Marlow, Spencer, Wendoree Park, Never Fail Park and Lower Mangrove; and
- Upstream of Mangrove Creek there is development at Laughtondale and Wiseman's Ferry. 257 people are estimated to live at Wiseman's Ferry (SJB, 2005).

The majority of riverside developments use on-site sewage management. Some settlements have reticulated water, for example Berowra Waters, Calabash Bay, and Dangar Island, while the remainder rely on rainwater tanks (NSWFA, 2004a; WMA, 2002; WRL, 2003).

There is no garbage service in Berowra Creek, with Council providing bins at the large marinas, such as Berowra Waters. While there is telephone and electricity available to all other riverside settlements, mains electricity is not available for residences at Coba Point (although there is telephone service) and petrol generators and solar panels are used instead (WMA, 2002).

2.9.7.2 Catchment Development

Mooney Mooney Creek catchment is mostly forested, however, urban centres exist at Mt White, Peats Ridge, Mangrove Mountain, Kariong and Somersby (WRL, 2003).

More that 60% of the population of Hornsby Shire live in the Berowra catchment, in the plateau above the river (DLWC, 1997).

A comparison of aerial photos from the 1940s and 2000s has estimated that the amount of residential land is estimated to have increased by 263.2% (507.2 ha) and of parkland/passive recreation/golf courses by 198.1% (80.7 ha) in the Lower Hawkesbury (Williams and Thiebaud, 2006).

2.9.7.3 Waterway Access and Usage

Public access has in part been limited by the steep topography, which has restricted road building and allowed for large areas of National Park and undeveloped land, and the private ownership of some foreshore land particularly in developed areas (WRL, 2003). The lack of access has placed pressure on the few access sites available. Popular public access points to the waterway include:

- Berowra Waters, with two marinas, a public boat ramp, two public wharves, residents wharves and parking, slipways, pontoons, a vehicular ferry, as well as other amenities such as picnic areas, a tidal swimming pool, kiosks, restaurants, casual parking and amenities. Berowra Waters is the main access route to river settlements on Berowra Creek, as well as being a regionally important tourist and boating centre. There is one road from east and west to this location (WMA, 2002);
- Crosslands is accessible by vehicle, and contains a Youth and Convention Centre, a public reserve and picnic facilities. It receives on average 50 long stay (more than 4 hours) visitors per day (WMA, 2002);
- Casual and visitor moorings exist at Joe Crafts Bay, Deep Bay and Neverfail Bay, and a boat launching ramp on west side of Berowra Creek (WMA, 2002);

- Brooklyn Wharf contains an extensive marina development, with rock walls confining the harbour area, as well as some wooden jetties, moorings, and a public baths enclosure. Brooklyn Wharf (near Flat Rock Point) is also used by the Ferry which travels to Dangar Island and Little Wobby Beach (WRL, 2003);
- Sandbrook Inlet is the hub for boating services and activities, in particular, recreational boat hire (such as house boats), as it has a sheltered location, ready access to the river, access via major road networks, and is close to Brooklyn. There are six marinas in Sandbrook Inlet (Sandbrook Inlet Marina, Wharf St Marina, Brooklyn Marina, Dolphin Boatshed Marina, Fenwicks Marina and Long Island Marina) (WRL, 2003);
- Near Brooklyn there are boat ramps at Parsley Bay, Flat Rock Point, Kangaroo Point and Mooney Mooney Point, and public wharfs at Little Wobby Beach, Mooney Mooney Point, Dangar Island and Kangaroo Point. Kangaroo Point public wharf is heavily used by charter and cruise boats and residents living upstream, and so tends to be avoided by recreational users (WRL, 2003); and
- Boat ramps are also found at Rowland Reserve (Pittwater) and Apple Tree Bay (Cowan Creek) (Kimmerikong, 2005).

Of the private facilities available in the Lower Hawkesbury, there are at least 878 moorings and 600 private berths not including those at Berowra Creek and Pittwater (Taylor and Hincks, 2005). There are 257 moorings and an unknown number of private berths in Berowra Creek (DLWC, 1997). There are approximately 3,600 permanent moorings and 189 private berths in Pittwater (Kimmerikong, 2005).

Of the 290 moorings within Sandbrook Inlet, 100 are private moorings associated with the six marinas in Sandbrook Inlet and one in Brooklyn Harbour. There are a further 320 fixed berths at the seven marinas (in addition to slipways and other typical marina facilities). The ceiling limit for moorings in Sandbrook Inlet and Parsley Bay has been reached.

Potential conflicts between waterway users and oyster lease operators have been noted, particularly in areas of congestion such as Sandbrook Inlet. In addition, water quality impacts from waterway users may also harm oyster harvesting potential (WRL, 2003).

2.9.8 Further Reading

For further reading regarding the human uses of the estuary, please refer to DLWC (1997), DPI Fisheries (2006), HNCMA (2005), Kimmerikong (2005), NSTOC (2005), SJB (2005), Taylor and Hincks (2005), WBM (2004), WBM (2006b), NSWFA (2004a), NSWFA (2004b), NSWFA (2004c), NSWFA (2005a), NSWFA (2005b), NSWFA (2005c), HRC (2003), NPWS (2002), Williams and Thiebaud (2006), WRL (2003), WMA (2002) and Bourges *et al.* (1998).

Details of moorings, berths and cradles in Sandbrook Inlet are provided on p106 and in Table 7.3 of WRL (2003).

2.10 Human Impacts

Population growth of the Lower Hawkesbury area has led to a large demand on land for residential, agricultural, commercial, industrial and recreational uses, and this has placed pressure on natural resources, and degraded water quality and natural ecosystems (DLWC, 1997). In turn, tourism, commercial fishing, oyster growing, boating and recreation may be adversely affected by continuing poor water quality and degraded ecosystems (DLWC, 1997).

Predicted growth for the population of Sydney, including Hornsby, is a 21.9% increase on 1991 levels by 2021 (WRL, 2003). Population growth in the future will place increasing pressure on natural resources to provide social and economic well being. There may be increasing pressure on commercial industries, such as oyster aquaculture and the Lower Hawkesbury Estuary fishery, to provide goods to the growing Sydney population. While topography may continue to limit development in the Lower Hawkesbury, a similar (21.9%) population increase is likely to be experienced in popular tourist locations along the river during holiday periods (WRL, 2003). Increasing population/urbanisation of surrounding areas, and subsequent loss of bushland has also placed increasing pressure on national parks to provide a variety of recreational opportunities (NPWS, 2002).

The environmental health of the lower catchment of the Hawkesbury-Nepean River is reportedly in decline, with increasing frequency of toxic algal blooms, excessive aquatic weed growth, reduced number of native fish, contamination of oyster beds, eroded river banks and siltation (HNCMA, 2005).

The following human activities (including upstream of Wisemans Ferry) have impacted the health of the Lower Hawkesbury River (WBM, 2006b; WRL, 2003):

- Changes to landuse within the catchment have altered runoff quality and volumes and increased the concentrations and types of pollutants entering the estuary;
- Agricultural and urban land uses have resulted in the clearing of terrestrial habitat and the removal/degradation of riparian vegetation;
- Overgrazing, cropping practices and flower and vegetable growing has caused soil loss and erosion, delivering sediment, nutrients and other pollutants (such as pesticides) to the waterway. Gravel roads, dirt tracks, farm tracks and access roads in rural areas may also add to sediment loads in rainfall runoff, and sedimentation of waterways (DLWC, 1997);
- The failure and overflow of onsite sewage systems, STP bypassing, licensed water discharges, boat discharges, boat anitfouling paints and slipway scrapings have all resulted in increased harmful pollutant loading in the estuary (WBM, 2006b);
- Water extraction for irrigation, town water supply and stock and domestic use, and dams (eg Mooney Dam) have reduced flows, natural flow variability and fish passage, particularly in the tributaries of the Lower Hawkesbury (WBM, 2006b; WRL, 2003). Water extraction is viewed as a particular problem in the Hawkesbury River with respect to changing the freshwater extent and flow regimes (HRC, 2003);
- Major civil works such as the causeway at Sandbrook Inlet, the Pacific Highway, the F3, and Main Northern Railway, have altered flow regimes (for tides and freshwater events) and sedimentation or erosion rates (WRL, 2003);

- Dredging, such as in Brooklyn Harbour, which has primarily been for navigation purposes has also resulted in hydrodynamic conditions which exacerbate sedimentation within the dredged channels (WBM, 2006b);
- Extractive industries (past and present) have also caused clearing and modifications to terrestrial habitat and increased pollutant loads in water and air (WRL, 2003);
- Waterway and foreshore recreation activities have resulted in: direct water pollution from vessel effluent and waste production; damage/clearing of foreshore areas for access and facilities; indirect water pollution from runoff from supporting infrastructure; pressure for dredging and associated issues; pressure on fisheries habitats and sustainable fisheries from recreational fishing; and damage/clearing of aquatic plants from the cumulative impacts of mooring and anchors;
- Competition and/or environmental degradation from introduced species, in particular, rabbits, goats, feral honeybees, pigs, deer, predation by feral cats and red foxes, and weed invasion in native habitats, such as aquatic weeds (*Caulerpa taxifolia*) and terrestrial weeds (bitou bush, boneseed, and exotic perennial grasses) (HNCMA, 2005);
- Bush rock removal and removal of dead wood and trees, on terrestrial land and in waterways, have removed burrows, nests and habitat for fauna (HNCMA, 2005); and
- High frequency fires and climate change have modified estuarine ecosystems (HNCMA, 2005).

2.10.1 Climate Change Impacts

The likely impacts of Climate Change for the Hawkesbury Nepean Catchment are outlined in CSIRO (2007). The remaining text in this section is sourced from this document unless otherwise referenced. CSIRO (2007) provides information about climate change and the likely consequences for the Hawkesbury Nepean Catchment and is based on work by the International Panel on Climate Change (IPCC) and work completed by CSIRO. The future Hawkesbury Nepean Catchment is likely to be warmer and drier. This climate is likely to have increased heat waves, extreme winds and fire risk. In addition to these drier average conditions, there is also potential for increases in the frequency and severity of extreme rainfall events. A wide range of possible changes to the climate to 2070 are described. The wide range in projected climate parameters is a result of a broad range of assumptions about future global emissions and differences in the way various climate models represent the climate system.

Risks to the estuary identified associated with the projected climate changes include:

- Reductions in freshwater flows are likely to have a negative impact on aquatic biodiversity and wetland ecosystems;
- More frequent droughts and fires are likely to increase stress on plants and animals;
- Changes to hydrodynamics (e.g. increased tidal inundation resulting from sea level rise and changes to freshwater flows) have the potential to modify condition and extent of estuarine wetlands; and
- Increases to the frequency of high pollutant loads events from extreme rainfall events and increased frequency of bushfires

The latest projected changes to the climate of the Hawkesbury Nepean Catchment are presented in Table 2-1.

Table 2-1 Current and Projected Climate Change in the Hawkesbury Nepean

	Present (1990)	Projected Change	
		2030	**2070**
Temperature			
Average	Richmond 17-19 °C	+0.2-+1.6 °C	+0.7-+4.8 °C
No. Days below 0°C	Sydney 0	Sydney 0	Sydney 0
No. Days above 35°C	Sydney 3	Sydney 4-6	Sydney 4-18
No. Days above 40°C	Sydney 0	Sydney 0-1	Sydney 0-4
Rainfall			
Annual Average	Richmond 801mm	-7-+7%	-20-+20%
Extreme Rainfall (i.e.1 in 40 year 1 day rainfall total)		-3-+12%	-7-+10%
Evaporation		+1-+8%	+2-+24%
No. droughts per decade (based on BOM criteria)	3	2-5	1-9
Extreme winds		-5-+8%	-16-+24%
No. Fire Days (i.e. #days with very high or extreme index)	Richmond 12	Richmond 12-14	Richmond 10-19

The ranges of projected changes to temperature and rainfall are significant and highlight the need for a considered and adaptable approach to the risk of climate change. Strategies for adapting to climate discussed in CSIRO (2007) are more aimed at farming than natural resource management, however, strategies considered relevant to the Lower Hawkesbury Estuary include:

- Opportunistic decision making- being ready to act on short notice to take advantage of weather conditions (this may apply, for example to rehabilitation strategies);
- Linking National Parks and remnant vegetation to support migration of species;
- Improving fresh water use efficiency; and
- Reviewing flood and fire management arrangements.

The Sydney Coastal Councils Group, of which Hornsby Council is a member, have undertaken a project which provides research on regional approaches to managing climate vulnerability in the Sydney Region. Project partners include the Australian Greenhouse Office (AGO) National Climate Change Adaptation Program two CSIRO Divisions (Sustainable Ecosystems, and Marine and Atmospheric Research) and the University of the Sunshine Coast.

The project will benefit stakeholders in the Sydney region through:

- Generating information about the likely impacts of climate change (eg. flooding, coastal erosion and temperature) and feasible adaptation strategies (eg. capital works, education, and planning) in the Sydney region;
- Deepening the understanding of the likely impacts of climate change and resulting adaptation options in the Sydney region through integration of existing models, vulnerability mapping, and an analysis of adaptive capacity;
- Building the capacity of stakeholders in the Sydney region to implement, and monitor the success of, adaptation strategies (eg. for infrastructure, health, and biodiversity);
- Working with stakeholders (eg. SCCG member councils and other stakeholders) to build adaptation strategies into institutional structures and processes (eg. asset management plans, coastal management plans, estuary management plans, floodplain management plans, local environment plans, and regional environmental plans).

2.11 Interactions

The processes interactions tree (Figure 2-5) gives a very simplified summary of the key interactions between the various environmental processes occurring throughout the Lower Hawkesbury Estuary. Descriptions of each linkage are provided below.

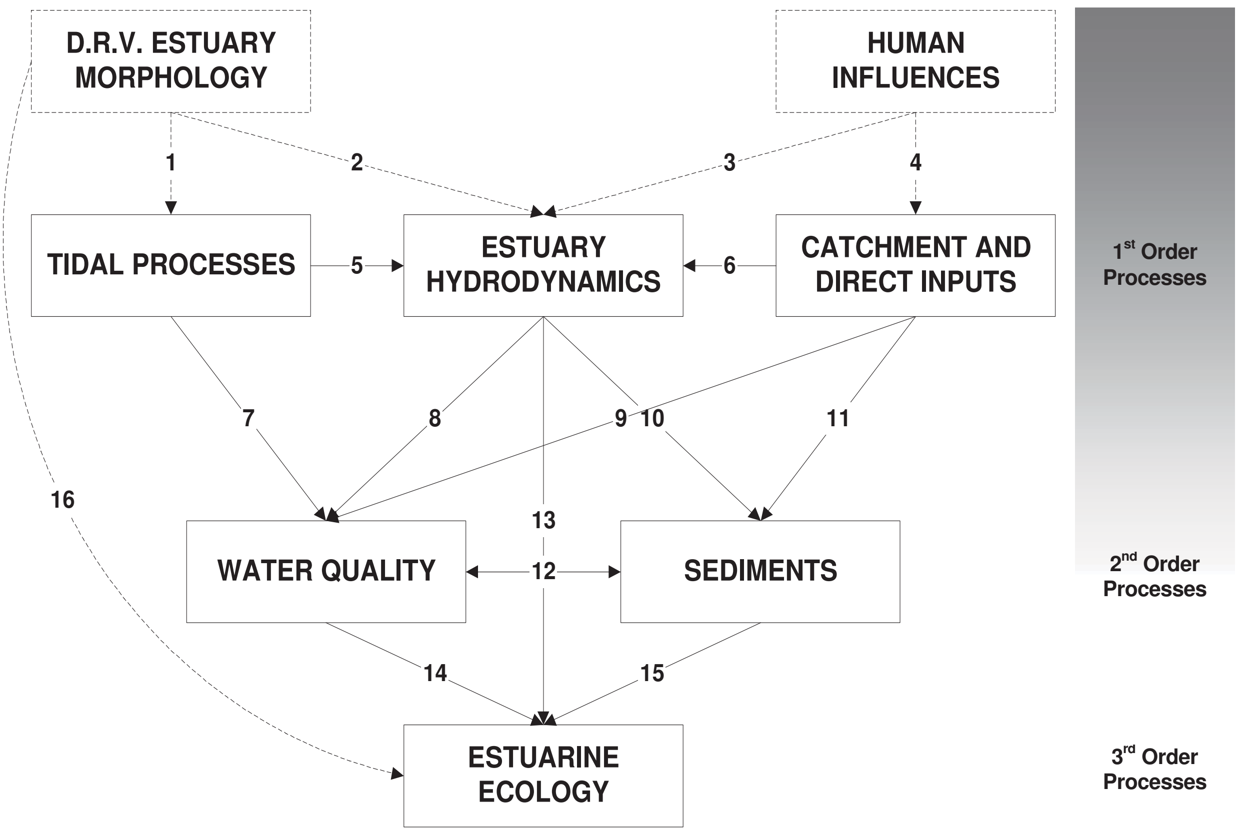


Figure 2-5 Estuary Processes Interaction Tree

In essence, the estuary processes can be considered at a series of different levels (refer Figure 2-5). The highest level (or 1st order) processes are generally unaffected by other natural processes, although they can be affected by human influences and interventions. The middle level (or 2nd order) processes are strongly influenced by the 1st order processes, but can also be affected somewhat by other 2nd order processes. The lowest level (or 3rd order) processes are affected by 1st and 2nd order processes, either directly or indirectly. 3rd order processes generally do not affect 2nd order processes, and similarly, 2nd order processes generally do not affect 1st order processes thus a one-way dominant flow is produced from top to bottom in the Estuary Processes Interactions Tree (refer Figure 2-5).

Link 1. Drowned River Valley (DRV) Estuary Morphology and Tidal Processes

The drowned river valley morphology of the Lower Hawkesbury River means that tides within the Study Area are approximately the same as full oceanic conditions (albeit delayed behind the tides on the coast). Tidal processes in the estuary would be significantly different if the estuary morphology was different, eg a barrier estuary system.

Link 2. Drowned River Valley Estuary Morphology and Estuary Hydrodynamics

The drowned river morphology of the estuary means that most of the Lower Hawkesbury River is a depositionary environment. That is, tidal velocities are slow because the flow conveyance is large. There are also backwater areas within drowned tributary valleys, such as Mooney Mooney Creek and Mangrove Creek.

Link 3. Human Influences and Estuary Hydrodynamics

Human activities can have significant impacts on estuary hydrodynamics. For example, the construction of the railway causeway between Brooklyn and Long Island has greatly impacted estuary hydrodynamics. It has reduced tidal flows to the section of estuary behind Long Island, and is likely to have increased flows within the main river channel during floods (as there is now no passage of flood flows between Long Island and the mainland).

To a lesser extent, dredging may also affect estuary hydrodynamics. Dredging has primarily been for navigation purposes only, and would result in hydrodynamic conditions that tend to exacerbate sedimentation within the actual dredged channels.

Link 4. Human Influences and Catchment & Direct Inputs

Changes to the catchment, along with direct inputs to the estuary, are probably the biggest impact of human activities on estuary processes in the Lower Hawkesbury area. Landuse changes within the catchment have altered runoff volumes, as well as pollutant runoff rates and the types of pollutants now entering the estuary. In addition, water extraction, dams (such as Mooney Mooney Dam) and other structures have modified and regulated catchment inputs, reducing natural environmental flows.

Also, human activities now introduce a range of direct inputs to the estuary, including STP and septic overflows, boat effluent discharges, boat antifouling paints (and other maritime pollutants), and licensed discharges.

Link 5. Tidal Processes and Estuary Hydrodynamics

Tidal processes are the dominant factor driving estuarine hydrodynamics in the study area. Flood events can also influence hydrodynamics, however, the infrequency of floods means that the vast majority of flow through the study area is the result of tides.

The main channel of the Hawkesbury River channel essentially forms a "torrent of tidal flow" when compared to hydrodynamic processes in the remainder of the study area. The side tributary channels receive local inputs, which, depending on the volume of the side tributaries and the volume of the inputs, can be pushed into the main channel 'torrent', which can then quickly remove the inputs from the entire study area.

Link 6. Catchment & Direct Inputs and Estuary Hydrodynamics

During low flow conditions, the catchment has no impact on the hydrodynamic processes of the Lower Hawkesbury estuary. During wet weather conditions that result in relatively high runoff flows from the local catchment, this runoff is quickly advected into the main channel, where it is then flushed away by the dominant tidal flows.

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. During particularly large floods, velocities increase well above typical values experienced under tidal conditions, both within the main river channel and within the side channel tributaries.

Link 7. Tidal Processes and Water Quality

Dominant tidal processes within the main channel and lower tributary reaches means that the water quality entering form the ocean during each flood tide is relatively good, and capable of assimilating most pollutants discharged in these zones. Middle and upper reaches which receive less tidal flushing may experience poorer water quality due to the slower frequency of pollutant removal – see Link 8.

Link 8. Estuary Hydrodynamics and Water Quality

The elongated shape of some sections of the study area (most notably Mooney Mooney Creek, Mullet Creek, Mangrove Creek, Berowra Creek, Cowan Creek and even Sandbrook Inlet) means that waters at the extremities of these sections of the estuary are not as well flushed as the main river channel. Thus, there is significant spatial variation in flushing capacity throughout the study area. This has the potential to generate similar spatial variability in water quality within the study area, as pollutants that are discharged to the more poorly flushed sections would be retained more than those discharged directly to the main river (eg from Peat or Dangar Island).

Link 9. Catchment & 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 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.

Link 10. Estuary Hydrodynamics and Sediments

Bed sediments within the estuary are inextricably 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 requires 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.

More quiescent backwater areas of Mangrove Creek, Mullet Creek and Sandbrook Inlet contain fine bed sediments, while the main river channel contains sandy muds and sands.

Link 11. Catchment & 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 within the general mud basin of the Lower Hawkesbury River (and side tributary valleys).

Rates of sediment accretion within the estuary, both at the alluvial deltas and within the deeper mud basin, 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.

Link 12. Water Quality and Sediments

Within estuaries, nutrients (particularly nitrogen, phosphorus and carbon) can migrate from the water column to the sediments, and from the sediments to the water column. Typically, organics within the water column settle to the bed, where they become buried within the sediments. Anaerobic bacteria within the sediments break down the organic material and remineralise it back into inorganic nutrients. Under certain environmental conditions, some, or all, of these nutrients can then be effluxed back into the water column where they are then converted to organic forms through the uptake by algae.

Some areas of the estuary will provide a net sink for nitrogen, such as around Brooklyn where typical TN concentrations at the upstream end are higher than at the downstream end. However, in some circumstances, this situation may be reversed and the area may be a net source of nitrogen (and other nutrients), such as sediments in Berowra Creek.

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 then 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. This is particularly the case in areas that are poorly flushed and sediments do not have much opportunity to be transported away prior to settlement, such as Sandbrook Inlet.

Link 13. 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, saltmarshes, and various invertebrates.

The drowned river valley morphology of the Lower Hawkesbury River means that slopes adjacent to the waterway are steep, and the actual intertidal area is very narrow. Nonetheless, mangroves have established in the study area, but tend to be concentrated in areas that are less steep, such as in the back water areas of Marramarra Creek at Big Bay.

Link 14. Water Quality and Estuarine Ecology

Water quality is also a factor in the structure of estuarine ecology. As water quality is a variable that 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 (ie eutrophication), such as has occurred in Berowra Creek. 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.

Within the Lower Hawkesbury Estuary, good water quality is essential for the economic viability of the local oyster farming industry. Oysters are filter feeders, and as such, intake pollutants within the water and can transfer those pollutants into their flesh. Areas close to urban development, transportation services and maritime facilities clearly have poorer water quality, which translates to a more depauperate and stressed ecological environment. For example, the level of pollutants in oyster flesh, and the level of oyster shell deformities were greatest at Sandbrook Inlet, an area of high boat usage and urbanisation.

Link 15. Sediments and Estuarine Ecology

The ecology of the bed sediments (ie benthos) can differ depending on the structure of the sediments, ie fine muds benthos is quite 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, such as bivalves.

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.

Link 16: 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 very 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.

3 STRATEGIC FRAMEWORK

3.1 Risk Management Approach

Future management of the Lower Hawkesbury Estuary should focus on the protection of assets in order to achieve long-term goals. Threats to these assets are considered to be 'risks' to the estuary. A risk is considered to be the probability of an event occurring, and the consequential impact of the event upon the asset or value. Under the Australian Standard for Risk Management AS NZS 4360-1999, risks are analysed in terms of their 'likelihood' and their 'consequence'. In the case of the Lower Hawkesbury Estuary, issues that affect the estuary (eg poor water quality), are considered to be risks to the Estuary's assets (eg functional ecosystems).

A risk assessment approach has been used as part of the development of this LHEMP to analyse the likelihood of each risk occurring and the consequences of the risk upon each of the estuary's assets. The risk assessment approach therefore allows a comparative analysis of the risks so that they can be prioritised for future management. This is the first time that such an approach has been used in the development of an Estuary Management Plan under the NSW Government Estuary Management Manual.

3.1.1 Estuary Assets

The Lower Hawkesbury Estuary's assets (values) were established during Focus Group Workshop 1. This workshop involved community participation by members, government agency representatives and local stakeholders. The following list of estuary assets was derived:

- High scenic amenity
- Functional and sustainable ecosystems
- Largely undeveloped surrounding lands
- Recreational opportunities
- Sustainable economic industries
- Culture and heritage
- Water quality to support user demands
- Community character
- Effective governance

The process that was followed in Workshop 1 to derive these assets has been explained in the "Summary Report: Community Workshop 1 for the Lower Hawkesbury Estuary Management Plan" (Daniell, 2007a), attached in Appendix B.

A brief description of each of the estuary assets is given below.

3.1.1.1 High Scenic Amenity

The Lower Hawkesbury Estuary is a *"unique and beautiful estuary of national significance and value"*. Other similar descriptions relating to the estuary's scenic amenity that were offered by the workshop participants included 'serenity', 'uniqueness', 'magnificence', 'steep slopes to water', 'natural beauty', and 'size and expansiveness'.

The summary of estuary processes (refer Chapter 2) provides a detailed discussion of the scenic amenity provided by the Lower Hawkesbury Estuary. Its catchment is heavily forested, providing a natural backdrop to steep, sheer sandstone cliffs and gorges. The drowned river morphology has lead to a steep incised topography with deep waterways, secluded bays and beaches. This topography has served as a barrier to development and exploitation of the land surrounding the waterway, and limited the burgeoning urban sprawl of Sydney. Instead, an estuary of high scenic amenity has been preserved in relatively close proximity to a major metropolitan centre, reminding visitors and residents of the natural beauty once present throughout the region.

3.1.1.2 Functional and Sustainable Ecosystems

Functional and sustainable ecosystems and biodiversity is an asset covering the entire Lower Hawkesbury River and catchment. Such ecosystems support environmental values, as well as economic industries such as oyster farming, commercial fishing, and agriculture, which in turn provide well being and income to local communities. This asset was described in Workshop 1 to encompass 'flora and fauna', 'diversity of environment', 'public health', 'good water quality', 'lifecycle of marine and land functions' and 'natural and other industries'.

3.1.1.3 Largely Undeveloped Surrounding Lands

In Workshop 1, the value of *"largely undeveloped natural catchments and surrounding lands"* was recognised as an estuary asset, and comments made during the workshop included 'extensive national parks', 'protection of biodiversity', 'low level development', 'recreational possibilities' and 'topography/steep slopes'.

The summary of estuary processes (refer Chapter 2) also notes the vast extent of natural vegetation across the Lower Hawkesbury. This has been sustained by the large number of national parks in the catchment. The steep Hawkesbury Sandstone cliffs are difficult and typically unsafe to build upon, and this has also been a major factor in saving the Hawkesbury from development in the past.

The value of the largely undeveloped catchment is in the protection of native terrestrial, riparian and aquatic ecosystems from damage or modification. In turn, the natural vegetation cover delivers lower volumes of catchment runoff, and with fewer pollutants, to the waterway. The naturally vegetated catchment also provides a range of recreational, educational and research opportunities, and supports those economic industries that rely on the wellbeing of the estuary's ecosystems.

3.1.1.4 Recreational Opportunities

"Recreational opportunities" have been recognised as an asset of the Estuary, with comments during Workshop 1 including 'land and water based activities', and 'an escape from the city'. The range of

recreational activities that currently take place in the estuary includes boating, fishing, water-skiing, swimming, bushwalking, picnicking, bird-watching, scenic appreciation, and relaxation.

The Lower Hawkesbury Estuary, with its vast area of natural vegetation, deep waterway with open channels and secluded harbours, and high quality of terrestrial and aquatic habitats, provides a significant recreational asset (that is, this asset is a derivative of other assets, outlined above). In addition to its natural values, the Lower Hawkesbury Estuary is in close proximity to metropolitan Sydney, as well as Gosford and the Central Coast, making it easily accessible to recreational users and tourists.

Further details of tourism and recreational activities and the numbers of users are given in Section 2.9.5.

3.1.1.5 Sustainable Economic Industries

"Sustainable economic industries" was recognised as an asset of the Estuary during Workshop 1. This asset was noted to include 'fish, prawn and oyster industries' and 'tourism and recreation providers', supported by the 'proximity to Sydney markets', and in turn this asset is said to 'provide employment' and 'increase community life quality'.

The Estuary Processes Summary (Chapter 2) outlined a number of economic activities undertaken in the waterway, such as commercial trawling and fishing, oyster farming and tourism as well as agriculture, industry and business in the catchment. Ensuring such economic industries are "sustainable" will support the community of the Estuary, as well as retain the Estuary's natural ecosystems into the future.

3.1.1.6 Culture and Heritage

This asset incorporates the *"culture and heritage"* of the estuary. Workshop 1 attendees noted the following comments in regard to culture and heritage: 'Aboriginal and European heritage', 'traditional industries' and 'local river communities".

There are known to be a large number of significant Aboriginal sites, particularly located in the national parks, as well as sites symbolic to European settlement of the area. Heritage sites are of local, regional and national significance. The history of Aboriginal and European culture and places associated with culture are also contained within the estuary, and this history has helped to shape the culture of the river today.

3.1.1.7 Water Quality to Support User Demands

This asset was defined as *"improving water quality that supports multiple uses"* during Workshop 1. Comments made during Workshop 1 and the significant water quality data presented in the Estuary Processes Summary (Chapter 2) indicates that, regardless of whether water quality should be defined as "good" or "bad", the water quality asset lies in its ability to sustain current and future uses and users.

The water quality of the estuary supports an abundant and diverse estuarine ecosystem, which in turn supports economic industries such as commercial fishing, oyster aquaculture, tourism and recreation. Presently, water quality is measured against a number of different standards, to define its ability to sustain economic industries (such as the guidelines for edible shellfish and fish), recreation and tourism uses (such as the guidelines for recreational contact) and aquatic ecosystems (such as the protection of aquatic ecosystem guidelines).

3.1.1.8 Community Character

The *"community character"* of the Lower Hawkesbury was shown to be a considerable asset during Workshop 1, with comments such as 'active interest and participation in caring for and preserving the estuary', 'diverse estuary users respectful of each other' and 'willingness of many in community to take action and responsibility' used to describe this character.

The community of the estuary is said to comprise: the 'river community', who live on the foreshore and feel a strong sense of connection with their surroundings; the 'catchment community', who live in the catchment, but also feel a sense of belonging and place on the estuary; and the 'user community', who work on the estuary (such as fishers and oyster growers) or recreate on or by the estuary, and who share this sense of belonging or concern. The character of this community is one of concern, education, passion and motivation towards the preservation of the estuary and its assets.

3.1.1.9 Effective Governance, Legal and Media

Following Workshop 1, an additional asset described as "Effective governance" was added to the list. This asset was described as comprising existing governance structures and existing regulations and legislation. For example, inclusion of a large portion of the catchment in National Park is a result of effective governance protecting the estuary.

3.1.2 Risks to Assets

Risks potentially affecting the Lower Hawkesbury Estuary's assets have been determined through consultation and a detailed review of existing background information. Participants of Focus Group Workshop No. 1 were asked to identify factors that they considered to be an issue for the Lower Hawkesbury Estuary. These issues were cross-checked with scientific data, where possible, and supplemented by additional issues as detailed in the summary of estuary processes (refer to Chapter 2).

The following list of risks has been developed, which incorporate all key issues identified through the consultation and information review stages:

- Risk of water quality and sediment quality not meeting relevant environmental and human health standards;
- Risk of climate change;
- Risk of regulated freshwater inflows;
- Risk of inappropriate land management practices;
- Risk of inappropriate or unsustainable development;
- Risk of over-exploiting the estuary's assets;
- Risk of introduced pests, weeds and disease;

- Risk of excessive sedimentation;
- Risk of residents and users lacking passion, awareness and appreciation of the estuary;
- Risk of inappropriate or excessive foreshore access and activities;
- Risk of inappropriate or excessive waterway access and activities;
- Risk of inadequate facilities to support foreshore and waterway access and activities;
- Risk of insufficient research;
- Risk of inadequate monitoring to measure effectiveness of EMP;
- Risk of not meeting EMP objectives within designated timeframes; and
- Risk of inadequate or dysfunctional management mechanisms.

Below, each of these risks has been described in terms of what the risk is, where it applies and where it impacts, and the planning and policy considerations for the risk. In addition, some considerations of the likelihood and consequence of the risk are provided, which helped with the risk assessment carried out during Workshop 2.

3.1.3 Objectives for Managing Risk

In keeping with the risk management approach, the objectives of this Estuary Management Plan are to minimise the identified risks so that they do not have potential detrimental impacts on the assets of the estuary. Targets for the Lower Hawkesbury Estuary Management Plan are related to reductions in the identified risks. Based on the “three tiered” principle of “Intolerable”, “Tolerable” and “Acceptable” risks, the primary target is to reduce all intolerable risks to a “Tolerable” level. The secondary target is then to reduce the risks to an “Acceptable” level.

3.2 Management Principles

3.2.1 NSW Coastal Policy 1997

The NSW Coastal Policy is the State Government’s response to the challenge of achieving a sustainable future for the NSW coastline while balancing environmental, economic, cultural and recreational needs. The policy is based on two fundamental principles: ecologically sustainable development (refer Section 3.2.1.1), and integrated coastal zone management (refer Section 3.2.1.2).

The NSW Coastal Policy 1997 applies to urban and non-urban areas along the NSW Coast, covering land:

- Three nautical miles seaward of the mainland and offshore islands;
- One kilometre landward of the open coast high water mark; and
- One kilometre around all bays and estuaries.

As such, the Lower Hawkesbury Estuary and its foreshores fall within the jurisdiction of the Coastal Policy.

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. DECC 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:

- To protect, rehabilitate and improve the natural environment;
- To recognise and accommodate natural processes and climate change;
- To protect and enhance the aesthetic qualities;
- To protect and conserve cultural heritage;
- To promote Ecologically Sustainable Development;
- To provide for ecologically sustainable human settlement;
- To provide for appropriate public access and use;
- To provide information to enable effective management; and
- To provide for integrated planning and management.

With regard to the Lower Hawkesbury EMP the Policy specifically recommends that detailed management plans for estuaries be prepared and implemented in accordance with the NSW Government's Estuary Management Manual.

3.2.1.1 Ecologically Sustainable Development

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

- *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.
- *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.
- *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.
- *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.

As the NSW Coastal Policy 1997 applies to the Lower Hawkesbury Estuary, the above principles of ecologically sustainable development should be reflected in all planning and management decisions.

3.2.1.2 Integrated Coastal Zone Management

NRMMC (2003) states that "the fundamental goal of Integrated Coastal Zone Management (ICZM) in Australia is to maintain, restore or improve the quality of coastal ecosystems and societies they support. A defining feature of ICZM is that it seeks to address both development and conservation needs within a geographically specific place – a single community, estuary or nation – and within a specified timeframe."

In essence, ICZM is a subset of ESD that relates specifically to the coastal zone. Within Australia, Coastal Zone Management needs to consider key drivers influencing the sustainable use of the coastal zone, including population growth and demographic shifts; industry trends; protection of the coastal resource base; and climate change (NRMMC, 2003).

3.2.2 Healthy Rivers Commission Reports

In 2004 the Healthy River Commission (HRC) was discontinued and the Natural Resources Commission (NRC) was established. Government has asked the Natural Resources Commission to consider the incorporation of any outstanding Healthy River Commission recommendations into Catchment Action Plans and Government programs.

3.2.2.1 HRC Review of the Relationship between Healthy Oysters and Healthy Rivers

The Healthy Rivers Commission Report on the relationship between Healthy Oysters and Healthy Rivers recognises the social and economic importance of the oyster industry. The review also recognises the role of oysters as critical indicators of river health.

A key finding of the report that is relevant to the Lower Hawkesbury Estuary Management Plan is that there was at that time, no explicit link between the aquaculture industry development plans and other land and water planning and management in NSW.

The Report contains five recommendations that the Commission considers are essential to the maintenance of healthy oyster growing catchments. These recommendations relate to all waterways where oyster cultivation for human consumption occurs or might be expected to occur in the future.

The recommendations involve:

- Determination of locations where oyster growing is a priority intended outcome and formalisation of these areas via inclusion in a statutory instrument;
- For areas where oyster growing is a priority intended outcome:
    - Directing of regional and local planning processes to achieve this outcome; (NB: this includes Estuary Management Plans)
    - Internalisation of the costs of new development to achieve this outcome;
    - Equitable cost sharing arrangements for existing land and water uses to achieve this outcome; and
- Government interaction with the oyster industry to ensure greater viability of the industry.

Many of these recommendations have since been met through the adoption of the Sustainable Oyster Strategy.

In relation to the development of the Lower Hawkesbury Estuary Management Plan, the report notes that measures to safeguard river health to allow for oyster cultivation for human consumption will also provide river health for aquatic ecosystem protection and primary contact recreation, both typical objectives for estuarine waters.

3.2.2.2 HRC Independent Inquiry into the Hawkesbury Nepean River System

Between 1997 and 1999, the NSW Healthy Rivers Commission conducted a public inquiry into the health of the Hawkesbury Nepean River system. The inquiry found that, while many parts of the system are in good health, smaller parts of the river system are in relatively poor condition. This includes streams in and below major urban centres (such as Hornsby and Penrith), and the Hawkesbury River from Windsor to Sackville.

The report focuses on management of the whole river system and identifies key actions to achieve a healthier river. Of interest to the current studies are the recommendations for certain river wide issues. For example the issue of boating wastewater discharge is discussed.

A key recommendation of the Healthy River Commission Inquiry is the need for a system-based view of the catchment in river management. This level of management is expected to be established through the Hawkesbury Nepean Catchment Management Authority.

On 29 February 2000, the New South Wales Government made decisions in respect of the Commission's findings and recommendations in those Reports. In its decision, the Government endorsed many of the recommendations of the Commission and in other instances determined an alternative strategy for addressing the Commission's findings. A Statement of Joint Intent (SOJI) to record the commitments of State agencies and relevant Councils and to implement the endorsed recommendations of the Commission was developed.

3.2.2.3 HRC Securing Healthy Coastal Rivers: A Strategic Perspective

Through the Healthy Rivers Commission Inquiries for individual River systems, a number of generic issues and resulting management challenges were found to be relevant for all Coastal Rivers. In summary, the common principles, that could be applied to the Lower Hawkesbury are:

- Rivers must be managed as whole systems;
- Rivers must be treated as assets with productive values to be sustained by carefully directed management and maintenance. Decisions about these must be governed by realistic assessments of their capabilities and recognition of their limitations;
- Management Plans must be more rigorous, more directive, and create obligations on the entities that possess powers and resources that can be applied to river management;
- Entities with river management responsibilities powers and resources must be accountable and answerable for the condition of rivers at the conclusion of each cycle of planning, action and assessment. The accountable entity must be answerable for the proper implementation of

agreed management processes, where actual river outcomes are subject to a variety of uncontrollable external outcomes.

- Government and communities must meet their obligations within explicit partnership arrangements for river management, based on unambiguous statements of their respective roles and responsibilities.
- Well-designed strategies for managing rivers will inevitably involve an adaptive approach, given the inherent uncertainties and lack of information on many matters.

3.3 Guidelines for Estuary Asset Protection

A number of policy recommendations regarding the estuary are contained in the available documentation. Where this advice is supported by the findings of the LHEMP, the recommendations have been summarised into the *Guidelines for Estuary Asset Protection* (as presented in Appendix D of this document). Future Council and regional policy documents and decisions regarding the estuary should include consideration of these recommendations.

In recognition that environmental consequences result principally from anthropogenic activities undertaken within the vicinity of the Lower Hawkesbury River the *Guidelines for Estuary Asset Protection* (Appendix D) should be incorporated and considered accordingly within planning instrumentation, during the development assessment process and during the operation and maintenance of foreshore infrastructure. It is anticipated that with adoption of the *Guidelines for Estuary Asset Protection* (Appendix D) and implementation of actions within this management plan, risks to estuary assets will be mitigated and reduced to levels considered acceptable by the community.

Best Practice standards for the estuary are consolidated from the documents listed below. Further information can be obtained from these documents which in many instances offer guidance on the implementation of Best Practice Standards:

- "Habitat Protection Plan No.3- The Hawkesbury- Nepean River System." September 1998, NSW DPI Fisheries;
- "Environmental Action for Marinas, Boatsheds and Slipways". June 2007, Department of Environment and Climate Change;
- "Coastal Management Manual, Volume-1" 2007 in press. Department of Environment and Climate Change;
- "NSW Oyster Industry- Sustainable Aquaculture Strategy" 2006, NSW Government; and
- "Hornsby Shire Council- Rivers Settlements and Foreshores Review" 2008, Hornsby Shire Council.

To ensure the *Guidelines for Estuary Asset Protection* (Appendix D) are implemented within the Lower Hawkesbury the following criteria is to be used when assessing activities or future proposals to be undertaken (DECC, 2007) by consent authorities and managers of foreshore infrastructure:

- Sustainability: the option is consistent with the principles of ecologically sustainable development and other relevant principles referred to in the NSW Coastal Policy 1997;
- Consistency with goals: the option promotes achievement of reducing risks to estuary assets;

- Likely impacts: the social economic and environmental benefits and impacts are acceptable to state, council and the community;
- Planning framework: the option is consistent with relevant policies and plans at the state, regional, catchment and local levels;
- Public domain: the option protects or enhances the public domain, particularly the public's right to access, use and enjoy foreshore reserves, beaches and waterways;
- Cultural: the option respects and promotes the cultural, social or spiritual value of the coastal environment;
- Acceptable risk: the level of risk to life, property and the environment is acceptable;
- Cost-Benefit: the cost-benefit of the option is positive, and superior to alternate options;
- Financial: the option can be adequately financed, both initially and in the long term;
- Legal & regulatory: the option is compatible with legal and regulatory constraints, including land tenure issues and approvals by Commonwealth and State Agencies;
- Community support: the community understands and supports the option.

4 MANAGEMENT STRATEGY

The Management strategy developed provides stakeholders and communities with a strategic direction for preparing, implementing and reviewing the Lower Hawkesbury Estuary Management Plan. The strategy adopts a whole of government approach that addresses principal risks to estuarine assets, reflects community values, integrates with planning initiatives and has regard to estuarine and catchment processes.

4.1 Assessment of Management Strategies

A comprehensive list of more than 800 strategies was developed through the community and stakeholder consultation, review of existing management plans and by the study team. Many of these strategies were similar, while some were impractical to implement. The list of strategies was subsequently able to be condensed to 148 distinct strategies.

A risk assessment methodology was used to distil this shortened list down to about 30 high priority strategies that can then be the focus of a well targeted and effective management plan. These 30 strategies are referred to as the short listed strategies.

4.1.1 Overview of Risk Assessment Methodology

A risk management approach was used as a basis for determining prioritisation of the different strategies. Essentially, the process involved assessing the degree to which each strategy reduced 1) the likelihood of occurrence and 2) the severity of the consequences, of each of the 16 risks. Each of the strategies was primarily assigned to one risk, being the risk that the particular strategy primarily met. The contribution of the strategy to other (secondary) risks was also considered as part of the risk assessment.

4.1.2 Detailed Description of Risk Assessment Methodology

During the second workshop, each risk was assessed against the individual estuary assets. That is, a judgement was made regarding the likelihood and consequence of each risk affecting each asset. The judgement was based on information provided to the workshop participants as presented in Table 4-1 and Table 4-2 (prepared by Ms Katherine Daniell, ANU PhD student).

Table 4-1 Likelihood Scale (source: K. Daniell)

	Likelihood Level Description				
	Rare	**Unlikely**	**Possible**	**Likely**	**Almost certain**
	1	**2**	**3**	**4**	**5**
Likelihood of risk **impacts** occurring	Occurs only in exceptional circumstances	Could occur but not expected	Could occur	Will probably occur in most circumstances	Is expected to occur in most circumstances

Table 4-2 Consequence Scale (source: K. Daniell)

Asset Category	*Consequence Level Description*				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
	1	**2**	**3**	**4**	**5**
Scenic amenity and national significance	Little to no impact, or short term (reversible) impacts, on scenic amenity Impacts have little to no community significance	Minor or medium-term impacts on scenic amenity (some reversible) Impacts have low community significance for the region and nation	Moderate or long-term impacts on scenic amenity (mostly irreversible) Impacts have some community significance for the region but little nationally	Major and permanent long-term impacts on scenic amenity Impacts have high community significance for the region and some nationally	Extreme and permanent long-term impacts on scenic amenity Impacts have high regional and national community significance
Functional and sustainable ecosystems	Little to no discernable effects on aquatic and/or terrestrial ecosystems or impact is so small to be considered trivial.	Aquatic and/or terrestrial ecosystem health temporarily compromised over a localised area. Possible minor changes in species abundance and community structure but these could be mistaken for being due to seasonal changes or natural variation. Recovery would likely occur within a short time frame.	Aquatic and/or terrestrial ecosystem health compromised in a localised area for a long time period OR temporarily over a wider area. May result in significant changes in native species abundance and community structure and/or major habitat loss and/or triggering of algal/nuisance species growth. Recovery may take several years.	Aquatic and/or terrestrial ecosystem health compromised over a wide area for a moderate term. May result in major changes in native species abundance and community structure and/or major habitat loss and/or triggering of algal/nuisance species growth. Recovery may take many years.	Aquatic and/or terrestrial ecosystem health severely compromised over a wide area and for a long term. May result in extensive losses of organisms and habitat with the potential for whole ecosystem destruction. Recovery may occur in the very long term or not at all.
Largely undeveloped natural catchments and surrounding lands	Little to no impact of development, or short term (reversible) impacts, on land-use patterns The quality and quantity of runoff remains unchanged (relative to normal variability patterns)	Minor or medium-term impacts of development on land-use patterns (some reversible) Possible minor changes to runoff quality and/or quantity outside normal variability	Moderate or long-term impacts of development on land-use patterns (mostly irreversible) Significant changes to runoff quality and/or quantity outside normal variability	Major and permanent long-term impacts of development on land-use patterns Major changes to runoff quality and/or quantity outside normal variability	Extreme and permanent long-term impacts of development on land-use patterns Extreme changes to runoff quality and/or quantity outside normal variability
Recreational opportunities	Little or no impact on recreational opportunities	Minor or medium-term impacts on some recreational opportunities, most activities remain unaffected	Moderate or long-term impacts on some recreational opportunities and/or minor impacts on most activities	Major and permanent long-term impacts on some recreational opportunities and/or moderate impacts on most activities	Severe and permanent damage to a large number of recreational opportunities
Sustainable economic industries	Little or no impact on resources, industries and activities of economic significance	Minor impacts on some resources, industries and activities of economic significance. Possible short-term losses of employment and/or financial hardship.	Moderate or long-term impacts on some resources, industries and activities of regional economic significance. Loss of employment and/or sustained financial hardship in some industries	Major impacts on some resources, industries and activities of regional AND national economic significance. Widespread employment losses and/or high industry financial	Severe and permanent impacts on some resources, industries and activities of high national economic significance. Widespread employment losses and/or

Asset Category	*Consequence Level Description*				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
	1	**2**	**3**	**4**	**5**
			(potentially recoverable in the medium term).	losses (potentially recoverable in the long term).	extreme financial losses (not recoverable in the long term) and/or total collapse of some industries.
Culture and heritage	Little or no impact on areas or items of cultural significance and traditional ways of life	Minor permanent impacts to some areas or items of local cultural significance and/or minor unwanted impacts on traditional ways of life	Permanent damage to some areas or items of local cultural significance and/or moderate unwanted impacts on traditional ways of life	Permanent damage to areas or items of local AND national cultural significance and/or major unwanted impacts on traditional ways of life	Widespread permanent damage to areas or items of national cultural significance and/or total decimation of traditional ways of life
Improving water quality that supports multiple uses	Insignificant impact on water quality and flora, fauna and habitat Insignificant impacts on optical properties, temperature, dissolved oxygen, nutrient levels and salinity outside of natural variability. Presence of toxins and undesirable species (heavy metals, pesticides, bacteria, algae etc.) do not exceed water quality guidelines (i.e. ANZECC, WHO) anywhere in the estuary	Minor localised effects on water quality but without long-term impacts on aquatic ecosystems. Minor localised impacts on optical properties, temperature, dissolved oxygen, nutrient levels and salinity outside of natural variability. Presence of toxins and undesirable species (heavy metals, pesticides, bacteria, algae etc.) exceed water quality guidelines (i.e. ANZECC, WHO) in a few areas (such as at discharge points) but does not limit most estuary uses (fishing, oyster farming, recreation) in other areas	Significant localised effects but without longer-term impact on aquatic ecosystems, and short-term and localised effects on water quality that impacts some estuarine uses. Significant localised impacts on optical properties, temperature, dissolved oxygen, nutrient levels and salinity outside of natural variability. Presence of toxins and undesirable species (heavy metals, pesticides, bacteria, algae etc.) exceed water quality guidelines (i.e. ANZECC, WHO) in a few areas that have short-term impacts on some estuary uses (fishing, oyster farming, recreation)	Damage to a moderate portion of the aquatic ecosystem resulting in moderate impacts on aquatic populations and habitats and long-term impact on water quality that impacts some estuarine uses. Significant widespread impacts on optical properties, temperature, dissolved oxygen, nutrient levels and salinity outside of natural variability. Presence of toxins and undesirable species (heavy metals, pesticides, bacteria, algae etc.) exceed water quality guidelines (i.e. ANZECC, WHO) in most of the estuary that have major impacts and/or long-term effects on some estuary uses (fishing, oyster farming, recreation)	Damage to an extensive portion of aquatic ecosystem resulting in severe impacts on aquatic populations and habitats and long-term impacts on water quality and most estuarine uses. Extreme widespread impacts on optical properties, temperature, dissolved oxygen, nutrient levels and salinity outside of natural variability. Presence of toxins and undesirable species (heavy metals, pesticides, bacteria, algae etc.) exceed water quality guidelines (i.e. ANZECC, WHO) in most of the estuary that have devastating long-term impacts on some estuary uses (fishing, oyster farming, recreation)
Community value	Little to no impact on local communities and their well-being, heath, social equity, access to services and participation levels (in local activities,	Minor long-term and/or moderate short-term impacts (mostly repairable) on local communities and their well-being, health, social equity, access to	Significant long-term and/or major short-term (mostly repairable) impacts on local communities and their well-being, health, social equity, access to	Major long-term and/or devastating short-term (some repairable) impacts on local communities and their well-being, health, social	Extreme and widespread devastating long-term impacts on all local communities and their well-being, health, social equity, access to

Asset Category	Consequence Level Description				
	Insignificant	Minor	Moderate	Major	Catastrophic
	1	2	3	4	5
	governance processes etc.)	services and participation levels (in local activities, governance processes etc.)	services and participation levels (in local activities, governance processes etc.)	equity, access to services and participation levels (in local activities, governance processes etc.)	services and participation levels (in local activities, governance processes etc.)
Governance, legal and media	Little or no impact on existing governance structures Low-level legal and regulatory issues Public concern limited to local complaints	Minor impacts on existing governance structures (minor changes required for improvement and/or small disagreements between governing agencies) Minor legal issues, non-compliances and breaches of regulations Minor, adverse local public or media attention and complaints	Moderate impacts on existing governance structures (significant changes required and/or disagreement between governing agencies) Serious breaches of regulations with possible investigation, report to authority with prosecution and/or moderate fine possible Significant adverse local public and media attention. Possible limited criticism from outside groups (NGOs, national media)	Major impacts on existing governance structures (major changes required and/or major disputes between governing agencies) Major breaches of regulations. Major litigation likely Significant adverse national media, public and NGO attention	Extreme impacts on existing governance structures (total breakdown of existing structures and/or irreconcilable disputes between governing agencies) Significant prosecution and fines. Very serious litigation including class action Serious international public and media outcry

The uncertainty and management effectiveness numbers were judged based on the key descriptors as described in Table 4-3.

Table 4-3 Uncertainty and Management Effectiveness Descriptors (source: K. Daniell)

Score	1	2	3	4	5
Uncertainty	Perception only	Perception and limited information	Limited information and limited expert knowledge	Information and limited process understanding	Information and process understanding
Management Effectiveness	Unsatisfactory	Poor	Satisfactory	Good	Excellent

For each risk, scores (or values) between 1 and 5 were assigned for the consequence, likelihood, uncertainty and management effectiveness, for each asset. An example (Risk #1) is shown in Figure 4-1, while the complete detail for all risks is provided in Appendix E.

Risk Name	Asset Category	Consequence	Likelihood	Uncertainty	Management effectiveness
Inappropriate or unsustainable development	Scenic amenity and national significance	4	3	4	4
	Functional & sustainable ecosystems	4	3	4	4
	Largely undeveloped surrounding lands	4	3	4	4
	Recreational opportunities	4	2	4	3
	Sustainable economic industries	3	2	4	4
	Culture and heritage	4	2	4	3
	Water quality for multiple uses	3	3	4	3
	Community value	4	2	4	3
	Governance, legal and media*	4	2	4	4
	Averaged value	3.78	2.44	4	3.56

Figure 4-1 Example Risk (Risk #1) Assessment Outcome from Workshop #2

The values for consequence, likelihood, uncertainty and management effectiveness were averaged across all assets with no weighting provided on any particular assets. Averaged values for uncertainty and management effectiveness were used as 'factors' for adjusting the consequence and likelihood averaged values. For 'uncertainty', an average value greater than 3.0 would increase the risk consequence and likelihood values (as there is less certainty about the impacts of the risk), whereas a value less than 3.0 would reduce the risk values, in accordance with the relationship shown in Figure 4-2a. For 'management effectiveness', an average value greater than 3.0 would reduce the risk values (as measures are already in place), whereas a value less than 3.0 would increase the risk values in accordance with the relationship shown in Figure 4-2b.

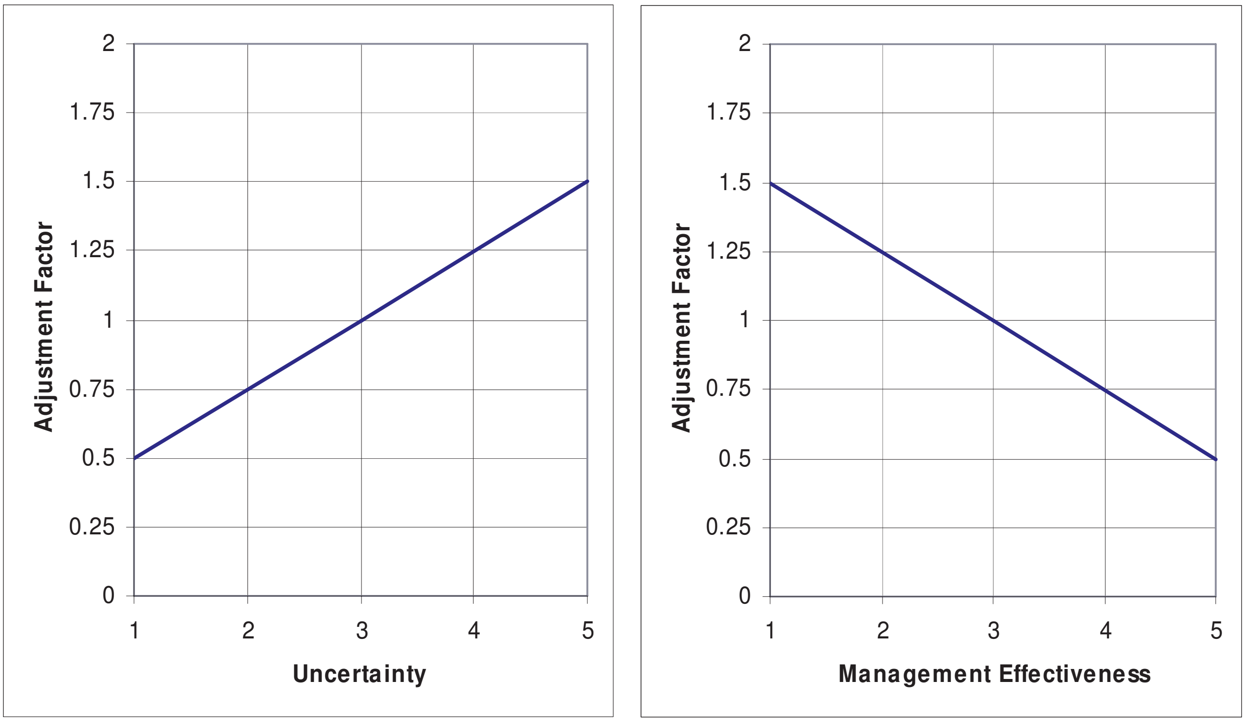


Figure 4-2 Risk Adjustment Factor for (a) Uncertainty – left; and (b) Mgt effect. - right

The adjusted risk values were therefore defined as:

- Adj. risk consequence value = workshop averaged value * uncertainty factor * mgt effect. factor
- Adj. risk likelihood value = workshop averaged value * uncertainty factor * mgt effect. Factor

For the example shown (Risk #1) above:

- Average uncertainty value = 4.0; therefore uncertainty factor = 1.25
- Average management effectiveness value = 3.56; therefore management effect. factor = 0.86
- Adjusted risk consequence value = 3.78 * 1.25 * 0.86 = 4.07
- Adjusted risk likelihood value = 2.44 * 1.25 * 0.86 = 2.63

The adjusted risk consequence and risk likelihood was then plotted on a two-dimensional chart (similar to the two-dimensional matrix adopted in the Australian Risk Standard). The relativity between risk consequence and likelihood defines the severity of the risk. For risks that have a high likelihood and a high consequence, the risk is considered 'intolerable'. For risks that have both low consequence and likelihood, the risk is considered 'acceptable'. A third category of risk, 'tolerable', lies in between these two extremes. The definition of these categories has been based on professional judgement, and is presented in Figure 4-4 The location of the lines, which separate the 'acceptable', 'tolerable' and 'intolerable' categories can also be represented in the form of a traditional risk matrix as shown in Figure 4-3 .

The thresholds between acceptable and tolerable and intolerable levels of risk are purposely asymmetric within the risk chart (Figure 4-4), as risk is considered to be increasingly intolerable with increased consequence. That is, a catastrophic consequence (level 5) is considered to still be intolerable regardless of how unlikely its occurrence may be.

For the above example, when the adjusted risk consequence and likelihood is plotted, the 'risk of inappropriate or unsustainable development' is defined as an 'intolerable' risk (Figure 4-4). The same process has been followed for all risks, the results of which are presented in Appendix E.

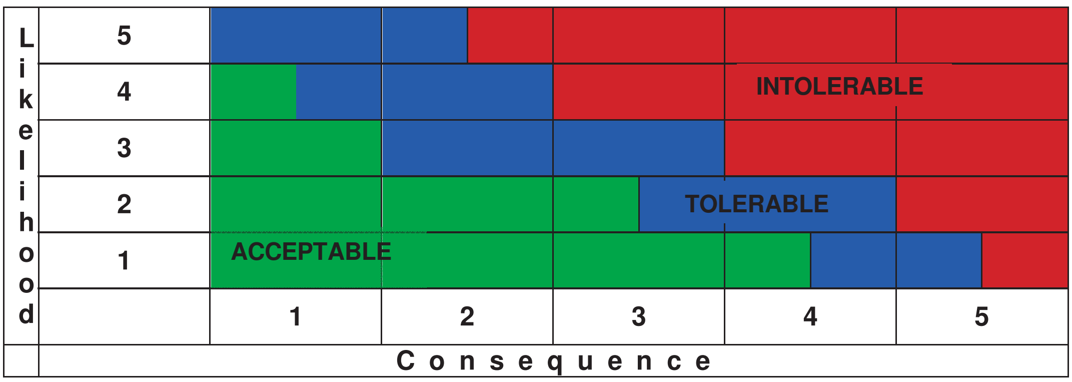


Figure 4-3 Risk Level Matrix

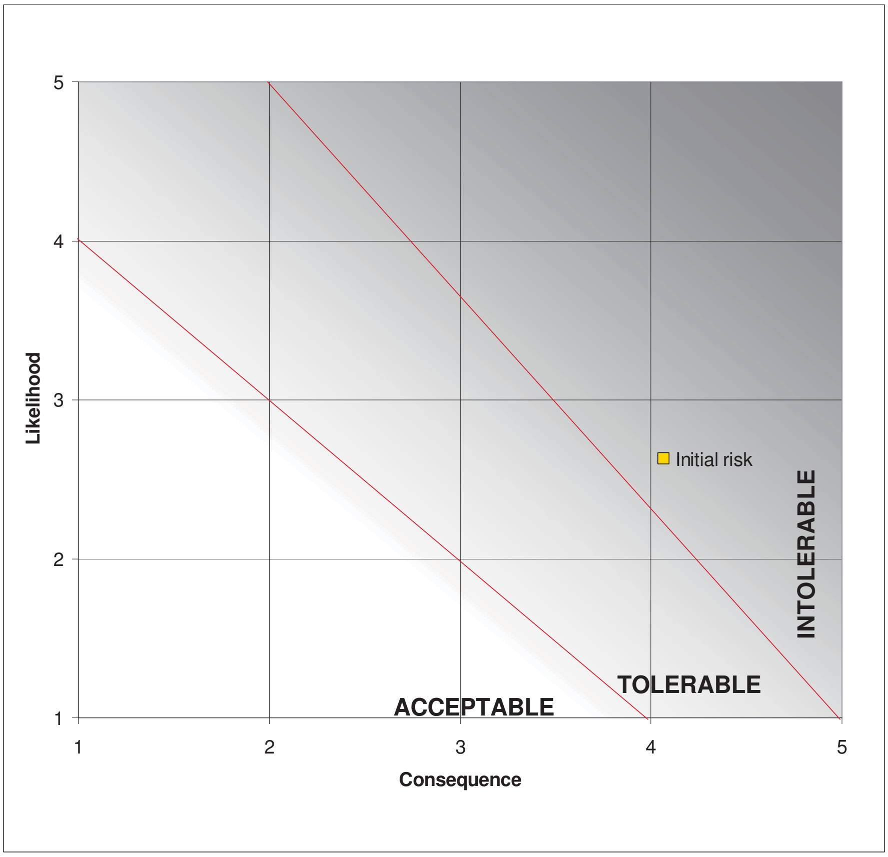


Figure 4-4 Risk Chart and Categorisation Based on Likelihood and Consequence (Example Risk #1 plotted)

All 148 strategies were assigned to risks as 'primary' or 'secondary' strategies. A strategy could only be a primary strategy for one risk. For each other risk that the strategy related to, it was designated a 'secondary strategy'.

For the example above (Risk #1), 27 strategies were identified as being capable of addressing the risk (or part thereof). Twelve strategies are primary strategies, (i.e. this is the primary risk that the strategy addresses) while 15 are secondary strategies (meaning that these have another risk that they address better than this one). The strategies addressing this risk are presented in Table 4-4and Table 4-5. All strategies have been given a unique identifier (strategy #) and have been categorised based on the type of strategy (viz: Planning, Monitoring/Research, Education, Compliance, Capital Works). These categories loosely accord with the different areas of Council responsibility.

Quantified reductions in risk resulting from these strategies were then determined. The initial risk assessment carried out in Workshop #2 was repeated <u>assuming that all identified strategies have been implemented</u>. For the specific example case, the consequence values have not changed, but the likelihood values have reduced considerably. Further, uncertainty has not changed, but management effectiveness has changed (refer Figure 4-5). For other risks, the consequence of the risk does change, however, the uncertainty of the risk outcomes generally do not change.

Table 4-4 Primary strategies Addressing Risk 1

Strategy #	Strategy	Category
1a	Conduct assessments to determine the carrying capacity of land areas (based on water, air, biodiversity and land capabilities) and limits for sustainable development within the entire catchment.	Research
1b	Collect information to inform amendments to planning controls based on the assessment of land capability, estuary carrying capacity (future population and development within the catchment) and ecological assessments..	Research
1c	State Government to reconsider regional strategies based on outcomes of sustainability and land capability assessments.	Planning
1d	Determine sustainable limits for recreational activities (types, numbers and locations) and the requirements for existing/new facilities and access to achieve sustainable limits on foreshores and waterways of the estuary (ie, suitable locations, unsustainable locations requiring removal, locations requiring restoration, new sustainable locations).	Research
1e	Review waterway access locations and requirements to consider all stakeholder needs with recommendations from the review informing appropriate Planning and Works Programs.	Research
1f	Develop and implement an Estuary Processes and Issues Checklist (EPIC) and integrate the checklist into councils planning controls. (The checklist is required to be completed and submitted with DA documentation. The checklist will require applicants and council planners to assess the likely impacts of DAs upon the natural processes, estuary values and sustainability of the Lower Hawkesbury Estuary).	Research
1g	Ensure planning instruments incorporate best practise: sediment, erosion and stormwater controls (eg construction controls plans and WSUD); use of water reduction devices and maximal permeable surfaces, landscaped area calculations: protection of native vegetation; sewage management (eg low risk OSSMs); restriction of landscaping and gardens to endemic species; energy efficient design and ESD.	Planning
1i	Ensure suitable controls are contained within planning instruments for the design of foreshore development including recreational facilities to maintain the estuary shoreline in as natural state as possible and minimises potential for bank erosion.	Planning
1j	Incorporate appropriate provision in planning instruments to require all Marinas to provide accessible pump out facilities as a component of their licence to operate in the Lower Hawkesbury.	Planning
1k	Incorporate provisions within planning controls to require all new dwellings or major alterations and additions to existing dwellings in the vicinity of priority oyster harvest areas to consider installation of pump out sewage systems where feasible.	Planning
1l	Encourage conservation of native vegetation on private land	Education

Table 4-5 Secondary strategies addressing Risk 1

Strategy #	Strategy Description	Category
2a	Undertake an audit of planning compliance to review the effectiveness of development consent conditions to protect estuary assets and achieve sustainability. (e.g. an audit of the types of development being approved for consistency with sustainable growth limits and estuary asset protection goals).	Planning
2c	In all Development Control Plans, information on the existing environmental context and desired future character is to be included in order to provide a more complete strategic approach	Planning
2f	Prohibit reclamation activities in all planning instruments	Planning
6a	Minimise clearing of vegetation on privately owned land via new LEP template (eg Clause 5.9) and existing biodiversity strategy	Planning
6b	State government to develop stronger deterrents for failure to comply with planning controls and regulations	Planning
2d	Define and map minimum buffer widths for riparian/foreshore vegetation in relevant planning documents (LEPs, DCPs etc) to protect estuary assets and account for landward migration of habitat due to sea level rise	Planning
2b	Define and map minimum buffer widths for riparian/foreshore vegetation in relevant planning documents (LEPs, DCPs etc) to protect estuary assets and account for landward migration of habitat due to sea level rise.	Planning
7a	Dredging of existing navigation channels is supported subject to appropriate environmental approvals	Planning
12ll	Provide incentives (eg grants or services) for a routine pumpout service to riverside settlements	Planning
10b	Incorporate strategies to mitigate local climate change impacts into planning instruments (ie with tools such as vulnerability maps)	Planning
6c	Enhance compliance with development consent conditions (sediment erosion controls, stormwater controls, permeable surface area, water reduction devices, urban design, vegetation removal etc). Increase and enforce penalties for non-compliance and unauthorised development (including renovations etc)	Compliance
7b	Use recommendations made in the Hornsby Shire Waterways Review (SJB, 2006) to inform waterway zoning in new LEP for the Lower Hawkesbury	Planning
6d	Increase compliance with development consent conditions (such as for maintenance of stormwater devices, permeable surface area, water reduction devices, urban design, vegetation removal etc) over the long term (ie, in the years after completion of a development) to ensure such conditions continue to be met	Compliance
7g	Progressively relocate or modify moorings considered to have a high environmental impact of be located in areas of high environmental significance or sensitivity.	Planning
12aa	Provide education to increase community acceptance of recycled water from STPs, and collection and re-use of stormwater, etc as per the STWCMS	Education
10a	Improve the understanding of local impacts which may arise from climate change (eg produce vulnerability maps) and the management responses to such impacts (changes to infrastructure, planning provisions etc)	Monitoring/Research

Risk Name	Asset Category	Consequence	Likelihood	Uncertainty	Management effectiveness
Inappropriate or unsustainable development	Scenic amenity and national significance	4	1	4	4
	Functional & sustainable ecosystems	4	2	4	4
	Largely undeveloped surrounding lands	4	1	4	4
	Recreational opportunities	4	2	4	4
	Sustainable economic industries	3	1	4	4
	Culture and heritage	4	1	4	4
	Water quality for multiple uses	3	2	4	4
	Community value	4	1	4	4
	Governance, legal and media*	4	1	4	4
	Averaged value	3.78	1.33	4	4

Figure 4-5 Reassessment of Risks Based on 100% Implementation of Identified Strategies

When adjusting the risk values for uncertainty and management effectiveness, the resulting risk values are:

- **Reassessed risk consequence value** = 3.78 * 1.25 * 0.75 = 3.54
- **Reassessed risk likelihood value** = 1.33 * 1.25 * 0.75 = 1.25

The reduction in risk values as a result of implementing all strategies is therefore:

- **Consequence risk reduction** = 4.07 – 3.54 = 0.53
- **Likelihood risk reduction** = 2.63 – 1.25 = 1.38

Note that there was a reduction in consequence value, despite no change in actual values when assessed against each individual asset, just because the increase in 'management effectiveness' factor reduced the adjusted consequence risk value.

The adjusted risk value following implementation of one or more strategies is called the 'transformed risk'. The transformed risk, following implementation of 100% of the strategies, and also, after the implementation of the 32 short listed strategies is plotted on the two-dimensional chart (Figure 4-6). The difference in plotting positions between the initial risk and the 100% transformed risk is the potential risk reduction. The risk remaining after all of the strategies are implemented is called the 'residual risk'.

The total risk reduction values are then apportioned against all of the strategies that contributed to the reduction (ie all primary and secondary strategies). A percentage of the total risk reduction is assigned to each strategy for both the risk consequence and the risk likelihood (Figure 4-7). This enables a relative allocation of risk reduction to the different strategies, and a relative allocation between changes in consequence and likelihood. The percentages of total risk reduction for both consequence and likelihood are then converted to a value for each strategy based on the actual reduction in value of risk consequence and likelihood. This allows for progressive recalculation of risks at any point in the future based on the successful implementation of specific strategies.

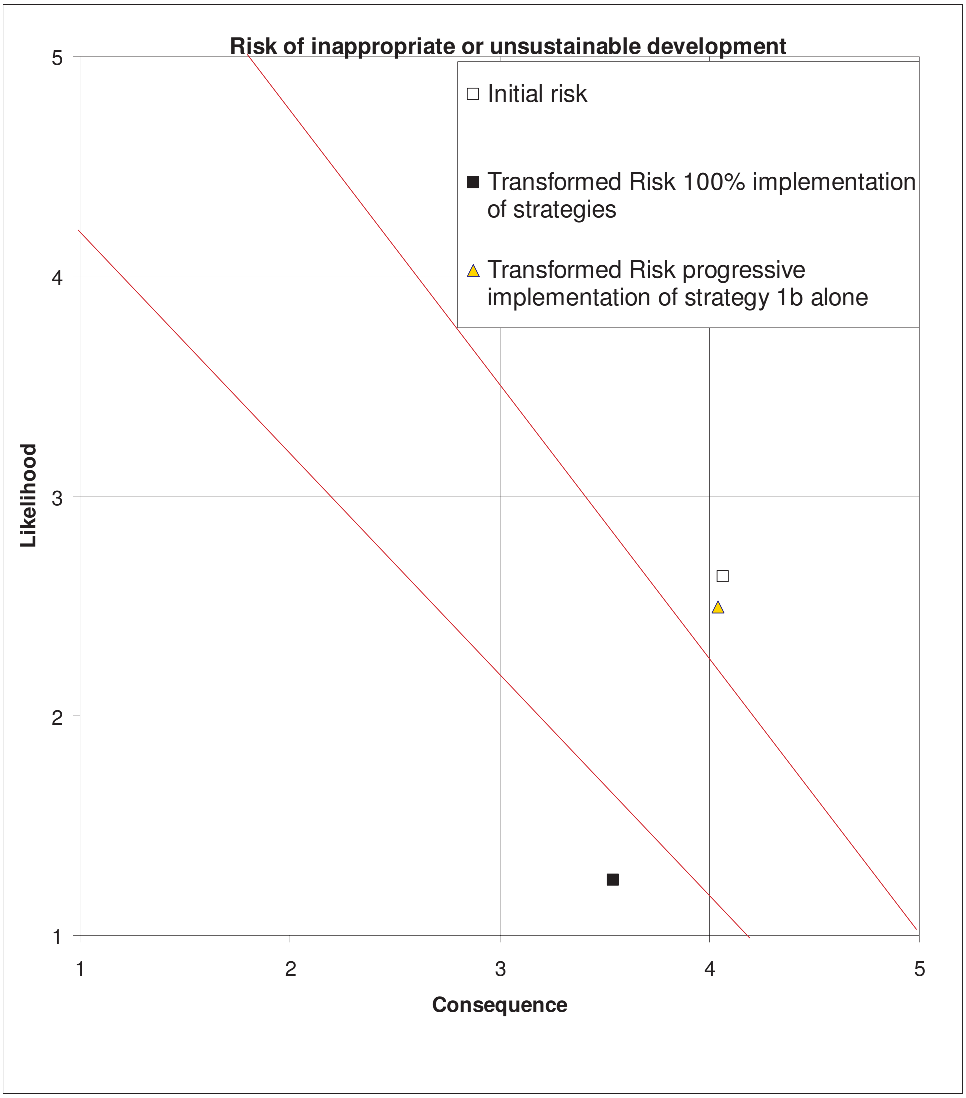


Figure 4-6 Risk Chart Showing Transformed Risks for Risk 1

Strategy #	Strategy Description	Category	Likelihood Risk Reduction (%)	Consequence Risk Reduction (%)
1a	Conduct assessments to determine the carrying capacity of land areas (based on water, air, biodiversity and land capabilities) and limits for sustainable development within the entire catchment	Research	5.0%	5.0%

Figure 4-7 An example of a Strategy Addressing Risk #1 Showing Percentages for Individual Risk Reductions

For the above example, Strategy 1b (*Collect information to inform amendments to planning controls, particularly the Local Environment Plan, based on the assessment of land capability, estuary carrying capacity (future population and development within the catchment), ecological assessments*) was considered to contribute 10% towards the total reduction in risk likelihood, and 5% towards the total reduction in risk consequence. Therefore, Strategy 1b contributes:

Consequence: 5% * 0.53 = **0.03**

Likelihood: 10% * 1.38 = **0.14**

With these reductions, the transformed risk following implementation of Strategy 1b can be plotted to graphically illustrate the impacts / benefits achieved for the strategy above (refer Figure 4-6). The plotting position is calculated as follows:

Transformed risk = Initial risk – total risk reduction

Consequence transformed risk = 4.07 – 0.03 = **4.04**

Likelihood transformed risk = 2.63 – 0.14 = **2.49**

When more than one strategy is implemented, then the summed total risk reduction is adopted. Risk reductions are cumulative. Therefore, progressive implementation will always include the risk reductions already achieved by preceding strategies, until 100% of strategies are implemented and the total potential risk reduction is reached.

Periodic reporting of progress of the Estuary Management Plan can thus be related to the total risk reduction achieved at that point in time for all 16 risks. It is noted that many strategies address a number of risks, therefore implementation of a select series of strategies could have a significant and rapid impact on the overall risk exposure of the Lower Hawkesbury Estuary.

4.1.3 Risk Prioritisation

For both likelihood and consequence, an aggregated risk reduction score for each strategy has been calculated by summing the risk reduction scores for each of the strategies. The summed likelihood and consequence risk reduction scores were then multiplied to give an overall 'Risk Reduction Potential'. This number is an indicator of the aggregated risk reduction potential of the strategy (across all 16 Risks).

For example, the *aggregated risk reduction score for "risk likelihood*" for strategy 1b is calculated by adding the risk reduction for this strategy from all risks that it contributes to. This particular sample strategy contributes to risks 1, 2, 3, 6, 8, 10 and 12. The aggregated total is 0.39. Similarly, the *aggregated risk reduction score for "risk consequence"* is 0.16. By multiplying these values together, a Risk Reduction Potential of 0.06 is calculated. This process has been undertaken across all 148 strategies. The results are provided in the detailed risk assessment tables in Appendix E, while the relative Risk Reduction scores are presented in Figure 4-8.

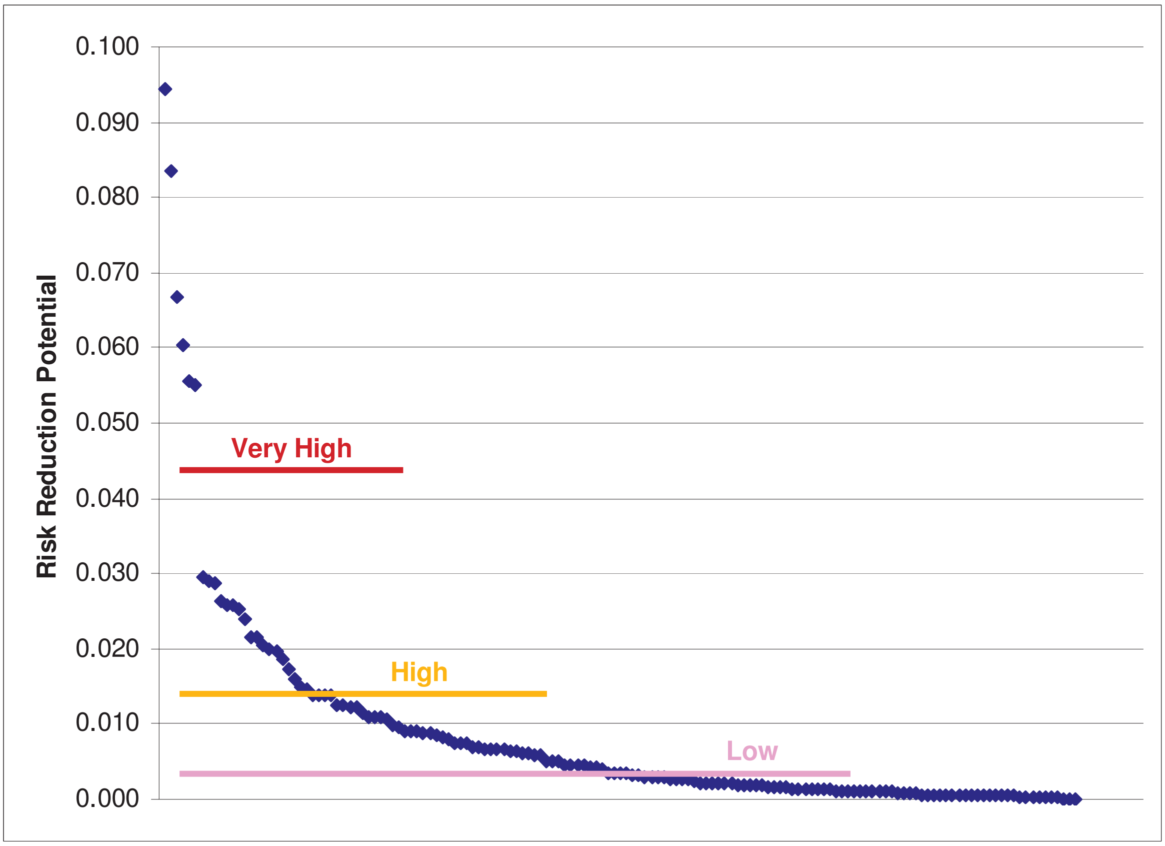


Figure 4-8 Relative Risk Reduction Potential Values for the 148 Strategies

4.2 Short Listed Strategies

A short-list of "high priority" strategies has been developed. This short list will form the initial focus for action within the LHEMP, aimed at reducing overall risks to assets. Short listed strategies have been identified based on:

- Risk reduction potential value (refer to Figure 4-8); and
- Ensuring all risks were addressed by one or more short listed strategies

The short-listed strategies are presented in Table 4-6 in priority order.

Table 4-6 Short Listed Strategies in Priority Order

Strategy #	Priority	Description
1a	1	Conduct assessments to determine the carrying capacity of land areas (based on water, air, biodiversity and land capabilities) and limits for sustainable development within the entire catchment
2e	2	Develop a strategy for sustainable recreation across the Lower Hawkesbury, which states the sustainability of locations, facilities and access based upon recreational survey and other data

Strategy #	Priority	Description
1b	3	Collect information to inform amendments to planning controls based on the assessment of land capability, estuary carrying capacity (future population and development within the catchment) and ecological assessments..
1g	4	Ensure planning instruments incorporate best practice: including sediment, erosion and stormwater controls (eg construction controls plans and WSUD); use of water reduction devices and maximum permeable surfaces, landscaped area calculations: protection of native vegetation; sewage management (eg low risk OSSMs); restriction of landscaping and gardens to endemic species; energy efficient design and ESD.
1d	5	Determine sustainable limits for recreational activities (types, numbers and locations) and the requirements for existing/new facilities and access to achieve sustainable limits on foreshores and waterways of the estuary (ie, suitable locations, unsustainable locations requiring removal, locations requiring restoration, new sustainable locations)
2v	6	Employ a River Keeper for the Lower Hawkesbury estuary, to assist in compliance, education and on-ground works (eg boat speeds and zones, seagrass protection, effluent discharges, littering, fishing, foreshore habitat protection, foreshore and waterway activities).
10a	7	Incorporate Climate Change Strategy to mitigate local climate change impacts into planning instruments/ management plans/ strategy activities (ie with tools such as vulnerability maps)
6a	8	Minimise clearing of vegetation on privately owned land, via new LEP template (eg Clause 5.9) and existing biodiversity strategy
9b	9	Submit the EMP to the appropriate Minister for gazettal by the NSW Government
1f	10	Develop an Estuary Processes and Issues Checklist (EPIC) and integrate the checklist into councils planning controls. (The checklist is required to be completed and submitted with DA documentation. The checklist will require applicants and council planners to assess the likely impacts of DAs upon the natural processes, estuary values and sustainability of the Lower Hawkesbury Estuary)
9a	11	Liaise with relevant state agencies to ensure integration of EMP actions into their relevant management plans/strategy activities (eg HNCMA's Catchment Action Plan, DPI Fisheries Sustainable Oyster Aquaculture Strategy etc)
9c	12	Establish a Lower Hawkesbury estuary management committee to be facilitated by HNCMA which incorporates Pittwater, Gosford and Hornsby Councils for a coordinated approach to estuary management.
12hh	13	Undertake remote and real time environmental monitoring for the Lower Hawkesbury (eg chlorophyll-a probes, wind speed probes, salinity, flow meters, satellite data), and make data available to the public.
2d	14	During the review of plans of management for all parks and reserves (both national and council managed), ensure estuary assets are preserved (including habitat values for native

Strategy #	Priority	Description
		animals, animals listed under the TSC Act 1995, prescribed burning and bushfire suppression undertaken according to park/reserve fire management plan, etc).
8b	15	Provide an annual progress report that gives a review of monitoring data, progress in implementing EMP actions and outlines the status of estuarine health
8c	16	Undertake an independent review and update of the EMP every three years to continually improve performance in meeting the EMP objectives and protecting estuarine health
9e	17	Lobby NSW Government to appoint an Estuary Manager for the entire Lower Hawkesbury, to administer and update existing management plans and access State, Federal and private industry funding sources, and to develop a Hawkesbury Estuary Management Plan.
10b	18	Improve the understanding of local impacts which may arise from climate change (eg produce vulnerability maps) and the management responses to such impacts (changes to infrastructure, planning provisions etc)
4a	19	Ensure adequate waste disposal facilities for people aboard boats and recreational fishers on land. This includes installation/provision of approved bins on hire boats, commercial fishing boats, moored boats and trailable boats, and supporting waste services on land.
5a	20	Establish a regular monitoring program to monitor the impacts of recreation at various locations and times of year (such as peak periods), to ensure ongoing sustainability of such locations
15a*	21	Consider a "Residents Pack" which outlines the estuary values, regional significance, ways to preserve such values, and includes existing brochures (from Councils, DPI Fisheries, NSW Maritime, NPWS etc) on stormwater, endemic plantings, bushcare, boating maps, seagrass maps, aquatic weeds, etc
2a	22	Undertake an audit of planning compliance to review the effectiveness of development consent conditions to protect estuary assets and achieve sustainability. (eg an audit of the types of development being approved for consistency with sustainable growth limits and estuary asset protection goals)
15b	23	Encourage vigilance in reporting non-compliance with regulations and environmental conditions/degradation (eg, sediment erosion controls, OSSMs, vegetation removal/destruction, stormwater control and maintenance, recreational activities etc) and pollution incidents (eg algal blooms, oils spills, chemical spills etc) to appropriate authorities (eg, "river hood watch program")
11a	24	Continue to lobby for reuse of water from STPs, to reduce freshwater demands in catchment
10d	25	Develop a set of biological indicators (eg, food chain or structural biota) which will assist in measuring climate change impacts.
8d	26	Provide a forum for discussion about issues relating to the estuary and EMP

Strategy #	Priority	Description
		progress
13a	27	Enhance weed management programs across catchment, particularly in estuarine vegetation
13b	28	Enhance existing pest eradication programs, particularly in estuarine habitats
2b**	29	Define and map minimum buffer widths for riparian/foreshore vegetation in relevant planning documents (LEPs, DCPs etc) to protect estuary assets and account for landward migration of habitat due to sea level rise
1i	30	Ensure suitable controls are contained within planning instruments for the design of foreshore development including recreational facilities to maintain the estuary shoreline in as natural state as possible and minimises potential for bank erosion
2n**	31	Riparian zones in priority agricultural areas fenced to prevent access of livestock to estuary, protect and encourage rehabilitation of riparian vegetation
15d**	32	Educate recreational users/general visitors about estuary values and the estuarine system, recreational impacts, and actions they may take to reduce impacts on priority areas (seagrass, harvest areas, recreational swimming) in the estuary (eg signage, boating stickers, brochures etc)

** These strategies were elevated due to preceding strategies requirements*

*** These strategies were elevated by up to two ranks to ensure a spread of strategies across the risk areas*

4.3 Implementation Details

Implementation details including costs and responsibilities were assigned for each of the 148 strategies. Additional details such as timing and a measurable indicator of implementation have been assigned for the short listed strategies. Implementation details for the short listed strategies are presented in Table 4-7. Each of the 148 strategies are considered to have the potential to contribute to reducing identified risks to estuary assets. As part of an adaptive management approach, these strategies should be referred to during plan reviews, in response to funding and grant opportunities and particularly as new information regarding estuary condition and process understanding is available.

Basic implementation information for all 148 strategies is provided in Table 4-8.

Table 4-7 Implementation Table for Short listed Strategies

Strategy #	Strategy	Type	Preceding Strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Timing	Measurable
1a	Conduct assessments to determine the carrying capacity of land areas (based on water, air, biodiversity and land capabilities) and limits for sustainable development within the entire catchment	Research		$50,000 for specific area, $200,000+ for LGA, $400,000+ for whole Lower Hawkesbury catchment	Staff time only for periodic review	HSC (Water Catchments team), HSC (Bushland and biodiversity) , GCC (Integrated Planning), GCC (Open Space and Leisure)	HNCMA, DoP, NSW DPI	Short Term	Quantified description of the estuary carrying capacity.
2e	Develop a strategy for sustainable recreation across the Lower Hawkesbury, which states the sustainability of locations, facilities and access based upon recreational survey and other data	Research	1d 16c	Staff time, or $30,000 external consultancy	Staff time only	HSC(Parks), HSC (Bushland and biodiversity) , GCC (Integrated Planning), GCC (Open Space and Leisure)	DECC, Maritime NSW, DPI Fisheries, HSC (Water Catchments team),	Medium Term	Documented sustainable Recreation Strategy
1b	Collect information to inform amendments to planning controls based on the assessment of land capability, estuary carrying capacity (future population and development within the catchment) and ecological assessments.	Research	1a	Staff time, or $50,000 external consultancy	Staff time only for periodic review	HSC (Water Catchments), GCC (Integrated Planning), GCC (Development)	DoP, HSC(Town Planning)	Medium Term	Compilation of relevant data in a format directly applicable to informing the LEP
1g	Ensure planning instruments incorporate best practice: including sediment, erosion and stormwater controls (eg construction controls plans and WSUD); use of water reduction devices and maximum permeable surfaces, landscaped area calculations: protection of native vegetation; sewage management (eg low risk OSSMs); restriction of landscaping and gardens to endemic species; energy efficient design and ESD.	Planning		Staff time only	Staff time only for periodic review	HSC (Town Planning Services) , GCC (Integrated Planning), GCC (Development)	DoP, HSC(Estuary Unit)	Immediate	Documented review of planning instruments and incorporation of best practice updates
1d	Determine sustainable limits for recreational activities (types, numbers and locations) and the requirements for existing/new facilities and access to achieve sustainable limits on foreshores and waterways of the estuary (ie, suitable locations, unsustainable locations requiring removal, locations requiring restoration, new sustainable locations)	Research		$20,000 for specific areas, $50,000 for whole Lower Hawkesbury estuary	Staff time only for periodic review	HSC (Estuary Unit), GCC (Integrated Planning), GCC (Open Space and Leisure)	NSW Maritime, DECC, DPI	Medium Term	Mapping of sustainable limits across the estuary (types, locations and numbers)
2v	Employ a River Keeper for the Lower Hawkesbury estuary, to assist in compliance, education and on-ground works (eg boat speeds and zones, seagrass protection, effluent discharges, littering, fishing, foreshore habitat protection, foreshore and waterway activities).	Capital Works		Establishment costs of $150,000	$80,000 per year	Maritime NSW,	HSC (Estuary Unit), GCC (Education and Compliance), DECC, DPI fisheries, HNCMA	Immediate	Position of River Keeper filled.
10 a	Incorporate Climate Change Strategy to mitigate local climate change impacts into planning instruments/ management plans/ strategy activities (ie with tools such as vulnerability maps)	Research		$80,000	Annual update / management costs of $10000	DECC	HSC (Estuary Unit), GCC (Integrated Planning), HNCMA	Immediate	Vulnerability maps and documentation of management response
6a	Minimise clearing of vegetation on privately owned land, via new LEP template (eg Clause 5.9) and existing biodiversity strategy	Planning		Staff Time Only	Staff Time only	HSC(Town Planning Services), HSC(Bushland and Biodiversity), GCC (Integrated Planning), DECC	HNCMA	Medium Term	Inclusion of additional protection zones in new template style LEP and biodiversity strategy
9b	Submit the EMP to the appropriate Minister for gazettal by the NSW Government	Planning		Staff time only	Staff time only	HSC (Estuary Unit), GCC (Integrated Planning)	DECC	Immediate	Gazettal
	Develop an Estuary Processes and Issues Checklist (EPIC) and integrate the checklist into councils planning controls. (The checklist is required to be completed and submitted with DA documentation. The checklist will require applicants and council planners to assess the likely impacts of DAs upon the natural processes, estuary values and sustainability of the Lower Hawkesbury Estuary)	Research		Staff time, or $30,000 external consultancy	Staff time only for periodic review	HSC (Estuary Unit), GCC (Integrated Planning), GCC (Development)	HSC (Town Planning Services) , HSC (Bushland and biodiversity) ,	Immediate	Use of EPIC by planners
	Liaise with relevant state agencies to ensure integration of EMP actions into their relevant management plans/strategy activities (eg HNCMA's Catchment Action Plan, DPI Fisheries Sustainable Oyster Aquaculture Strategy etc)	Planning		Staff time only	Staff time only	HSC (Estuary Unit), GCC (Integrated Planning)	DECC, NSW Maritime, DoL, DPI Fisheries, HSC (Town Planning Services), HNCMA	Immediate	Documentation of meetings, correspondence etc.

Strategy #	Strategy	Type	Preceding Strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Timing	Measurable
9c	Establish a Lower Hawkesbury estuary management committee to be facilitated by HNCMA which incorporates Pittwater, Gosford and Hornsby Councils for a coordinated approach to estuary management.	Planning		Staff time only	Catering / resourcing costs of $15, 000 per year	HNCMA	DECC, NSW Maritime, DoL, DPI Fisheries, HSC (Estuary Unit), GCC (Integrated Planning)	Immediate	Committee established and functioning.
12hh	Undertake remote and real time environmental monitoring for the Lower Hawkesbury (eg chlorophyll-a probes, wind speed probes, salinity, flow meters, satellite data), and make data available to the public.	Research		Data collection and management set up may cost up to $300,000	Annual management costs	HSC (Estuary Unit), GCC (Education and Compliance)	DECC	Immediate	Annual monitoring reports
2d	During the review of plans of management for all parks and reserves (both national and council managed), ensure estuary assets are preserved (including habitat values for native animals, animals listed under the TSC Act 1995, prescribed burning and bushfire suppression undertaken according to park/reserve fire management plan, etc).	Research		Within existing budget of relevant plan reviews	Within existing budget of relevant plan reviews	DECC, HSC(Parks), HSC (Bushland and biodiversity), GCC (Open Space and Leisure)	DPI, Maritime NSW	Immediate and ongoing	Documented evidence in reviewed POMs
8b	Provide an annual progress report that gives a review of monitoring data, progress in implementing EMP actions and outlines the status of estuarine health	Research		Staff time or completed by external consultant for $15, 000 per year	Staff time or completed by external consultant for $15, 000 per year	HSC (Estuary Unit), GCC (Open Space and Leisure), GCC (Education and Compliance)	DECC, NSW Maritime, DoL, DPI Fisheries, HNCMA	Short Term	Documentation of annual progress report
8c	Undertake an independent review and update of the EMP every three years to continually improve performance in meeting the EMP objectives and protecting estuarine health	Research		External consultancy of $40, 000	More detailed review will cost in the vicinity of $100,000	HSC (Estuary Unit), GCC (Integrated Planning)	DECC, NSW Maritime, DoL, DPI Fisheries	Medium Term and ongoing	Updated EMP
9e	Lobby NSW Government to appoint an Estuary Manager for the entire Lower Hawkesbury, to administer and update existing management plans and access State, Federal and private industry funding sources, and develop a Hawkesbury Estuary Management Plan.	Capital Works		Recruitment and first year salary and overheads $100, 000	Annual Salary plus overheads $90,000	HSC (Estuary Unit), GCC (Integrated Planning), GCC (Open Space and Leisure)	HNCMA, DECC	Short Term	Appointment of Estuary Manager
10b	Improve the understanding of local impacts which may arise from climate change (eg produce vulnerability maps) and the management responses to such impacts (changes to infrastructure, planning provisions etc)	Planning	10a	Staff time only	Staff time only for periodic review	HSC (Environmental Sustainability and Health), GCC (Integrated Planning), GCC (Information Management and Technology)	DoP, HSC (Bushland and biodiversity) ,	Short Term	Inclusion of climate change strategies in planning instruments (e.g. LEP)
4a	Ensure adequate waste disposal facilities for people aboard boats and recreational fishers on land. This includes installation/provision of approved bins on hire boats, commercial fishing boats, moored boats and trailable boats, and supporting waste services on land.	Capital works	1a , 16c	Pump out facilities more than $300,000	Ongoing costs of more than $100,000 per year	NSW Maritime	HSC (Waste Management),), GCC (Open Space and Leisure), GCC (Education and Compliance)	Short Term	Installation of additional waste services and evidence of maintenance
5a	Establish a regular monitoring program to monitor the impacts of recreation at various locations and times of year (such as peak periods), to ensure ongoing sustainability of such locations	Research		$20,000 - $50,000 to set up	$20, 000 per year	HSC (Estuary Unit),), GCC (Open Space and Leisure), GCC (Education and Compliance)	NSW Department of Tourism, Sport and Recreation, DECC, NSW DPI	Immediate and ongoing	Reporting of additional monitoring
15a	Consider a "Residents Pack" which outlines the estuary values, regional significance, ways to preserve such values, and includes existing brochures (from Councils, DPI Fisheries, NSW Maritime, NPWS etc) on stormwater, endemic plantings, bushcare, boating maps, seagrass maps, aquatic weeds, etc	Education		Mostly staff time compiling existing brochures. Additional printing and delivery costs of approximately $20,000.	printing and delivery allow $10, 000 per year	HSC(Estuary Unit), GCC (Education and Compliance)	HNCMA, DECC, Maritime NSW, DPI Fisheries	Medium Term	Distribution of residents pack
	Undertake an audit of planning compliance to review the effectiveness of development consent conditions to protect estuary assets and achieve sustainability. (eg an audit of the types of development being approved for consistency with sustainable growth limits and estuary asset protection goals)	Planning		Internal audit - may require additional temporary staff at $20,000	Staff time only	HSC (Assessments), GCC (Development), GCC (Organisational Development)	Hornsby Council (Estuary Unit)	Medium Term	Audit report
	Encourage vigilance in reporting non-compliance with regulations and environmental conditions/degradation (eg, sediment erosion controls, OSSMs, vegetation removal/destruction, stormwater control and maintenance, recreational activities etc) and pollution	Education	15a	Staff time only - possibly set up 1800 number and data base for recording incidents which will cost approximately $10, 000. To be answered by existing reception staff	Staff time only	HSC(Estuary Unit), GCC (Education and Compliance)	HNCMA, DECC, Maritime NSW, DPI Fisheries	Immediate	Implemented program / evidence of reporting

Strategy #	Strategy	Type	Preceding Strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Timing	Measurable
	incidents (eg algal blooms, oils spills, chemical spills etc) to appropriate authorities (eg, "river hood watch program")								
11a	Continue to lobby for reuse of water from STPs, to reduce freshwater demands in catchment	Research		External Consultancy $100000	N/A	DECC, Sydney Water	DECC, NSW Maritime, DoL, DPI Fisheries, HSC (Estuary Unit), GCC (Water and Sewer Operations)	Medium Term	Reductions in catchment new water demand
10d	Develop a set of biological indicators (eg, food chain or structural biota) which will assist in measuring climate change impacts	Research	10a	$30,000	Staff time only for periodic review	DECC	HSC (Estuary Unit), GCC (Integrated Planning), GCC (Open Space and Leisure), HNCMA, HSC (Bushland and biodiversity)	Short Term	Documentation of biological indicators
8d	Provide a forum for discussion about issues relating to the estuary and EMP progress	Education		Staff time	Catering / resourcing costs of approximately $10,000 per year	HSC (Estuary Unit), GCC (Education and Compliance)	DECC, NSW Maritime, DoL, DPI Fisheries, HNCMA	Immediate	Forum minutes
13a	Enhance weed management programs across catchment, particularly in estuarine vegetation	Capital Works		Highly variable across the catchment - where possible partnerships with landholders and volunteer groups should be utilised	Ongoing maintenance is crucial for weed eradication and watering prior to establishment.	HNCMA	HSC(Estuary Unit), GCC (Maintenance Services), GCC (Open Space and Leisure), HSC (Bushland and biodiversity) ,	Short Term	Additional works – including maintenance
13b	Enhance existing pest eradication programs, particularly in estuarine habitats	Capital works		Development of a pest management strategy approximately $30,000. Implementation will be variable but may be included in existing staff time	Highly variable	DPI Fisheries	HNCMA, DECC, HSC (Estuary Unit),), GCC (Maintenance Services), GCC (Open Space and Leisure),, HSC (Bushland and biodiversity)	Short Term	New pest management initiatives
2b	Define and map minimum buffer widths for riparian/foreshore vegetation in relevant planning documents (LEPs, DCPs etc) to protect estuary assets and account for landward migration of habitat due to sea level rise	Planning		Staff time, or $30,000 external consultancy	Staff time only	DECC	HSC(Town Planning Services), GCC (Integrated Planning), GCC (Information Management and Technology)	Medium Term	Maps showing buffer widths
1i	Ensure suitable controls are contained within planning instruments for the design of foreshore development including recreational facilities to maintain the estuary shoreline in as natural state as possible and minimises potential for bank erosion	Planning	2c	Staff time only		HSC (Town Planning Services), GCC (Integrated Planning), GCC (Development), GCC (Maintenance Services), GCC (open Space and Leisure)	DoP	Medium Term	Review of planning instruments and documentation of suitable controls
2n	Riparian zones in priority agricultural areas fenced to prevent access of livestock to estuary, protect and encourage rehabilitation of riparian vegetation	Capital Works		Fencing $100,000 plus	Ongoing maintenance costs approximately 10% capital costs	HNCMA	DECC, HSC(Bushland and Biodiversity), GCC (Open Space and Leisure), CEN	Medium Term	Completion of additional fencing.
15d	Educate recreational users/general visitors about estuary values and the estuarine system, recreational impacts, and actions they may take to reduce impacts on priority areas (seagrass, harvest areas, recreational swimming) in the estuary (eg signage, boating stickers, brochures etc)	Education	15a	Staff time only	Staff time only	HSC (Estuary Unit), GCC (Education and Compliance, GCC (Integrated Planning), GCC (open space and Leisure).	HNCMA, DECC, Maritime NSW, DPI Fisheries	Medium Term	Compilation / development of educational resources and use of these resources.

Table 4-8 Implementation Information for all Management Strategies

Strategy #	Rank	Strategy	Category	Preceding strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Time Frame
RISK 1 **Risk of inappropriate or unsustainable development**									
1a	**1**	Conduct assessments to determine the carrying capacity of land areas (based on water, air, biodiversity and land capabilities) and limits for sustainable development within the entire catchment.	Research		$50,000 for specific area, $200,000+ for LGA, $400,000+ for whole Lower Hawkesbury catchment	Staff time only for periodic review	HSC (Estuary Unit), GCC, HSC (Bushland and biodiversity)	HNCMA, DoP, NSW DPI	Short Term
1b	**3**	Collect information to inform amendments to planning controls based on the assessment of land capability, estuary carrying capacity (future population and development within the catchment) and ecological assessments.	Research	1a	Staff time, or $50,000 external consultancy	Staff time only for periodic review	HSC (Estuary Unit), GCC	DoP, HSC(Town Planning)	Medium Term
1c	**51**	State Government to reconsider regional strategies based on outcomes of sustainability and land capability assessments.	Planning	1a	Staff time only		DoP	HSC (Town Planning Services) , GCC	Medium Term
1d	**5**	Determine sustainable limits for recreational activities (types, numbers and locations) and the requirements for existing/new facilities and access to achieve sustainable limits on foreshores and waterways of the estuary (ie, suitable locations, unsustainable locations requiring removal, locations requiring restoration, new sustainable locations).	Research		$20,000 for specific areas, $50,000 for whole Lower Hawkesbury estuary	Staff time only for periodic review	HSC (Estuary Unit), GCC	NSW Maritime, DECC, DPI	Medium Term
1e	**45**	Review waterway access locations and requirements to consider all stakeholder needs with recommendations from the review informing appropriate Planning and Works Programs.	Research		Staff time, or $30,000 external consultancy per area	Staff time only for periodic review	HSC (Parks), GCC	HSC (Estuary Unit), HSC (Town Planning Services), HSC (Bushland and biodiversity) , GSC, stakeholders	Medium Term
1f	**10**	Develop and implement an Estuary Processes and Issues Checklist (EPIC) and integrate the checklist into councils planning controls. (The checklist is required to be completed and submitted with DA documentation. The checklist will require applicants and council planners to assess the likely impacts of DAs upon the natural processes, estuary values and sustainability of the Lower Hawkesbury Estuary).	Research		Staff time, or $30,000 external consultancy	Staff time only for periodic review	HSC (Estuary Unit), GCC	HSC (Town Planning Services), HSC (Bushland and biodiversity) ,	Immediate
1g	**4**	Ensure planning instruments incorporate best practise: sediment, erosion and stormwater controls (eg construction controls plans and WSUD); use of water reduction devices and maximal permeable surfaces, landscaped area calculations: protection of native vegetation; sewage management (eg low risk OSSMs); restriction of landscaping and gardens to endemic species; energy efficient design and ESD.	Planning		Staff time only	Staff time only for periodic review	HSC (Town Planning Services) , GCC	DoP, HSC (Estuary Unit)	Immediate
1i	**29**	Ensure suitable controls are contained within planning instruments for the design of foreshore development including recreational facilities to maintain the estuary shoreline in as natural state as possible and minimises potential for bank erosion.	Planning	2d	Staff time only	Staff time only	HSC (Town Planning Services), GCC	DoP, HSC (Estuary Unit)	Medium Term
1j	**33**	Incorporate appropriate provision in planning instruments to require all Marinas to provide accessible pumpout facilities as a component of their licence to operate in the Lower Hawkesbury.	Planning		Staff time only	Staff time only	HSC (Town Planning Services), GCC	DECC, HSC (Estuary Unit)	Medium Term
1k	**35**	Incorporate provisions within planning controls to require all	Planning		Staff time only	Staff time only	NSW DPI, NSW Food	DECC, HSC (Town	Medium

Strategy #	Rank	Strategy	Category	Preceding strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Time Frame
		new dwellings or major alterations and additions to existing dwellings in the vicinity of priority oyster harvest areas to consider installation of pumpout sewage systems where feasible.					Authority, HSC (Estuary Unit)	Planning Services)	Term
1l	57	Encourage conservation of native vegetation on private land	Education		Depends on incentives and education program	Staff time for maintenance of program	HNCMA, HSC (Bushland and biodiversity) ,	GCC, DECC	Medium Term
RISK 2 **Risk of over-exploiting or degrading the estuary's biodiversity and other assets**									
2a	22	Undertake an audit of planning compliance to review the effectiveness of development consent conditions to protect estuary assets and achieve sustainability. (eg an audit of the types of development being approved for consistency with sustainable growth limits and estuary asset protection goals).	Planning		Internal audit – may require additional temporary staff at $20, 000	Staff time only	HSC (Assessments), GCC	HSC(Estuary Unit)	Medium Term
2b	30	Define and map minimum buffer widths for riparian/foreshore vegetation in relevant planning documents (LEPs, DCPs etc) to protect estuary assets and account for landward migration of habitat due to sea level rise.	Planning		Staff time, or $30,000 external consultancy	Staff time only	DECC	HSC(Town Planning Services), HSC(Estuary Unit), GCC	Medium Term
2c	103	In all Development Control Plans, information on the existing environmental context and desired future character is to be included in order to provide a more complete strategic approach.	Planning	2a, 2b	Staff time only	Staff time only	HSC(Town Planning Services), GCC	HSC (Estuary Unit)	Short Term
2d	14	During the review of plans of management for all parks and reserves (both national and council managed), ensure estuary assets are preserved (including habitat values for native animals, animals listed under the TSC Act 1995, prescribed burning and bushfire suppression undertaken according to park/reserve fire management plan, etc).	Research		Within existing budget of relevant plan reviews	Within existing budget of relevant plan reviews	DECC , HSC(Parks), HSC(Bushland) and Biodiversity), GCC	DPI, Maritime NSW	Immediate
2e	2	Develop a strategy for sustainable recreation across the Lower Hawkesbury, which states the sustainability of locations, facilities and access based upon recreational survey and other data.	Research	1d 16c	Staff time, or $30,000 external consultancy	Staff time only	HSC(Parks), HSC (Bushland and biodiversity) , GCC	HSC (Estuary Unit), DECC, Maritime NSW, DPI Fisheries	Medium Term
2f	122	Prohibit reclamation activities in all planning instruments.	Planning		Staff time only	Staff time only	HSC (Town Planning Services) HSC(Estuary Unit), GCC	DoP, DECC	Long Term
2g	77	Liaise with the Metropolitan LALC and other indigenous groups to assess if the current level of management of aboriginal sites around the estuary is appropriate.	Planning		Staff time or $10, 000 external consultancy		DECC	HSC (Parks), HSC(Estuary Unit), GCC, HNCMA	Medium Term
2h	138	Prepare management plans for commercial and recreational fishing (based upon the findings of commercial and recreational fishing surveys and research into fishing impacts) which outline fishing parameters to sustain fish stocks and aquatic habitats (including zones appropriate to various fishing amounts (bag limits) and practices, use of bycatch devices and non-target species avoidance techniques). The plan needs also to address potential issues with visiting commercial fishers.	Planning	16d	Developing the plans - $80, 000	Existing Management	DPI Fisheries	Councils, Maritime NSW	Long Term
2i	105	Ensure commercial fishers minimise the catch of non-target species, the incidental catch of non-utilised species, marine mammals, reptiles, seabirds and impacts on associated or dependent species using such measures as mesh or gear modifications, closed areas and bycatch reduction devices.	Compliance		Staff time only – implementation of existing requirements	Staff time only	Commercial Fishers	DPI Fisheries, DECC, Maritime NSW	Long Term
2j	102	Enforce compliance of recreational fishers with regulations	Compliance		Staff time only –	Staff time only	DPI Fisheries	DECC, Maritime NSW	Long Term

Strategy #	Rank	Strategy	Category	Preceding strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Time Frame
		on bag limits, minimum fish sizes etc			implementation of existing requirements				
2k	106	Educate all commercial fishers on methods to minimise the catch of non-target species, the incidental catch of non-utilised species, marine mammals, reptiles, seabirds and impacts on associated or dependent species. Such methods include mesh or gear modifications, closed areas and bycatch reduction devices.	Education	2h	Staff time only	Staff time only	DPI Fisheries	DECC, Councils	Long Term
2l	141	Educate commercial fishers to ensure they understand the immediate action required to mitigate impacts on protected or endangered species from their trawling operations	Education	2h, 2k	$30,000 project implementation and materials	Staff time only	DPI Fisheries	DECC, Maritime NSW	Long Term
2m	94	Identify significant seagrass beds on NSW Maritime boat charts and stickers and undertake education program to promote protection of seagrass	Education	5c, 5d	$10,000 in design, printing costs	Staff time only	Maritime NSW,	DPI, HSC (Estuary Unit)	Long Term
2n	34	Riparian zones in priority agricultural areas fenced to prevent access of livestock to estuary, protect and encourage rehabilitation of riparian vegetation.	Capital works		Fencing $100,000 plus	Ongoing maintenance costs approximately 10% capital costs	HNCMA	DECC, HSC(Bushland and Biodiversity), GCC	Medium Term
2o	59	Undertake comprehensive of mapping of the extent and condition of riparian habitats (including mangroves, saltmarsh and wetland species) in the Lower Hawkesbury and review periodically	Research		$80,000	Staff time to distribute and encourage the use by all agencies of the GIS data	DPI Fisheries	HSC (Estuary Unit), GCC, DECC	Medium Term
2p	90	Improve native vegetation condition through revegetation of priority areas (based on habitat mapping)	Capital works	2o	Rehabilitation works from $100, 000	Ongoing maintenance costs approximately 10% capital costs	HNCMA	DECC, HSC(Bushland and Biodiversity), GCC	Medium Term
2q	100	Expand bush regeneration programs and conservation programs for specific priority species	Capital works	2o	Variable, volunteer based programs have demonstrated good results from negligible funding		HNCMA	DECC, HSC(Bushland and Biodiversity), GCC	Long Term
2r	101	Provide incentives to landholders to conserve significant habitats and native vegetation identified on private land (e.g. through property vegetation plans and voluntary conservation agreements)	Capital works	2o	$100,000 plus	Ongoing maintenance costs approximately 10% capital costs	HNCMA	DECC, HSC(Bushland and Biodiversity), GCC	Long Term
2s	80	Initiate a program for the removal of rubbish (including derelict boats) from riparian areas. The clean up program should focus on larger items such as derelict boats and dumped construction materials, with input and assistance from industry groups and volunteers.	Capital works		$5, 000 – works mainly volunteer based	Annual program $5000	HNCMA, HSC (Estuary Unit)	Clean up Australia day Council, CMA, DPI Fisheries, GCC, DoL	Medium Term
2t	146	Identify, protect, enhance and rehabilitate sites of Indigenous cultural significance, in collaboration with local indigenous groups (e.g. middens subject to erosion)	Capital works	2g	Variable, depending on requirements	Variable, depending on requirements	DECC	HSC (Town Planning Services), GCC, NSW Maritime, HNCMA	Long Term
2u	147	Identify, protect, enhance and rehabilitate sites of European heritage significance, in collaboration with local historical societies.	Capital works		Variable, depending on requirements	Variable, depending on requirements	DECC	HSC (Town Planning Services), GCC, NSW Maritime	Long Term
2v	6	Employ a River Keeper for the Lower Hawkesbury estuary, to assist in compliance, education and on-ground works (eg boat speeds and zones, seagrass protection, effluent discharges, littering, fishing, foreshore habitat protection, foreshore and waterway activities).	Capital works		Establishment costs of $150,000	$80,000 per year	NSW Maritime,	HSC (Estuary Unit), GCC, DECC, DPI fisheries, HNCMA	Immediate
2w	94	Install marker buoys and warnings around seagrass habitats to deter boaters from accessing and damaging these habitats	Capital works	5c, 5d	$50,000 plus	Ongoing maintenance costs approximately 10% capital costs	NSW Maritime	HSC (Estuary Unit), GCC, DECC, DPI fisheries, HNCMA	Long Term
2x	136	Encourage the development and implementation of selective fishing gear, trawl practises/equipment and by-	Research	2h, 2i	$100, 000 plus	Ongoing research is required to ensure	DPI Fisheries	HSC (Estuary Unit),	Long Term

Strategy #	Rank	Strategy	Category	Preceding strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Time Frame
		catch reduction devices amongst commercial fishers and researchers				continual improvement		GCC, DECC	
RISK 3 **Risk of inappropriate or excessive foreshore access and activities***									
3a	50	Restrict foreshore access in areas of high environmental sensitivity	Compliance	2o, 1a, 1d, 5a	Variable depending on areas and appropriate methods	Variable depending on areas and appropriate methods	DECC, NSW DPI	HSC (Estuary Unit), GCC	Medium Term
3b*	Not used								
3c	91	Rehabilitate recreational areas on the foreshore and implement Foreshore Annual Maintenance Program	Capital works	2o, 1a, 1d, 5a	Likely to be in excess of $100,000	Ongoing maintenance costs approximately 10% capital costs	HSC (Works)	DECC, DoL, HSC (Estuary Unit), GCC	Long Term
RISK 4 **Risk of inadequate facilities to support foreshore and waterway access and activities**									
4a	19	Ensure adequate waste disposal facilities for people aboard boats and recreational fishers on land. This includes installation/provision of approved bins on hireboats, commercial fishing boats, moored boats and trailable boats, and supporting waste services on land.	Capital works	1a ,16c	Pump out facilities more than $300000	NSW Maritime	HSC (Waste Management), GCC	HSC(Estuary Unit)	Short Term
4b	79	Initiate planning of the Lower Hawkesbury section of the Great Hawkesbury Walk.	Capital works		Staff time only (for planning component)	DoL	DECC, HSC (Parks), GCC, Tourism NSW	DECC, HSC, GCC, Tourism NSW	Medium Term
RISK 5 **Risk of inadequate monitoring to measure effectiveness of EMP**									
5a	20	Establish a regular monitoring program to monitor the impacts of recreation at various locations and times of year (such as peak periods), to ensure ongoing sustainability of such locations.	Research		$20,000 - $50,000 to set up	$20, 000 per year	HSC (Estuary Unit), GCC	NSW Department of Tourism, Sport and Recreation, DECC, NSW DPI	Immediate
5b	46	Establish and implement one recreational water quality monitoring program (such as Beach/Streamwatch by EPA) for the entire Lower Hawkesbury.	Research		$100, 000 to set up and undertake first years monitoring	$80, 000 a year, including monitoring and reporting	DECC	HSC (Estuary Unit), GCC	Medium Term
5c	40	Undertake periodic mapping of aquatic habitats (including the extent and condition of benthic, intertidal zone, water column and water surface habitats) throughout the Lower Hawkesbury	Research		$100, 000 to set up and undertake first years monitoring	$30, 000 a year, including monitoring and reporting	NSW DPI	DECC, HSC(Estuary Unit), GCC, HNCMA	Medium Term
5d	63	Develop key biological indicators and establish a biological monitoring program for aquatic and riparian habitats	Research		$100, 000 to set up and undertake first years monitoring	$50, 000 a year, including monitoring and reporting	NSW DPI, HSC (Estuary Unit)	DECC, GCC, HNCMA	Medium Term
5e	64	Develop a comprehensive ecosystem health water quality monitoring program across the Lower Hawkesbury	Research	5a, 5b, 5c, 5d	$200, 000 to set up and undertake first years monitoring	$100, 000 a year, including monitoring and reporting	NSW DPI, DECC, HSC (Estuary Unit)	DECC, GCC, HNCMA	Medium Term
5f	87	Determine a set of parameters to indicate the progress in implementation of the EMP and to measure/indicate the effectiveness of actions in achieving EMP goals and protecting estuarine health.	Research	5a, 5b, 5c, 5d, 5e	$50,000		NSW DPI, DECC, HSC (Estuary Unit)	DECC, GCC, HNCMA	Medium Term
5g	92	Ensure monitoring programs are given a high priority to enable measurement of the effectiveness of the EMP.	Research		Staff Time		NSW DPI, DECC, HSC (Estuary Unit)	DECC, GCC, HNCMA	Long Term

Strategy #	Rank	Strategy	Category	Preceding strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Time Frame
RISK 6 **Risk of inappropriate land management practices**									
6a	8	Minimise clearing of vegetation on privately owned land via new LEP template (eg Clause 5.9) and existing biodiversity strategy	Planning		Staff Time Only	Staff Time only	HSC(Town Planning Services), HSC(Bushland and Biodiversity), GCC, DECC	HNCMA	Medium Term
6b	74	State government to develop stronger deterrents for failure to comply with planning controls and regulations	Planning		Staff Time – additional resources may be required	Staff Time – additional resources may be required	DoP	HSC(Assessments), GCC	Medium Term
6c	97	Enhance compliance with development consent conditions (sediment erosion controls, stormwater controls, permeable surface area, water reduction devices, urban design, vegetation removal etc). Increase and enforce penalties for non-compliance and unauthorised development (including renovations etc)	Planning		Staff Time – additional resources may be required	Staff Time – additional resources may be required	HSC (Assessments), GCC	DECC, HSC (Environmental Sustainability and Health)	Long Term
6d	47	Increase compliance with development consent conditions (such as for maintenance of stormwater devices, permeable surface area, water reduction devices, urban design, vegetation removal etc) over the long term (ie, in the years after completion of a development) to ensure such conditions continue to be met	Compliance		Staff Time – additional resources may be required	Staff Time – additional resources may be required	HSC (Assessments), GCC	DECC, HSC (Environmental Sustainability and Health)	Medium Term
6e	48	Increase the number of rural residential and smaller area landholders (less than 100 ha) attending management training for rural residential block and small farm management. The education should increase awareness of rural impacts on the estuarine environment, and provide solutions to manage such impacts.	Education		Advertising and staff follow up - $15, 000	Staff Time – additional resources may be required	HNCMA	HSC (Bushland and Biodiversity), GCC	Medium Term
6f	49	Increase the area of non-urban land managed within its capability	Education		$15,000	Staff time	HNCMA	HSC (Bushland and Biodiversity), GCC	Medium Term
6g	67	Implement education strategy for commercial and industrial sectors of the catchment to increase awareness of their impact on estuarine environment, and provide solutions to mitigate such impacts	Education		$30,000	Establishment fee	HSC(Environmental Sustainability and Health), GCC	DECC, HNCMA	Medium Term
6h	52	Educate residents as to best practise catchment management (fertilisers, chemicals, pesticides, threat of weeds to bushland, and encourage the removal of exotic species and replacement with suitable indigenous plants, domestic animals)	Education		$30,000		HSC (Bushland and Biodiversity), GCC	DECC, HNCMA	Medium Term
6i	145	Provide incentives for the establishment of riparian filters to treat run-off from areas which may generate potentially high pollutant loads in runoff (eg, livestock, turf farms etc)	Capital/On-ground works		$20,000		DECC, NSW DPI Fisheries	HSC (Bushland and Biodiversity), GCC, HNCMA	Long Term
6j	144	Undertake soil conservation works such as fencing, gully control structures, track/trail, fire trails and rural road stabilisation and revegetation to reduce soil erosion	Capital/On-ground works				HSC (Bushland and Biodiversity), GCC	DECC	Long Term
RISK 7 **Risk of inappropriate or excessive waterway access and activities**									
7a	134	Investigate which zoning, in accordance with LEP standard instrument, offers greatest protection to Big Bay and Marramarra Creek and incorporate into new LEP	Planning		Staff time only	Staff time only	HSC(Town Planning Services), HSC(Estuary Unit), GCC	DECC, DoP	Long Term
7b	84	Use recommendations made in the Hornsby Shire	Planning		Staff time only	Staff time only	HSC (Estuary Unit)	HSC (Town Planning	Medium

Strategy #	Rank	Strategy	Category	Preceding strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Time Frame
		Waterways Review (SJB, 2006) to inform waterway zoning in new LEP for the Lower Hawkesbury						Services)	Term
7c	39	Update existing boating maps (boat and PWC speeds, access, and vessel size limits in various zones) for the entire Lower Hawkesbury to reflect findings of bank erosion studies, significant aquatic and riparian habitats, priority harvest area requirements, and other relevant environmental studies	Education		Staff time and printing costs of $20 000	Printing within existing budgets	NSW Maritime Authority, HSC (Estuary Unit)	DECC, DPI Fisheries, HSC(Estuary Unit),GCC	Medium Term
7d	119	Implement exclusion zones for recreational/private boating in specific oyster harvest area to protect sanitary water quality, using appropriate methods	Planning		Staff Time and signage costs of up to $15000	Staff time only	NSW Maritime Authority	DPI Fisheries, HSC (Estuary Unit), GCC	Long Term
7e	99	Investigate innovative methods to restrict the numbers of boats or the size of vessels in areas of high environmental sensitivity/significance.	Planning		Staff time or indicative consultancy costs of $20,000	staff time only	NSW Maritime Authority	DPI Fisheries, DECC, Council, HSC (Estuary Unit)	Long Term
7f	121	Ensure no net increase in existing moorings/berthings is permitted throughout the Lower Hawkesbury. Only permit additional berthings in marinas where they replace existing swing moorings.	Planning		Staff time only	Staff time only	NSW Maritime Authority	HSC(Estuary Unit and Town Planning Services), GCC, Stakeholders	Long Term
7g	76	Progressively relocate or modify moorings considered to have a high environmental impact or are located in areas of high environmental significance or sensitivity.	Planning		Staff time only	Staff time only	NSW Maritime Authority	DPI Fisheries, HSC (Estuary Unit)	Medium Term
7h	118	Dredging of existing navigation channels is supported subject to appropriate environmental approvals	Planning		Highly variable depending on areas and extents, likely to be at least $250000	Highly variable depending on areas and extents, likely to be at least $250000 every five years	NSW Maritime Authority	DECC, DoL, HSC (Estuary Unit)	Long Term
7i	109	Enhance compliance activities and enforcement of penalties for all waterway regulations and consider increasing deterrents for non compliance with regulations (boat speed zones, effluent discharges, seagrass protection, littering, permanent occupation of boats, illegal overnight mooring of boats etc)	Compliance		Increased compliance officers likely to cost approx $100, 000 per year. Capital costs may be required for resources such as boats, mobile phones, vehicles etc	Annual costs of about $100000 per additional staff member	NSW Maritime Authority	DPI Fisheries, Councils	Long Term
7j	53	Develop and implement a program for auditing boats for methods used to contain waste from boat maintenance, effluent discharge practises, rubbish disposal, oil discharge from bilge pumps and all other environmental issues associated with boat usage. This could reasonably be combined with NSW Maritime audits of moorings.	Compliance		Staff time only	Staff time only	NSW Maritime Authority, HSC(Environmental Sustainability and Health), GCC	DECC, Councils	Medium Term
7k	123	Develop a "River Code" which outlines acceptable boating activities/behaviour (focussing on environmental impacts) and includes updated boating maps. The "River Code" could incorporate existing NSW Maritime and other brochures relating to the environment and appropriate behaviour (boat speeds etc). Options for distribution of "River Code" should be considered (eg, stickers, with licence applications, broad advertising etc)	Education		$30,000 for printing and resources, development of the code could be completed in-house with existing staff or at a cost of $10, 000 by external consultants	Ongoing printing costs of approximately $10,000 per year	NSW Maritime Authority	DPI Fisheries, DECC, Council, HSC (Estuary Unit)	Long Term
RISK 8 **Risk of inadequate or dysfunctional management mechanisms**									
8a	148	Transfer the management of Kangaroo Point pumpout to an appropriate State government agency	Planning		Administration with existing staff time	Transfer of existing costs from Council to state government	HSC (Estuary Unit), GCC	NSW Maritime, DECC, DoL	Long Term
8b	15	Provide an annual progress report which gives a review of monitoring data, progress in implementing EMP actions	Research		Staff time or completed by external consultant	Staff time or completed by	HSC (Estuary Unit),	DECC, NSW Maritime, DoL, DPI Fisheries,	Short Term

Strategy #	Rank	Strategy	Category	Preceding strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Time Frame
		and outlines the status of estuarine health			for $15, 000 per year	external consultant for $15, 000 per year	GCC	HNCMA	
8c	16	Undertake an independent review and update of the EMP every three years to continually improve performance in meeting the EMP objectives and protecting estuarine health	Research		External consultancy of $40, 000	More detailed review will cost in the vicinity of $100000	HSC (Estuary Unit), GCC	DECC, NSW Maritime, DoL, DPI Fisheries	Medium Term
8d	26	Provide a forum for discussion about issues relating to the estuary and EMP progress	Education		Staff time	Catering / resourcing costs of approximately $10,000 per year	HSC (Estuary Unit), GCC	DECC, NSW Maritime, DoL, DPI Fisheries, HNCMA	Immediate
8e	137	Establish an MOU for data sharing (e.g. between SWC, NSW Food Authority, HSC, HNCMA, GSC, PC etc). Compile and manage a supporting database for the MOU for all monitoring data for the Lower Hawkesbury.	Research		Compilation of database either in-house with existing staff or undertaken by external consultant for approximately $50, 000	Ongoing database management by staff or external consultant at approximately $10,000 per year	HSC (Estuary Unit), GCC	DECC, NSW Maritime, DoL, DPI Fisheries, NSW Food Authority, HNCMA	Long Term
RISK 9 **Risk of not meeting EMP objectives within designated timeframes**									
9a	11	Liaise with relevant state agencies to ensure integration of EMP actions into their relevant planning instruments/management plans/strategy activities (eg HNCMA's Catchment Action Plan, DPI Fisheries Sustainable Oyster Aquaculture Strategy etc)	Planning		Staff time only	Staff time only	HSC (Estuary Unit), GCC	DECC, NSW Maritime, DoL, DPI Fisheries, HSC (Town Planning Services) , HNCMA	Immediate
9b	9	Submit the EMP to appropriate Minister for gazettal by the NSW Government	Planning		Staff time only	Staff time only	HSC (Estuary Unit), GCC	DECC	Immediate
9c	12	Establish a Lower Hawkesbury estuary management committee to be facilitated by HNCMA which incorporates Pittwater, Gosford, Hornsby Councils for a coordinated approach to estuary management.	Planning		Staff time only	Catering / resourcing costs of $15, 000 per year	HNCMA	DECC, NSW Maritime, DoL, DPI Fisheries, HSC (Estuary Unit), GCC	Immediate
9d	60	Investigate possibilities for involving universities, the CSIRO and/or other research organisations in research programs that implement actions within this plan (eg habitat mapping, biological monitoring program, etc.)	Research		Staff time only	Staff time only	HSC (Estuary Unit), GCC	DPI Fisheries, DECC, HNCMA	Medium Term
9e	17	Lobby NSW State Government to appoint an Estuary Manager for entire Lower Hawkesbury, to administer and update existing management plans and access State, Federal and private industry funding sources, and to develop a Hawkesbury estuary management plan.	Capital/On-ground works		Recruitment and first year salary and overheads $100, 000	Annual Salary plus overheads $90, 000	HSC (Estuary Unit), GCC (Integrated Planning), GCC (Open Space and Leisure)	HNCMA, DECC	Short Term
RISK 10 **Risk of climate change**									
10a	7	Incorporate Climate Change Strategy to mitigate local climate change impacts into planning instruments/ management plans/ strategy activities (ie with tools such as vulnerability maps)	Research		$80,000		DECC	HSC (Estuary Unit), GSC, HNCMA, HSC (Bushland and biodiversity) ,	Immediate
10b	18	Improve the understanding of local impacts which may arise from climate change (eg produce vulnerability maps) and the management responses to such impacts (changes to infrastructure, planning provisions etc)	Planning	10a	Staff time only	Staff time only for periodic review	HSC (Environmental Sustainability and Health), GCC	DoP, HSC (Bushland and Biodiversity)	Short Term
10c	42	Through the estuary management program, investigate novel actions to reduce carbon emissions	Research		Staff time only		HSC (Estuary Unit), GSC, HNCMA	DECC, HNCMA	Medium Term

Strategy #	Rank	Strategy	Category	Preceding strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Time Frame
		/ aim toward carbon neutrality in undertaking estuary management tasks (eg, planting of trees to offset boat use when sampling, etc)							
10d	25	Develop a set of biological indicators (eg, food chain or structural biota) which will assist in measuring climate change impacts	Research		$30,000	Staff time only for periodic review	DECC	HSC (Estuary Unit), GSC, HNCMA, HSC (Bushland and biodiversity)	Short Term
RISK 11 **Risk of regulated freshwater inflows**									
11a	24	Continue to lobby for reuse of water from STPs, to reduce freshwater demands in catchment	Research		External Consultancy $100000	N/A	DECC, Sydney Water	DECC, NSW Maritime, DoL, DPI Fisheries, HSC (Estuary Unit), GCC	Medium Term
11b	38	Regulate surface and ground water extraction (through licences etc) based upon assessment of required environmental flows.	Planning	11a	External Consultancy $50, 000	Adaptive management and review annually initially at a cost of $45000 per year	DECC, DWE	DEW, NSW Maritime, DoL, DPI Fisheries, DECC	Medium Term
11c	110	Develop and implement a plan of management to maintain sustainable environmental flows as a component of total water cycle management (based upon studies and modelling of sustainable flows).	Planning		Staff time only	Staff time Only	DECC	HSC (Water Catchments), GCC, DPI Fisheries	Long Term
11d	37	Increase the uptake of water and energy reduction devices through greater planning controls, incentives, free water reduction audits for homes/businesses etc	Planning	11a, 11b	Highly variable depending on metering and monitoring choices	Highly variable depending on metering and monitoring choices	DECC	Councils, NSW Maritime, DoL, DPI Fisheries	Medium Term
11e	113	Implement re-use options (such as dual reticulation, drinking water or other system) for treated effluent from STPs and their reticulation systems (eg sewer mining)	Planning		Within existing budgets	Staff time Only	Sydney Water	DECC, GCC, HSC (Town Planning Services)	Long Term
11f	58	Undertake a comprehensive environmental flows investigation for all tributaries to the Lower Hawkesbury. This should include determining groundwater and surface water extraction rates/volumes, contributions from all sources (urban runoff, STPs), and ecological flow requirements.	Capital works		Capital costs high, in the millions, however may be a saving when considered against other water security options	Highly variable, annual infrastructure maintenance costs about 10% capital costs	Sydney Water	Councils, DECC, NSW Maritime, DoL, DPI Fisheries, HNCMA	Medium Term
RISK 12 **Risk of water quality and sediment quality not meeting relevant environmental and human health standards**									
12a	96	Ensure fishing practises and oyster growing practises avoid artificially attracting large numbers of birds into oyster harvest zones	Planning		Staff time only	Staff time only	DPI Fisheries	DECC	Long Term
12b	81	Declare all waterway area in the Lower Hawkesbury as a 'no discharge zone'	Planning		Staff time Only (although such regulations would need to be supported by compliance activities and infrastructure such as pumpout facilities)	Staff time only	DECC	NSW Maritime Authority	Long Term
12c	83	Extend regulations for holding tanks to both grey and black water for recreational and commercial vessels.	Planning	11d	Staff time Only (although such regulations would need to be supported by compliance activities and infrastructure such	Staff time only	DECC	NSW Maritime Authority	Long Term

Strategy #	Rank	Strategy	Category	Preceding strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Time Frame
					as pumpout facilities)				
12d	**120**	Lobby State government to increase deterrents for effluent discharges and other forms of pollution from vessels using the waterways.	Planning		Staff time only	Staff time only	HSC (Estuary Unit), GCC	DECC	Long Term
12e	**108**	Prepare and implement a strategy for pumpouts across the Lower Hawkesbury Estuary (eg public use of commercial pumpouts, installation of additional public pumpouts etc)	Planning		Strategy preparation by External Consultancy – approximately $60, 000. Implementation will cost at least one million dollars	Ongoing costs of hundreds of thousands per year	NSW Maritime	HSC (Estuary Unit), GCC	Long Term
12f	**78**	Provide incentives to install oil absorbant devices within bilge water holding tanks for all moored and berthed vessels.	Planning		Indicative cost $5000		NSW Maritime	HSC (Estuary Unit), GCC, HNCMA	Medium Term
12g	**112**	Review Emergency Spill Management Action Plans to ensure they are adequate to protect estuarine assets for all LGAs with Lower Hawkesbury waterway	Planning		External Consultancy of $15000	Staff time only	DECC	HSC, GCC, NSW Maritime Authority	Long Term
12h	**98**	Provide incentives (eg grants or services) for a routine pumpout service to riverside settlements	Planning		Indicative cost of $20000		DECC	HSC, GCC, NSW Maritime Authority	Long Term
12i	**127**	Develop a sewage management strategy for riverside settlements as part of the 'Sanitary Surveys' undertaken by NSW Food Authority with consideration given to eliminating sewage leaching to the estuary.	Planning		Strategy developed by external consultancy approximately $50 000	N/A	NSW Food Authority	DECC, HSC (Environmental Sustainability and Health), GCC	Long Term
12j	**139**	Encourage Sydney Water to consider an assessment of alternatives for management of sewage at Brooklyn, including effluent reuse.	Planning		Staff time only	Staff time only	HSC (Estuary Unit), GCC	DECC, NSW DPI	Long Term
12k	**131**	Ensure use of correct procedures for advising of algal blooms and marine pests (caulerpa, stingers etc) occurrence (such as through RACC)	Compliance		Staff time only	Staff time only	HSC (Estuary Unit), GCC, Sydney Water	DECC, DPI Fisheries, NSW Maritime Authority	Long Term
12l	**124**	Ensure compliance of correct waste disposal from Marinas and vessels	Compliance		Staff time only	Staff time only	NSW Maritime Authority	HSC (Environmental Sustainability and Health), GCC	Long Term
12m	**32**	Ensure all boating facilities (marinas, slipways, private boat sheds, ferries, boat ramps etc) have containment areas for boat operation and maintenance (especially anti-foul paints, fuel storage tanks) and use best practise methods for mitigating environmental impacts. Perform follow-up audits to ensure recommendations are completed.	Compliance		Staff time only	Staff time Only	HSC(Environmental Sustainability and Health), GCC	HSC, GCC, DECC	Medium Term
12n	**125**	All Councils within the Lower Hawkesbury are to conduct Emergency spill management as per relevant Emergency Action Plan.	Compliance		Staff time only	Staff time only	HSC(Environmental Sustainability and Health), GCC		Long Term
12o	**65**	Ensure all onsite septic systems throughout the catchment are audited for efficient operation and recommendations of audits enacted. Enforce penalties where correct operation and outcomes of audit are not enacted.	Compliance		Staff time only	Staff time only	HSC(Environmental Sustainability and Health), GCC	HSC (Estuary Unit)	Medium Term
12p	**132**	Sydney Water to continue to inform Councils and appropriate estuary users when STP's begin bypassing.	Compliance		Staff time only	Staff time only	Sydney Water	HSC(Estuary Unit), GCC	Long Term
12q	**133**	Implement a program to audit private sewer connections (such as NSW Government's former "pipechecks" program) and ensure audit recommendations are enacted	Compliance		Staff time only	Staff time only	Sydney Water	HSC(Estuary Unit), GCC	Long Term
12r	**140**	Reconsider licence conditions upon EPA licence renewals to reduce load of pollutant discharged	Compliance		Staff time only	Staff time only	DECC	HSC(Estuary Unit), GCC	Long Term
12s	**115**	Ensure compliance with greywater reuse policy (i.e. DWE and Council Policies)	Compliance		Staff time only	Staff time only	HSC(Environmental Sustainability and Health), GCC	DWE, DECC	Long Term
12t	**104**	Audit commercial and industrial areas with regard to mitigating impacts on estuarine assets.	Compliance		External consultancy of $20, 000	Ongoing audit and advice approximately	HSC(Environmental Sustainability and	DECC	Long Term

Strategy #	Rank	Strategy	Category	Preceding strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Time Frame
						$20 000 biannually	Health), GCC		
12u	**142**	Promote the use of oil absorbent devices for the removal of fuels and oils from bilge water	Education		Staff time only	Staff time only	HSC(Environmental Sustainability and Health), GCC	NSW Maritime Authority. DECC	Long Term
12v	**62**	Provide information to residents to improve management of on-site sewage disposal, particularly in proximity to oyster harvesting areas, and on alternative disposal methods.	Education	12i, 12o, 12q	Completed using staff time within existing education programs, additional printing and resource of approximately $15, 000	Staff time only	HSC(Environmental Sustainability and Health), GCC	DECC, NSW DPI	Medium Term
12w	**41**	Apply best practise stormwater management and asset management for stormwater infrastructure through preparation, implementation and regular review of stormwater management plans across the Lower Hawkesbury catchment.	Capital works	12b (in parallel to 12x)	Preparation of stormwater management plan will cost approximately $200, 000. Implementation costs will be in the millions	Ongoing costs of hundreds of thousands of dollars per year as implementation, evaluation and monitoring continue	HSC(Works and Estuary Unit), GCC	DECC	Medium Term
12x	**82**	Consider end of pipe treatment for all direct stormwater outlets to the estuary	Capital works	in parallel to 12w	End of pipe solutions such as bioretention measures for urban areas within the catchment would cost millions of dollars	Maintenance costs are high a regular checking and cleaning are required in order for end of pipe solutions to be successful	HSC(Catchment Remediation), GCC	DECC	Medium Term
12y	**127**	Eliminate all sources of sewer overflows (including pumping stations, mushrooms, sewer chokes) in both dry and wet weather throughout the Lower Hawkesbury catchment.	Capital works	12bb	Completely illuminating overflows for all possible storm conditions is not possible. Increasing the design storm for infrastructure is likely to cost millions of dollars.	Ongoing maintenance costs approximately 5% of capital costs per year	Sydney Water	HSC, GSC	Long Term
12z	**128**	Continue to upgrade STP effluent quality to minimise pollutant loads and enable greater re-use	Capital works				Sydney Water	DECC	Long Term
12aa	**117**	Provide education to increase community acceptance of recycled water from STPs, and collection and re-use of stormwater, etc as per the Sustainable Total Water Cycle Management strategy	Education	12w, 11c	Completed using staff time within existing education programs, additional printing and resource of approximately $15, 001	Staff time only	HSC(Estuary Unit), GCC	Sydney Water	Long Term
12bb	**129**	Investigate increasing wet weather capacity of STPs in catchment to ensure no bypassing during wet weather	Capital works		Investigations approximately $40, 000, capital works at least hundreds of thousands		Sydney Water	DWE	Long Term
12cc	**116**	Install appropriate sewage disposal at public facilities located near waterways in the parks, reserves and foreshore recreational areas	Capital works		Improved onsite disposal upgrades for public toilets in parks etc will cost approximately $20 000 each, where possible connection to centralised system may be achieved for less.	Ongoing maintenance costs of approximately $2000 per year	HSC(Parks), GCC	DoL	Long Term
12dd	**73**	Investigate, and implement as appropriate, solid waste, green waste and recyclables collection for Riverside Settlements	Capital works		Investigations may be undertaken by existing staff time or by consultancy for approximately $10,		HSC(Waste Management), GCC	DECC	Medium Term

Strategy #	Rank	Strategy	Category	Preceding strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Time Frame
					000. Implementation costs will vary according to methods but are likely				
12ee	**111**	Ensure that all state-owned road and rail infrastructure within the catchment has adequate stormwater management for water quality and flows	Capital works	12w	Implementation of improved stormwater management in accordance with plan described in 12.28 is likely to cost hundreds of thousands of dollars	Ongoing costs are likely to be about 5% capital costs	RailCorp, Roads and Traffic Authority	HSC(Estuary Unit), GCC	Long Term
12ff	**130**	Ensure use of low residue herbicides and adopt practices to minimise input to the waterway	Capital works		Cost of adopting this policy of council and state govt owned lands minimal. Implementation of education strategies for households to be incorporated into existing programs.		HSC (Bushland and Biodiversity), GSC	DECC, DoL	Long Term
12gg	**143**	Improve management of leachate and runoff from waste disposal sites	Capital works	12w	Investigations and assessments completed by external consultants and likely to cost between $50, 000 and $150, 000. Implementation of improved management practices and infrastructure		HSC(Catchment remediation), GCC	DECC	Long Term
12hh	**13**	Undertake remote and real time environmental monitoring for the Lower Hawkesbury (e.g. chlorophyll-a probes, wind speed probes, salinity, flow meters, satellite data), and make data available to the public.	Research		Data collection and management set up may cost up to $300000	Annual management costs	HSC(Estuary Unit), GCC	DECC	Immediate
12ii	**68**	Investigate opportunities for allowing flushing under the causeway at Sandbrook Inlet	Research		$50,000		HSC(Estuary Unit), GCC	DECC	Medium Term
12jj	**69**	Determine sources of sediment contamination and impacts of contaminants on estuarine health, through sediment and water quality testing across the Lower Hawkesbury	Research		80,000		HSC(Estuary Unit), GCC	DECC	Medium Term
12kk	**54**	Establish an ongoing sediment monitoring program for the estuary concentrating on areas of known heavy metal contamination or boat maintenance services.	Research		$100,000		HSC(Estuary Unit), GCC	DECC	Medium Term
12ll	**126**	Complete mapping of stormwater drainage system in all areas of the Lower Hawkesbury catchment and ensure maps are regularly updated	Research		$80,000		HSC(Works), GCC	DECC	Long Term
RISK 13 **Risk of introduced pests, weeds and disease**									
13a	**27**	Enhance weed management programs across catchment, particularly in estuarine vegetation	Capital works		Highly variable across the catchment – where possible partnerships with landholders and volunteer groups should be utilised	Ongoing maintenance is crucial for weed eradication and watering prior to establishment.	DPI Fisheries, HNCMA	HSC(Estuary Unit), GCC, HSC (Bushland and biodiversity)	Short Term
13b	**28**	Enhance existing pest eradication programs, particularly in estuarine habitats	Capital works		Development of a pest management strategy approximately $30, 000. Implementation	Highly variable	DPI Fisheries	HNCMA, DECC, HSC (Estuary Unit), GCC, HSC (Bushland and	Short Term

Strategy #	Rank	Strategy	Category	Preceding strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Time Frame
					will be variable but may be included in existing staff time			biodiversity)	
RISK 14 **Risk of excessive sedimentation (human induced)**									
14a	**93**	Investigate the potential for increased sedimentation as a result of bushfires and prescribed burning	Research		External consultancy $15, 000	N/A	HSC(Bushland and Biodiversity), GCC	HNCMA, DECC	Long Term
14b	**107**	Determine sedimentation rates for the estuary as required.	Research	12j2, 14a	External Consultancy approximately $100, 000	N/A	HSC(Estuary Unit), GCC	HNCMA, DECC	Long Term
14c	**44**	Prepare and implement creek rehabilitation plans to restore and maintain native vegetation in the riparian zone	Capital/On-ground works	2b	Preparation of creek rehabilitation plans approximately $30 000 per creek. Implementation costs will vary between creeks, indicative range between $40, 000 - $200, 000 per creek	approximately 10% capital costs	HSC(Bushland and Biodiversity), GCC	HNCMA	Medium Term
RISK 15 **Risk of residents and users lacking passion, awareness and appreciation of the estuary**									
15a	**23**	Consider a "Residents Pack" which outlines the estuary values, regional significance, ways to preserve such values, and includes existing brochures (from Councils, DPI Fisheries, NSW Maritime, NPWS etc) on stormwater, endemic plantings, bushcare, boating maps, seagrass maps, aquatic weeds, etc	Education		Mostly staff time compiling existing brochures. Additional printing and delivery costs of approximately $20 000.	Printing and delivery allow $10, 000 per year	HSC(Estuary Unit), GCC	GSC, HNCMA, DECC, Maritime NSW, DPI Fisheries	Medium Term
15b	**21**	Encourage vigilance in reporting non compliance with regulations and environmental conditions/degradation (eg, sediment erosion controls, OSSMs, vegetation removal/destruction, stormwater control and maintenance, recreational activities etc) and pollution incidents (e.g. algal blooms, oils spills, chemical spills etc) to appropriate authorities (e.g., "river hood watch program")	Education	15a	Staff time only – possibly set up 1800 number and data base for recording incidents which will cost approximately $10, 000. To be answered by existing reception staff	Staff time only	HSC(Estuary Unit), GCC	GSC, HNCMA, DECC, Maritime NSW, DPI Fisheries	Immediate
15c	**75**	Encourage local residents to participate in conservation and bush regeneration schemes	Education	14c	Staff time only	Staff time only	HSC(Bushland and Biodiversity), GCC	HNCMA, DECC	Medium Term
15d	**36**	Educate recreational users/general visitors about estuary values and the estuarine system, recreational impacts, and actions they may take to reduce impacts on priority areas (seagrass, harvest areas, recreational swimming) in the estuary (e.g. signage, boating stickers, brochures etc)	Education	15a	Staff time only	Staff time only	HSC(Estuary Unit), GCC	GSC, HNCMA, DECC, Maritime NSW, DPI Fisheries	Medium Term
15e	**85**	Provide a general understanding and appreciation of Aboriginal culture and occupation of the Lower Hawkesbury, within the parks, reserves and other foreshore recreational areas, with appropriate brochures, signage and interpretation programs.	Education		Up to $20000		DECC	HSC(Bushland and Biodiversity), GCC, HNCMA	Medium Term
15f	**71**	Participate in community events to highlight unique values of estuary and promote estuary management program	Education		Staff time only	Staff time only	HSC(Estuary Unit), GCC	HNCMA, DECC, Maritime NSW, DPI Fisheries	Medium Term
15g	**135**	Provide information about the estuary on the Internet through all local councils' home pages, and promote the	Education		Staff time only	Staff time only	HSC(Estuary Unit), GCC		Long Term

Strategy #	Rank	Strategy	Category	Preceding strategies	Indicative capital cost	Indicative on-going cost	Lead Responsibility	Support Responsibility	Time Frame
		estuaries website (www.estuary.hornsby.nsw.gov.au) and links between Councils websites for Lower Hawkesbury.							
15h	**88**	Develop a schools estuarine education program, which includes a resource kit and practical experience in bush regeneration work, water quality monitoring and other tasks	Education	15a	Staff time only (utilising existing brochures and resources)	Staff time only	DECC, HSC (Estuary Unit)	HSC, GCC, HNCMA, DPI Fisheries	Medium Term
15i	**89**	Investigate program of guided tours to promote education about the estuary	Education	15a	Establishment costs of $20 000	Staff time and existing resources	DECC, HSC (Estuary Unit)	HSC, GCC, HNCMA, DPI Fisheries	Medium Term
15j	**86**	Provide interpretive / heritage signage at strategic locations to explain key features, waterways and estuary significance	Capital/On-ground works	15e	$40,000		HSC(Estuary Unit), GCC	HNCMA, DECC, Maritime NSW, DPI Fisheries	Medium Term
					RISK 16 **Risk of insufficient research**				
16a	**61**	Establish MOU's (Memorandums of Understanding) between Council and universities and other research organisations to encourage research into the estuary	Planning		Staff time only	Staff time only	HSC(Estuary Unit), GCC	Universities, HNCMA, DPI Fisheries, DECC	Medium Term
16b	**70**	Develop a catchment and estuarine model to illustrate the interactions between the estuary and catchment influences	Research		$200,000	Staff time only	HSC(Estuary Unit), GCC	DECC, HNCMA	Short Term
16c	**56**	Undertake periodic surveys of the types, numbers and locations of various recreational activities on all foreshores and waterways of the Lower Hawkesbury.	Research		Mostly staff time, additional printing costs etc of approximately $10 000	Staff time only	HSC(Estuary Unit), GCC	NSW Tourism, DECC, DPI Fisheries	Medium Term
16d	**114**	Undertake periodic survey of recreational and commercial fishers to determine volumes, species and locations of fish caught across the entire Hawkesbury Estuary	Research		Mostly staff time, additional printing costs etc of approximately $10 000	Staff time only	DPI Fisheries	Commercial fishers, DECC, HSC (Estuary Unit)	Long Term
16e	**66**	Undertake research into the impact of catch numbers, trawl methods (such as otter boards) and other influences on the long term sustainability of all fish species (target and non-target) in the Hawkesbury Estuary	Research		Undertaken by existing DPI Fisheries Staff or External consultancy of approximately $100000	Staff time only	DPI Fisheries	Commercial fishers, DECC HSC (Estuary Unit)	Medium Term
16f	**43**	Undertake a study to identify locations of bank erosion in the estuary and determine the causes of such erosion (e.g., wind waves, boat wake) and remediate as required	Research	1d	External consultancy of approximately $150000	Staff time only	HSC(Estuary Unit), GCC	DECC, Maritime NSW, HNCMA	Medium Term
16g	**55**	Determine physical processes (hydrodynamics) of the estuary using in stream flow gauges, bathymetric survey etc	Research		External consultancy of approximately $150001	Staff time only	HSC(Estuary Unit), GCC	DECC, Maritime NSW	Medium Term

** Strategy 3b "Promote the use of public transport to recreational facilities" was removed at the draft review stage as it was considered inappropriate for an Estuary Management Plan*

5 IMPLEMENTING THE PLAN

This section outlines the overall strategy for implementing the Plan as part of an adaptive management approach.

5.1 Implementation of "Quick Win" Strategies

The "Quick Win" strategies are those that can be implemented without significant further investigation required, and have a high environmental benefit to economic cost ratio. The identification of these strategies will allow the momentum that has been built through the development of the Plan to be harnessed and continued into the implementation stage. Implementation of the Plan will be greatly dependent upon the enthusiasm and participation of relevant government and community stakeholders. Achieving implementation of the quick win strategies early on is expected to maintain and increase support and interest among stakeholders.

The identified Quick Win Strategies are:

- **1g** Ensure planning instruments incorporate best practice: including sediment, erosion and stormwater controls (eg construction controls plans and WSUD); use of water reduction devices and maximum permeable surfaces, landscaped area calculations: protection of native vegetation; sewage management (eg low risk OSSMs); restriction of landscaping and gardens to endemic species; energy efficient design and ESD.
- **9a** Liaise with relevant state agencies to ensure integration of EMP actions into their relevant management plans/strategy activities (eg HNCMA's Catchment Action Plan, DPI Fisheries Sustainable Oyster Aquaculture Strategy etc)
- **9b** Submit the EMP to the appropriate Minister for gazettal by the NSW Government
- **9c** Establish a Lower Hawkesbury estuary management committee to be facilitated by HNCMA, which incorporates Pittwater, Gosford and Hornsby Councils for a coordinated approach to estuary management

5.2 Council Management Plan

The Local Government Act 1993 (LG Act) defines the powers, duties and functions of all local councils in New South Wales. Under sections 402-406 LG Act, a council must prepare and adopt an overall 'Council Management Plan' (CMP).

Council Management Plans relevant to the Lower Hawkesbury Estuary are:

- HSC, 2005, "Hornsby Shire Council Management Plan 2005/06-2007/08",
- GSC, (undated) City Management Plan 2007/08 – 2009/10
- WSC, Warringah Management Plan 2007/2010

A CMP is required to:

- list the 'principal activities' that are proposed to be undertaken within at least the following three years (for example, coastal zone management projects);

- specify objectives and performance targets for each principal activity (for example, estuary management objectives and targets);
- outline the means by which a council intends to achieve these targets;
- describe the manner in which a council ‘proposes to assess its performance in respect of each of its principal activities’;
- provide statements on matters prescribed by regulation, which relate to stormwater, coasts and estuaries and waste (clause 28(1) Local Government (General) Regulation 1999 (LGG Reg));
- include relevant details on any proposed principal activity to ‘properly manage, develop, protect, restore, enhance and conserve the environment in a manner that is consistent with and promotes the principles of ecologically sustainable development’ (section 403(2) LG Act; these are referred to as ‘environmental protection activities’ in clause 28(2) LGG Reg);
- observe requirements for public consultation and involvement regarding ‘environmental protection activities’ (clause 29(1) LGG Reg); and
- reflect the application of the principles of ecologically sustainable development in relation to that part of the CMP dealing with ‘environmental protection activities’ (clause 29(1)(a) LGG Reg).

A council must consider its SoE report when preparing that part of a draft CMP dealing with ‘environmental protection activities’ (clause 29(1)(b) LGG Reg). One of the principal activities that a CMP may address is activities made in response to priorities identified in the relevant SoE report (section 403(2) LG Act). These provisions provide important links between the CMP and SoE reporting.

5.3 Collaborative Agreements

It is intended that this LHEMP will be submitted to the appropriate Minister for Gazettal. However, it may also be appropriate to prepare a Memorandum of Understating (MoU) between the many stakeholder groups responsible for the implementation of the Plan.

A Memorandum of Understanding (MoU) may be used to demonstrate agreement on the management objectives and strategies and commitment to implementation of the LHEMP. A Draft MoU of this nature was prepared for the Brooklyn EMP (WBM 2006). The signatories of this MoU would agree to implement the LHEMP according to the implementation tables contained within the document, to the best of their abilities.

The MoU would not be intended to create legally binding financial and resource commitments, nor would it intend to be inconsistent with, or limit the powers of, the legislation that the signatory parties operate under.

Example terms of a MoU (modified from the Brooklyn Estuary Management Plan WBM 2006) include:

- The parties agree with the motivations and the process for the development of the Lower Hawkesbury Estuary Management Plan;
- The parties agree with the management issues identified for the estuary, and concur with prioritisation of the defined objectives, which is used to help direct future management works and actions;

- The parties accept the outcomes of the risk assessment process, which have been used to develop a short-list of preferred strategic management actions;
- The parties accept the responsibilities for implementation of the strategic management actions, as outlined within the Implementation Schedules (refer to Table 4-7 and Table 4-8);
- The parties agree to actively implement the strategies, to the best of their financial and resource capabilities, in accordance with assigned responsibilities within the Lower Hawkesbury Estuary Management Plan;
- The parties agree to review the Estuary Management Plan on a periodic basis, as nominated in the Plan, and adopt specified contingency actions if implementation of the Plan is delayed or ineffective; and
- The parties agree to share data and information that is of relevance for informing estuary management decisions and to aid and monitor the implementation of the Plan.

For the implementation of the Lower Hawkesbury Estuary Management Plan agreement for the implementation of the MoU will be sought between government, commercial and community stakeholders.

5.4 Funding Arrangements

Implementation costs for the Estuary Management Plan, for just the 32 short-listed strategies, are in the order of $2.2 million, while the cost of implementing all 148 strategies is approximately $8.9 million. A breakdown of these costs into the different strategy types is provided in Table 5-1.

Table 5-1 Total Cost of Estuary Management Plan Implementation

	Planning	Research	Education	Compliance	Capital Works	*Total*
Short-listed Strategies	$50,000	$1,425,000	$30,000	$0	$730,000	*$2,235,000*
All Strategies	$675,000	$3,280,000	$260,000	$120,000	$4,565,000	*$8,900,000*

Funding of the implementation of the Estuary Management Plan is expected to be sourced through a variety of mechanisms. The availability of funds will depend on government programs, the identification of these programs and subsequent preparation and success of grant applications. Securing grants will be an important component of plan implementation.

5.5 Estuary Management Program

A large contribution of the required funds may be sourced from the NSW Estuary Management Program. The program provides dollar for dollar funding for strategies included in an adopted Estuary Management Plan prepared according to the NSW Estuary Management Manual (eg. This Plan).

Hawkesbury Nepean Catchment Management Authority

Funding may be available through the Hawkesbury Nepean Catchment Management Authority (HNCMA). In the past, the HNCMA has submitted a Regional Investment Strategy to the federal government based on the targets from the Catchment Action Plan. Money is then allocated to the HNCMA depending on how targets align with government priorities. The HNCMA has indicated that an ongoing relationship with local government is a high priority (Ruth Williams, HNCMA, pers. comm..)

Catchment Remediation Program

Funding may also be available through local government. Hornsby Council has a catchment remediation program that utilises environmental levy money to fund capital works within the catchment. This program may apply to stormwater works, leachate mitigation and creek rehabilitation within estuarine areas.

Recreational Fishing Trusts

All revenue raised by the NSW recreational fishing fee is placed into two Trust Funds dedicated to improving recreational fishing:

- the Recreational Fishing (Freshwater) Trust Fund; and
- the Recreational Fishing (Saltwater) Trust Fund.

Anyone can apply for funding from the Recreational Fishing Trusts, including fishing clubs and organisations, universities, councils, community groups, individuals and so on. Joint applications are also encouraged.

Grants are determined by The Minister for Primary Industries who receives advice on Trust Fund expenditure from the Advisory Council on Recreational Fishing, which consists of people with expertise in all aspects of recreational fishing. Two sub-committees of the Advisory Council, the Recreational Fishing Saltwater and Freshwater Trust Expenditure Committees assess funding applications and then the Advisory Council makes recommendations for funding priorities to the Minister.

Funding applications must relate to the improvement of recreational fishing. Successful projects are usually funded for one year however funding may be provided for up to a maximum of three years from the initial grant.

Priorities for funding from the Trust Funds include:

- recreational fisheries enhancement;
- angler education, information and training;
- research on popular recreational species;
- recreational fisheries access and facilities; and
- recreational fisheries sustainability.
- maximise the benefits to geographic areas or numbers of recreational fishers;

- leverage off other projects; and
- incorporate matched funding or in-kind contribution by the applicant.

Caring for Our Country

Caring for our Country will commence on 1 July 2008 bringing together delivery of a raft of Commonwealth natural resource management funding programs into an integrated package. The programs consolidated under this program will include the Natural Heritage Trust, the National Landcare Program, the Environmental Stewardship Program, and elements of the Working on Country program. *Caring for Our Country* provides $2.25 billion in funding over five years from 1 July 2008 to June 2013. The program will focus on achieving strategic results and invest in six national priority areas:

1. a national reserve system,
2. biodiversity and natural icons,
3. coastal environments and critical aquatic habitats,
4. sustainable farm practices,
5. natural resource management in remote and northern Australia, and
6. community skills, knowledge and engagement..

Strategies within the Hunter Estuary Management Plan may be able to apply for funding grants in relation to priorities 1 through 4 and priority 6. The program will allow for non-government organisations, regional bodies, Local Government and State, Territory and Australian Government agencies to apply for program funds to help achieve these national priorities.

The first invitations for proposals are expected to be released in September 2008.

5.6 Agency Responsibilities

A number of agencies have responsibility for implementation of the Plan. These agencies were listed in Table 1-1. Each of the management strategies has also been assigned a lead agency, and a number of supporting agencies (as highlighted in Table 4-7 and Appendix E).

5.7 Lower Hawkesbury Estuary Management Committee

Presently, Hornsby Council is co-ordinating estuary management for the lower Hawkesbury Estuary. Future management of the estuary will be co-ordinated by a Lower Hawkesbury Estuary Management Committee. This Committee should include representatives of relevant government agencies, stakeholders and the wider community (as described in the Estuary Management Manual and the Draft Coastal Zone Management Manual).

Terms of reference should be drafted for the Committee. Sample Terms of Reference which have been modified from the Brooklyn Estuary Management Committee are included as Appendix F.

Given the number of stakeholders likely to be represented, it may be desirable to set up a technical subcommittee to facilitate decision making and technical review of investigations and actions.

5.8 Community Involvement

On-going community involvement is crucial to the success of the Plan. Opportunities for community input will include contributions through the Lower Hawkesbury Estuary Management Committee (once established), participation in rehabilitation works and education programs. Changes to behaviours of the wider community are essential to ensure long term sustainability for the estuary. It is hoped that through periodic progress reporting and implementation of the Plan, community understanding and commitment to the estuary will be improved.

5.9 Reporting Mechanisms

The Lower Hawkesbury Estuary Management Plan will be subject to on-going review to ensure continuing validity and relevance. This review process will include annual performance reviews and a detailed review after three years. An additional trigger for review of the Plan will be the release of the anticipated NSW Coastal Zone Management Manual.

The condition, scientific knowledge, planning frameworks and public aspirations specific to the Lower Hawkesbury Estuary are all expected to change with time. It is therefore essential that as these elements change, management decisions are adjusted or modified within an adaptive framework.

To gain a better appreciation for the relative success of the Plan, a series of performance measures can be assessed on a periodic basis. Different types of performance measures are discussed in Section 5.12.

5.10 Plan Review

It is proposed that the Lower Hawkesbury Estuary Management Plan is reviewed on a regular basis, and completely updated within a period of about 3 years. The regular review of the Plan (which may occur annually, for example) is necessary to allow modifications / alterations to the management of the estuaries, on an as-needed basis, within the context of an adaptive management framework.

The periodic Estuary Management Plan reviews should cover the topics described in Table 5-2. This table also outlines who is responsible for conducting the periodic reviews.

It is possible that the NSW Government's Estuary Management Program, under which this Plan has been prepared and will be implemented, may change in the future. A new Coastal Zone Management Manual is currently in preparation, and will combine and replace the existing Estuary Management Manual (1992) and the Coastline Management Manual (1990).

Table 5-2 Framework for future review of the Lower Hawkesbury Estuary Management Plan

Review Period	Review tasks	Responsibility
Annual	• Assess primary, secondary and tertiary performance measures, and determine appropriate contingencies if performance measures do not meet targets • Review funding arrangements and allocations for current and future management strategies • Review resourcing and staffing allocations for current and future management strategies • Provide report on progress of Estuary Management Plan implementation, results of annual review, and any modifications required to the Plan coming out of the review • Present and where possible, interpret any environmental monitoring / research undertaken as part of the EMP • Provide newsletter for posting on Council web sites, disseminated via email and other avenues to community and stakeholder contacts	Estuary Management Committee or appointed external consultant To be coordinated through Council Officers and reported to Councils, relevant stakeholders and government agencies
Upon Release of the NSW Coastal Zone Management Manual	• Assess consistency with manual • Identify opportunities to align more closely with the manual to facilitate gazettal • Update timeframes	Estuary Management Committee or appointed external consultant To be coordinated through Council Officers and reported to Councils, relevant stakeholders and government agencies
3 Yearly *(first review to be completed by end 2011)*	• Review latest information to determine potential changes to the condition or understanding of the Estuary Processes; • Determine changes to community values, issues and aspirations; • Assess the consistency of the plan with contemporary government policies and plans; • Assess the continuing relevance of the values and risks; • Determine the appropriateness of the implementation plan to meet these objectives; • Assess the overall effectiveness of each management strategy implemented to date; • Identify opportunities to integrate the plan across a larger area; • For strategies requiring on-going commitment, assess the value in maintaining implementation of those strategies; • Assess the overall effectiveness of each management strategy implemented to date • Reconsider the management options that were not short-	Estuary Management Committee or appointed external consultant To be coordinated through Council Officers and reported to Councils, relevant stakeholders, government agencies and the general community

Review Period	Review tasks	Responsibility
	listed and included in the original Plan • Update the Estuary Management Plan document to reflect proposed strategies for implementation over the next 3 year period, and seek endorsement by stakeholders, government agencies and the community. • Consider either completely revising the document or simply updating some aspects of the existing EMP	

5.11 Residual Risk

The residual risk is the risk remaining after implementation of risk treatments (i.e. strategies). This parameter can be used for monitoring on-going implementation of strategies.

The spreadsheets created for the risk assessment allows for cumulative calculation of residual risk during the implementation of the Plan. This will be a useful tool to report Plan progress. An example of how residual risk may be plotted for individual risks is shown in Figure 5-1. In this example, the progressive implementation assumes that all short-listed strategies have been implemented, while 100% implementation assumes that each of the original 148 strategies has been implemented. This example also shows the reduction of the risk from intolerable, to tolerable and finally to an acceptable level. Refer to Appendix E for further examples.

5.12 Performance Measures, Targets and Contingencies

The success of the Estuary Management Plan should be gauged through its ability to achieve the designated objectives and targets. The targets are discussed in Section 3.1.3 and relate ultimately to reducing risks to an “acceptable” level.

Performance measures have been specified to help determine how well the Plan has achieved its objectives.

5.12.1 Primary Performance Measures

The first set of performance measures should ascertain whether the strategies are being implemented within the timeframe designated in the Plan. As such, the primary performance measures are simply a *measure of implementation*. A useful tool may be the residual risk, as discussed in Section 5.11.

Organisations responsible for implementation will need to review the Plan carefully and ensure that adequate resources are allocated to the various strategies to ensure that the timeframe for implementation of ten years is achieved.

Clearly, a high degree of co-ordination will be required to manage the successful implementation of all the strategies within the designated timeframe. This co-ordination for implementation of the plan is to be facilitated by the Lower Hawkesbury Estuary Management Committee. .

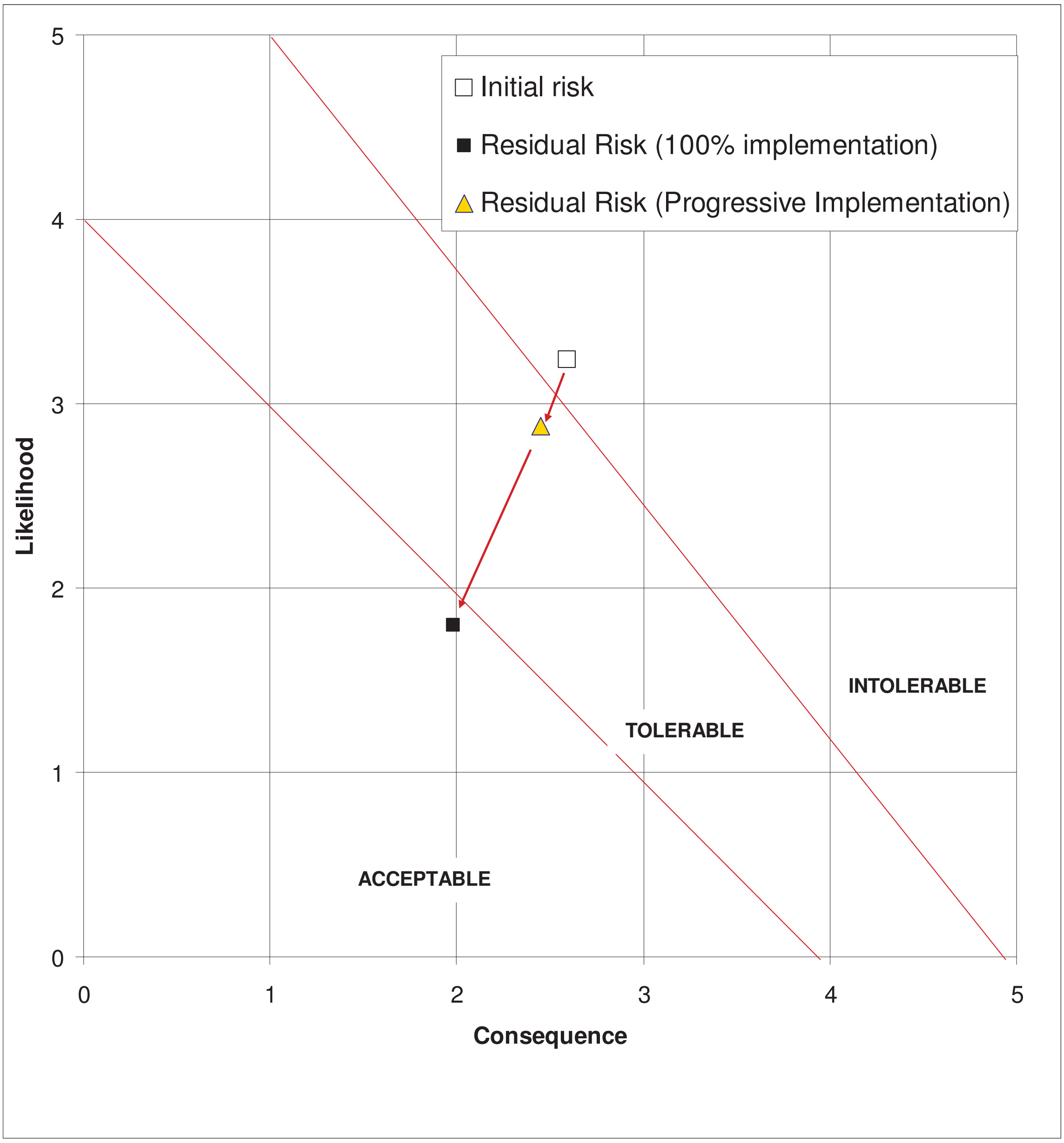


Figure 5-1 Example of residual Risk plotted for Risk 2

Specific questions to be answered are:

- What strategies have been implemented?
- Have all strategies with a nominated timeframe within the review period been implemented?

If it is determined that the strategies are not being implemented to the nominated timeframe then one or both of the following *contingencies* should be adopted:

- Determine the cause for the delay in implementation. If delays are funding based, then seek alternative sources of funding, including a formal request to Councils to increase contributions to the Plan. If delays are resource-based, seek additional assistance from stakeholder agencies and/or consider using an external consultancy to coordinate implementation of the Plan; and

- Modify and update the Estuary Management Plan to reflect a timeframe for implementation that is more achievable. The revised Plan would need to be endorsed by all relevant stakeholders and agencies responsible for implementation.

5.12.2 Secondary Performance Measures

The second set of performance measures relate to *measuring specific outputs* from the individual strategies, as appropriate. In terms of risk management, this aspect refers to the degree to which this strategy reduces the risk. The theoretical percentage of risk reduction achieved by each of the strategies is the product of the likelihood. These measurables define what the specific outcome from each action should be. If these outputs are delivered as defined, then the action (or strategy) is considered to have been successful.

Outputs will vary according to the individual strategy and are identified as the “measurable” with the implementation schedule for the short listed strategies (refer to Table 4-7).

The specific question to be asked here is:

- Of the strategies that have been implemented, has the nominated ‘measurable’ been achieved?

If specific outputs, as defined by the ‘measurables’, are not generated from implementation of the Plan then the following *contingencies* need to be adopted:

- Determine the reason for not producing the specified output. If the reason involves a lack of funding or resources, then similar contingency measures to those described for the primary performance measures should be adopted. If the reason is of a technical nature, then expertise in the area should be consulted to overcome the technical problem. DECC and other government agencies should have the necessary in-house expertise to assist in most cases; and
- Review the appropriateness of the specific output of the management strategy, and if necessary, modify the output described in the Plan to define a more achievable product.

5.12.3 Tertiary Performance Measures

The third set of performance measures are aimed at *measuring the outcomes of the Plan*, and as such relate to the specific management objectives of the Plan (refer Section 3.1.3) and goals of the Plan (as described in Section 1.5.2), and how implementation of the Plan has made a difference to the biophysical and social environments of Lower Hawkesbury Estuary (eg reduction in pollutant loads, improvement in swimming conditions, increase in biodiversity etc). The main mechanism for gauging whether these objectives have been achieved, or not, is monitoring. Therefore, monitoring of various elements of the physical, biological and social environment is an essential component of assessing the overall success of the Estuary Management Plan.

Monitoring itself forms a crucial element of the Estuary Management Plan, as specified in Strategy 8b (Develop and Implement an Estuary Health Monitoring Program).

The specific question to be asked here is:

- Have relevant risks been reduced?
- Are all risks now at a tolerable level?

- Which risks are at an acceptable level?

If, after a reasonable period of time, the specific objectives of the Plan are not being achieved by the strategies being implemented, then the following contingencies should be adopted:

- Carry out a formal review of the implemented management strategies, identifying possible avenues for increasing the effectiveness of the strategy in meeting the Plan objectives;
- Commence implementation of additional management strategies that may assist in meeting Plan objectives (possibly 'fast-track' some longer term strategies as necessary);
- Reconsider the objectives of the Plan to determine if they set impossible targets for future estuary conditions, and adjust the Plan, as necessary. Any such changes to the Plan would need to be endorsed by the stakeholders and relevant government agencies, as well as the public.

5.13 Factors for Success

The success of the Lower Hawkesbury Estuary Management Plan can be improved by the following factors:

- Gazettal by the Minister
- Agreement on the objectives, risks, strategies and implementation schedules by all state and local government agencies, stakeholders and the general community;
- Understanding and acceptance of responsibilities for the implementation of the various aspects of the Plan;
- Commitment by those involved to dedicate appropriate time and resources to achieve the objectives and timeframe of the Plan; and
- Sourcing of appropriate funds, through grants, user contributions, and in-kind commitments from community.

An important aspect is the acceptance and agreement by the local community. Without significant support by the local community, Councils and the other agencies will not receive the pressure to ensure that the long-term sustainable management of Lower Hawkesbury Estuary remains a high priority.

6 GLOSSARY AND ACRONYMS

1% AEP	1% chance of happening in any one year (approximately equivalent to a 100 year average return interval).
2% AEP	2% chance of happening in any one year (approximately equivalent to a 50 year average return interval).
5% AEP	5% chance of happening in any one year (approximately equivalent to a 20 year average return interval).
Acid Sulphate Soils (ASS)	Soils that contain iron sulphides. When the sea level rose and inundated land (see Post-glacial Marine Transgression), sulphate in the seawater mixed with land sediments containing iron oxides and organic matter. The resulting chemical reaction produced iron sulphides. When exposed to air, these sulphides oxidise to produce sulphuric acid.
AEP	Annual Exceedence Probability
Alluvial delta	Sediment washed from the catchment and deposited via flooding / runoff processes in a fan shape
ANZECC guidelines	Guidelines for water and sediment quality, prepared by the Australian and New Zealand Environmental Conservation Council
Benthic fauna	Fauna living on or in the bed of the estuary
Benthic metabolism	Where organic material is broken down within the sediments
Benthic microalgae	Microscopic algae that reside within bed sediments
Benthos	Collection of organisms living on or in the bed of the estuary
Boat wake	Bow wave that are generated by a boat as it moves across a water surface
CAP	Catchment Action Plan (developed by the HNCMA)
Catchment runoff	The flow of water across the ground surface within a catchment following rainfall
CEN	Community Environment Network (a non-government organisation based on the Central Coast)
Chlorophyll-a	A measure of green plant material abundance and biomass in the water and is considered to be a good surrogate measure for phytoplankton productivity within the water.
CL Act 1989	Crown Lands Act
CMA Act 2003	Catchment Management Authorities Act
CV Act 1979	Commercial Vessels Act

DCP	Development Control Plan
DEC	Former NSW Department of Environment and Conservation
DECC	NSW Department of Environment and Climate Change
DG Act 1975	Dangerous Goods Act
Digital Terrain Model (DTM)	Digital representation of a ground surface, based on interpolation between specified survey points.
DIPNR	The former NSW Department of Infrastructure Planning and Natural Resources
DNR	The former Department of Natural Resources (now mostly contained with in DECC with some functions now within DWE)
DOP	Department of planning (formerly a part of DIPNR)
Ebb tide	Outflowing tide (flowing seaward)
Ecological communities	Assemblages of plant and or animal populations
EIS	Environmental Impact statement
El Nino	A weather phenomenon that occurs in the eastern and central equatorial Pacific Ocean. During an El Niño, winds weaken and sea temperatures become warmer (see also La Nina)
EMP	Estuary Management Plan
EMS	Estuary Management Study
Environmental Flows	Fresh water flow that is maintained (or not allowed to be used for other, typically anthropogenic, purposes) solely for environmental reasons, to maintain the health and biodiversity of a particular water-related entity, such as an estuary (Peirson et al 2002)
EPA	NSW Environment Protection Authority (now included in DECC)
EP & A Act 1979	Environmental Planning and Assessment Act
EPI	Environmental Planning Instrument (includes LEP, REP and SEPP)
Epiphytic algae	Algae that is attached to another plant (typically seagrass) which it depends for mechanical support but not for nutrients
EPS	Estuary Processes Study
ESD	Ecologically Sustainable Development
Eutrophic	Water that is characterized by large nutrient concentrations and high productivity (ie algae). (see also oligotrophic)
Fetch	Horizontal distance over which a wind blows in generating waves

Flood tide	Incoming tide (flowing landward)
FM Act 1994	Fisheries Management Act
GSC	Gosford City Council
Half tide level	The average water level over the whole tidal cycle (half way between high and low tides)
HNCMA	Hawkesbury Nepean Catchment Management Authority
HHW(SS)	High High Water (solstice springs) – highest level that tides reach (during solstice [king] tides)
Holocene	Geological age relating to approximately the last 10,000 years
HRC	Healthy Rivers Commission (ceased to exist in 2004)
HSC	Hornsby Shire Council
Hydrodynamics	The movement of water
Hydrosurvey	Survey of the underwater surface of a waterway
ISLW	Indian Springs Low Water – lowest level that tides reach
ISLW	Indian Spring Low Water
Isopac	A geographic measure of the difference between two digital terrain models
ISQG	Interim Sediment Quality Guidelines – see ANZECC
La Nina	A weather phenomenon that involves unusually cold ocean temperatures in the equatorial Pacific Ocean (see also El Nino).
LEP	Local Environmental Plan
LGA	Local Government Area
LG Act 1993	Local Government Act
Longshore transport	The movement of sand parallel to the coast within the active wave zone. Also called alongshore transport as it is move along the shoreline.
Macroalgae	Marine algae visible to the naked eye
Marine sand	Sands derived from the ocean (typical of beach sand)
MHL	Manly Hydraulics Laboratory
MHW	Mean High Water (averaging both Spring and Neap tides)
MHWM	Mean High Water Mark
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
Microalgae	Marine algae that is not visible to the naked eye (requires

	microscopic identification)
MLW	Mean Low Water (averaging both Spring and Neap tides)
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MS Act 1935	Maritime Services Act
Ms Act 1998	Marine Safety Act
Nav. Act 1901	Navigation Act
NHT	National Heritage Trust (Money available for Environmental projects from the partial sale of Telstra)
NPWS	NSW National Parks and Wildlife Service (now included in DECC)
NP&W Act 1974	National Parks and Wildlife Act
Nutrients	An element or simple compound necessary for the health and survival of an organism. Mostly refers to Carbon, Phosphorus, and Nitrogen.
OSSM	On-site Sewage Management
PC&WM Act 1995	Ports Corp and Waterways Management Act
PEO Act 1997	Protection of the Environment Operations Act
Photosynthesis	The conversion of sunlight to energy by plants (including algae) producing oxygen as a by product
POM	Plan of Management (within this report the abbreviation specifically refers to a POM prepared under the National Parks and Wildlife Act, 1974)
Propagule	A part of a vegetative body capable of independent growth if detached from the parent (eg seeds, spores)
REP	Regional Environmental Plan
R&FI Act 1948	Rivers and Foreshores Improvement Act
Riparian vegetation	Vegetation that grows in close proximity to a waterway.
Salinity	Measure of the amount of dissolved salts within water
Saltmarsh	An area that is colonised by salt-adapted (‘halophytic’) plants
SEPP	State Environmental Planning Policy
SREP	Sydney Regional Environmental Plan
STP	Sewage Treatment Plant
Suspended load	Transportation of sediment whereby the sediment particle is entrained within the water column and is moved with the water

	flow (see also bed load)
STWCMS	Sydney Total Water Cycle Management Strategy
Tidal distortion	Distinct difference in tidal characteristics between flood tide and ebb tide cycles
Tidal prism	The volume of water that is conveyed during a tide. Can be measured at any point within the estuary as the total volume passing between low water slack and high water slack
TN	Total Nitrogen
TP	Total Phosphorus
TSC Act 1995	Threatened Species Conservation Act
WM Act 2000	Water Management Act
WSUD	Water sensitive urban design

7 REFERENCES

ACUN, 2003, "Biological Monitoring Program for Berowra Creek Estuary: Preliminary Study and Design. " ACU National

Bourges S, Carpenter M, Coade G, Scanes P, Koop K, 1998, "Oxygen and Nutrients Fluxes Quantified under Experimental Conditions on Sediment from Deep and Shallow Sites in Berowra Creek", Environment Protection Authority

Breen D A, Avery R P, Otway N M, 2005, "Broadscale Biodiversity Assessment of the Hawkesbury Shelf Marine Bioregion Final Report", for the NSW Marine Parks Authority

Chapman M G, Underwood A J, 2004, "Biological Monitoring of Macrofauna in Mangroves in Berowra Creek", Centre for Research on Ecological Impacts of Coastal Cities (EICC), University of Sydney

Chapman M G, Underwood A J, 2005, "Biological Monitoring of Macrofauna in Artificial Units of Habitat on Rocky Intertidal Shores in Berowra Creek", Centre for Research on Ecological Impacts of Coastal Cities (EICC), University of Sydney

CSIRO 2007 "Climate Change in the Hawkesbury Nepean Catchment" Prepared for the NSW Government by the CSIRO.

Daniell, K.A. 2007a *Summary Report: Community Workshop 1 for the Lower Hawkesbury Estuary Management Plan*. Available as Appendix A in: BMT WBM (2007) Lower Hawkesbury Estuary Synthesis Report, prepared for the Hornsby Shire Council and BMT WBM, NSW, Australia.

Daniell, K.A. 2007b *Summary Report: Stakeholder Workshops 2 & 3 for the Lower Hawkesbury Estuary Management Plan*, June 2007. Report prepared for the Hornsby Shire Council and BMT WBM, NSW, Australia.

DLWC, 1997, "Berowra Catchment Economic Scoping Study", Economics Unit, Urban Water, Department of Land and Water Conservation

DP, 2005, "Representations Report for the Environmental Impact Statement for the Brooklyn and Dangar Island Sewerage Scheme", (Department of Planning)

DPI Fisheries, 2006, "NSW Oyster Industry Sustainable Aquaculture Strategy – Final Report", NSW Department of Primary Industries

Ecology Lab, 1998, "Berowra Creek Estuary Processes Study Aquatic Ecological Investigations Final Report", The Ecology Lab Pty Ltd

HNCMA, 2005, "Hawkesbury-Nepean Draft Catchment Action Plan 2006-2015", Hawkesbury Nepean Catchment Management Authority

HRC, 2003, "Independent Review of the Relationship Between Healthy Oysters and Healthy Rivers Final Report", NSW Healthy Rivers Commission

HSC – Hornsby Shire Council (2006) *Brooklyn Estuary Management Study*. Online [URL]:http://www.hornsby.nsw.gov.au/uploads/documents/2006_Brooklyn_Estuary_Management_Study.pdf

HSC – Hornsby Shire Council) (2002) *Berowra Creek Estuary Management Study and Management Plan*. Online

HSC, 2005, "Hornsby Shire Council Management Plan 2005/06-2007/08", Hornsby Shire Council

Kimmerikong, 2005, "Scoping Study: Hawkesbury-Nepean River Estuary Management Final Report", (Kimmerikong Pty Ltd)

MHL, 2002, "Berowra Creek Chlorophyll Trial", NSW Department of Public Works and Services Manly Hydraulics Laboratory

NPWS, 2002, "Ku-ring-gai Chase National Park and Lion Island, Long Island and Spectacle Island Nature Reserves Plan of Management", NSW Department of Environment and Conservation National Parks and Wildlife Service

NPWS, 2004, "The Old Great North Road", http://www.nationalparks.nsw.gov.au/npws.nsf/Content/The+Old+Great+North+Road

NSW Government (1992) Estuary Management Manual, NSW Government, NSW, Australia.

NSWFA, 2004a, "Sanitary Survey Report for Coba Bay Shellfish Harvesting Area at Berowra Creek", NSW Food Authority New South Wales Shellfish Program

NSWFA, 2004b, "Sanitary Survey Report for Kimmerikong Bay Shellfish Harvesting Area at Berowra Creek", NSW Food Authority New South Wales Shellfish Program

NSWFA, 2004c, "Sanitary Survey Report for Marramarra Creek Shellfish Harvesting Area at Berowra Creek", NSW Food Authority New South Wales Shellfish Program

NSWFA, 2005a, "Coba Bay Harvest Area (Berowra Creek) Management Plan", NSW Food Authority

NSWFA, 2005b, "Kimmerikong Bay Harvest Area (Berowra Creek) Management Plan", NSW Food Authority

NSWFA, 2005c, "Marramarra Creek Harvest Area (Berowra Creek) Management Plan", NSW Food Authority

SJB, 2005, "Hornsby Shire Waterways Review", SJB Planning Pty Ltd

NSW Oyster Industry 2007. Sustainable Aquaculture Industry Strategy

Standards Australia 2004a AS/NZS 4360:2004*, Risk Management.*

Standards Australia 2004b HB 436:2004, *Risk Management Guidelines – Companion Handbook*

Standards Australia 2006 HB 203:2006, *Environmental risk management—Principles and processes.*

SydneyWATER, 2005, “Supplement to the 2000 Environmental Impact Statement for the Brooklyn and Dangar Island Priority Sewerage Program”, Sydney Water Corporation

SydneyWATER, 2006, “Determining Authority’s Report for Brooklyn and Dangar Island Sewerage scheme”, Sydney Water Corporation

Taylor C, Hincks R, 2005, “Economic Evaluation of Lower Hawkesbury River Boat Pump-out Options”, (Roylat Services Pty Ltd and Hincks & Associates Pty Ltd)

The Middle Way, 2005, “The Potential Environmental Impacts of a Substantial Population Growth in the Northern Region of Sydney”, The Middle Way Pty Ltd for the Northern Sydney Regional Organisation of Councils (NSROC)

URS, 2007 “Q27/2006- Sediment and antifoul monitoring program- Final report”

WBM, 2004, “Brooklyn Estuary Management Study and Plan: Review and Consideration of Estuary Processes Information”, WBM Pty Ltd

WBM, 2006a, “Brooklyn Estuary Management Plan”, WBM Pty Ltd

WBM, 2006b, “Brooklyn Estuary Management Study Final Report”, WBM Pty Ltd

Williams R J, Thiebaud I, 2006, “A Monitoring Framework for the Hawkesbury Nepean River”, NSW Department of Primary Industries Cronullla Fisheries Centre

WMA, 2002, “Berowra Creek Estuary Management Study and Management Plan”, Webb, McKeown & Associates Pty Ltd

WRL, 2003, “Brooklyn Estuary Processes Study”, Eds B M Miller, D C van Senden Water Research Laboratory

APPENDIX A: ALL RELEVANT REFERENCES

Priority	Database	Description
1	HSC Reports	1997 Berowra Catchment Economic Scoping Study.pdf
1	HSC Reports	1998 Berowra Creek Estuary Process Sudy Aquatic Ecological Investigations.pdf
1	HSC Reports	1998 Berowra Creek- A Hydrodynamic Investigation.pdf
1	HSC Reports	1998 Oxygen and Nutrients fluxes quantified under experimental conditions on sediment from deep and shallow sites in Berowra Creek.pdf
1	HSC Reports	1998 Sydney regional coastal management strategy.pdf
1	HSC Reports	1998 Sydney Regional Policy and Strategy for Water Qaulity Monitoring.pdf
1	HSC Reports	2002 Berowra Estuary Management Plan.pdf
1	HSC Reports	2003 Brooklyn Estuary Processes Study.pdf
1	HSC Reports	2003 Brooklyn Estuary Processes Study_Appendices Vol 2.pdf
1	HSC Reports	2003 HRC_Review of the oyster industry.pdf
1	HSC Reports	2003_Biological monitoring of Berowra Creek.doc
1	HSC Reports	2004 Coba Bay Sanitary Survey NSW Food Authority.pdf
1	HSC Reports	2004 Estuary Biological Monitoring Report.pdf
1	HSC Reports	2004 Kimmerikong Bay Sanitary Survey NSW Food Authority.pdf
1	HSC Reports	2004 Marramarra Creek Sanitary Survey NSW Food Authority.pdf
1	HSC Reports	2004 Review and consideration of Brooklyn Estuary processes information.pdf
1	HSC Reports	2004_EICC Report Biological Monitoring.pdf
1	HSC Reports	2005 Economic evaluation of Hawkesbury River pumpout options.pdf
1	HSC Reports	2005 Environment Division Education Strategy.pdf
1	HSC Reports	2005 Environment Divisional Education Action Plan.pdf
1	HSC Reports	2005 Hawkesbury Nepean River Estuary Management scoping report.pdf
1	HSC Reports	2005 HCS ManagementPlan2005-2008.pdf
1	HSC Reports	2005 Waterways review.pdf
1	HSC Reports	2005_07 Brooklyn EMS for public exhibition.pdf
1	HSC Reports	2005_07 Environmental Impacts of a substantial population growth in the Northern Region of Sydney_NSROC.pdf
1	HSC Reports	2005_Draft_ Northern Sydney sub-regional planning stategy.pdf
1	HSC Reports	2005_EICC Report Biological Monitoring.pdf
1	HSC Reports	2006 Brooklyn Estuary Management Study.pdf
1	HSC Reports	2006 Hawkesbury Shelf Bioregional Assessment.pdf

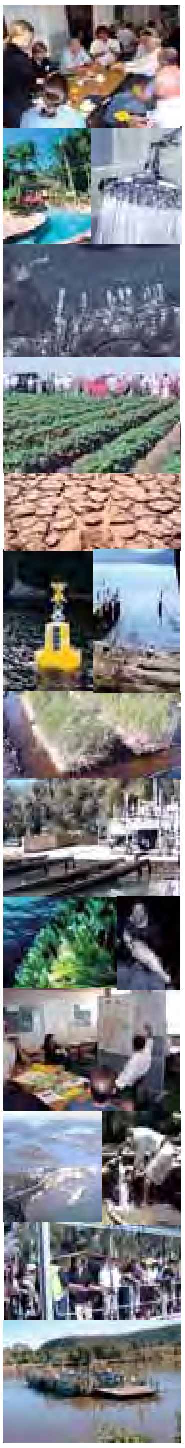
Priority	Database	Description
1	HSC Reports	2006_Brooklyn_Estuary_Management_Plan.pdf
1	HSC Reports	2006_DRAFT_Hawkesbury Nepean Catchment Action Plan.pdf
1	HSC Reports	2006_Monitoring Framework for HN estuarine vegetation.doc
1	Water Resource Info	Australia, C. o. (2006). National Cooperative Approach to Integrated Coastal Zone Management. Framework and Implementation Plan, Natural Resource Management Ministerial Council (NRMMC).
1	Water Resource Info	Meizlish, M. (2004). Coastal Zone Risk Management and Communication An Assessment of Practices and Opportunities in Sydney's Coastal Councils, Sydney Coastal Council Group Inc. and the Institute of Environmental Studies, UNSW, Sydney: 47.
1	Water Resource Info	Industry, N. O. (2006). Sustainable Aquaculture Strategy PUBLIC CONSULTATION DOCUMENT.
1	Water Resource Info	Service, N. N. P. a. W. (2002). KU-RING-GAI CHASE NATIONAL PARK AND LION ISLAND, LONG ISLAND AND SPECTACLE ISLAND NATURE RESERVES PLAN OF MANAGEMENT, NSW National Parks and Wildlife Service: 75.
2	HSC Reports	1993 Water Quality in Berowra Creek Catchment.pdf
2	HSC Reports	1995 Heritage DCP.pdf
2	HSC Reports	1996 Berowra Creek- a review of environmental issues for management.pdf
2	HSC Reports	1996 Coastal State of the environment reporting guidelines for Sydney.pdf
2	HSC Reports	1996 Contaminants in sediments from Calabash Point Berowra Creek.pdf
2	HSC Reports	1996 Water Quality guidelines for sydneys estuarine, fresh and groundwaters.pdf
2	HSC Reports	1998 Berowra Creek – A Review of Environmental Issues for Management.pdf
2	HSC Reports	1998 Berowra Creek Estuary Process study- sediment characteristics and processes.pdf
2	HSC Reports	1998 Berowra Creek Estuary Processes Study Estuarine Water Quality.pdf
2	HSC Reports	1998 Berowra Creek Estuary Processes study review and interpretation of existing data.pdf
2	HSC Reports	1999 Distribution of Seagrass, Mangrove and Saltmarsh in the Cowan Creek Catchment Management Area.pdf
2	HSC Reports	2000 Commercial and recreational fishing survey for Berowra Creek Estuary.pdf
2	HSC Reports	2000 Geomorphic Categorisation of Streams in the Hawkesbury Nepean DLWC.pdf
2	HSC Reports	2002-2003 Annual Water Quality Report.doc
2	HSC Reports	2003-2004 Annual Water Quality Report.doc
2	HSC Reports	2004 Evaluation of the effectiveness of the 2002 upgrades of HHSTP and WHSTP.doc

Priority	Database	Description
2	HSC Reports	2004 Inaugural Estuary annual report.pdf
2	HSC Reports	2005 Estuarine vegetation monitoring (summary).doc
2	HSC Reports	2005 Estuarine vegetation monitoring.pdf
2	HSC Reports	2005 Estuary Biological Monitoring Report.pdf
2	HSC Reports	2005 REF Triploid oyster farming in the Hawkesbury River.pdf
2	HSC Reports	2005 SCCG Groundwater Management Handbook.pdf
2	HSC Reports	2005 West Hornsby STP effluent reuse study.pdf
2	Water Resource Info	Organisation, W. H. “Guidelines for safe recreational water environments, Coastal and fresh waters.”
2	Water Resource Info	2002 K.J.E. Walsh, H. B., J.Church, A.B. Pittock, K. L. McInnes, D.R. Jackett, T.J. McDougall Using sea level rise projections for urban planning in Australia.
2	Water Resource Info	2003 Roberts, D. E. C., M.G. . Ecologically sustainable management of Estuarine foreshores and saltmarsh.
2	Water Resource Info	Gurran, D. N., C. Squires, et al. MEETING THE SEA CHANGE CHALLENGE: Best Practice Models of Local and Regional Planning for Sea Change Communities in Coastal Australia, The University of Sydney: 12.
3	HSC Reports	2000-2001 Annual Water Quality Report.doc
3	HSC Reports	2002_Effect of sewage effluent on oysters within Berowra Creek.doc
3	HSC Reports	2004 Estuary_analysis_final report.doc
3	HSC Reports	2004 Hornsby Integrated Land Use and Transport Strategy.pdf
3	HSC Reports	2004 Hornsby Integrated Land Use and Transport Strategy_site analysis.pdf
3	HSC Reports	2005 Sustainable Water Cycle Management Strategy Vol 1.pdf
3	HSC Reports	2005 Sustainable Water Cycle Management Strategy Vol 2.pdf
3	HSC Reports	2005 Sustainable Water Cycle Management Strategy Vol 3.pdf
3	HSC Reports	2005 Sustainable Water Cycle Management Strategy Vol 4.pdf
3	Water Resource Info	Peter Cottingham, P., C. Walsh, et al. (2003). “Urbanization impacts on stream ecology – from syndrome to cure?”
3	Water Resource Info	Dekker, A., G, J. Anstee, M, et al. (2003). “Seagrass Change Assessment Using Satellite Data for Wallis Lake, NSW.” (Technical report 13/03).
3	Water Resource Info	Fisheries, N. (2004). Fishkills in NSW.
3	Water Resource Info	Fisheries, N. (2004). Protocol for investigating and reporting fishkills.
3	Water Resource Info	Hardiman, S. and B. Pearson (1995). “Heavy metals, TBT and DDT in the Sydney rock oyster (Saccostrea commercialis) sampled from the Hawkesbury River estuary, NSW, Australia.” Marine Pollution Bulletin 30(8): 563-567.
3	Water Resource Info	(2005). “Handbook for sediment quality assessment.”
3	Water Resource Info	Jackson, K. L. a. O., D.M. (1999). Review of Depuration and its role in Shellfish Quality Assurance. FRDC Project No.96/355,

Priority	Database	Description
		NSW Fisheries.
3	Water Resource Info	Standards, A. (2005). “AS 4997-2005 Guidelines for the design of Maritime Structures.”
3	Water Resource Info	Stuart L Simpson, G. E. B., Anthony A Chariton, Jenny L Stauber, J. C. C. Catherine K King, Ross V Hyne, Sharyn A Gale, Anthony C Roach,, et al. (2005). Handbook for Sediment Quality Assessment. Bangor, CSIRO.
3	Water Resource Info	McArthur, L. C. and J. W. Boland (2006). “The economic contribution of seagrass to secondary production in South Australia.” Ecological Modelling 196(1-2): 163-172.
3	Water Resource Info	(2002). The Value of Water: Inquiry into Australia’s management of urban water, Report of the Senate Environment, Communications, Information Technology and the Arts References Committee: 414.
3	Water Resource Info	Harvey, K. (2006). Impact of the invasive rush Juncus acutus on the native rush J. kraussii in coastal saltmarsh: Response of invertebrate species assemblages. Institute for Conservation Biology and School of Biological Sciences, University of Wollongong. Wollongong, University of Wollongong: 131.
4	HSC Reports	2001 Street Sweeping Report.doc
4	HSC Reports	2002_Berowra Estuary Management Plan_Fig1_Catchment Map.pdf
4	HSC Reports	2002_Berowra Estuary Management Plan_Fig2_Estuary Map.pdf
4	HSC Reports	2002_MHL Berowra Creek Chlorophyll Trial.pdf
4	HSC Reports	2003_Hail Report Mangrove Defoliation.doc
4	HSC Reports	2004 Kangaroo Pt Risk Assessment.pdf
4	HSC Reports	2004_Algal species report by microalgal services.doc
4	Water Resource Info	Newham, L. T. H., S. M. Cuddy, et al. (2004). “Informing the design of catchment contaminant cycle modelling- a survey of end-user needs.”
4	Water Resource Info	Prato, T. (2005). “Bayesian adaptive management of ecosystems.” Ecological Modelling 183(2-3): 147-156.
4	Water Resource Info	Garcia-Quijano, J. F. and A. P. Barros (2005). “Incorporating canopy physiology into a hydrological model: photosynthesis, dynamic respiration, and stomatal sensitivity.” Ecological Modelling 185(1): 29-49.
4	Water Resource Info	Van Nes, E. H. and M. Scheffer (2005). “A strategy to improve the contribution of complex simulation models to ecological theory.” Ecological Modelling 185(2-4): 153-164.
4	Water Resource Info	Walter V. Reid, H. A. M., Angela Cropper, Doris Capistrano,, K. C. Stephen R. Carpenter, Partha Dasgupta, Thomas Dietz, Anantha Kumar, et al. (2005). “Millennium Ecosystem Assessment Synthesis Report.”
4	Water Resource Info	Underwood, A. J. C., M.G. and Roberts, D.E. (2003). “A practical protocol to assess impacts of unplanned disturbance: a case study in Tuggerah Lakes Estuary, NSW.” Ecological Management and Restoration 4(supplement): 4-8.

Priority	Database	Description
4	Water Resource Info	Oaten-Stewart, A. B., J.R. (2001). “Temporal and spatial variation in environmental impact assessment.” Ecological Monographs 71(2): 305-339.
4	Water Resource Info	Zhang, Y., Z. Yang, et al. (2006). “Measurement and evaluation of interactions in complex urban ecosystem.” Ecological Modelling 196(1-2): 77-89.

APPENDIX B: REPORTS ON COMMUNITY WORKSHOPS (DANIELL 2007A AND 2007B)



Summary Report: Stakeholder Workshops 2 & 3 for the Lower Hawkesbury Estuary Management Plan

Document prepared for the:
Hornsby Shire Council &
WBM BMT

Document prepared by:

Katherine Daniell
BE(Civil)(Hons)/BA, GradIEAust
PhD Scholar
The Fenner School of Environment and Society
The Australian National University
Canberra ACT 0200
Ph. 0419 848 256
katherine.daniell@gmail.com

June 2007

EXECUTIVE SUMMARY

This document presents a process description and findings from the second two stakeholder workshops for the creation of the Lower Hawkesbury Estuary Management Plan (LHEMP) that were held at the Hornsby Shire Council Chambers on the 15th of February and the 1st of March 2007. It follows on from the "Summary Report: Community Workshop 1 for the Lower Hawkesbury Estuary Management Plan" (Daniell, 2007) found in Appendix A of the "Lower Hawkesbury Estuary Synthesis Report" (WBM Pty Ltd, 2007). For the ease of an autonomous reading of this report, the methodology designed for the stakeholder engagement process in the production of the LHEMP and several key outcomes from the first community workshop have been repeated from the previous summary report.

The second stakeholder workshop for the creation of the LHEMP was attended by a diverse range of representatives from State Government Departments, Local Governments, industry, and governing agencies and associations. The 19 participants worked through a risk assessment process based on the Australian Standard for Risk Management (AS/NZS 4360:2004), where the assets (values) and risks (issues) defined by stakeholders in the first workshop became the basis for assessment. For each risk, the "consequences" and "likelihoods" of risk impacts on the nine previously defined estuarine assets were outlined by participants, as well as an associated "risk level", the uncertainties related to these classifications, and the level of current management effectiveness of the risk related to each asset. From this information, the priority of the risks (acceptable, tolerable, or intolerable) was computed and the results discussed. From this assessment, all risks were classified as requiring treatment (tolerable or intolerable). The third stakeholder workshop was then used to develop strategies and actions for the treatment of these risks, as well as to identify monitoring needs, stakeholder responsibilities and stakeholder preferences related to the proposed strategies and actions. Individual brainstorming of strategies and actions preceded the collective "strategy mapping" for each risk. This third workshop was attended by 18 representatives from State and Local government, industry, agencies, associations and local residents.

As the plan is still in the analysis and writing stage, only evaluation results related to the use of the approach from a methodological viewpoint will be presented, rather than an evaluation of physical results and external impacts of the approach. From preliminary analyses, it can be seen that the approach produced relatively positive relational and learning outcomes. However, the effectiveness of the approach in improving the estuarine management and preservation of assets will have to wait until the plan is enacted to be properly assessed. Based on these preliminary evaluations, this report presents discussion on the participatory approach used in the LHEMP process, as well as a number of recommendations for future practice and research areas which warrant further study. It is hoped that the lessons learnt during this process may aid the later phases of the LHEMP implementation and allow others to undertake similar processes to improve estuarine management and regional sustainability.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

Acronym	**Definition**
ABC	Association for Berowra Creek
ANU	Australian National University
BIA	Boating Industry Association of NSW
CMA	Catchment Management Authority
DEC	NSW Department of Environment and Conservation
DNR	NSW Department Natural Resources
DoL	NSW Department of Lands
DPI	NSW Department of Primary Industries
EMP	Estuary Management Plan
GCC	Gosford City Council
HN	Hawkesbury Nepean
HNC	Hawkesbury Nepean Catchment
HTA	Hawkesbury Trawlers' Association
HSC	Hornsby Shire Council
LHEMP	Lower Hawkesbury Estuary Management Plan
NPWS	NSW National Parks and Wildlife Service (now included in DEC)
NSW	New South Wales
NSWBOA	NSW Boat Owners' Association
NSWFA	NSW Farmers' Association
NSWMA	NSW Maritime Authority
OFA	NSW Oyster Farmers' Association
STP	Sewage Treatment Plant
SWC	Sydney Water Corporation
THREPS	Hawkesbury River Environment Protection Society Inc

DISCLAIMER

In this summary of workshops for the creation of the Lower Hawkesbury Estuary Management Plan, every effort has been made to correctly represent the views of the participants. However, it is acknowledged that some of the author's interpretations could vary slightly from those intended. Please contact the author with your concerns if you believe any major misrepresentations have occurred. Only information directly presented or discussed in the workshops has been included in these summaries and so the content of this report is largely based on stakeholder opinions and the author's own interpretations, analyses and perceptions of the planning process.

1. INTRODUCTION

This document presents a process description and findings from the second two stakeholder workshops for the creation of the Lower Hawkesbury Estuary Management Plan (LHEMP) that were held at the Hornsby Shire Council Chambers on the 15th of February and the 1st of March 2007. It follows on from the "Summary Report: Community Workshop 1 for the Lower Hawkesbury Estuary Management Plan" (Daniell, 2007) found in Appendix A of the "Lower Hawkesbury Estuary Synthesis Report" (WBM Pty Ltd, 2007). For the ease of an autonomous reading of this report, the methodology designed for the stakeholder engagement process in the production of the LHEMP and several key outcomes from the first community workshop have been repeated from the previous summary report.

1.1 Project background

The creation of the Lower Hawkesbury Estuary Management Plan (LHEMP) is one of the first broader scale plans of its type to be implemented in Australia. This initiative follows recommendations from a Hawkesbury Nepean River Estuary Scoping Study Report (Kimmerikong, 2005) that to improve effectiveness, estuaries should be managed relative to catchment boundaries or a "whole-of-estuary" approach rather than based on administrative local council area boundaries. It was considered that developing such an approach would "*be more strategic, would facilitate an understanding of the links between issues, allow priorities to be identified, and enable more effective and efficient management of issues by improving exchange of information and coordination of activities*" (Kimmerikong, 2005).

Currently on the Lower Hawkesbury River past Wiseman's Ferry not all parts of the estuary and tributary creeks are covered by estuary management plans. Following the NSW Estuary Management process, the Berowra Creek Estuary Management Plan (HSC, 2002) is currently in a review phase and the plan for the Brooklyn Estuary (HSC, 2006a) is in the final stages of being accepted by the Hornsby Shire Council (HSC) and the Gosford City Council (GCC). Gosford City Council has also established the "Brisbane Waters Plan of Management" and Pittwater Council is developing a Pittwater Estuary Management Plan, both of which are downstream of the proposed plan coverage and are outside the Hawkesbury-Nepean Catchment Management Authority's jurisdiction. The areas currently encompassed by plans in the proposed Lower Hawkesbury Estuary Management Plan are highlighted in Figure 1.

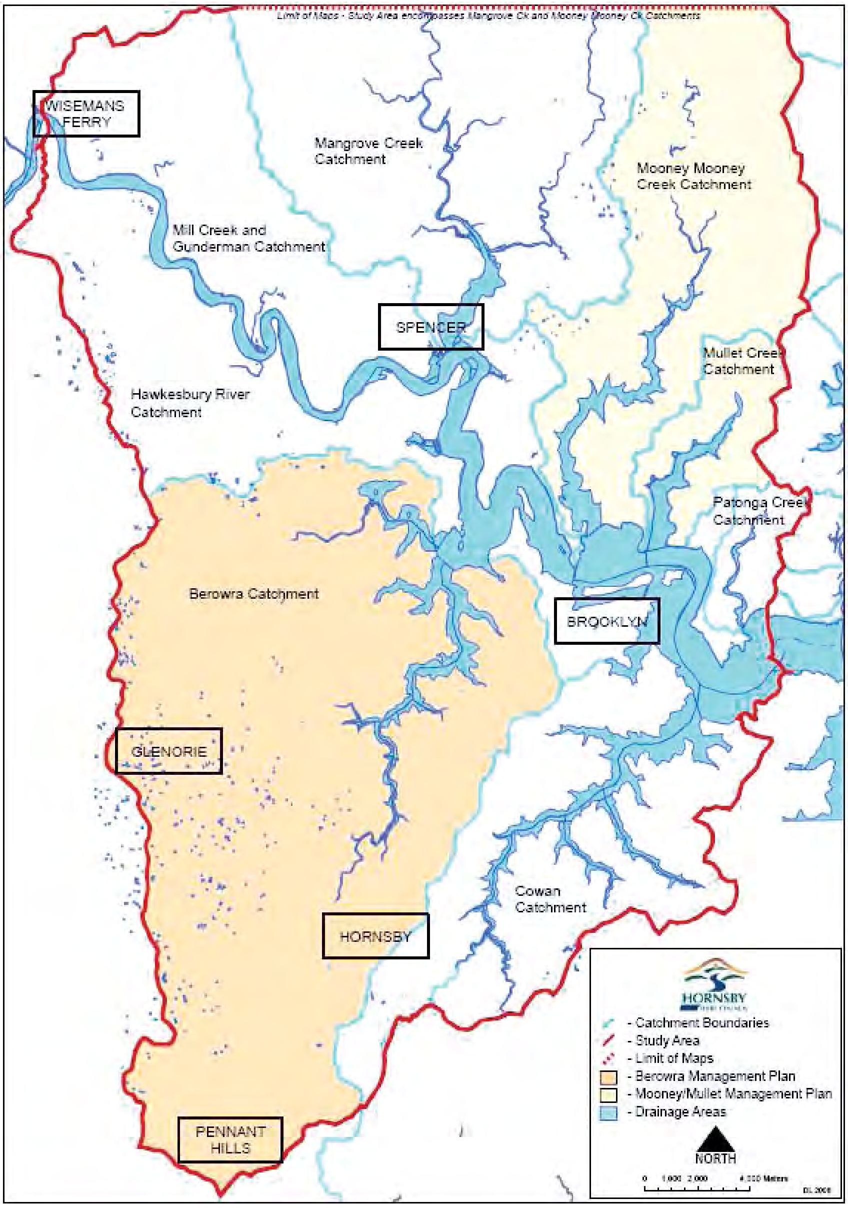


Figure 1: LHEMP boundaries and existing management plan areas (HSC, 2006)

In order to include the other parts of the estuary in the Lower Hawkesbury River currently not encompassed by an existing plan of management, the Hornsby Shire Council is funding the enlargement process. The LHEMP project is to be conducted in close cooperation with the Gosford City Council that also has jurisdiction over a large area of the proposed plan area, as well as with a large range of stakeholders and State Government representatives. WBM Pty. Ltd. and SJB Planning were selected as consultants through a public tender process to run the project in collaboration with the Hornsby Shire Council and researchers from the Australian National University.

1.2 Project aims

The project aims to create a regional "Lower Hawkesbury Estuary Management Plan". This planning process will help to:

- Capitalise on previous work such as the existing Hornsby Shire Council's and Gosford City Council's estuary planning, monitoring programs, and numerous regional studies;
- Allow the collective analysis and sharing of knowledge about the estuary and its surrounding communities from a range of different perspectives (stakeholder communities', government representatives' and scientists') in order to aid future visions of sustainable development of the estuary and how these can be achieved through good quality planning and management strategies;
- Investigate how other recent stakeholder, government or community initiatives can be integrated into a regional plan (such as the NSW Oyster Industry Sustainable Aquaculture Strategy (DPI, 2006) and the Hornsby Shire Council's Community Sustainability Indicators Program (HSC, 2004));
- Develop an effective and cost effective monitoring (data collection program), evaluation and reporting process to drive the future planning and management of the estuary; and
- Showcase the region's proactive approach to supporting research and "best practice" participatory processes (including their continuous evaluation) as an example for other regions to follow to improve their own estuary planning and management processes.

Compared to the current small scale estuary plans developed for parts of the study area, creating the LHEMP will ensure:

- Better use of local and regional knowledge;
- Improved strategic goals and objectives which are based on a system-wide understanding of the estuary;
- All values and issues related to the Lower Hawkesbury River will be considered and not confined to local areas;
- More efficient and effective use of Government resources;
- Greater potential to access and integrate funding and research opportunities; and
- Creation of opportunities for projects and community groups to address similar problems in different parts of the estuary.

2. PROJECT PROCESS AND TIMELINE

The process for this project was outlined in the Tender Document (HSC, 2006b), originally developed by the Hornsby Shire Council's Estuary Manager, Mr Peter Coad, and his colleagues. The project process differs from that of the NSW Estuary Management Program for a number of reasons including time and budgetary constraints. The proposed process relies instead on a stronger stakeholder-based approach of integration of their knowledge, use of the Australian Risk Management Standard AS/NZS 4360:2004, and use of existing reports and scientific studies carried out in the region. This will be performed in two principle ways: through running a series of three stakeholder workshops and through a document review. Plan writing and public exhibition of the plan will occur before it is rewritten and submitted to the Hornsby Shire Council and Gosford City Council for approval.

2.1 Project process

The process for the series of three workshops has been developed based on Ms Daniell's PhD work on decision aiding for water management and planning (Daniell et al., 2006) as outlined in the project Tender Document (HSC, 2006b). Specific methods and processes used in the workshops are then decided upon in collaboration with WBM Oceanics and HSC. A general overview of the workshops' content is outlined in Table 1.

Table 1: Stakeholder Workshop Series Overview

Workshop No. 1 **Management Situation**	Identify stakeholders' values (assets) and issues related to the estuary - How and by whom are these currently being managed? - Are the resources to manage them sufficient?
	Identify overall goals, objectives and a vision for the estuary
Workshop No. 2 **Risk Analysis**	Assess estuarine risks (related to defined issues) for their consequences on the assets and the associated likelihood of these impacts - Determine risk level - Classify the uncertainty of this prediction - Estimate the current effectiveness of risk management
	Evaluate and prioritise risks - Classification as "Acceptable, Tolerable or Intolerable"
Workshop No. 3 **Strategy Formulation**	Define strategies and their associated actions to treat priority risks - Which stakeholders and resources are required to carry them out?
	Determine target states of risk reduction the actions are to achieve - Select indicators, monitoring needs and information dissemination strategies to evaluate and improve management

These three workshops have also been developed to be combined with the document and scientific review process (carried out by the consultant team of WBM Pty Ltd and SJB Planning); following the stages of the Australian Risk Management Process as outlined in Figure 2.

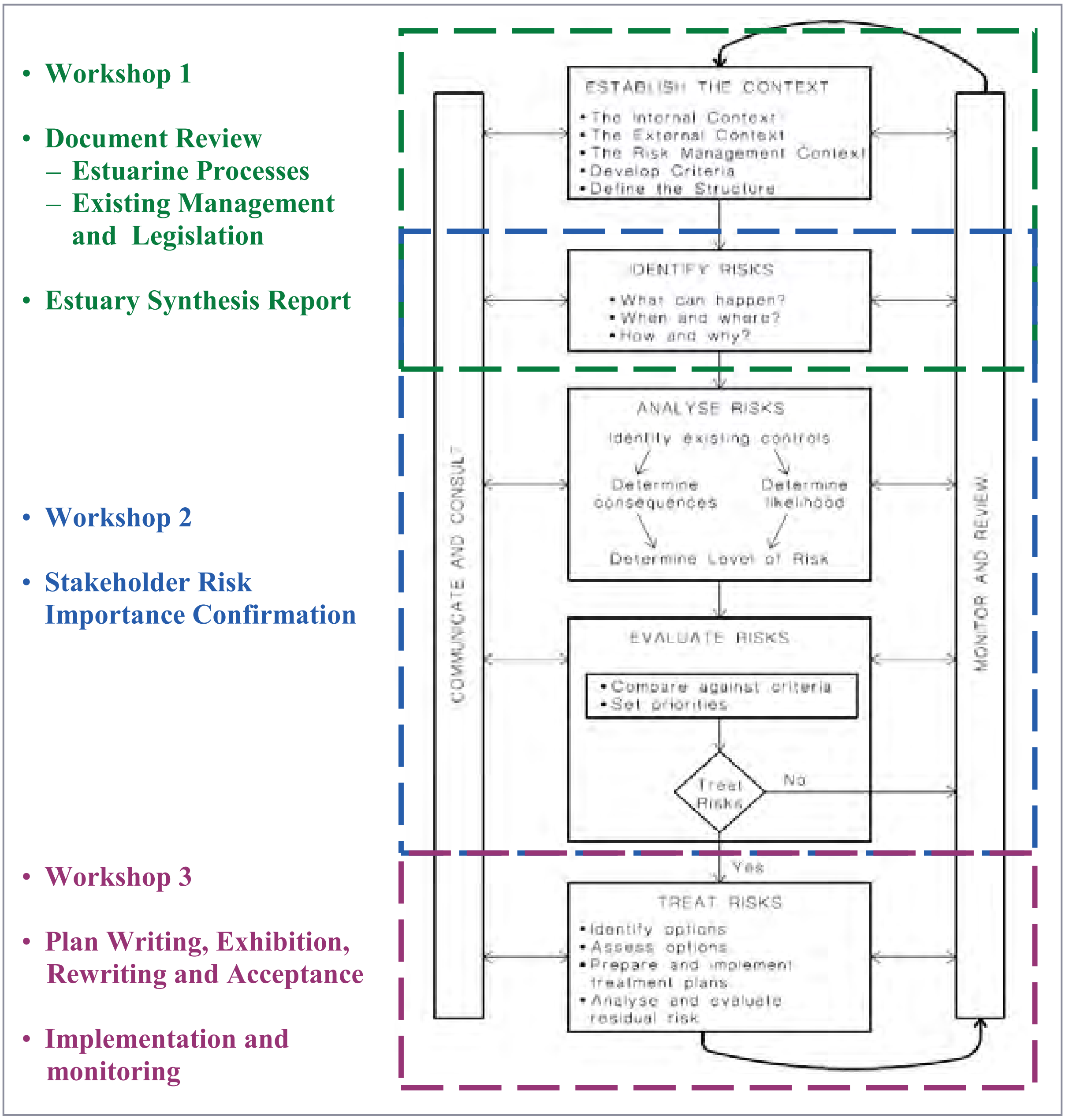


Figure 2: LHEMP Process following the Risk Management Standard AS/NZS 4360:2004

2.2 Timeline

The project process outlined in the Tender Document (HSC, 2006b) was defined to be carried out over a period of approximately 1 year. The current proposed timeline for the LHEMP project is outlined in Table 2.

Table 2: Proposed LHEMP Project Timeline

Month	Actions
October 2006	Inception meeting and project planning
November 2006	1st participatory workshop (3rd November) and document review
December 2006	Document review
January 2007	State of the Estuary Report written and distributed to stakeholders
February 2007	2nd participatory workshop (15th February)
March 2007	3rd participatory workshop (1st March)
April 2007	Plan writing
May 2007	Public exhibition of plan for comment
June 2007	Plan rewrite
July 2007	Plan submission to council
August 2007	Plan implementation

The project will also be externally evaluated throughout and following the process by a project team from the Australian National University for a PhD project and as part of an international evaluation project. This international evaluation project is funded by the French National Research Agency under their "Agriculture and Sustainable Development" program which has been created to comparatively examine applications of participatory Natural Resources Management initiatives in approximately 30 case studies around the world.

2.3 Workshop No. 1 summary

The first community stakeholder workshop was held at the Hornsby Shire Council Chambers on Friday the 3rd of November from 9.30am to 3.30pm. The day's activities were attended by 30 participants from a number of government departments (DPI, NSWMA, DNR, NSWFA, DoL); authorities and associations (HN CMA, SWC, NSWBOA, Oceanwatch, HTA, HNC Foundation, OFA NSW, NSW BIA, ABC); Local Government representatives (HSC, GCC); and community representatives (local industries, commerce and residents). The workshop was facilitated by staff of WBM Pty Ltd, SJB Planning and the Australian National University.

The aim of the first workshop, as suggested in Table 1, was to define the current management situation in the Lower Hawkesbury River from the stakeholders' perspectives. This was achieved by eliciting participants' values (assets), issues (risks) and goals related to the estuary, as well as to define the estuarine stakeholders and which resources they possess or require to improve the management of the estuary. A variety of individual and group activities, as shown in Figure 3, were used to obtain and synthesise this information including: individual oral presentations; individual brain storming on cards; group card categorisation; spatial mapping; issues/values cross-impact matrices; group issue and value questionnaires; and large group discussions.

Figure 3: Workshop 1 Activities

For further information on these activities, please refer to "Summary Report: Community Workshop 1 for the Lower Hawkesbury Estuary Management Plan" (Daniell, 2007).

2.4 Preliminary outcomes and preparation for Workshop No. 2

From Workshop No.1 and the external document review performed by WBM Pty Ltd. and SJB Planning, a list of nine estuarine asset categories was developed for use in the following stages of the LHEMP development process (eight from the workshop and one from the external document review*):

- Scenic amenity and national significance
- Functional and sustainable ecosystems *(including biodiversity)*
- Largely undeveloped natural catchments and surrounding lands
- Recreational opportunities
- Sustainable economic industries
- Culture and heritage
- Improving water quality that supports multiple uses
- Community value
- Effective governance*

A list of 15 estuarine risks was also developed by WBM Pty Ltd from the stakeholders' "issues" collected in Workshop No. 1 and the external review of documents:

1) Risk of water quality and sediment quality not meeting relevant environmental and human health standards
2) Risk of climate change
3) Risk of regulated freshwater inflows
4) Risk of inappropriate land management practices
5) Risk of inappropriate or unsustainable development
6) Risk of over-exploiting the estuary's assets
7) Risk of introduced pests, weeds and disease
8) Risk of excessive sedimentation
9) Risk of residents and users lacking passion, awareness and appreciation of the estuary
10) Risk of inappropriate or excessive foreshore access and activities
11) Risk of inappropriate or excessive waterway access and activities
12) Risk of inadequate facilities to support foreshore and waterway access and activities
13) Risk of insufficient research
14) Risk of inadequate monitoring to measure effectiveness of the EMP
15) Risk of not meeting EMP objectives within designated timeframes

Prior to the second workshop, the set of nine values, the Risk Management Standard (AS/NZS 4360:2004) and a number of other references (ANZECC, 2000; Billington, 2005; Everingham, 2005; Fletcher et al., 2004; SP AusNet, 2006; Standards Australia, 2004a; Standards Australia, 2004b; Standards Australia, 2006; World Health Organisation, 2003; Umwelt Environmental Consultants, 2006) were used by Ms. Daniell to develop a series of "Risk Tables". These tables were first distributed to participants in Appendix B of the "Lower Hawkesbury Estuary Synthesis Report" (WBM Pty Ltd, 2007) and are also provided in Appendix A of this document.

3. WORKSHOP NO.2

The second stakeholder workshop was held at the Hornsby Shire Council Chambers on Thursday the 15th of February 2007 from 9.30am to 3.30pm. The day's activities were attended by 19 representatives from a number of government departments (DPI, NSWMA, DNR, NSWFA, DoL, DEC, NPWS); authorities, associations and industry representatives (HNCMA, SWC, HTA, HNC Foundation); and Local Government representatives (HSC, GCC). The workshop was facilitated by Katherine Daniell (Australian National University), Philip Haines, Michelle Fletcher, Verity Rollason (WBM Pty Ltd), and Michael Baker (SJB Planning). External evaluation (including video and audio recording) of the process was carried out by Natalie Jones and Ian White (Australian National University).

Due to a number of unforeseen process and external constraints, this workshop only involved stakeholders with governance roles in the estuary plan region. The effects of this deviation from the original planned process structure will be briefly discussed in Sections 3.7 and 3.8 on the participants' evaluation of this workshop, and later in more depth in Section 5.1.

3.1 Workshop aims

The aim of the second workshop, as suggested in Table 1, was to perform a "risk assessment" on a number of risks identified in the first stakeholder workshop and external document review. From the assessment results, the risks could then be prioritised for subsequent treatment. More specifically, the objectives of this workshop were to:

- Receive "agency" (a term used here to refer to stakeholders with governance or managerial roles) confirmation and endorsement of the outcomes from the first stakeholder workshop and conclusions drawn in the "Lower Hawkesbury Estuary Synthesis Report" (WBM Pty Ltd, 2007). This includes the definitions of the "asset" (values) categories, "risk" (issues) list and synthesised goals for the estuary.
- Further identify the risks elicited in the first workshop and Synthesis Report;
- Use the "Risk Tables" to perform a risk assessment on these risks including a definition of the "consequences" and "likelihoods" of their impacts on the asset categories, the subsequent "risk level" and associated "knowledge uncertainty" and "management effectiveness" levels;
- Discuss and receive reactions on the prioritised list of risks;
- Evaluate and obtain feedback about the project process and content, in order to improve the next workshop.

3.2 Workshop process overview

The activities undertaken during the second workshop are given in the Agenda which can be found in Appendix B. To achieve the objectives outlined in Section 3.1, the day was broken down into a number of sessions. The workshop commenced with a general welcome, project background update and a presentation of the day's agenda, followed by a brief session of personal introductions. Prior to morning tea, a session was run to obtain the participants' confirmation on the estuarine goals, assets and risks, and the risk analysis method to be used during the day's activities was presented. Between morning tea and lunch, two risks were discussed and assessed as a whole group, then after lunch the group was broken up into pairs to assess the remaining risks. Once the assessments were completed, the priority categories were computed and the results discussed as a whole group.

3.3 Introductions & confirmation of goals, assets and risks

As part of the personal introductions, participants were asked to introduce themselves to the group giving their name, which agency they represented and, in a few words, the biggest risk that they believed the estuary faces. This session provided a good overview of many of the issues identified in the first workshop, including the following responses:

- Storm water discharges;
- Risks outside catchment and development within it;
- Overdevelopment and overuse (x2);
- Catchment impacts (urban) on water quality;
- Drier forecast for the river basin and effect on other risks;
- Impacts of water quality;
- Lack of freshwater inflows into the river;
- Developments in the catchment, and impacts on water quality and quantity;
- Pollution from residential lots;
- Development in the catchment and associated water use;
- Pollution and overuse;
- Cumulative effects of all the different impacts all flowing into the one area;
- Inappropriate development and catchment-based pollution;
- Upper catchment influences and compliance: development not complying with legislation, onsite maintenance and non-compliance with standards, policing of use on the waterways / overuse; and
- People.

These introductions were followed by WBM Pty Ltd's presentation of the goals, asset categories and list of risks. Firstly, the 3 amalgamated goals (refer Figure 4) were discussed, specifically to allow agency members who did not attend the first workshop to voice their opinions on their formulation.

Goal 1: Recognise and respect the unique and diverse scenic and natural environment of the estuary through the integrated and holistic management of human and environmental interests.

Goal 2: Maintain sustainable economic, recreational and social uses without compromising the high quality and functional estuarine ecosystems upon which they rely.

Goal 3: Preserve and foster the sense of belonging, culture and respect for the estuary among existing and new residents/users.

Figure 4: Amalgamated LHEMP goals from the first workshop (WBM Pty Ltd, 2007)

The discussion about the formulation of these goals predominately focussed on the lack of specific emphasis on the preservation and enhancement of "sustainable ecosystems" that support many of the other assets. It was suggested that this ecosystem importance be more strongly highlighted in the first goal (for example by using more active words "*Preserve and enhance*" instead of "Recognise and respect") and equally in the second goal. Suggestions for changes to the second goal included switching the order of the phrase to avoid the use of "without compromising": "[*Conserve, protect and enhance*] / [*Maintain*] *functional and sustainable estuarine ecosystems upon which economic, recreational and social uses rely",* so that the idea of "quality" ecosystems supporting the social, recreational and economic uses was strongly supported. For the third goal, there was discussion as to whether the word "*heritage*" should be added, or whether it can be considered as part of the word "culture". It was also strongly suggested that "*managers*" be added to the stakeholders in the 3rd goal: "*Preserve and foster the sense of belonging, culture* [, *heritage*] *and respect for the estuary among existing and new residents, users and managers"*.

During this discussion, a number of agency representatives voiced their opinions that they did not want to take the responsibility for "signing-off" on these goals, and that prior to the LHEMP's acceptance they should be resubmitted equally to other community and commercial stakeholders for their comments. Support and respect for the community and commercial stakeholders was also voiced more generally, including the value that they contribute to the creation of the EMP and the need for their continued inclusion in the process to ensure the success of the plan and its impacts on the estuarine region.

Following on from this discussion, the list of asset categories developed predominately during the first workshop promoted no further discussion and so were taken as being accepted for the following phases of the planning process.

The list of risks was accepted in a similar fashion, although it was noted that *"treated sewerage"* should be added to the sources of "regulated freshwater inflows", documented under Risk No. 3 in the Synthesis Report (WBM Pty Ltd, 2007). The question of "inadequate management" as a risk was also raised as further risk that should be considered. The discussion highlighted how inconsistencies between different Council planning practices and State Legislation could lead to the possibility of local plans and objectives being overridden by State or Federal Government. Difficulties in integrating plans and objectives over spatial and administrative scales were also seen as drivers of potential management failures. Based on these views, a 16^{th} risk, "*Risk of inadequate or dysfunctional management mechanisms",* was proposed as an addition to the 15 previously defined risks.

3.4 Risk analysis method

The method to be used to analyse the list of risks in the morning and afternoon sessions was presented to participants by Ms. Daniell prior to morning tea, using the diagram similar to that in Figure 5 as a basis for explanation.

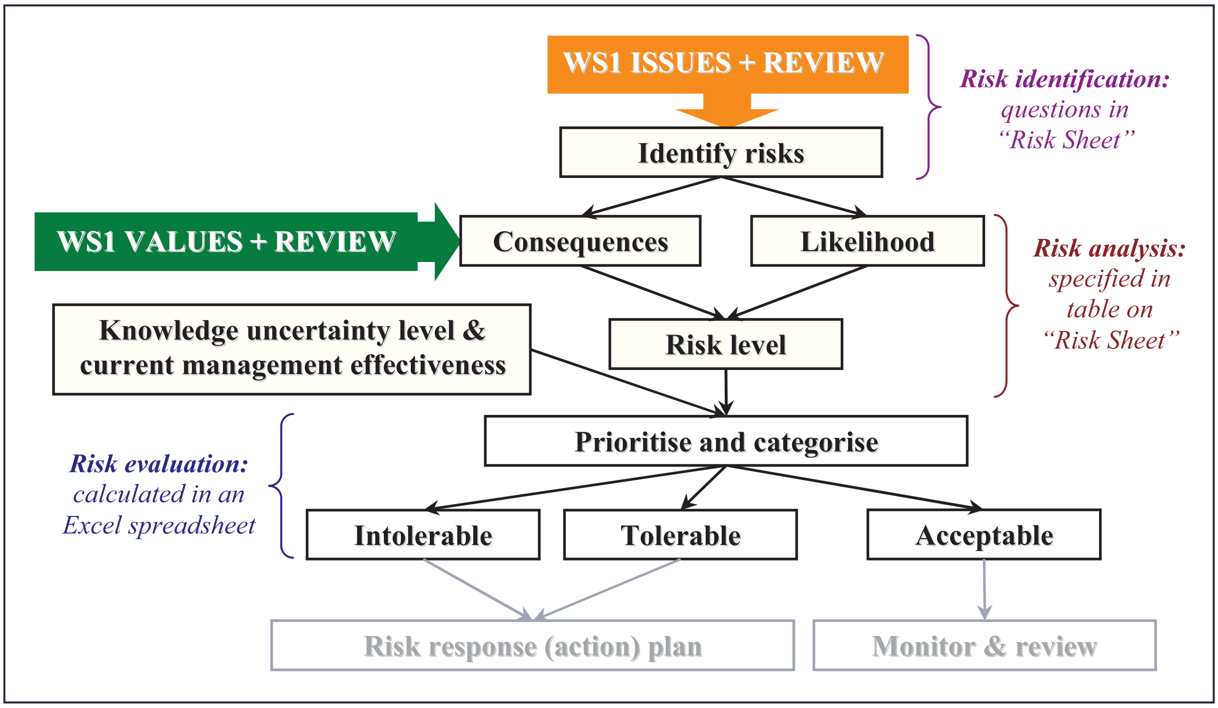


Figure 5: Risk assessment outline in Workshop 2

A "Risk Sheet", mentioned in Figure 5 and shown in Appendix C, was developed as a guide to aid participants through the "risk identification" and "risk analysis" stages of the Australian Risk Management Standard AS/NZS 4630:2004 (refer Figure 2). The questions on the "Risk Sheet" used to complete the risk identification, following on from the risk descriptions in the Synthesis Report (WBM Pty Ltd, 2007), are given in Table 3.

Table 3: Questions for risk identification

RISK SHEET QUESTIONS
What is the risk?
What are the sources / causes of this risk?
What are the main potential impacts of this risk?
Where, or to whom, will these impacts occur?
What are the current strategies used to manage this risk?

An example was then given to demonstrate how to use the "Risk Tables" to fill out the table for assessment of the risk against each of the asset categories. This assessment included identifying pairs of consequences and likelihoods of risk impacts on each of the estuarine assets, and then finding an associated "risk level", i.e. a function of the consequence and likelihood as outlined in the "Risk Level Matrix" shown in Figure 6 and in Appendix A.

Likelihood Level Description	*Consequence Level Description*				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	H	H	V	E	E
Likely	M	H	H	V	E
Possible	L	M	H	V	V
Unlikely	L	L	M	H	V
Rare	L	L	M	H	H

LEGEND

- **E = Extreme risk**
- **V = Very high risk**
- **H = High risk**
- **M = Moderate risk**
- **L = Low risk**

Figure 6: Risk matrix example (adapted from AS/NZS HB 203:2006)

A level of "knowledge uncertainty" related to these assessments and the current level of "management effectiveness" (for mitigating a risk's impacts relative to an asset category) was also to be assigned. Once the table was filled out, the risk could then be evaluated into one of three categories: intolerable; tolerable; or acceptable, as a function of the risk's "risk level", "knowledge uncertainty" and "management effectiveness", as conceptualised in Figure 7.

Figure 7: Risk prioritisation: intolerable, tolerable and acceptable

Those risks categorised as either tolerable or intolerable, would then go on to be treated in the third stakeholder workshop as part of the risk response (or action) plan for the estuary. No further action on risks found to be "acceptable" would be undertaken except for routine monitoring, and review at a later date (to determine if the risks' status have changed and require management attention).

3.5 Facilitated stakeholder risk analysis

Following morning tea, the first risk to be treated, the "Risk of excessive sedimentation", was facilitated by Ms. Daniell as a whole group session. The group worked through and discussed each of the questions on the "risk sheet" (Table 3), with the responses to these questions being written on flip chart sheets by the facilitator, as shown in Figure 8.

Figure 8: LHEMP facilitated stakeholder risk analysis

Once the group had discussed each of these questions, they moved on to filling out together the risk sheet's table using the "risk tables" (Appendix A). This included determining the "consequences" and "likelihoods" of risk impacts on nine previously defined estuarine assets, as well as an associated "risk level", the uncertainties related to these classifications, and the level of current management effectiveness of the risk related to each asset. Discussion on the values in each of these boxes was relatively rapid with, on average, three or four different opinions being solicited and discussed before decisions were recorded and the facilitator moved the conversation on to the next box. During these discussions, participants noted that there was a real need to document assumptions when they were going through the assessments, so the results could be later traced back to specific thinking. The "notes" section on the risk sheet's table was dedicated to this purpose and the participants were encouraged to discuss their assumptions or thoughts, with the main issues being noted by the facilitator.

Halfway through the sedimentation example, after 40 minutes of work, one of the participants suggested that the large group should also go through the assessment procedure for the water quality risk together, as there were likely to be a large range of opinions presented and that the participants wanted to hear the others' views. It was originally planned that each group would treat this risk in their small groups as the validation case for checking the results of the other risks. However, as the consensus in the room appeared to be that if the participants in the room were broken up into small groups, some of the knowledge, information and useful exchanges related to this important issue would not be possible. It was therefore decided that the water quality risk would be treated as a whole group and the remaining section of the sedimentation risk would be completed in each small group for the purposes of validation.

Discussion on the water quality risk, "Risk of water quality and sediment quality not meeting relevant environmental and human health standards", was livelier than for the excessive sedimentation risk and almost all group members participated in the discussions. The specific definition of the risk and the "Standards" to which the estuary's water quality should adhere incited a particularly lively discussion. It was suggested that guidelines for the direct harvesting areas outlined in the NSW Oyster Industry Sustainable Aquaculture Strategy (DPI, 2005) could be taken as an "aspirational goal" for all estuary waters. However, despite some agreement with this aspiration for human uses of the waterway, it was noted that for other objectives such as ecosystem health, the guideline levels of faecal coliforms may potentially be too low as other estuarine species use them as food sources. Therefore, adhering to the ANZECC guidelines for the "protection of aquatic ecosystems" with the exception of oyster harvesting and recreational zones (where the ANZECC "Recreational water contact guidelines (primary and secondary) are to be followed), would also be of benefit to the estuarine ecosystems. It was noted that this approach would also be consistent with the Healthy Rivers Commission's water quality objectives for the Hawkesbury-Nepean Region.

Emerging issues not yet covered under the current water quality guidelines such as the impacts of new medications (e.g. anti-cholesterol drugs) and hormones were also discussed. It is believed that a current lack of information about the impacts of such substances on the estuary is an issue that should be treated as part of this risk and the evolution of the guidelines related to it. However, it was outlined that STP systems are being continuously updated to attempt to treat potentially damaging new substances and each STP discharge in the estuary area is currently toxicology-tested for, and must meet the guidelines for, about 115 substances. The other water monitoring programs carried out in the estuary by SWC, HSC and the NSW Food Authority (including the oyster growers) were also mentioned at this stage. Finally, the issue of discharges emanating from areas of acid sulphate soils and the difficulty in defining indicators to measure their effect on the estuarine assets was raised but no conclusions drawn.

Overall, the five questions on the risk sheet for the water quality risk took about 15 minutes of discussion to complete, and the table of consequences, likelihoods, risk level, knowledge uncertainties and management effectiveness about 45 minutes to complete. After the definition of the risk, the other questions were relatively quick to complete as the participants were just asked to add onto or comment on whether they were in agreement with the risk summaries in the Estuary Synthesis Report (WBM Pty Ltd, 2007). The results from these discussions were transcribed from the flip chart and white board table onto a risk sheet, as shown in Figure 9.

Figure 9: Example of a completed risk sheet

The completion of the water quality risk was followed by the lunch break. During this time, the facilitators discussed how the afternoon session could be changed to maintain the objective of completing all 15 risks by the end of the day, considering the time that had been reallocated to completing the water quality risk as a large group. It was decided that the remaining participants (a few had to leave at lunchtime) would treat a couple of the remaining risks in groups of two or three. Following lunch, the participants were therefore split up into small groups and allocated a couple of risks each. The groups (or pairs) then worked on their allocated risks with the aid of the risk tables and Synthesis Report (WBM Pty Ltd, 2007), as shown in Figure 10.

Figure 10: Small group risk analysis

Facilitators were also on hand to answer any queries and to retrieve the completed risk sheets from the groups to speed up the computer entry of results. The small groups or pairs finished their risks after approximately an hour and a half of work. They were then invited to complete the day's evaluation form, observe the results entry into an Excel spreadsheet (Figure 11) and to help themselves to a cup of tea or coffee while waiting for the completed risk analysis outcomes.

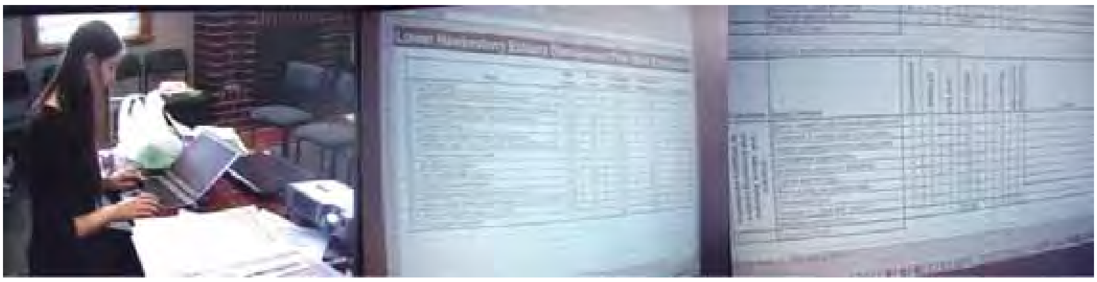
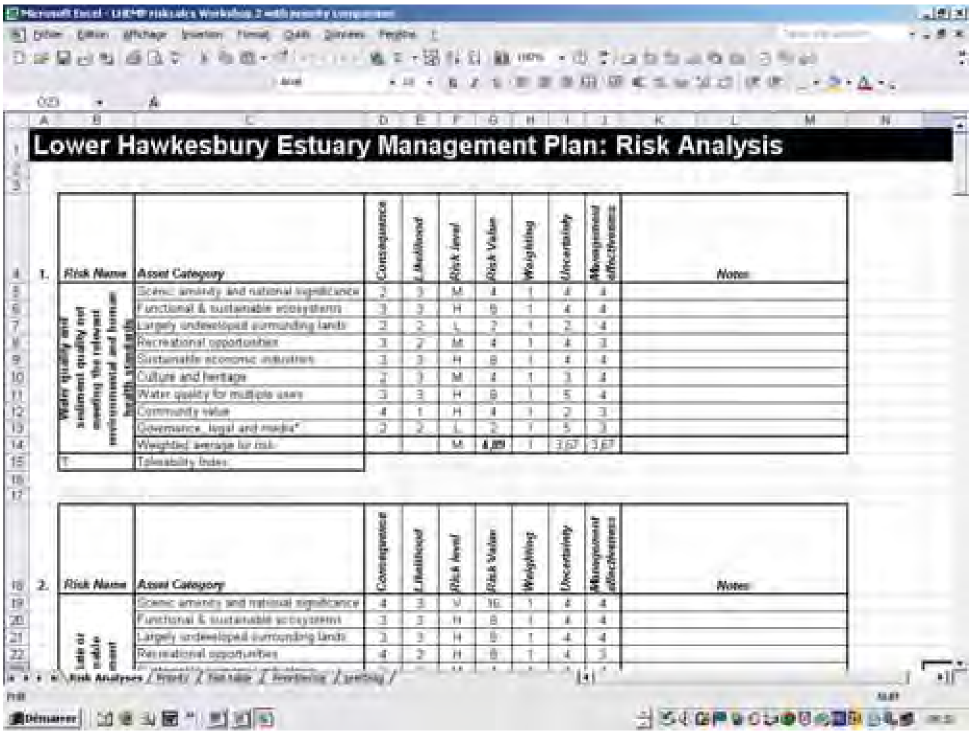


Figure 11: Real-time computer entry of the risk analysis results

From the values in the risk sheets' tables, the individual asset risk levels were numerated into the pre-prepared Excel spreadsheet using a logarithmic scale (base 2), as used in the CERAM method of environmental risk analysis (Wild River and Healy, 2006). The overall risk level for each risk was then calculated as the average of the nine asset risk level values. Similarly, the overall knowledge uncertainty and management effectiveness values were calculated as an average of the nine asset values. It was originally planned to determine weighting preferences for each of the nine values and then use a weighted average calculation. However, time constraints in the workshop process did not allow for this extra information to be obtained. These three averaged values were then used to look-up the relevant prioritisation category (acceptable; tolerable; or intolerable) which was based on an approximation of the diagram in Figure 7. An example table for the water quality risk (as projected onto the wall during the workshop for the participants to look at) is shown in Figure 12.



Lower Hawkesbury Estuary Management Plan: Risk Analysis

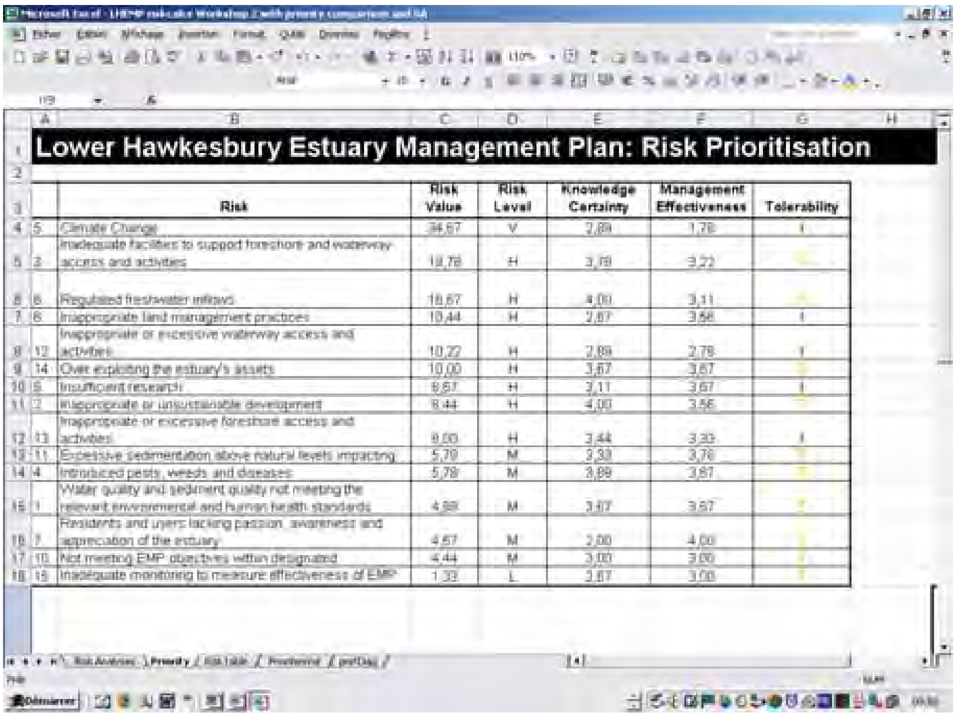
1.	Risk Name	Asset Category	Consequence	Likelihood	Risk level	Risk Value	Weighting	Uncertainty	Management effectiveness	Notes
	Water quality and sediment quality not meeting the relevant environmental and human health standards	Scenic amenity and national significance	2	3	M	4	1	4	4	
		Functional & sustainable ecosystems	3	3	H	8	1	4	4	
		Largely undeveloped surrounding lands	2	2	L	2	1	2	4	
		Recreational opportunities	3	2	M	4	1	4	3	
		Sustainable economic industries	3	3	H	8	1	4	4	
		Culture and heritage	2	3	M	4	1	3	4	
		Water quality for multiple uses	3	3	H	8	1	5	4	
		Community value	4	1	H	4	1	2	3	
		Governance, legal and media*	2	2	L	2	1	5	3	
		Weighted average for risk			M	4,89	1	3,67	3,67	
	T	Tolerability Index								

2.	Risk Name	Asset Category	Consequence	Likelihood	Risk level	Risk Value	Weighting	Uncertainty	Management effectiveness	Notes
	[illegible]	Scenic amenity and national significance	4	3	V	16	1	4	4	
		Functional & sustainable ecosystems	3	3	H	8	1	4	4	
		Largely undeveloped surrounding lands	3	3	H	8	1	4	4	
		Recreational opportunities	4	2	H	8	1	4	3	

Risk Analyses / Priority / Risk table / Prioritising / prefDag

Figure 12: Overall risk level and tolerability calculation tables

Once all of the results from the risk sheet tables had been entered into the computer, the final list of risk levels and tolerability indices were presented to the participants (Figure 13) and some time was allocated to discussing and interpreting the results.



Lower Hawkesbury Estuary Management Plan: Risk Prioritisation

	Risk	Risk Value	Risk Level	Knowledge Certainty	Management Effectiveness	Tolerability
5	Climate Change	34,67	V	2,89	1,78	I
3	Inadequate facilities to support foreshore and waterway access and activities	18,78	H	3,78	3,22	
6	Regulated freshwater inflows	16,67	H	4,00	3,11	
8	Inappropriate land management practices	10,44	H	2,67	3,56	I
12	Inappropriate or excessive waterway access and activities	10,22	H	2,89	2,78	I
14	Over exploiting the estuary's assets	10,00	H	3,67	3,67	
5	Insufficient research	8,67	H	3,11	3,67	I
2	Inappropriate or unsustainable development	8,44	H	4,00	3,56	
13	Inappropriate or excessive foreshore access and activities	8,00	H	3,44	3,33	I
11	Excessive sedimentation above natural levels impacting	5,78	M	3,33	3,78	
4	Introduced pests, weeds and diseases	5,78	M	3,89	3,67	
1	Water quality and sediment quality not meeting the relevant environmental and human health standards	4,89	M	3,67	3,67	
7	Residents and users lacking passion, awareness and appreciation of the estuary	4,67	M	2,00	4,00	
10	Not meeting EMP objectives within designated	4,44	M	3,00	3,00	
15	Inadequate monitoring to measure effectiveness of EMP	1,33	L	3,67	3,00	

Figure 13: Risk prioritisation results

3.6 Whole group discussion of results

From the Excel spreadsheet calculations, all of the risks were classified as requiring treatment (either tolerable or intolerable). Before examining these results in more detail, the participants were asked if they had any difficulties in filling in the risk sheets. The two principle comments related to this question were that for one of the risks, "Risk of inadequate monitoring to measure effectiveness of the EMP", the group that treated it did not assess the risk's impacts against the majority of the assets, due to a perceived lack of relevance. It was thought that this risk was in some ways a "second order" risk and rather difficult to assess in the same way as the others. Other participants noted that the risks, as outlined in the Synthesis Report, were very broad. This meant that, in some cases, concrete examples within a risk had been taken as a starting point to be able to perform the assessment. Such specific examples (such as looking at fishing and oyster industries within the "sustainable economic industries" asset category), were noted as qualifying comments on the risk sheets. A couple of participants remarked that they still felt defining large risks to be a useful activity, especially to help to decide whether more time should be spent in the following stages of the planning process in defining the sources and causes of the risks, as well as strategies and actions to treat these more specific areas of the risks.

At the beginning of the discussion of results, it was noted that some risks were pushed into the intolerable region by not only their risk level but also their high knowledge uncertainty (i.e. "risk of inappropriate land management practices"), their low score of management effectiveness (i.e. "risk of inappropriate or excessive waterway access and activities") or all three factors combined (i.e. "risk of climate change"). This type of information could be useful for helping to develop strategies to treat the risks in the next workshop. For example, risks with a high level of knowledge uncertainty may be suited to being treated with research-based solutions, or other similar methods of reducing this knowledge uncertainty.

When looking at the prioritisation of the risks, one participant mentioned that the water quality risk was not as high as could have been expected, and that the result was rather "counterintuitive", based on the major concerns highlighted earlier in the day such as pollution and stormwater runoff (for the full list of concerns refer to Section 3.3). The meaning behind the result was then discussed among the other participants. Theoretically, this risk had not been classed as intolerable due to its moderate risk level, relatively low knowledge uncertainty, and high management effectiveness. It was thought that this result may have not been as highly prioritised, despite its perceived importance, as every risk had also been assessed against "water quality" as an asset. Therefore, the importance of maintaining or improving water quality to support the estuarine uses and ecosystems was also an inherent part of the assessment of all risks, and some risks that have larger potential impacts on water quality were highly prioritised (i.e. inappropriate land management practices: for example land clearing can increase erosion and sediment levels in the estuary, as well as allowing more polluted runoff to reach the estuary). In an attempt to justify these differences of perceived importance of risks and the assessment procedure, one participant mentioned that if they had been asked "*what risk will have the largest impacts on the estuary but does not receive enough management attention*" the list of initial "biggest risks" may have been rather different. This view was backed up by one of the participants who had treated the "risk of climate change", saying that it was a good example as the risk's impacts are likely to occur with significant impacts, yet the management regime is not there and the knowledge uncertainty is high.

3.7 Participant workshop debriefing and evaluation questionnaires

Following the discussion of prioritisation results, the participants were asked whether they had any other comments or questions related to the workshop or the LHEMP process. The first question from a participant was a general process question directed at the project management team related to whether further risk assessment at a sub-risk level would be carried out to determine the internal priorities of a risk (i.e. prioritising the treatment of boat discharges over onsite septic systems in the water quality risk). WBM Pty Ltd replied that in the next workshop strategies and actions will be developed for all the "sub risks", or to treat the various "causes and effects" of the risks, and then prioritised by participants. However, due to a lack of time and budget, each sub-risk would not be rigorously assessed in, or after, the next workshop using the same risk assessment method. If such a level of detail were aspired to, then the actions would have to be individually assessed at a later date.

The next comment brought up related to how areas of responsibility for each agency could be defined throughout the planning process. An example from the first workshop, "*who is responsible for removing a dead cow found on the estuary foreshore?*", was used to illustrate the point that there is a lot of overlap between management agencies of the estuary and foreshores. This management overlap was seen as being one of the reasons that "*issues sometimes get bumped from local to state government, then between departments, and often nothing gets done*". Reactions to these comments included that the recent "Waterways Review" (SJB Planning, 2005) had started to review management responsibilities and these were laid out in the "Governance Table" (Attachment 9; SJB Planning, 2005). However, this table is not yet sufficiently specific to provide illumination for a definitive answer to issues such as the "dead cow". It was noted that responsibilities for certain actions will be investigated in the next workshop and further defined in the plan writing stages of the LHEMP process, although defining workable management responsibilities will require ongoing planning and cooperation between all agencies.

Finally, one participant commented that, compared to the last workshop, this workshop was very effective as *"if you can keep emotion out of it you can move forward a lot more effectively"*. When prompted by the facilitator to expand on this comment, the participant responded that "*sometimes* *emotion can polarise debate around certain issues that don't pose a "real risk'"*". Another participant commented that this was sometimes difficult as emotion surrounding important issues is natural. The point was returned that, as the estuary is so big, focussing on just a couple of issues may not be a very effective way of moving forward. The facilitator replied that the methods used in the next workshop would attempt to reduce this problem and encourage participants to focus on developing strategies and actions for the whole range of intolerable and tolerable risks.

To find out how all the participants thought the workshop had been run and how the future ones could be improved, evaluation questionnaires were distributed during the computer entry of the final results from the risk sheets. It is considered that one of the most important aspects of participatory processes is the continuous monitoring and evaluating which should occur throughout them. Giving participants the possibility to individually reflect on the objectives, content, process and outcomes of the process they are involved in can be invaluable to both the participants and facilitators for a number of reasons, including:

- Determining the degree to which expectations have been met;
- Understanding perceptions including whether: the workshop was useful or valuable; there are any important problems or conflicts that need to be resolved; the required tasks had been adequately understood and completed; and the facilitation and possibilities to participate were adequate;
- Verifying if anything major has been overlooked (in the project definition or context, stakeholders who should have been present, and resources required by the participants);
- Finding out what has been gained through the workshop process, such as learning outcomes and the building of relationships between stakeholders; and
- Providing the opportunity to comment or raise any other concerns.

The questionnaire provided to participants addressed the ideas listed above and contained 14 "open" and "closed" answer questions. The questionnaire is given in Appendix D.

3.8 Workshop No. 2 questionnaire results

Despite a number of participants having to leave the workshop at lunchtime, thirteen responses were returned to the facilitators, indicating a 65% coverage of the workshop attendees. Responses were received from a good distribution of participants including state and local government representatives and industry representatives.

Participants were firstly asked to outline what they believed the objectives of the workshop to be, and whether or not they had been satisfactorily achieved. For the most part, responses for the workshop objectives were largely consistent with what the facilitators had presented at the beginning of the session, including: "*Risk assessment for EMP*", "*To determine and discuss issues and risks to the estuary primarily with representatives from government agencies*" and *"Confirm all stakeholders* *were supportive of the risks identified in the synthesis report following WS1. Prioritise risks"*. As to whether these objectives had been achieved, one participant responded categorically "yes" and eight responded yes with some justification or minor reservations. Responses with reservations included: "*Yes, but it can be subjective and outcomes would be very different given stakeholder participation*", *"Prioritisation of objectives will be achieved, whether or not this is a true indication of priorities is another matter"* and "*Yes - though difficult with whole of estuary*". The remaining four participants were still unsure as to whether the objectives had been achieved. Their comments included: "*Not clear yet - there were challenges especially related to pockets of information spread between attendees*", "*I think some participants were still not satisfied with a number of risks which were quite broad. However, this process would not be possible with a longer list of risks or more specific risks"* and "*To some degree - the process was difficult to apply to such a large area - the results were based on considerable generalisations"*. These comments highlight some of the difficult choices and trade-offs that need to be made within the constraints (i.e. time, budget, existing knowledge and available methods) of the LHEMP planning process. Each spatial and risk scale chosen has its advantages and disadvantages, as do the methods used. For example, as highlighted by one of the participants, risk analysis is often a fundamentally subjective process and thus who participates and how can have an important impact on the outcomes. This can be viewed positively or negatively, as the risk analysis process can be time and cost effective, especially in cases of extreme uncertainty and complexity where other more scientific or "objective" methods of analysis may not be possible. This issue is further discussed in Section 5.2.

On whether participants found the workshop useful or valuable for them, the responses were overwhelmingly positive with the exception of only one participant who responded: "*Done it all before*". Reasons cited in the positive responses included:

- *Yes, first risk assessment process*
- *It demonstrated a different style of stakeholder participation*
- *Useful in terms of hearing what the other stakeholders are thinking*
- *Getting broader view of full scope of issues in estuary and various interests and stakeholders*
- *It was useful in that it demonstrated the number of government agencies that bear some responsibility for management issues on the estuary*
- *Showed use of outcomes of workshop #1; Increased understanding of process of development of LHEMP*

When asked "*who else should have participated in the workshop?*", the majority of participants did not respond. The remaining responses highlighted that other agencies involved in the estuary should have shown up and other responses included: "*More council planners, to understand objectives/issues of an EMP"* and *"Most players were there, however more community and stakeholder reps would have provided more local information and balance"*

The following questions focussed on the impacts of the workshop activities. Firstly, the question "*How did the day's activities help you work with and relate to the other participants*" elicited a range of responses. Some responses focussed on the idea that the activities aided getting to better know the views and roles of other stakeholders, including: "*Gained a better understanding of individual agency responsibilities and knowledge with regards to the estuary*", "*It was good to hear the views and objectives and knowledge of other participants*", "*Identify each different person's value in relation to the jobs and research they do*" and "*It provided insight of various agendas – priorities*". The activities were also thought to have "*effective facilitation*", a "*pleasant atmosphere",* and to have promoted "*good interaction*" and "*good open and honest discussion"*. Only one participant voiced the feeling that the activities had not been able to change certain differences of opinion and existing working relations with other stakeholders.

The next closed question helped to further quantify the opinions expressed by participants related to the outcomes of the workshop. The percentages of responses corresponding to each level of agreement of the statements are represented in Figure 14.

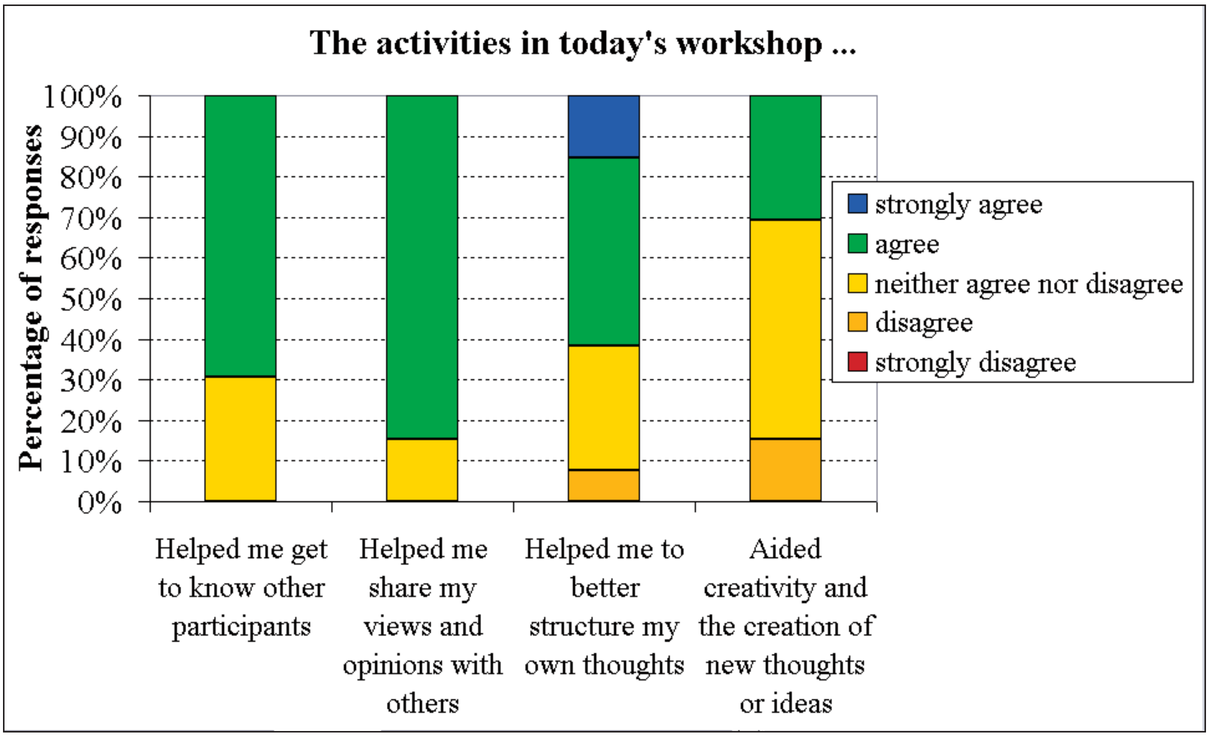


Figure 14: Questionnaire responses - workshop 2 activity outcomes

From Figure 14, it can be seen that overall there were reasonably high levels of agreement that the workshop's activities helped participants to get to know one another and to share their views and opinions with others. Opinion was more largely divided over the capacity of the workshop activities to help participants to better structure their own thoughts, with a couple of participants strongly agreeing and one disagreeing. Likewise, opinion was divided over whether the workshop's activities aided creativity and the creation of new thoughts or ideas, with the responses lightly swayed towards being in agreement.

Responses to the most important things that participants learnt through the workshop included a number of main themes. Firstly, examples of learning about how there are diverse and interrelated issues, risks and stakeholders' views in the estuary included: "*There are many, many, interrelated issues impacting on estuary, regulated (or not regulated) in many ways*"; "*There are numerous aspects to every identified risk and there is a need to define parameters*"; and "*The diverse opinions and thoughts on each of the issues discussed - some presumably based on perception as much as facts*". Next themes that followed on from the last comment were about the subjectivity inherent in the process and aspects of facilitation: "*Decision making is often subjective, difficult to facilitate in a group environment*"; "*Facilitation/workshop techniques. Some issues were perception based as opposed to factual*"; and "*The need for strong facilitation*". Finally, learning about "*Aspects of risk assessment*" and "*The risk assessment process*" were cited, as well as general aspects of collective work that included: "*Some people always push the party agenda*" and "*there are some good people working to protect the catchment. Collectively people can advance*". A quantification of the participants' depth of learning resulting from the workshop relative to a number of other domains is represented in Figure 15.

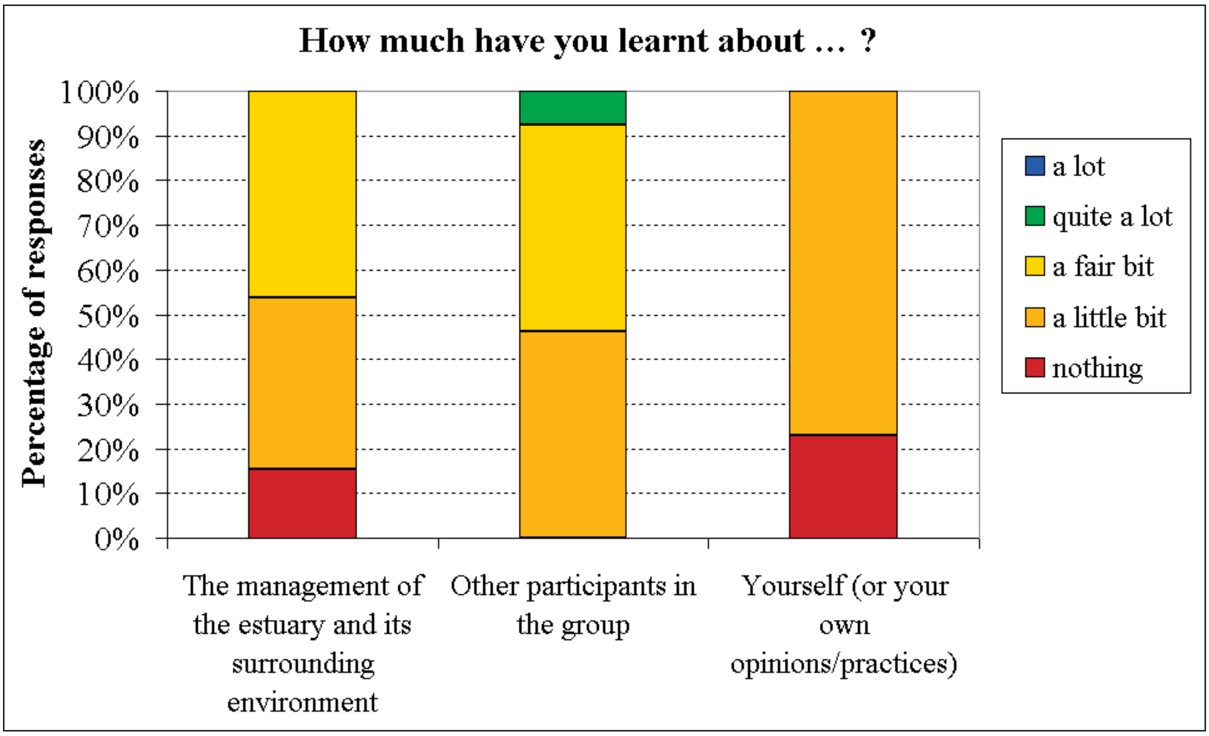


Figure 15: Questionnaire responses - workshop 2 learning outcomes

From Figure 15, it can be seen that through the workshop there were only a few people who learnt nothing about either the management of the estuary and its surrounding environment or themselves and their own opinions and practices. It appears that during the second workshop, participants learnt more about the other participants in the group than estuary management, and comparatively less about themselves, as there were no responses over just "a little bit". These views were largely backed up in the previous open question where learning about aspects related to other participants or group work were mentioned in 7 out of the 11 responses received.

The next section of the questionnaire looked at whether the participants were satisfied with the facilitation of the workshop and how the facilitation could be improved. All but one of the participants were satisfied with the facilitation including comments from "*went OK*" and "*yes, great work given topic and time"* to *"It was well done in terms of government agencies and their lingo"*, with the last participant giving a facilitation satisfaction of "*7/10*". A number of points were raised about how the facilitation could be improved. These included:

- *Better explanation of just what was perceived by WBM to be the meat of each risk category. Heading and info in report didn't correspond with facilitator comments;*
- *If the participants had more time to understand the risk matrix process, the session could have been more productive;*
- *Information provided earlier - too short a time to get through information;* and
- *It could have been a touch more eager to move things along.*

Participants were also asked what they generally liked and disliked about the workshop, and how it could be improved. The likes were predominately related to the workshop process and content, including:

- *Agency discussion - different points of view;*
- *Broad scope for issues;*
- *The bringing together of the stakeholders;*
- *Well managed and conducted;*
- *There could be a way forward and a balanced discussion of problems and not so emotional as workshop 1;*
- *Matrix forced you to work out / question each risk in detail;*
- *Good honest discussion, open;*
- *Opportunity to attempt application of risk assessment;* and
- *Opportunity to be involved and contribute.*

Apart from one comment about the room being stuffy, the majority of the dislikes also focussed on the workshop process and content. These issues included:

- *A tendency to occasionally get bogged down with trivia;*
- *The time allocated I think was a little insufficient;*
- *Complexity of the matrix form of risk analysis;*
- *Focus on whole estuary under discussion rather than more specifics;*

- *Difficult to adequately integrate the summary document or expert knowledge into the process of risk assessment;*
- *Broad scope of topics asked to address in a short time;* and
- *It was a bit fuzzy. A numeric output might help the outcome. A focus group might have similar outcome.*

Suggested improvements followed on to provide some possible solutions to the issues highlighted in the last set of responses. These included:

- *Possible focus on some hotspots as examples;*
- *Less ambitious about how much that was to get done in one day;*
- *Use of geographic base;*
- *Assessing previous information and feeding it into the process and increased definition/specificity of risks;*
- *Following original outline. i.e. working in small groups to draw on more knowledge than just in pairs;*
- *Timing. Perhaps circulate a worked example before the workshop;* and
- *Suggest for the next one you adopt a less formal approach - e.g. risk assessment ratings are not readily understood by community and stakeholder reps.*

Finally, participants were asked for any remaining comments or questions they had related to anything in the workshop or overall project process. Extracts from some of these comments, both complementary and constructive for future work, included:

- *It's a positive step to complete a plan for the Lower Hawkesbury and I support it fully;*
- *There may be other ways to reach desirable ends and end product - Test will be to stakeholders;*
- *Results will need to be applicable to specific sites/areas, legislation, policies;*
- *I felt the delivery of presentations was very professional;*
- *Documents being circulated a bit earlier would be useful;* and
- *Very ambitious project but clearly many stakeholders on board, improving likelihood of success.*

These evaluation outcomes and comments were all taken on board by the project team and were used to help prepare and improve the third stakeholder workshop.

3.9 Preliminary outcomes and preparation for Workshop No. 3

Considering the risk evaluation results from the second workshop that had defined all risks as being either "tolerable" or "intolerable", the decision was taken to continue to study and treat all of the risks in the third stakeholder workshop as part of the risk response (or action) plan for the estuary (as represented in Figure 5). In an attempt to validate these findings, despite a number of methodological imperfections which occurred in the workshop due to last minute changes to meet stakeholders' wishes, both a follow up study of risk priority preferences and a brief sensitivity analysis of the risk assessment outcomes were undertaken.

3.9.1 Perception based stakeholder risk priorisation

Based on some of the debriefing and evaluation comments, as well as an interest in comparing and cross-checking the risk analysis results with the participants' perceptions of risk importance, WBM Pty Ltd sent a follow up email to the workshop participants asking them to rank the list of sixteen risks as either a high, medium or low priority from their points of view. A fifty percent response rate from the participants was achieved, with a visual representation of the responses given in Figure 16.

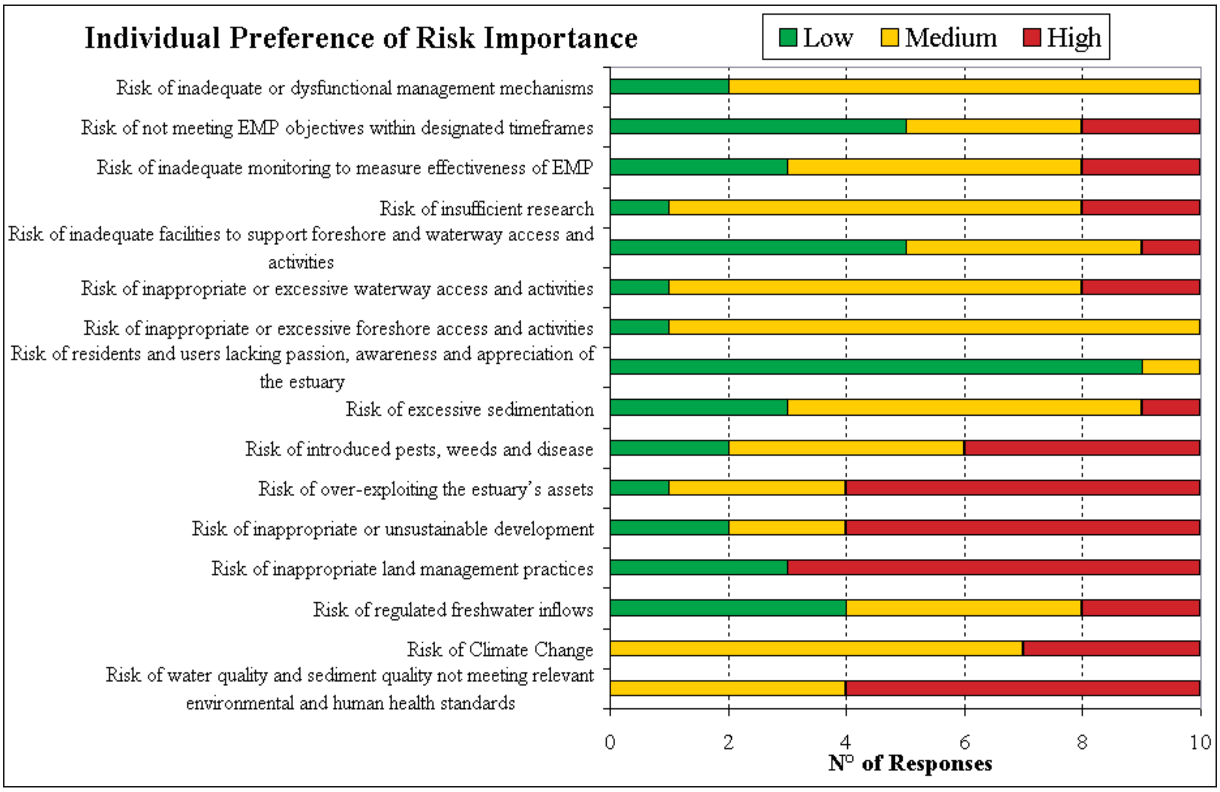


Figure 16: Stakeholder risk priorities

From a quick visual analysis of Figure 16, the "risk of residents and users lacking passion, awareness and appreciation of the estuary" can be identified as the lowest prioritised risk. Apart from this risk, the overall ranking of the other risks is dependent on the method of statistical analysis used. For example, if the risk with the largest number of "high priorities" is to be ranked first, then the "risk of inappropriate land management processes" would achieve this position. However, if the numbers of high, then medium, priorities (or a number of other methods) were to be considered for achieving the top rank, then the "risk of water and sediment quality not meeting relevant environmental and human health standards" would be ranked first. A limited number of statistical analyses were performed on these stakeholder risk priorities to determine their rankings including: attributing different numerical values to the three priority categories and taking averages; sorting based on numbers of quantities of risks in each priority category; and medians. From these analysis options, the rank ranges for the perception of each risk's priority are given in Table 4.

Table 4: Rank ranges for stakeholder defined risk priorities

Risk Name	Rank Range
Water quality and sediment quality not meeting relevant environmental and human health standards	1-2
Inappropriate land management practices	1-3
Over-exploiting the estuary's assets	1-3
Inappropriate or unsustainable development	1-4
Climate Change	5-6
Introduced pests, weeds and disease	5-6
Insufficient research	5-7
Inappropriate or excessive waterway access and activities	5-7
Inadequate monitoring to measure effectiveness of EMP	5-9
Regulated freshwater inflows	5-11
Excessive sedimentation	5-12
Inappropriate or excessive foreshore access and activities	5-14
Inadequate or dysfunctional management mechanisms	5-15
Not meeting EMP objectives within designated timeframes	11-14
Inadequate facilities to support foreshore and waterway access and activities	13-15
Residents and users lacking passion, awareness and appreciation of the estuary	14-16

Observation of the risk rank range levels in Table 4 shows a number of differences between the stakeholder perceptions of the risk, versus the multi-asset based risk assessment. Specifically, the water quality risk is perceived to be the most important, as described in the risk evaluation session debriefing (Section 3.7). The other major difference was the particularly low comparative ranking of the "risk of inadequate facilities to support foreshore and waterway access and activities". This could potentially be due to a number of factors including that these values only represent the "agency" perspective and that for these agencies' management domains, this factor is not immediately thought of as a priority.

3.9.2 Risk assessment sensitivity analysis

In order to understand which aspects of the risk assessment most influenced the numerical outcomes, a sensitivity analysis of a number of different factors was undertaken. In all of these analyses, the original values given by the participants have been conserved. It is noted that it is likely that some of the small groups had different styles of interpreting the risk tables from others, and thus due to a lack of validation risk to check these differences, the results of the risk assessment can only be taken as a general guide. This aspect of the risk assessment process is described in more detail in Section 5.1.

However, a number of different aspects related to the mathematical model of calculating risk levels, asset weightings and ranking based on different factors can still be analysed.

In total, the effect of 33 different combinations of parameters was used to test the sensitivity of the model and risk rankings. Three base mathematical models were used as a part of these combinations for calculating the risk levels based on the consequence and likelihood ratings: firstly, the original logarithmic scale (base 2), as previously described and used in the CERAM method of environmental risk analysis (Wild River and Healy, 2006), where the risk levels vary from 0 to 128; secondly, the traditional model of: risk level = consequence x likelihood where the risk level ratings vary between 1 and 25; and finally, a model of: risk level = consequence + likelihood where the risk levels range from 2 to 10. In each of these cases, the final rankings were examined when sorted based on the values of the: risk levels; knowledge uncertainty; and management effectiveness.

The impact of the asset weightings (which were all equal in the original model) on the rankings were also modified to examine the model's sensitivity to these parameters (with the risks only then being sorted according to the resulting risk level). To consider this in a more meaningful way than randomly or systematically adjusting the weightings one by one and then in different groups, which although an interesting exercise would be extremely time consuming, the choice was made to define four scenarios of preferred weightings. In simpler terms, groups of assets were chosen to be "preferred" over others according to a preference for: environmental enhancement and maintenance of ecosystem services [ENV]; an active and an economically and socially viable community [CE]; successful management of the estuary's water quality to support multiple uses [MAN]; and maintenance of the undeveloped nature, scenic beauty and heritage of the estuary [HIST]. The asset groups favoured in each of these scenarios are presented as follows.

[ENV]: functional & sustainable ecosystems; water quality for multiple uses
[CE]: community value; sustainable economic industries; recreational opportunities
[MAN]: effective governance; water quality for multiple uses
[HIST]: scenic amenity & national significance; largely undeveloped surrounding lands; culture & heritage

In each of these cases, the relevant asset weightings were increased from 1 to 5, and then to 10, to look at the impact of more extreme preferences relative to the other assets.

From these 33 different parameter changes, the maximum and minimum rankings of each of the risks are displayed in Table 5. The full summary table is presented in Appendix E. The ranks are given according to the risk levels and then the knowledge uncertainty and management effectiveness. Risks of the "intolerable" kind are noted in red and those considered as "acceptable" in green. All black values were calculated as "tolerable" risks.

Table 5: Rank ranges in risk model sensitivity analyses

Risk Name	Risk Level Rank Range	Knowledge Uncertainty and Management Ineffectiveness Rank Range
Climate Change	**1-9**	1-4
Regulated freshwater inflows	**1-14**	5-14
Inadequate facilities to support foreshore and waterway access and activities	**1-4** [a]	6-12
Inappropriate land management practices	**4-9**	2-8
Inappropriate or excessive waterway access and activities	**3-6** [b]	2-5
Over-exploiting the estuary's assets	**1-8**	10-11
Insufficient research	**5-9**	7-10
Inappropriate or unsustainable development	**2-10**	9-15
Inappropriate or excessive foreshore access and activities	**4-10** [c]	7-9
Excessive sedimentation above natural levels impacting the environment	**9-12**	8-14
Introduced pests, weeds and diseases	**9-12**	13
Water quality and sediment quality not meeting the relevant environmental and human health standards	**10-13** [d]	11-12
Residents and users lacking passion, awareness and appreciation of the estuary	**10-14**	1-15
Not meeting EMP objectives within designated timeframes	**7-14**	3-6
Inadequate monitoring to measure effectiveness of EMP	**15** [e]	3-4

Table notes: [a] also 1 (tolerable) found and the likelihoods are likely to be somewhat overrated compared to other risks; [b] also 5 (tolerable) found; [c] also 9 (intolerable) found; [d] also 12 (acceptable) found; [e] this risk assessment was not entirely completed during the workshop.

From Table 5, it can be seen that based on the participants' input and the sensitivity of the evaluation model, a number of the risks are more sensitive than others in terms of their relative rankings of risk levels: in particular, the "risk of regulated freshwater inflows", which was extremely sensitive to the asset weightings. This was the only risk to range from "intolerable" to "acceptable" over the analyses. Under all equal weightings, this risk was "tolerable". However, under all three mathematical models, when the weightings were changed on the [ENV], [MAN] and [CE] scenarios, this risk became "intolerable", and under the [HIST] scenario became "acceptable". Interestingly, regulated freshwater inflows received much discussion during the first and second workshops, with opinions ranging widely on how much of a risk they actually posed. This range of opinions is also backed up in the risk perceptions in Figure 13. It therefore appears that if there had been time to collect stakeholder preferences on the importance of different assets relative to one another, a more specific picture of this risk (relative to the concerned stakeholders) could have been calculated using this risk assessment model.

Other elements of this sensitivity analysis worth noting were that the tolerability indices tended to follow the relative ranks of the knowledge uncertainties, as well as the level of management ineffectiveness (second ranking column in Table 5), as should be expected. The water quality risk became “acceptable” under one [MAN] scenario where the weightings advantaged the positive perception of management systems in place to manage this risk (as discussed earlier in Section 3.6); otherwise it remained largely insensitive to other parameter changes and largely differently ranked when compared to the risk priority preferences in Table 4. Although not looked at in great detail here, the selection of tolerability index boundaries is another aspect of the model used in this workshop that could be easily debated with participants and tested for their sensitivity on the final results.

If such a risk assessment process were to be repeated, a suggestion to better analyse and aid understanding of these risks would be to specifically define the specific “inherent” part of each risk (when there is no management or the management systems in place for this risk fail), as well as the “residual” risk (the risk posed when the management systems are in place and working as they should). In the case of this workshop process, the “management effectiveness” was used as a surrogate for the difference between these two risks levels, but it may become clearer from the participants’ points of view if these two different risks were made explicit. It is most likely that the inherent (unmanaged) water quality risk would be ranked extremely high (extrapolating from the priorities) and that the “residual” risk (as it is currently managed) would not pose an excessive problem compared to other less well managed risks.

Other potential variants on the process used for carrying out these risk prioritisations could include breaking the risks down into “sub-risks” or risks concentrating on “sub-areas” of the whole estuary. If such analyses were to be carried out, more time should be dedicated to the task. In the future, other multi-criteria methods of analysis could also be used for asset preference elicitation and the ranking procedures used in the model (rather than the simple weighted average method used in this workshop). However, in a participatory setting, these choices of methods should be carefully made, as some of the more difficult to understand mathematical models may not be as readily accepted by participants as the basis for the already subjective task of risk ranking.

4. WORKSHOP NO.3

The third stakeholder workshop was held at the Hornsby Shire Council Chambers on Thursday the 1st of March 2007 from 9.30am to 3.30pm. The day's activities were attended by 18 participants from a number of government departments (DPI, NSWMA, DEC, NPWS, DoL); authorities and associations (HNCMA, SWC, NSW BOA, Oceanwatch, HNC Foundation, NSW BIA, THREPS); Local Government representatives (HSC) and community representatives (local industries and residents). The workshop was facilitated by Philip Haines, Michelle Fletcher, Verity Rollason (WBM Oceanics), Michael Baker (SJB Planning) and Katherine Daniell (Australian National University). External evaluation (including video and audio recording) of the process was carried out by Natalie Jones (Australian National University).

4.1 Workshop aims

The aim of the third workshop, as suggested in Table 1, was to formulate strategies to "treat" all of the tolerable and intolerable risks, as classified in the second workshop. More specifically, the objectives of this workshop were to:

- Develop strategies and actions to treat the causes and effects of the 16 estuarine risks;
- Determine which stakeholders and resources are required to put the strategies in place and carry the actions out;
- Determine target states of risk reduction and select indicators, monitoring needs and information dissemination strategies to achieve them;
- Obtain stakeholder preferences for actions; and
- Evaluate and obtain feedback about the project process and content in order to improve the final stages of the project and future processes.

4.2 Workshop process overview

The activities undertaken during the third workshop are given in the Agenda which can be found in Appendix B. To achieve the objectives outlined in Section 3.1, the day was broken down into a number of sessions. The workshop commenced with a general welcome, presentation of the day's agenda and a session of personal introductions. This was followed by a short project background update and presentation of the strategy mapping technique to be used for the day's activities. Prior to morning tea, a session of individual brainstorming was run to determine potential strategies and actions for each of the 16 risks. Between morning tea and lunch, the strategy mapping exercise was undertaken as small groups. Once the small groups had finished their own risks, they could then add to the strategy maps of the other groups' risks. After lunch, responsibilities and monitoring needs were added to the maps and the participants distributed their preferences on strategies or actions for each of the risks. The workshop was ended with the final participant evaluation questionnaire.

4.3 Introductions & reconfirmation of goals, assets and risks

Following the general welcome and agenda for the workshop, a round of personal introductions was started with everyone being asked to present themselves to the group giving their name, where they were from, plus, in 10 words or less, “an innovative or radical strategy” to address one of the estuarine risks. The session of introductions lasted approximately 15 minutes with the responses drawn from the strategy question ranging in “radicalness”. It was interesting to note that the perception of “radical” relied not only on new or “out-there” ideas, but rather on what could actually occur. Thus strategies seen to be utopian or near impossible to achieve, even if they were already established goals for the management of the estuary, were seen as “innovative or radical”. One strategy of this kind put forward by a participant, *“work together to put this plan in place and see the outcomes”*, elicited laughter from the rest of the participants, potentially because of the perceived “innovative” nature of such a proposal!

Other strategies to manage the estuarine risks put forward by the participants included:

- more monitoring throughout the catchment system to know what is going in and coming out;
- focussing attention on underlying factors (i.e. population growth; ecosystems being primary);
- a big police operation against illegal development;
- assess risks and peoples’ different perceptions of them to supplement knowledge of what the risks actually are and their magnitudes;
- undertake an environmental and economic impact study of the whole estuary for different risks (i.e. study of boating risk impacts now compared with 15 years ago to help identify “real” estuarine risks);
- conversion of all STPs to recycled water plants to reduce nutrients and flows to the river;
- zone estuary for different waterway uses and put speed limits on vessels;
- create an inventory for the estuary and catchment so we know what we are managing (i.e. fish stocks; maps of sea grasses);
- need to encourage ‘responsible use of the river’ through education and making facilities for responsible use available;
- investigate triggers for collapse of assets (i.e. fish populations);
- “zap” sedimentation: need to first establish where it is coming from;
- educate in more “user-friendly” ways (i.e. develop brochures and booklets related to estuarine issues as “people don’t read lengthy documents”; approach schools);
- establish risks and the priority they pose to the estuary and surrounding land so that management efforts can be prioritised appropriately;
- guarantee environmental flows and periodic flooding (i.e. go back to original system, productivity and values);
- use less water in Sydney and recycle effluent for drinking;

- determine what values and services the estuary provides, then make people who use it pay to look after it;
- develop a strategic approach to managing the ecological footprint of the estuary: break the estuary down into development areas and business areas; determine the impacts of global warming on these areas and their footprints; and
- develop the collective vision and collaboration to put the LHEMP in place.

After this round of introductions, WBM Pty Ltd presented the background information to this third workshop in a five minute summary, which included a brief recap of the activities in the first and second workshops, including how the "issues" developed in Workshop 1 became "risks" and the "values" became estuarine "assets". The updated goals for the estuary were then presented, as shown in Figure 17, followed by the lists of previously defined 9 estuarine assets and 16 risks.

Figure 17: Estuarine goals developed by WBM Pty Ltd from Workshop 1 and 2 inputs

This presentation was not met with too much vocal comment or criticism. One participant commented that where "functionality" or "sustainability" of ecosystems is mentioned, "biodiversity" should also be attached to these terms, as *"functionality could occur with a fraction of the species"*. On the risk prioritisations, there was a small objection raised by a couple of participants about the "medium" ranking of the "dysfunctional management" risk, thinking that it should have been a higher risk. Another participant also described the risks and underlying causes as being confused (i.e. the "residents lacking awareness" and "dysfunctional management"), as some are causes of others. The facilitator replied that many of the risks were in fact interrelated and could be considered as risks or causes in certain circumstances but that they still all needed to be examined for potential treatment.

4.4 Strategy mapping method

After WBM Pty Ltd's project background update, the method to be used to create input to the Lower Hawkesbury Estuary Action or "Risk Response" Plan in this workshop was presented to participants by Ms. Daniell. The "strategy mapping" technique had been specifically adapted for the risk management treatment process of the estuary after being originally adapted from Ackermann and Eden's (2001) "Oval Mapping Technique". It was first developed and tested for the context of water management as part of Ms. Daniell's PhD work and the European Project, "Aquastress", in Montpellier, France (Daniell and Ferrand, 2006).

The strategy mapping technique was to be used to: develop strategies and actions to treat the risks; define who would be responsible for carrying out the actions; and determine how these strategies could be monitored (i.e. required indicators, information for management, and data). More specifically the objectives of using the technique in this workshop were to:

- Encourage creativity and active participation; and
- Visually structure information and allow everyone to see and add to the information produced: "piggy-back" brainstorming.

The construction of the strategy maps was explained using the image in Figure 18 as a basis.

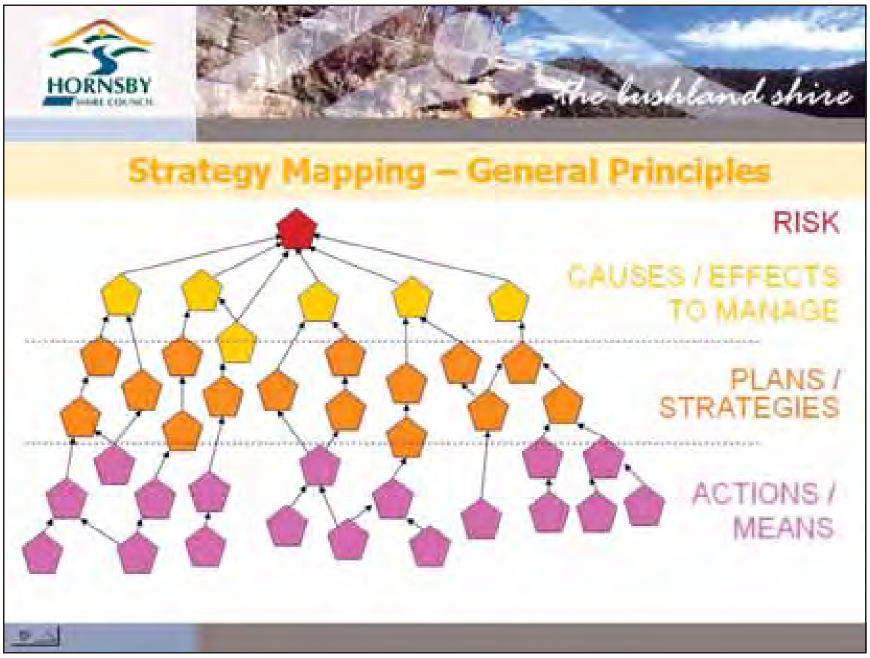


Figure 18: General principles of the strategy mapping technique

The risks and their causes and effects that had already been identified in the first two workshops became the top rows of the strategy maps, as shown in Figure 18. The strategies (or plans) and actions (or means) for each risk were to first be generated on coloured cards through a session of individual brainstorming. Two minutes was to be allocated for each risk. The idea was to try to write as many cards as possible (one card per action or strategy) in the two minutes and to be creative. The feasibility of actions could be commented on at a later stage of the process, as the creative ideas may feed others' ideas in the meantime – thinking "outside the square".

The individual contributions would then be sorted by risk, and preliminary structuring of the cards would take place in small groups. The strategies and actions were to be added by the participants under the associated causes or effects of the risk. They could be joined in a hierarchical fashion to show the dependencies of each strategy and action on the rest of the possible management system. Once all of the existing cards had been structured on the maps, other strategies and actions could be added by the groups to fill the maps out (i.e. "piggy-backing" and further formalisation of ideas). If there were some causes and effects that had been left unmanaged, these areas should be especially targeted. After the small groups had finished with their attributed risks, the participants would be free to look at and add to the other groups' strategy maps. They could add strategy or action cards, comment on what was already there (if they were against or in agreement with the strategies and actions), but were asked not to remove anything.

Following the completion of the strategy maps, the participants would then be asked to define stakeholder responsibilities (i.e. who would (or could) be responsible for carrying out the actions), as well as to determine how the effects of the actions could be monitored (i.e. required indicators and targets, information for management, data). These stakeholder responsibilities and monitoring needs could be added onto the map using Post-its®, as represented in Figure 19.

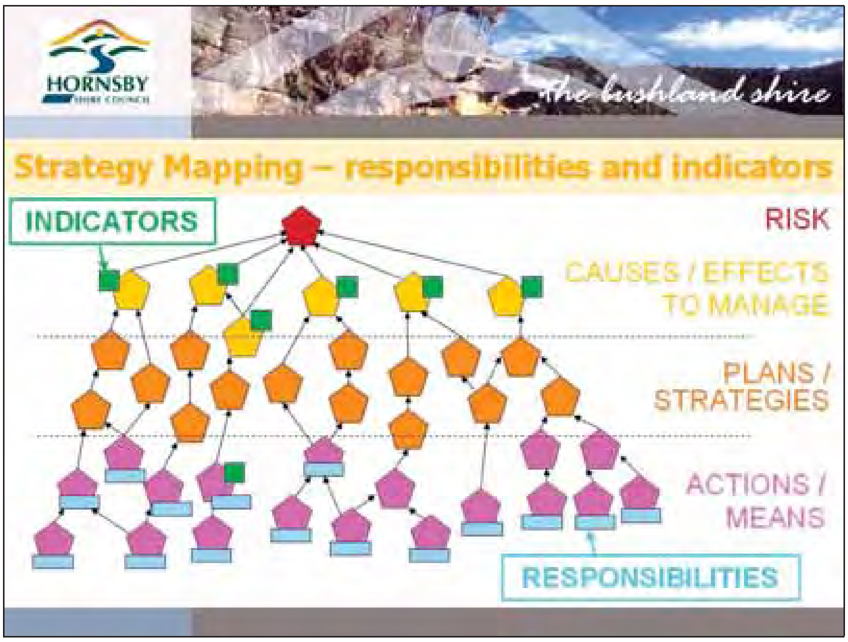


Figure 19: Adding stakeholder responsibilities and indicators to the strategy maps

At the end of the mapping exercise, participants would then be asked to distribute their preliminary preferences on the strategies or actions, so that these preferences could be considered by the consultant team in the plan write-up. To visualise these preferences, each participant would be given 16 sticky dots to distribute on the strategies and actions of the 16 risks. They were asked to first initial them and then place them on their preferred actions on each of the maps (no more than one dot per action).

4.5 Participant strategy mapping

To start the strategy mapping exercise, WBM Pty Ltd led the session of individual brainstorming for each risk. All of the participants in the room were handed a pile of orange and pink cards by the facilitators and asked to write on the top of each card the number of the risk they were writing the cards for, as well as their initials for tracking and confirmation purposes. The two minutes of brainstorming for each risk were carefully timed by one of the facilitators, with a signal being given at 1min30 for each risk, to allow the participants to finish off the risk they were working on and to prepare for the next one. During the two minutes for each risk, the session facilitator would introduce the risk with its previously identified causes and effects with the aid of a pre-prepared PowerPoint slide which would remain on the screen for the participants to refer to during their brainstorming.

The participants worked very productively and conscientiously through this 32 minute period of brainstorming, producing over 700 separate strategy and action cards between them. They were then invited to take a well earned morning tea break while the facilitators sorted the cards into piles for each risk and checked that all the risk maps had been correctly pre-prepared with the risk name and yellow cause and effect cards.

After morning tea, the participants were asked to split up into 4 groups and to try to avoid having too many similar interests in each group (i.e. no two participants with the same affiliation and a mix of community and agency representatives). This self selection process appeared to work reasonably well, although one group did not have an agency representative. Each group of four to five participants was then allocated half a room each with four pre-prepared risk strategy maps, the corresponding piles of strategy and action cards from the brainstorming session, and a facilitator. In most groups, the participants, either individually or in a pair, decided to start the process of organising the cards on the maps for each risk. This choice sped up the strategy mapping process quite remarkably and allowed much more time for the participants to discuss, alter and add to the maps after the initial structuring. It was interesting to note the different techniques of participants for attempting this task. Some participants sorted all the cards into sources, causes and hierarchies before sticking them to the map, whereas others worked with one card at a time, sticking it to the map and drawing in its interdependencies. Photos of the individual card sorting and structuring, then group map restructuring, are shown in Figure 20.

Figure 20: Card structuring on risk strategy maps

In this structuring phase the participants were told they were also able to add yellow strategy or effect cards to the maps if required. Once the maps were largely constructed, the group members could then work together and discuss options to manage their risks, adding more cards to the maps. When the groups were satisfied with their four maps they were then encouraged to view and add to the other 12 risk strategy maps. Discussions over the strategy maps during this phase are shown in Figure 21.

Figure 21: Small group discussion over risk strategy maps

These phases of the strategy mapping were completed more quickly than what had been planned for in the workshop agenda (Appendix E), with most groups being satisfied with their risk strategy maps and the other groups' maps before lunchtime. This meant that they had a reasonable amount of time to talk with other participants about particular strategies or other more general topics. These conversations continued between participants through the lunch break, as shown in Figure 22.

Figure 22: Lunchtime conversations

After lunch, participants were asked to move on to identifying indicators, targets and monitoring strategies to manage the risks and implementation of actions, as well as potential stakeholder responsibilities for actions. A couple of participants noted at this stage that they could not yet definitively place management responsibilities on the actions (unless it was already part of a planned program), as they would have to confirm them with their superiors. To be able to do this at a later date, the participants asked that WBM Pty Ltd provide them with a copy of the proposed action tables as soon as they were written, so that they would be able to seek out the required confirmations of management responsibility. Despite this potential issue, most strategy maps were marked with quite a number of stakeholder responsibility and monitoring PostIts®. Defining “concrete” indicators and monitoring strategies to measure the impacts of actions in reducing or mitigating the risks were found to be a challenge by some participants. For example, “erosion” was marked on one indicator or monitoring PostIt®. Erosion could be considered as an indicator, but for this indicator to be useable, a target state of erosion needs to be established spatially and temporally, and data will have to be collected using special techniques over various spatial scales and at different time intervals. Monitoring schemes to this scale of detail were rarely noted, except where reference was made to existing monitoring schemes in the estuary region. This issue is further discussed in Section 5.4. Part way through the defining of stakeholder responsibilities and monitoring needs, a number of participants had to leave early, so the distribution of preferences and workshop evaluation were brought forward in time from what had been originally programmed in the Agenda (Appendix E). The remaining participants then went back to defining monitoring needs and stakeholder responsibilities after they had completed these other activities.

4.6 Participant preference distribution

Considering the risk strategy maps, the participants were asked to think about which strategies or actions they would prefer to see put in place through this planning process. They were then each handed 16 sticky yellow dots to distribute on their preferred strategies and actions over the 16 risks strategy maps. The participants were asked to mark their initials on their dots and to only leave one dot per strategy or action card. This activity was useful as it allowed the participants more time to read and absorb the content of the 16 risk strategy maps before making their choices. It was also mentioned to the participants that if they did not find enough actions that they wanted to support, they still had the opportunity to add more strategy or action cards. Figure 23 shows the participants considering their preferences and one excerpt of a map with a couple of highly prioritised strategies.

Figure 23: Participant preference distribution for actions and strategies

These priorities were then to be considered by WBM Pty Ltd in the plan writing phase after the strategy maps had been condensed into a useable format.

4.7 Participant evaluation questionnaires

When the participants had finished their distribution of preferences, they were each given an evaluation questionnaire relating to the third workshop and overall LHEMP process. The objectives of the questionnaire were similar to those outlined for the second workshop in Section 3.7. In addition, the objective of this last questionnaire was to determine:

- the participants' thoughts on the whole Lower Hawkesbury Estuary Management Planning process;
- how the methods used throughout the workshop processes have been perceived;
- how the participants had perceived their own participation in the process; and
- how the LHEMP process could be improved.

The questionnaire provided to participants contained 13 "open" and "closed" questions in the first section on the third workshop and a further 7 "open" questions in the second part on the overall LHEMP process. The questionnaire is given in Appendix D.

4.8 Workshop No. 3 questionnaire results

Despite a number of participants having to leave the workshop at lunchtime, fourteen responses were returned to the facilitators, indicating a 74% coverage of the workshop attendees. Responses were received from a good distribution of participants, including state and local government, authorities association, and community representatives. A number of participants filling out the evaluation forms are shown in Figure 24.

Figure 24: Participants completing the evaluation questionnaires

In the first section of the questionnaire, participants were asked to outline what they thought the objectives of the workshop were, and whether or not they had been satisfactorily achieved. In terms of workshop objectives, all responses were very consistent with what the facilitators had presented at the beginning of the session, including: "*Develop specific actions and strategies to address risks identified in workshops 1 and 2*" and "*Get an idea of priority strategies and management actions as input to developing a draft plan*". Considering whether these objectives had been achieved, eight participants responded with a qualified "yes", including:

- *Yes, numerous actions and strategies were assigned to each risk - all participants had equal opportunity to suggest responses to each risk as well as comment on others;*
- *Good supplementary information was generated that could add value to a comprehensive strategy review (which could simply involve updating the Kimmerikong 2005 report on estuary management in the Hawkesbury River);*
- *Yes, it worked. A few far flung, idealised ideas about;* and

- *Broad input was achieved but truly effective solutions are elusive because underlying pressures can't be addressed*

Three participants responded with a version of "partially" that included:

- *You are moving closer. More definition of what would be acceptable levels of detail for actions would have helped e.g. give a good example and a stupid one in introduction to narrow the range of responses;*
- *Time was very limited and probably did not allow discussion and full understanding of all the input, so answer is partially met. Probably tried to achieve too much;* and
- *To a degree - lots of doubling up, some gaps not a lot of work on difference between dreams/ideals vs. achievable actions.*

Finally, three participants were either not sure if the objectives were achieved or did not answer the question directly. These responses included:

- *A lot of the actions were not plausible;*
- *Do not know. I cannot assimilate all the information provided under each risk and evaluate it in the process used today;* and
- *Not sure that there was enough shared understanding of the issues (risks) for informed contribution.*

It was interesting to note from these responses, that the participants who had not taken part in the preceding workshop, or both workshops (both agency and community representatives), had more difficulty assimilating and producing the large amounts of information in this third workshop.

On whether participants found the workshop useful or valuable, the responses were overwhelmingly positive. These responses included:

- *Provided a wider view of the uses, issues and risks associated with the estuary;*
- *Useful opportunity to share ideas, understandings and to network;*
- *Better familiarity with how risks perceived. Opportunity to think a bit laterally and contribute to development of plan;*
- *It was useful in reigniting the sense of community empowerment;*
- *The approach is good and one that I am very familiar with. It gives everyone a feeling of "being heard" and ownership;*
- *Made me think. New ideas. Meet new people;* and.
- *Good to share concern and passion for our beautiful river.*

Unlike in the last workshop, the question "*who else should have participated in the workshop?*" elicited a broad range of responses including a number of "no's" and the response "*No one that wasn't* *invited*". Other participants (who may not have been aware of who was invited) thought that the following people or agencies should have had representatives attending the workshop:

- Commonwealth for Healthy Rivers Commission;
- Senior environment and planning staff from both councils;
- Indigenous people;
- Federal Government; and
- Wider range of experts (i.e. hydrologists).

Next, the questions focussed on the impacts of the workshop activities. The question, "*How did the day's activities help you work with and relate to the other participants*", was met with a range of responses. One participant was sceptical of the workshop's capacity to aid working and relating to the other participants: "*Fairly limited but some useful discussion of issues helped to share ideas*". However, all the other responses were more positive and included:

- *Provided a good ground for cross pollination of ideas and perspectives;*
- *Abundant opportunity for discussion;*
- *More open process (than previous 2 workshops) allowed increased tapping of people's expertise;*
- *Developed appreciation that all want best outcome for estuary;*
- *Good opportunities to meet residents and interested parties;*
- *Helps develop a team mentality;* and
- *Each workshop has increased my awareness of these processes and issues associated with presenting and managing such a process. Got to know and hear more from other participants.*

The next closed question helped to further quantify the opinions expressed by participants related to the outcomes of the workshop. The percentages of responses corresponding to each level of agreement of the statements are represented in Figure 25.

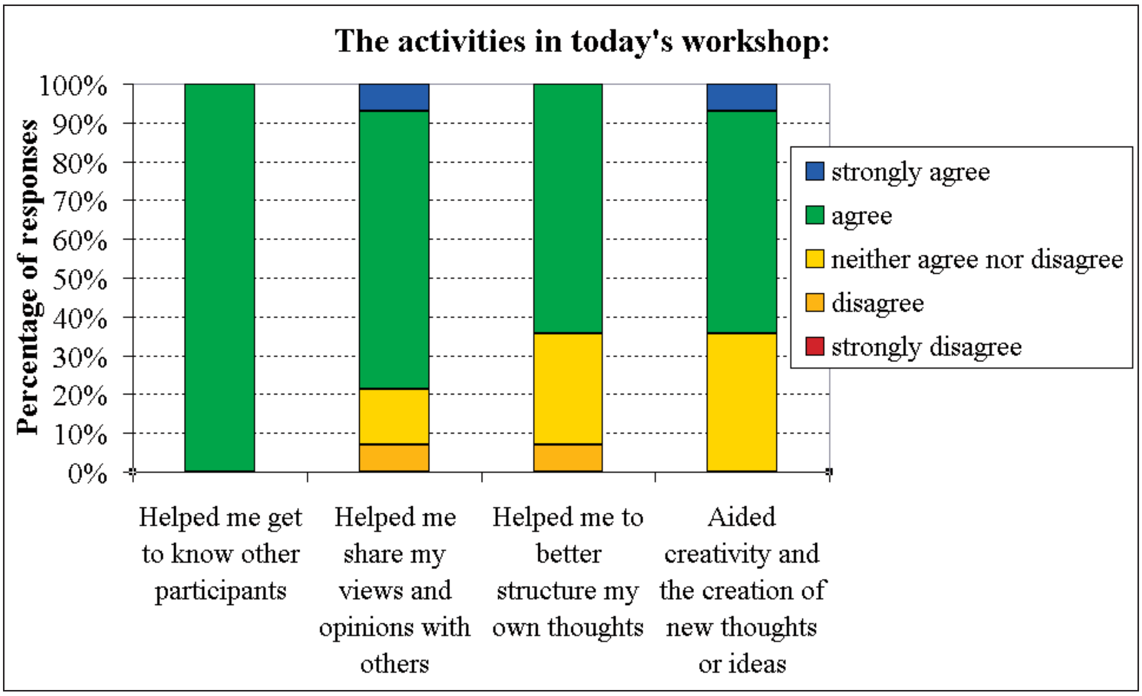


Figure 25: Questionnaire responses - workshop 3 activity outcomes

From Figure 25, it can be seen that overall there were high levels of agreement that the workshop's activities helped participants to get to know one another. Opinion was a little more divided, although still mostly positive, as to whether the workshop's activities allowed participants to share their views and opinions with others and aided creativity and the creation of new thoughts or ideas. To a slightly lesser extent, opinion was divided over whether the activities aided the participants to better structure their own thoughts.

Responses to the most important things that participants learnt through the workshop were more diverse than in the previous workshops. These responses included:

- *A range of challenges to the estuary exist and are ever evolving;*
- *There is no one right way to address identified risks. Collaboration is essential;*
- *That there are no better ideas out there that we have not thought of;*
- *How complex EMP preparation is!*
- *It is extremely difficult to tap local "expert" knowledge in a way that is useful and where the data collected can be retrieved;*
- *Many different views (understandably). Has helped me to formulate and form up my own opinions;*
- *There's lots to do - where will the $$ and political/mgmt will come from?*
- *Being open and learning from others, some who come from completely different disciplines;*
- *Nothing new, but clarified some existing ideas;*
- *That change will always be incremental;*

- *How important compliance is, extension of research and monitoring data to planners and Federal government funding bodies;*
- *The multi-faceted nature of environmental issues;*
- *Wide diversity of expectations of the plan's outcomes and abilities i.e. some think we can influence the Westminster system of government and others a pump out potty for small boats (night soil collector for boats);* and
- *Gathering need for management that goes beyond Councils and State agencies.*

A quantification of the participants' depth of learning resulting from the workshop relative to a number of other domains is represented in Figure 26.

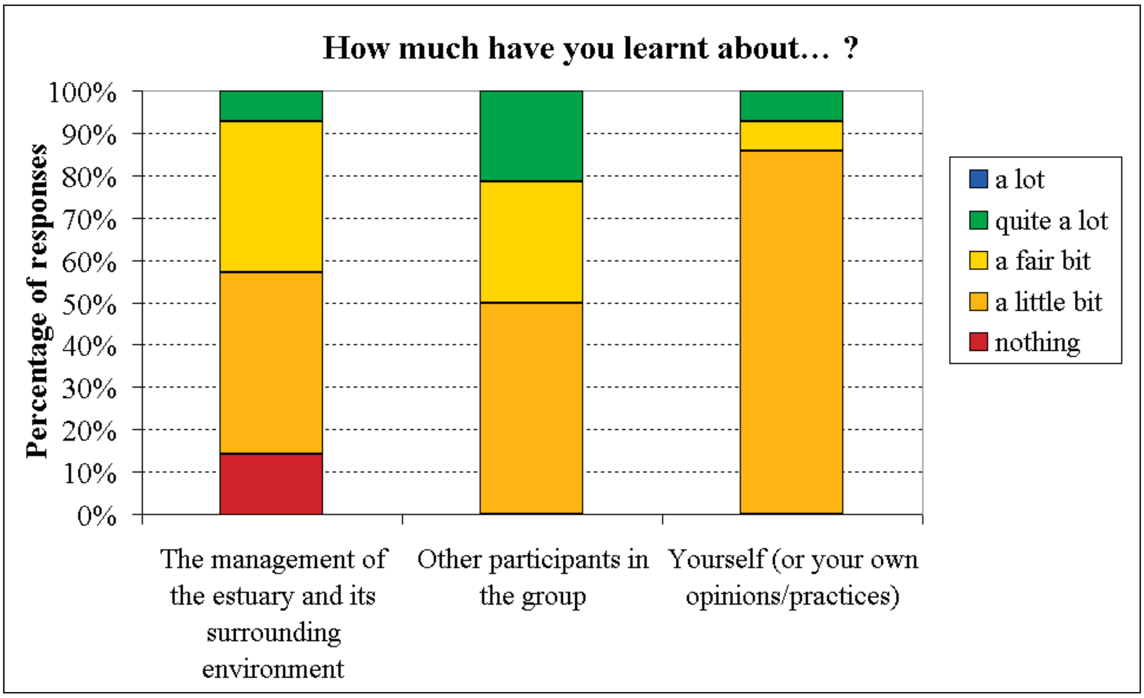


Figure 26: Questionnaire responses - workshop 3 learning outcomes

From Figure 26, it can be seen that through the workshop there were only a few people who learnt nothing about the management of the estuary and its surrounding environment. It also appears that more was learnt comparatively about other participants in the group than about themselves, as only 15% of participants stated having learnt more than just "a little bit", compared to 50% when looking at other participants in the group.

The next section of the questionnaire examined whether the participants were satisfied with the facilitation of the workshop and how the facilitation could be improved. All but three of the participants were satisfied with the facilitation, with one being "reasonably" satisfied, one not responding and last replying that more direction was needed. A number of good points were raised about how the facilitation could be improved. These included:

- *Needed improved facilitation of groupwork, need more time to cover the wealth of issues;*
- *Less time on each step (except first) - seemed to be a fair bit of wandering and waiting;*
- *A little more time at the input stage - maybe even workshop pre-work;*
- *The difference between strategies and actions was unclear;* and
- *Perhaps fewer risks/threats to be analysed. This did however allow people to land at same answers from different directions.*

Another comment not entirely related to the facilitation of the third workshop, but rather the whole process, was also made: *"The community involved in the EMPs had ownership of them until they were excluded from the second workshop".* This particular comment and another of other similar issues will be further discussed in Section 5.

Participants were also asked what they generally liked and disliked about the workshop, and how it could be improved. The likes were wide-ranging from the food to the opportunity to be involved. Some of the other responses included:

- *Shows overlapping and interrelated nature of estuary;*
- *Opportunity to comment and receive comment on suggested strategies and actions;*
- *Interaction with other participants, made you think;*
- *Working with a significant subset of information (4 risks) and then having the opportunity to take in the work of the other groups in an unstructured way. Cards worked quite well to communicate ideas;*
- *Talking with the other stakeholders;*
- *The venue was the right size and comfortable - the pace was about right;*
- *The opportunity to participate and exchange views with a variety of people;*
- *Innovative, mixed participants;*
- *It attracted a range of people with different interests and skills;* and
- *The group focussed on basically same goals. Well facilitated and timed.*

The simplest of the dislikes included: filling in the evaluation form; that people's thought patterns were a little confusing; and that "*these things never reach a final conclusion*". Other more specific dislikes included:

- *Some comments were close to accurate language but many could have been clearly defined (i.e. not concisely worded) - there is a risk of different interpretations;*
- *Blame mentality of some - where everyone lives - should be collective responsibility;* and
- *No. of issues, difficulties in covering all issues, broad scope of risks.*

Finally, a couple of potentially more major objections were voiced as dislikes. The first related to hoping that the material generated in the workshop was going to be supplementary information and not form the core contents of the management strategies in the EMP, as otherwise the participant would be "*not happy*". The second comment described how exclusion from participating in the second workshop had been a "*very disempowering experience*".

Based on these dislikes, there were some clear improvement strategies described to help overcome them and improve the workshop and future planning processes. Firstly to address the "disempowering experience" of being excluded from the second workshop, it was suggested that: "*The government agency workshop could still have gone ahead but the process explained differently to how it was in the letter, so that the members of both committees (EMP) were not disempowered and they retained ownership in the process"*. On the issue of the workshop material not forming the core contents of the LHEMP, the following was suggested: "*Background information from a review of existing major strategies and management would have been a useful building block to identify what else is required and where are the gaps"*.

Other general improvements to the workshop that could be made included:

- *More time to refine / delineate some comments which were arguably ambiguous;*
- *Improved facilitation of groupwork. More rigid listing of additions;*
- *Participation of federal funding body. A lot of the issues are across jurisdictional and they have been left out or not represented in the process;*
- *Fewer chocolate biscuits should be provided;* and
- *Outline of staged workshops or further input points so we can see / contribute to plan development.*

4.9 LHEMP process evaluation results

The following section outlines the responses to the final seven questions of the participant questionnaire provided in Appendix F. They relate to the participants' overall thoughts and perceptions of the LHEMP process.

First of all, the question, *"What motivated you most to take part in this planning process?",* was posed. A number of participants replied that they had been motivated to take part in the process as it was their work, their responsibility to represent their group's interests, or that they were responsible for managing certain areas of the estuary and surrounding lands. However, it is noted that not all people in these positions with responsibility over the estuary's management, or interests to represent, attended the workshops, so what were some of the other underlying reasons for attending? Responses outlining some of these extra motivators included passion, desires and concern to help and improve the effective management of the estuary:

- *I believe it will make a difference to the environment and people who use the resource;*
- *Concern for estuaries and the chance to use my expertise;*

- *Because we want to work in the community and it is also my backyard;*
- *Previous studies / work with Hornsby Council on the river;*
- *A desire to participate effectively in the management of the natural resources of the area;*
- *Agreement that increased integration of estuary management will increase the likelihood of objectives being met;*
- *My passion for the estuary and contributing to the development of an ecologically sustainable plan. Also contributing to the well being of the community which is impacted by the health of the river system;* and
- *Mainly professional interests (planning, policy, ecology) and my concern for the lack of planning and management (or its implementation) on the river.*

One participant voiced this concern very strongly, stating simply that *"The River needs help".* Adding a suggestion to this comment on how to help, the participant noted the opinion that *"a river keeper is too mild - how about a River King with a band of knights as enforcers?".*

The next question, "*How do you think this process is helping to better manage the estuary?",* yielded a variety of responses from "*not sure it is helping yet – but give it time*" to "*Community and agency involvement helps develop groundswell of support towards sustainable management concept*". Some of the more hesitant responses included:

- *It may help a little but can't deal with the underlying growth factors that are the real problem (population + economic growth);*
- *The process provides a focus for the estuary, brings all these parties together to at least discuss and endeavour to try and plan / improve the estuary;*
- *Only time will tell;*
- *Will only help if it doesn't end in a report that isn't widely communicated and adopted;* and
- *Hopefully we will take some goodwill forward.*

On the more positive points of how the process is helping to better manage the estuary, responses included:

- *Brings people who share similar concerns together;*
- *If implemented, especially into best practices and planning instruments, improved outcomes ought to result;*
- *Getting different groups (govt + community) talking together and operating under agreed framework;*
- *This is an attempt to address estuary wide issues, not site / community specific issues;*
- *Incorporating all agencies and community / commercial representatives;*
- *broad stakeholder involvement increases awareness of issues and includes many in creating solutions;* and
- *Hornsby council is a model other groups should follow.*

Finally, related to previous questionnaire comments and making reference to the community representatives not being involved in the second workshop, one participant noted that "*Disempowerment of the community in the process undermined a lot of commitment and work by many over the last years in preparation of the studies and plans*". The context surrounding this comment will be analysed in more detail with a number of others in Section 5.

Following on from what the process may be able to achieve, the participants were asked about their own contributions to the process: "*Do you believe that your contribution to these workshops and planning process has been valued by the project team and other participants?"*. All responses except one were a version of "yes" or "hopefully", with the last one related to the difficulties that will be discussed in Section 5. Of the "*yes*" responses, a couple of the qualifying statements included:

- *Yes - always welcomed and comments encouraged;*
- *Yes, but hard to be sure;*
- *Yes - in proportion as one of many people;*
- *Yes. There seems to be material support and generally focussed aims;* and
- *Generally yes, but greater knowledge of the waterway and its issues would have allowed greater input.*

As to whether the participants thought that outside stakeholder communities would accept the EMP resulting from the project process, responses to the question, *"Do you think the estuary management plan resulting from this process will be well accepted by the participants and outside stakeholder communities?",* were very varied. Comments resulting from this question appeared to indicate hope for successful outcomes, but that the project was still not finished and a number of areas would still require further thought and attention before the final plan is produced and implemented. The responses received were as follows:

- *Yes as there have been extensive opportunities for participation;*
- *Maybe not by more extreme of community as they felt excluded in the risk ranking;*
- *I hope so, but more tangible, grass roots actions required before EMP nears completion;*
- *Probably - legislation and on-ground works - most people will ask whether their interests are accumulated (i.e. what is in it for stakeholders?);*
- *Not sure - is there a process for "sign-off"? What happens next? Ask each participant to promote the multi-stakeholder process and contents to their organisation/ networks. Provide a summary brochure etc. - promote it;*
- *Perhaps by participants. Or will it become yet another strategy / plan on the shelf?*
- *I do not know, it will be interesting to see what happens;*
- *Like any plan, it will satisfy some and not others but most will be indifferent unless it affects them directly, which is unlikely;*
- *Yes, although I am not convinced anything will change. It will at least be a benchmark;*

- *It should be if the results are communicated accurately and effectively;*
- *It should be. It has good representation from interested parties;*
- *Probably, because of the broad input;*
- *Possibly - if the objective, strategies and outcomes are clear, achievable and measurable within a timeframe and within reasonably expected resources;* and
- *Depends how it is produced and distributed. Try and keep it simple but retain the power.*

As a follow up to all the previous questions, the participants were asked, "*Overall, how do you think this estuary planning process could be improved?*". Most responses related to the contents of the workshops or improving the place of the project in the larger context. Related to the contents of the workshops, potential improvements included: adding a brief photographic presentation in the workshops or case study example "*to demonstrate the inter-relatedness of river issues and the multiple benefits to all if appropriate action is taken*"; not using the categorisation of "risks" in place of issues as "*they are a mixture of threats, pressures and management issues. Better classification and analysis would improve the process*"; identifying better whether the plan is "*trying to operate at broad or specific level*"; "*A little more time in workshops and maybe pre-work where input is required*"; and installing a series of "*Interviews with participants to identify key strategies / plans / major projects*".

On process improvements of a contextual nature, short suggestions included: reducing "*the top-down approach which has come to dominate the process*"; and the probable need for "*further meetings of some people*" and "*more expertise in different areas*". More elaborate suggestions on how the process could be improved included:

- *If this planning has the responsibility of higher level of government. Or supported by higher government levels;*
- *By placing it in a well understood niche within the catchment management world. There are loads of catchment / estuary management forums and it's hard to pick the role or relationship of one to another;* and
- *Although it would have taken longer, maybe including all EMPs - require greater statutory weight, need greater consideration and enforcement.*

Finally, the participants were asked, "*Do you have any other comments or questions about this workshop or the overall project?*". To this question, half the questionnaire respondents left comments of varying note, from small remarks such as "*No. I look forward to the outcomes*", "*It's frustrating that the real factors causing problems can't be dealt with at the local level*" and "*Thank you Hornsby Council*", to those of a more substantial nature related to the project's progression. These included:

- *Potentially a further workshop required for further discussion of actions;*
- *Work forward to end results - like to see a flexible document able to be adapted over time e.g. 5 years;* and

- *It would be valuable to be able to view the synthesis of the workshop notes in a table of some sort and comment on that. – It will be easier to start pinning responsibilities when today's info is synthesised i.e. approx 60-70 cards per sheet x 16 sheets = 1100-1200 cards for which to assign responsibility i.e. impossible to be thorough or attentive and some ideas could easily be overlooked.*

This last observation on project complexity related to the previously mentioned issue of community representatives not taking part in the second workshop: "*I am sure the process was well intentioned and I would like to see adoption of the plans by Government agencies and the community with a financial commitment by government and support by active participation by a management committee*", and will be further discussed, along with some of the other comments, in Section 5.

4.10 Preliminary outcomes and preparation for plan writing

As some participants mentioned in the evaluation questionnaires, the challenge after the strategy formulation workshop was to turn the content of the results into something useful for the rest of the LHEMP process. The final outcomes from the third workshop were the 16 risk strategy maps shown in Figure 27.

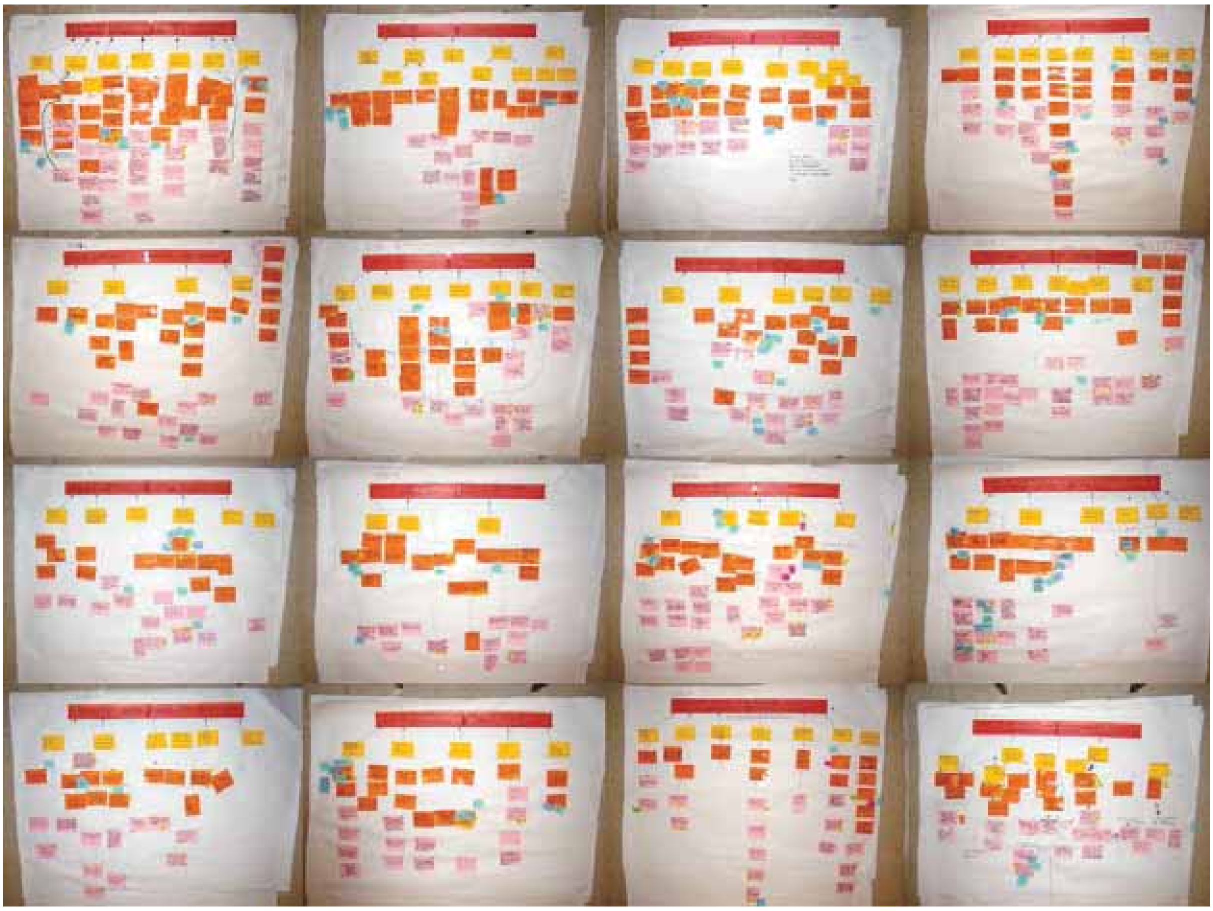


Figure 27: Workshop 3 outcomes – 16 risk strategy maps

In total, these maps included collectively around 900 cards, PostIts® and comments. In order for this information to be used effectively by WBM Pty Ltd and SJB Planning in the plan writing process, it was first treated in a number of ways by Ms. Daniell.

The first step undertaken was to convert all of the maps' information into an electronic format. This process was performed using the software DecisionExplorer®, a program specifically designed for cognitive and strategy mapping of complex problems. Each of the colours and categories of cards, PostIts® and comments were conserved in DecisionExplorer® to aid with the analysis of these concepts. An example of the "water quality" risk's paper version to electronic format is shown in Figure 28.

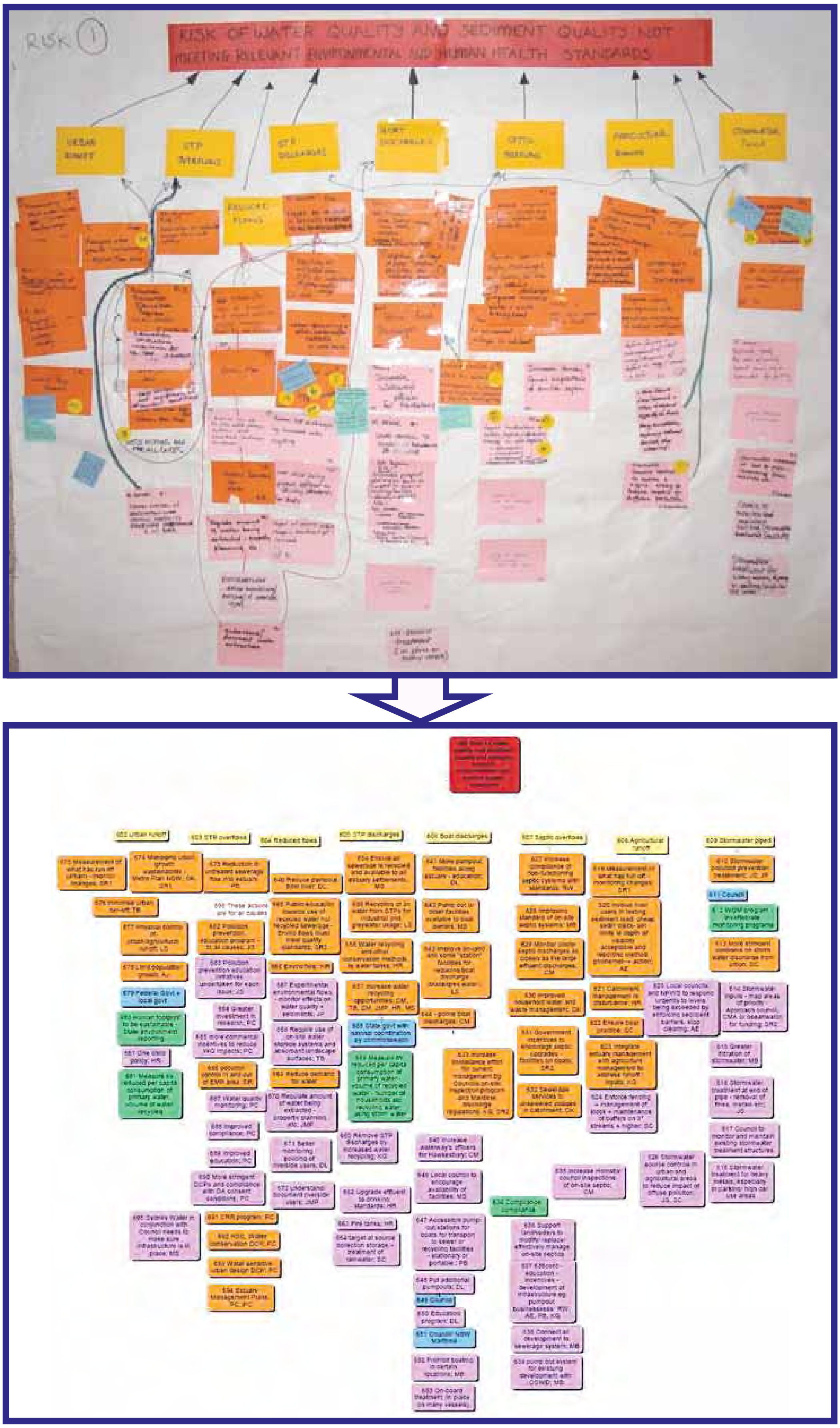


Figure 28: Conversion of a paper map to an electronic version using DecisionExplorer®

From DecisionExplorer®, the elements written on the various categories of cards (Risks, causes/effects, strategies, actions, responsibilities, monitoring needs and comments) were then extracted to Microsoft Excel for further treatment. The hierarchies between actions and strategies found in the original strategy maps were checked for consistency and some rearrangements made where necessary (some strategies were found to be actions of other strategies, as a couple of participants had outlined in the workshop evaluations). Monitoring needs, responsibilities, priorities and other comments associated with particular actions or strategies were transferred directly into tabular format. To make the information more accessible for the use of plan writing and the development of an "action" or "risk response" table, a number of other operations were performed:

- Repeated actions or strategies under the same risks were merged into one when discovered;
- Some of the more "radical" strategies or actions were checked for feasibility within the bounds of this planning jurisdiction. Those found to lie outside were omitted (i.e. Federal Government responsibility);
- Where actions were similar to those proposed in existing plans covering the estuarine study area (either written down by the participants or discovered during the plan analysis), references to these existing actions and their proposed timeframes were noted;
- Where actions or strategies were marked for treating more than one risk, the reference to the other risk(s) was noted; and
- A preliminary coherency check was undertaken between strategies and actions to examine compatibility. Those thought to be incoherent (i.e. in terms of time for implementation, opposite system impacts) were marked as needing more analysis before the plan is written.

This risk-response table based on the participant contributions comprised 317 actions distributed over the 16 risks, an average of just under 20 actions per risk. This table has been sent to WBM Pty Ltd and SJB Planning for consideration in conjunction with their review of existing management strategies, planning documents and legislation. An example image of this risk-response table is given in Figure 29.

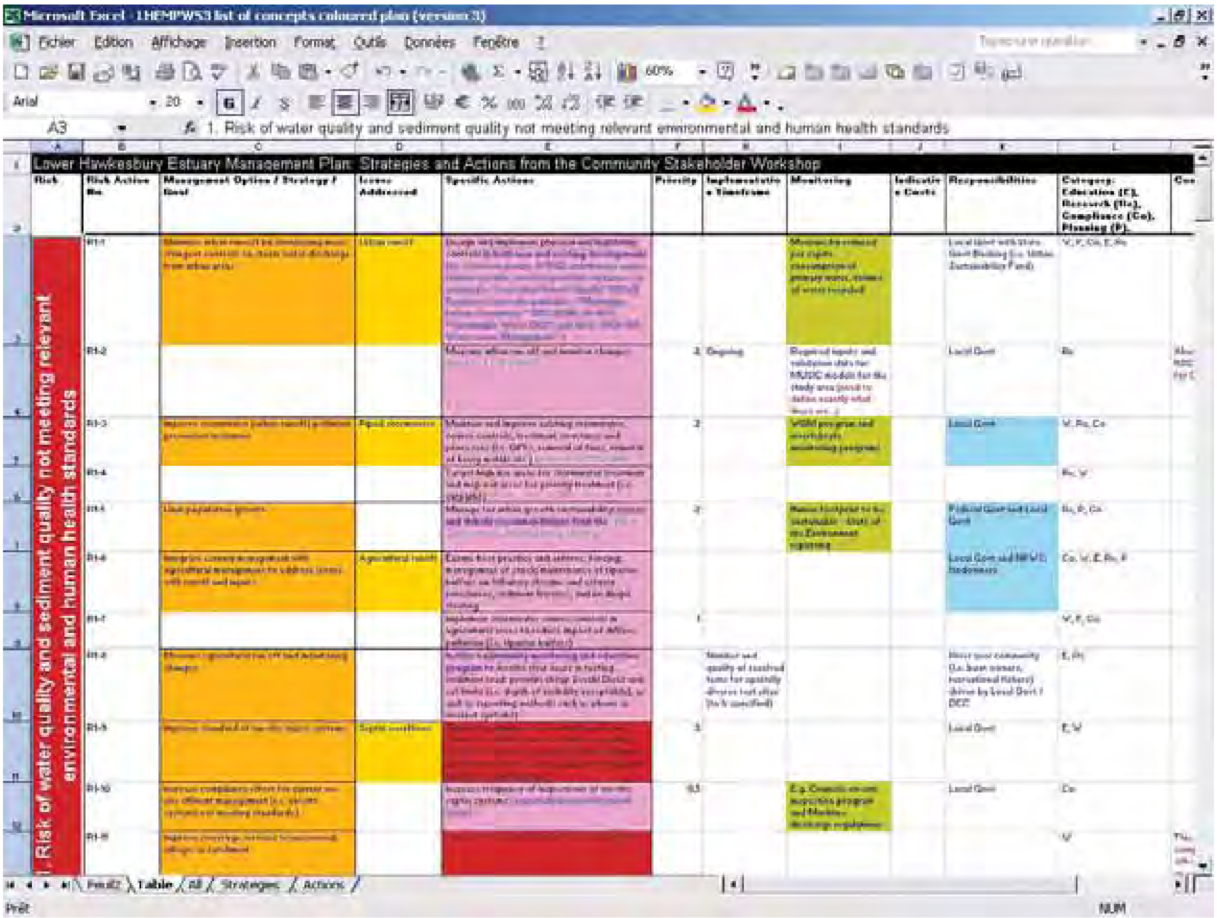


Figure 29: Stakeholder informed "risk-response" table

At this stage of the process, the strategies and actions have not yet been properly analysed together to determine potential outcomes in the system, including their effects on all the assets, or whether there are sufficient resources and stakeholder motivation available to implement them. Once the full "risk response" table has been developed, more analysis of the table's elements can be undertaken in collaboration with stakeholders to further inform the estuary management process.

5. DISCUSSION

Considering the results of the participant evaluations and other questions developed from observations of the LHEMP process and preliminary outcomes, there are a number of key themes that have arisen and that merit further discussion. These themes include: the effects of last minute program changes in participatory processes; advantages and disadvantages of the risk assessment approach; complexity and its impacts on synthesis and integration; and monitoring, evaluation and management cycles. The discussion presented here only represents the author's views which are based on the analysis of participant evaluations, video and audio recordings, as well as personal observations and reflection.

5.1 Effects of last minute program changes

It can be observed from the participant evaluations of the second and third workshops, that the last minute program changes to undertake the risk assessment with only "agency" representatives had a certain number of repercussions on the process, both positive and negative. It is noted that the choice to change the process after the first workshop from its original form was vigorously debated amongst the members of the project team before a final decision was made, and that the change to the "agency" only workshop was not the only option on the table. Other potential options (largely driven by time and budgetary constraints) included: not going ahead with the final workshops but, instead, the consultant team would contact agency and community representatives individually; just proceeding with the strategy but not the risk assessment workshop (instead, the consultant team could carry this out themselves); carrying out the risk assessment with only a small group of experts, then moving on to the planned strategy workshop; and not changing from the planned program.

Arguments put forward for not changing from the original program, and against the other options proposed, included:

- Not inviting the participants to the second or third workshops after telling them in the first session that they would be part of a participatory process and responsible for making many of the planning decisions (partly because of time and budgetary constraints!) would be seen as bad form and could produce a "backlash" against the process and the future success of the process;
- Risk assessment is an inherently subjective process (especially in this broad context), even if it attempts to explicit uncertainties, and so the interest in using it is to get stakeholders to better understand the nature of risks though developing a common (values-based) assessment of them and to then use this method as a basis for "calculating" priorities for treatment;
- As risk assessment is subjective, all stakeholders have just as much potential to contribute to it (especially as some of the assets the risks were to be assessed against were not particularly technical, such as "scenic amenity"), and many of the "community" representatives have more in-depth knowledge and or scientific expertise on the estuarine system, industries and community values than some of the agency staff external to the estuary;

- Performing an external, small group or agency-only risk assessment would lead to the need to "sell" the results to the other participants in the following workshop and that the risk prioritisation could be refused and the process compromised;
- Facilitation and support methods could be developed to perform the risk assessment process with a large group of participants; and
- In terms of time and budget, it would likely be just as costly, if not more so, for the consultant team to carry out the rest of the project work without the participatory workshops.

Arguments put forward for changing the program, especially for the "agency-only" workshop option, included:

- It is often difficult to get agency representatives to participate in large participatory workshops with community representatives for a number of reasons. Firstly, they sometimes feel obliged to represent only the "public image" of their role and the current political lines of their institutions rather than their true feelings on management possibilities. Next, large workshops can often be rather confrontational, with agency representatives getting "attacked" by some community representatives on gripes they have with the agency's policies which are often out of the control of the particular representatives and that they feel they have little control over. Finally, many agency representatives have large jurisdictions of management and limited time to participate in all the planning and management processes that take place in their territory, so they are required to prioritise their actions and often only participate in the most important or personally interesting processes;
- Agency support and funding is required for the successful support and implementation of this plan. There is more chance of getting this support (especially from agencies that do not usually participate in our programs), if there is an "agency-only" workshop. It may be seen as something unusual and thus worth attending, less confrontational and a good opportunity to discuss management issues from a purely management point of view. The "risk-assessment" session may also be seen as an "appropriate" agency task that can tap their expertise.
- Community involvement is very important to the success of this plan, but so are the agencies as without them it will be near to impossible to fund and implement the plan. If the changes to the program are sufficiently well explained, the community representatives will understand why they took place, even if they are initially disappointed. They have already participated well in the first workshop to develop the lists of assets and risks that will be assessed, and will also have the opportunity to create strategies and actions for these risks, so in the overall process they will not have lost much of the directional power.
- It would be better to run the agency workshop as an extra one to keep the original program of three mixed stakeholder workshops, but time and budget will probably not allow for this eventuality.

Based on these arguments, the decision was taken to change the original plan, with the risks of potential community backlash and associated process difficulties well known.

In effect, many of the issues at the base of these arguments did eventuate, both of the positive and negative variety. Some disappointment and community backlash did result from being them being "excluded" from the second workshop, as was witnessed from the results of the surveys, in the body language of some of the community members at the third workshop, especially during the presentation of the second workshop's findings and risk prioritisation, and possibly from the small number of community representatives who decided not to participate in the third workshop. However, those community representatives who attended the third workshop did seem sensitive to the difficulties that their exclusion from the second workshop had created, perhaps holding them back from publicly criticising the process to best help work towards successful project outcomes. Voicing their real feelings in the evaluation questionnaires and to the project organisers was possibly sufficient.

The final comment of one of the disappointed community representatives: "*I am sure the process was well intentioned and I would like to see adoption of the plans by Government agencies and the community with a financial commitment by government and support by active participation by a management committee*", helps to represent this understanding of the importance of working towards common goals of collaborative and successful estuary management, even if is sometimes not a particularly easy process.

Based on this last comment, it is hoped that the final stages of this project and continuing commitment of all stakeholders in the region can hope to overcome the difficulties and misunderstandings caused by certain choices and constraints on this process, in order to be able to retain and improve their commitment to helping the estuary and its effective management. For the community representatives who did not participate in the second workshop and all the other stakeholders and project organisers, although being an unfortunate way to discover it, the last minute changes to the workshop program did also uncover some potentially positive outcomes.

The more positive points of the changed program, were that the "agency-only" workshop did create interest among the many agency staff concerned with the management of the Lower Hawkesbury estuary. The workshop was very well attended and managed to attract some representatives high up in the management chains, who had not previously been known to participate in the Hornsby Shire Council's estuary management planning processes. It was also apparent that the agency-only environment allowed the participants to take part in *"good open and honest discussion"* that they may not be usually able to do in the presence of community members and to focus on some of their shared concerns over management difficulties, talking in their own "*lingo*". One of the commercial representatives who took part in the second workshop suggested that: "*for the next one you adopt a* *less formal approach - e.g. risk assessment ratings are not readily understood by community and stakeholder reps".* This may have been a good indication that the choice to only include agency representatives did make some sense, especially since some of the agency participants seemed to enjoy taking part in the more closed and technical approach that was thought to be less "*emotional*".

In whichever way this discussion is viewed, there were certainly positive and negative outcomes to the last minute program change. The difficulties encountered may have been able to be mitigated to a better degree with certain retrospective changes. Now they will have to be worked through as best as possible. However, learning from these experiences, it is most likely that the best way to avoid such problems in the future is to try to sort out the best possible program at the start of a project and stick to it; even if this means defining a "flexible" project structure which can be changed under a certain number of conditions.

Finally, there were a couple of other last minute changes that also had certain impacts on the project, but this time that occurred within or separate to the workshops. In the first workshop, the whole group discussion method used in the final session was too time consuming to reach the desired outcomes of a list of synthesised goals, assets and risks. In the end, the asset list was fully completed but the goals and risk lists were synthesised by WBM Pty Ltd for the Synthesis Report (WBM Pty Ltd, 2007). Although not severely impacting the rest of the process, this led to a little confusion over "ownership" of the goals and risks, as in the second workshop some agency representatives did not want to comment on the goals if they were developed directly by the whole stakeholder group, or, on the other hand, to be seen to be changing the goals around without the input of the community representatives. A similar type of confusion resulted in the third workshop, as some participants did not feel as if they had been included in the creation of the risks, as they did not realise that the input of their "issues" in the first workshop had been synthesised into the "risk" list. This misunderstanding may have been avoided if the Synthesis Report had been sent directly to all participants in the process, rather than just the participants of the second workshop (with the other participants having to specifically "request" a copy). For future workshops in the preliminary phase of problem identification and goal setting, it may be worth reworking the methods or increasing the workshop length to be able to complete the planned synthesis activities as a whole group in the available time. Likewise, sending the synthesis report to all participants may help to reduce confusion over process and outcomes.

In the second workshop, a last minute change to the workshop program was requested by the participants to run through the "water quality" risk as a whole group. Although this change was accepted by the facilitator so as to not go against the participants' collective wishes, it did have a couple of ramifications on the risk assessment process, and particularly its validation. The extra time spent collectively on the water quality risk, although productive, meant that there would be less time available for the small groups to work their way though the other required risks. In light of this problem, the solution found was to break the large group down into much smaller groups than originally planned (i.e. pairs or threes rather than groups of four or five), so that all risks could be completed in the available workshop time. This solution did achieve its original objective to finish the risks, but time to complete another risk (such as the end of the sedimentation example) for validation purposes did not eventuate. This leaves the question of whether the results of the risk assessment can be validated, as different groups may have different tendencies of rating behaviour. Theoretically, it is now very difficult to validate these results although their sensitivity can be further examined, as was shown in Section 3.9.2. However, "legitimisation" of the results can still take place if the participants believe sufficiently in the process or the capacities of the other participants to accept their judgements. Such an agreement to support the results, despite their potential weaknesses, is in some ways what occurred. The participants "accepted" without too many complaints that all of the risks had been prioritised as either tolerable or intolerable and they were willing to "treat" them all in the next phase of the process. It is likely that the rating of all risks as "requiring a response" helped the lack of opposition to the risk assessment process, both from the participants who took part in it and those in the third workshop. In essence, this meant that the second workshop did not have as much of an impact on changing the content of the LHEMP process as could have been the case. There was thus less opposition and reaction to it.

Finally in the third workshop, a couple of last minute program changes were made, firstly, as the strategy mapping exercise did not take as long as planned, and secondly, as some participants had to leave early. The changes were made to allow participants who needed to leave early to prioritise their actions and to fill out their evaluation questionnaires. Despite the fact that other participants did not have to leave, they also wanted to follow suit and ended up also assigning their action priorities and filling out their evaluation questionnaires before going back to the other activity that had been planned (i.e. adding responsibilities and monitoring needs to the strategy maps). This program change seemed to prompt more participants to leave when they were satisfied by their contributions to the strategy maps, rather than wait around for the end of the planned workshop time and the planned events of sharing certain strategies of the risk strategy maps and discussing the next phases of the workshop. In the end, there were so few participants left working on the strategy maps that even some of the facilitation team took the advantage of leaving early. This rather interesting exit phenomenon which not many of the participants witnessed (as they had also already left) presented some obvious difficulties in officially closing the session, and so a final official close never really occurred. Most participants were thanked individually and asked about their visions and hopes for the rest of the process before leaving, but a collective strategy for the next steps of the process was not officially presented. It will be interesting to see if this program change has any later impacts on the LHEMP process, but for the moment it is too early to tell. In retrospect, to avoid this problem the workshop probably should have been officially closed early just after the questionnaires were returned, and then the participants who didn't have to leave invited to continue to work after the workshop's close.

As a summary to this discussion on the effects of last minute program changes, it is worth specifying that change is a natural part of participatory processes. However, this change and the need to accommodate flexibility in participatory processes presents some interesting challenges to researchers, consultants and project managers who work with them, as the outcomes are often unpredictable for a variety of good reasons, just three of which are mentioned here.

Firstly, the power base of decision making and process or project content often shifts in the direction of the participants and their interests, which can be difficult for the project instigators to deal with, as often their personal objectives for the process and outcomes will not be entirely achieved. The validation issue of the risk assessment process is a good example of this, where the project team was aiming for a "validation" of a more scientific and robust kind, but instead had to live with a "legitimisation" of results, something potentially more important for most of the workshop participants.

Next, there is the question of uncertainty of reaching outcomes (or especially those specifically planned by the project team), as inviting participation has a tendency to "open-the-box", define problems differently and create innovative ways of approaching and managing them. Not knowing exactly where a participatory process is going to lead to at the end, even if there are some excellent unforeseen outcomes, will at the beginning of the process sometimes require a "leap-of-faith" from the project managers, which, when considering their responsibilities, they are sometimes not willing to make.

Finally, learning and changes in social relations and conflicts can occur as a result of (or lack of) participatory processes, both of which have been observed through this LHEMP workshop process. Decisions to instate or stop participatory approaches to management are both likely to change the state of informal learning, stakeholder capacity building, social relations between people (both inside and outside the stakeholder communities) and conflicts, so project managers are often rather cautious about changing the status quo of management operations.

All this means that change resulting from participatory processes is probably inevitable, but with good management and careful design of projects, taking into account known constraints, this change can be of the positive kind and actively encouraged through the use of well chosen methods. Flexibility and the ability to develop effective contingency plans in the event of unexpected changes, and having enthusiastic and experienced facilitators, can also help to improve the chance of success of participatory processes and their outcomes, as well as reduce the more negative impacts of last minute program changes.

5.2 Comments on the risk assessment approach

From the author's knowledge, the use of the Australian Risk Management Standard (AS/NZS 4360:2004 and HB 436:2004) and the associated Environmental Risk Management Guide (HB 203:2006) for broad or regional scale estuary management has never before been attempted. This means that although the approach used here was based on a number of other studies, as outlined in Section 3.4, the approach was specially crafted to meet the needs of the LHEMP process. In particular, the direct linkage between the stakeholders' list of values in the first workshop that became the assets upon which the risks were evaluated in the assessment process. The approach developed for this process can thus be thought of as "values-based participatory risk management" and this section will discuss a number of advantages, disadvantages and potential improvements related to this specific approach.

From the evaluation results and observation of the risk analysis process used in this LHEMP, some lessons have been learnt that may help to improve the repeat of such a project in a different context. As has already been mentioned in the previous sections (Section 3 and in Section 5.1), risk assessment is inherently subjective and values-based. It is thought that by making some parts of this stakeholder values base explicit, the acceptability of such an approach can be improved, as it can be focussed on the "real" concerns of the stakeholders. Furthermore, the inescapable subjectivity included in the risk assessment can be explicitly taken into account by using a participatory process in which all concerned and interested stakeholders can take part. It must be realised that a risk assessment will always be biased by who participates and the extent of their knowledge, so it is important to include the most capable and knowledgeable people (this includes all types of knowledge such as local, technical, legal, managerial or political), as well as those required to support and legitimise the outcomes of the assessment. Great care and attention should therefore be taken when organising such a process so that the most relevant participants are able to take part to ensure the success of the assessment results, both in terms of stakeholder legitimisation and scientific validation.

In retrospect, a number of different types of stakeholder group formations could have been chosen for the LHEMP risk assessment, all resulting in different outcomes. As discussed in Section 5.1 and as seen from the participants' evaluations in Sections 3.84.8 and 4.9, there are likely to be advantages and disadvantages to every type of group definition. Learning from the experiences of this LHEMP process, the most important element for running a successful risk assessment process may be to carefully choose and stick to a general participation plan right from the beginning of a process, stating clearly reasoning for choices. If there are differences of opinion with this participation plan, these can then be discussed and adaptations made before the process begins.

However, independent of which group of stakeholders (or even external experts) carry out the "risk assessment" part of the risk management process, it is thought that the first steps used in the LHEMP process of how to carry out the initial context establishment and definition of "assets" or values could provide a number of advantages for quality stakeholder participation where the participants have the opportunity to influence the future direction and focus of the planning process. The influence is easy to trace, as the risk analysis subsequent to the initial context establishment is based entirely on impacts to "stakeholder community" agreed values. This means that the risk impacts examined will be analysed against what is the most important for the stakeholders.

In the case of the LHEMP, it was the "agency" representatives who performed the risk analyses against the community stakeholder-endorsed "asset" criteria to develop a prioritisation of the risks (which were also developed from the stakeholders' input in the first workshop). Working from this stakeholder-developed base of important factors, such a process can help the risk assessment participants to better understand the complex impacts of risks and management practices on "whole of estuary" values or assets. It also leaves the stakeholder community with some control of direction, even if they may not have the management or scientific expertise to carry out the detailed analyses. For the LHEMP, it was possible that a few scientific or local "experts" with knowledge about the estuarine system or risks being studied (i.e. climate change) could have added to the robustness of the risk analyses, although, as already mentioned, all such choices may have different impacts on the process outcomes. It is noted that as a later stage of this planning and management process, it would be beneficial to work further on the sustainability assessment, or in-depth risk assessment, of options (the strategies and their actions) for treating the risks related to all stakeholder values, as well as local, state, Federal Government and international norms of sustainability where possible (such as embodied carbon and water indices or "State of the Environment" indicators). External experts may be able to be more readily involved in this second stage of evaluation.

This question of how to best include external scientific expertise in the "values-based participatory risk management" process is an interesting one. It should be noted that the "values" or "assets" decided upon in the first context establishment stage will also be likely to change, based on who participates in this phase of the process. Decisions must be made as to whether the assets proposed for protection and enhancement are pertinent at other spatial and temporal scales. The importance of considering such scales will of course depend on the original objectives of the process. If the risk management process has a high importance outside the local scale, then it may be useful to have external experts consider whether there are other elements or values that may have been overlooked by local stakeholders (for example carbon and nutrient balances, international food requirements and intra- and inter-generational equity). They could then also become involved in the risk assessment in their areas of expertise. However, care must be taken that such an inclusion of outside expertise does not harm the "legitimacy" of the process in the eyes of the more local stakeholders.

Another potential advantage of the "values-based participatory risk management" process used for the LHEMP is that an attempt is made to explicit or "measure" different types of uncertainties, so that more informed decisions can be made by taking them into account. Firstly, a "risk" in itself relates to the concept of an uncertainty, and so determining the "likelihood" that an impact of the occurrence of this risk will have (and its consequence), as outlined in the Australian Risk Management Standard is a way of understanding this uncertainty. Next, the uncertainties regarding "knowledge" are made explicit, specifically those related to the predictions of likelihoods and consequences (meaning how much the participants consider is already known and documented about these risks). Finally, by undertaking sensitivity analyses of the risk assessment model and differences in stakeholder preferences, uncertainties related to procedural choices and their effects can be better analysed and understood. After outlining all these uncertainties, how they and the risks are accepted and reacted to is another societal, value and perception-based question (i.e. are the participants risk averse or risk seeking/accepting?). By running a participatory risk management process, such questions can be collectively considered in the final strategy making and action prioritisation phase to treat the risks. Natural preferences of the participants, including their preferred risk orientation behaviours will be elicited and discussed through their preferred strategies and actions, potentially reducing the conflict that otherwise could occur if options which were in opposition to their traditional risk behaviour orientations were imposed on a stakeholder community.

5.3 Complexity and its effects on synthesis and integration

Estuary management is a process characterised by interconnecting and complex problems which exhibit high levels of conflict and uncertainty. Increasing use and appreciation of estuaries for a variety of reasons and activities, largely driven by population growth, has led to conflicts between competing water uses and the management institutions and regimes that favour specific uses (potable water, sanitation, food production, commercial and many others such as social recreational and spiritual uses). Uncertainties, including political decisions, climate variability and change, human behaviour and knowledge (i.e. technological innovation and scientific understanding), also add to the complexity of developing effective estuary management processes.

Processes such as the one used for the development of the Lower Hawkesbury Estuary Management Plan attempt to embrace and to work to structure and to understand the complexity of estuarine processes and the effects of management regimes on them. In order to achieve this goal, there is a need to gather and facilitate the integration or synthesis of a many types of knowledge: scientific or technical knowledge and expertise; local community and stakeholder knowledge; as well as managerial, political or legal knowledge. Many different methods may be employed to facilitate the gathering and integration of these knowledge bodies. However, each choice of method will possess its own advantages, disadvantages and introduce a variety of trade-offs, especially related to oversimplification or challenges related to too much complexity. In the former case, oversimplification may lead to a loss of legitimacy from many stakeholders' points of view if their visions are not seen to be taken into account. In the latter case, embracing the "full" complexity of the estuarine system and its management regimes presents major challenges for integration and synthesis of understanding and information.

In the LHEMP process, a number of challenges related to embracing the "full" complexity of the estuarine system were encountered. Within the process, two principal knowledge collection and integration or synthesis methods were used: the participatory stakeholder workshops; and the external scientific and legislative literature review carried out by the consultants (WBM Pty Ltd and SJB Planning). In the case of the participatory stakeholder workshops, an extraordinarily large amount of information was collected and knowledge exchanged in the short time allocated. However, the time constraints, and potentially the methodological constraints, meant that often the full expertise and knowledge bodies of the participants were difficult to tap. To reduce this problem, it was common for the participants to refer to scientific reports or existing studies that should be considered by the consultant team. Nevertheless, the capacity (especially from a time and budgetary perspective) for the consultant team to carry out an in-depth study of all of the cited documents and to synthesise the perspectives and information in a "complete" fashion remained somewhat limited. Another limitation of embracing the "full" complexity of the estuarine system relates to the possibility for the creation of useful "models" of the system that can be used to examine the validity or coherence of proposed actions for improving the management and general state of the estuary. Many typical scientific modelling techniques would struggle to take into account all of the important factors presented during the workshops and external review of estuarine processes and management arrangements, and validating such complex models would likely be nearly impossible. It is thought that the Bayesian Belief Network modelling technique proposed by the Hornsby Shire Council to continue the analysis of the strategies and risk scenarios proposed in this workshop series may prove a more adapted technique to deal with some aspects of uncertainty and complexity. However, the results should be treated cautiously and just as a general guide and learning tool, as the inner-workings of such a model, as with other types of extremely complex models, will be largely impossible to scientifically validate.

The time and budgetary constraints for carrying out a complete review of all relevant documents for management of the estuary, especially one that could be available prior to the second and third workshops, may also have had an impact on the effectiveness of the overall participatory process. As one of the participants mentioned in the evaluation, the lack of a review of which management strategies were currently in place in the estuary (apart from the legislative review), and which actions of these strategies had already been carried out or proposed, limited the capacity of participants to add onto existing knowledge. This meant that participants did not know whether the strategies and actions they proposed in the third workshop were coherent or possible to carry out with those currently in place or even if those that they proposed were original suggestions. Despite these difficulties, it is hoped that a review of existing and planned management strategies concerning the estuary's management can be undertaken, compared and merged with the outcomes from the "stakeholder informed risk response table" (Figure 29) to produce a more complete and coherent plan. In order to further overcome these difficulties and avoid problems that could result from the final synthetic action or risk response plan, it is suggested that there be another review of this action plan by stakeholders (especially those likely to be responsible for actions within it) before it is put on public exhibition. This stakeholder review will likely allow the plan to be adapted and re-appropriated (especially management responsibilities), giving its propositions more weight and a higher chance of successful implementation.

Apart from the time and budgetary constraints, it is thought that the process carried out in the LHEMP of including both a multiple speciality consultant team (environmental science and engineering, as well as planning and legislation) to carry out the knowledge review and synthesis activities and a relatively large scale participatory process for stakeholders to work together and express their views was a positive approach to dealing with issues of knowledge integration in such a complex management context. The interaction between consultant expertise, managerial experience, innovative research practice and stakeholder knowledge provided a rich environment for exchange and the capacity to work quickly towards the goal of producing the LHEMP. Investigating such work-team arrangements for future planning processes could prove to be an interesting research topic, as could how scientific or other types of expertise and knowledge could be even better capitalised upon in the future.

5.4 Monitoring, evaluation and management cycles

Estuary planning and management is a continuous process that requires on-going monitoring and evaluation to determine if management objectives are being reached, as well as dissemination of the right monitoring information so that management strategies can be adapted when required (often through a new cycle of planning). It is suggested that monitoring and evaluation can be most useful for managing resources when a system for how the process is to be carried out is designed as part of the overall planning stage, rather than being tacked onto the end of a management process (SKM, 2004). This LHEMP process therefore had as a goal to incorporate the analysis, synthesis and creation of monitoring and evaluation strategies (including objectives, information needs, indicators and data) throughout the workshop process and adjacent review.

In the first workshop, goals for the estuarine system were developed, which were principally summarised as the "preservation and further enhancement" of the estuarine values or assets. During this first workshop, when the "values" and "issues" were defined, the participants were also asked to answer the following monitoring related questions: "*What existing information and data can be used* *to describe this value / issue and who holds it?*"; and "*What additional information and data would be necessary to describe this value / issue?*". This first phase of collecting existing and required knowledge on information and data sources yielded a large number of responses (summarised results presented in the first stakeholder workshop report (Daniell, 2007)).

However, as with the difficulties in carrying out a review of the existing and already proposed management strategies and actions before the second two workshops (discussed in Section 5.3), time and budgetary constraints did not permit the expert review of the information and data sources outlined by the participants to be carried out before the second and third workshops. This, therefore, had the same impacts on the third workshop, with stakeholders not knowing whether they were adding onto existing monitoring systems and proposing indicators when they were writing the "monitoring needs and indicators" for the strategy maps. It was also interesting to note that during this activity, some participants appeared to find the definition of specific indicators or data collection programs for monitoring quite a challenge. More specifically, a few participants found it difficult to focus on how to "measure" work towards objectives and targets. For example, there was a large discussion over water quality objectives where "water quality" written on one of the strategy maps as a monitoring need was required to be further broken down into specific indicators for a variety of uses such as "faecal coliforms" for primary contact recreation activities (i.e. swimming) and oyster harvesting or "salinity levels" for certain estuarine flora and fauna (i.e. sea grass and oysters). Although it would have been useful, indicators or data were rarely more specifically defined by stakeholders to incorporate when and where data measurements would be taken, how the indicator would be constructed from data sources and how the information products from the indicators could be best constructed and disseminated to aid managers and other stakeholders (refer to Fleming (2005) for a more in depth discussion on how effective monitoring and evaluation strategies can be constructed). Perhaps this situation could have been aided by a longer explanation and example of what kind of "monitoring needs" description could most aid the estuarine management processes.

In any case, it is envisaged that many of the stakeholder responses regarding information needs, indicators and data will still be followed up in the consultants' plan writing phase and resubmitted to stakeholders for comment before plan finalisation. As time and budgetary constraints will limit the extent of this process, it is advised that a separate monitoring integration project be carried out as a priority action, as suggested by a number of stakeholders on the strategy maps. This project may then be able to further capitalise on the first phase of information collection carried out throughout this planning process and further increase the value of monitoring activities for management of the estuary, as well as potentially reduce stakeholder costs in certain areas. Steps that need to be carried out (strategies and actions) to put this project in place were largely addressed in the "strategy map" treatment of the two risks: "*Not meeting EMP objectives within designated timeframes*"; and "*Inadequate monitoring to measure effectiveness of EMP*", so it is hoped that the risk-response plan will outline the required strategies and actions to put this "integrated monitoring and reporting strategy" in place, thus providing a sound proposal that can then be specifically funded to help the effective management of the estuary.

During the final workshops, there were a number of needs and issues highlighted that could be addressed in the "integrated monitoring and reporting strategy". One such need was for good information dissemination strategies that: provide simple systems for information disposal and retrieval; provide managers and stakeholders with relevant and easily understandable information (i.e. simple maps with indicator values rather than lengthy reports); and underpin required stakeholder or general public education needs. One issue highlighted was that Occupational Health and Safety Regulations currently prevent some stakeholders from aiding monitoring and evaluation processes (and other projects that could be beneficial for the estuary). This issue had been encountered specifically at a local government level in council managed zones, where the local government is required to take out insurance for community volunteers on projects such as "clean-up" days. Such costs unfortunately currently limit the number of good-willed or altruistic community stakeholder aided initiatives that can be carried out, including estuarine monitoring programs. Finding alternative solutions to this type of issue as part of the "integrated monitoring and reporting strategy" may prove very beneficial for effective management of the estuary in the long term.

Process monitoring of the planning process is also another very important part of an effective monitoring and evaluation strategy, a practice that has been embraced during the development of the LHEMP and partially discussed in Sections 3.7 and 4.7. External process monitoring (carried out in large part by researchers from the Australian National University) and participant evaluations provide valuable knowledge about benefits of, and potential problems or issues related to, the planning process before any such problems or issues become unmanageable. If such evaluations and participant comments are taken seriously, much can be learnt and processes and management continuously adapted and improved. These discussion sections have largely benefited from and been illuminated by the evaluation results of the LHEMP process. It is hoped that others may also learn from the implementation description and evaluation results of this LHEMP process.

5.5 Comparative evaluations, lessons learnt and future practice recommendations

Throughout the design and implementation of the participatory LHEMP process many lessons have been learnt about a variety of themes, the majority of which have been examined in the previous sections of this report. Comparing the closed question responses to the participant evaluation questionnaires over all three workshops adds a little weight to a number of general lessons that can be derived from the all the previous analysis of the LHEMP process. Figure 30 shows the comparison of the workshops' "effects", as perceived by the participants.

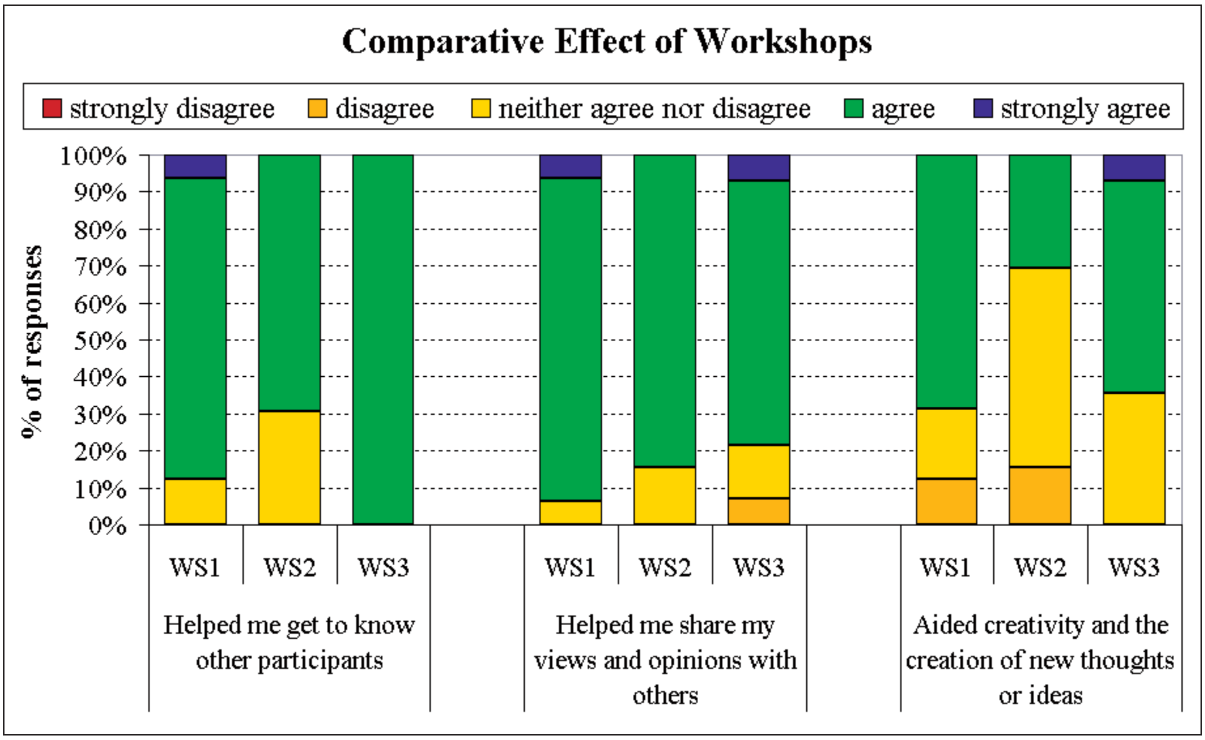


Figure 30: Participant perceived effects of the three workshops

From Figure 30, it can be seen that the majority of participants were generally in agreement with the statements that the workshops helped them to get to know the other participants, helped them to share their views and opinions with others and to a lesser extent that the workshops aided creativity and the creation of new thoughts and ideas. It appears that the second workshop had the least impact on these factors, in particular the aiding of creativity and the creation of new thoughts and ideas, most probably due to its more constrained format. The third workshop was the most amenable to aiding creativity and the creation of new thoughts and ideas, most probably as, unlike in the second workshop, the method used was much more open and specifically designed to broaden thinking patterns. It also seems that the third and first workshops were most useful for getting to know the other participants, most likely due to their more open designs and the periods of small group work which allowed good levels of interaction. The first workshop also appeared to have helped participants to share their views and opinions with others the most, possibly due to the couple of periods of individual presentation and open debates.

The various methods used in the three workshops also appear to have had similar types of impacts on the depth of learning, as shown in Figure 31. The more heavily structured risk assessment process in the second workshop did not seem quite as conducive to learning about any of the three areas: management of the estuary and its surrounding environment; other participants in the group; or themselves (or their opinions and practices). The first workshop appeared to produce the largest learning outcomes related to the other participants in the group and the third workshop's activities seemed conducive to the participants' greater learning about themselves and their own opinions or practices.

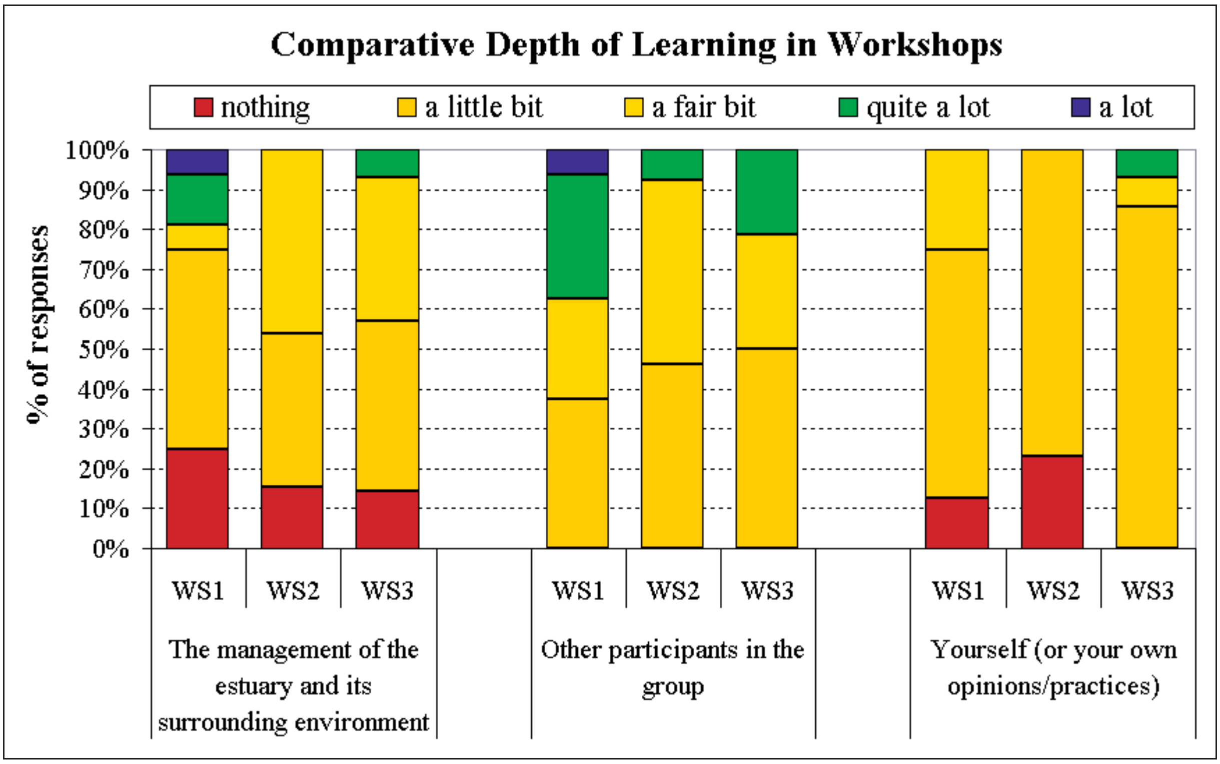


Figure 31: Participant perceived depth of learning over the three workshops

Pertaining to both the comparative results in Figure 30 and Figure 31, it is noted that the participants who filled in the evaluation questionnaires varied in each workshop, so differences in the interpretation of questions or other factors may reduce the confidence in the capacity to effectively compare the results across workshops. However, the results do appear to support intuitive assumptions about the purpose and effects of different workshop methods, and thus present an interesting base for discussion.

Overall, the LHEMP process provided a number of benefits that included:

- Learning, mutual understanding and relationship building between all stakeholders (and project team members, including the consultants and researchers);
- Development of a common set of estuarine values (assets) and a focus on the issues (risks) were considered to be the most important to stakeholders and that formed the basis for all subsequent analyses: this meant that the stakeholders were largely responsible for problem definition and goals for the planning process;
- Management of conflicts: methods used in the workshops were selected to give everyone a voice in an atmosphere that was not too confrontational. This choice appeared to have the desired effect of allowing the participants to move forward but still appreciate that there were differences of opinion and a need to find compatible solutions: conflicts were outlined and acknowledged but not made the major focus of the planning process.

- Acknowledgement and analysis of uncertainties that may impact on the effectiveness of estuarine management: looking at the likelihood of risk impacts; estimating the level of knowledge uncertainty related to risk level predictions; and the risk prioritisation model sensitivity analysis; and
- An attempt to structure the estuarine system's natural complexity (and its management): through the "multi-asset" risk analysis; and by creating the strategy maps to structure the relations between the actions, strategies and risk effects and causes (plus the monitoring needs and responsibilities).

A number of suggestions or recommendations for the next stages of the LHEMP process are proposed here that could help to overcome a few of the difficulties already discussed and improve the process outcomes. Most of them have already been proposed within the previous sections of this report (or are already planned in the project definition) but those believed to be the most important are summarised here:

1) The risk-response table created by the consultant team from the fusion of the "stakeholder informed risk-response table" and the actions developed through a review of current management strategies in the region should be sent to stakeholders so that they can check and negotiate their responsibilities for actions before the draft plan exhibition. This process will especially give agencies the possibility of obtaining the required support and endorsement that may prove invaluable for the successful implementation of all of the plan's recommended actions.
2) Simple brochures and potentially a poster of the LHEMP process should be produced and distributed through stakeholders to their peers and to the broader public to increase awareness of the importance of estuarine management. This may be able to underpin future education campaigns and promote acceptance of the process by stakeholders and occasional estuarine users.
3) The "integrated monitoring and reporting strategy", as suggested by the stakeholders, should be developed and implemented as a follow up project to this planning process (if it is not specifically recommended as one of the plan's actions). This would allow stakeholders to capitalise on the first phase of information collection carried out throughout this planning process. It would also help to further increase the value of monitoring activities already carried out in the estuary and provide an effective base for effective future estuarine management

There are also a small number of more general suggestions about the use of participatory processes that could help to improve general understanding and future management and planning projects. Firstly, honesty about the potential positive and negative outcomes of participatory processes is required. This is especially important for the project implementers to acknowledge to the managing institutions and participants. All participatory processes, and the choice of the methods used within them, will require many choices and potential trade-offs that will have a variety of impacts on the management or process situation including the possibility of: changed power structures between participants (and non-participants); relationships changes and conflicts; and trade-offs between stakeholder process legitimacy and “scientific” or “methodological” validity from an external point of view. As participatory processes are real-world processes, they will also be carried out under real world constraints which will often include time and budgetary constraints. This means that decisions underpinning their design and implementation can not always be made in collaboration with everyone who would like to be involved, or to an “ideal” methodological standard due to a lack of time and other resources. Last minute changes or unforeseen contextual constraints are also more than likely to impact the process at some stage of its implementation but negative impacts may be able to be minimised by flexible and experienced process managers or facilitators. It is also acknowledged that many questions remain about the best ways of treating complexity and managing uncertainty and conflicts, thus highlighting the need for more research and innovative practical trials like this LHEMP process to be able to push continual improvement and sustainable management processes forward.

6. CONCLUSIONS

This report has presented the process, preliminary findings and a discussion related to the second two stakeholder workshops held to aid the creation of the Lower Hawkesbury Estuary Management Plan (LHEMP). It has followed on from the "Summary Report: Community Workshop 1 for the Lower Hawkesbury Estuary Management Plan" (Daniell, 2007) found in Appendix A of the "Lower Hawkesbury Estuary Synthesis Report" (WBM Pty. Ltd., 2007), outlining how the key outcomes of the first stakeholder workshop have been integrated into the two following workshops.

The second stakeholder workshop was attended by a diverse range of representatives from State Government Departments, Local Governments, industry and governing agencies and associations. The 19 participants worked through a risk assessment process based on the Australian Standard for Risk Management (AS/NZS 4360:2004), where the assets (values) and risks (issues) defined by stakeholders in the first workshop became the basis for assessment. For each risk, the "consequences" and "likelihoods" of risk impacts on the nine previously defined estuarine assets were outlined by participants, as well as an associated "risk level", the uncertainties related to these classifications, and the level of current management effectiveness of the risk related to each asset. From this information, the priority of the risks (acceptable, tolerable, or intolerable) was computed and the results discussed. From this assessment, all risks were classified as requiring treatment (tolerable or intolerable). The third stakeholder workshop was then used to develop strategies and actions for the treatment of these risks, as well as to identify monitoring needs, stakeholder responsibilities and stakeholder preferences related to the proposed strategies and actions. Individual brainstorming of strategies and actions preceded the collective "strategy mapping" for each risk. This third workshop was attended by 18 representatives from State and Local government, industry, agencies, associations and local residents.

As the plan is still in the analysis and writing stage, only evaluation results related to the use of the approach from a methodological viewpoint were presented, rather than an evaluation of physical results and external impacts of the approach. From preliminary analyses, it can be seen that the approach produced relatively positive relational and learning outcomes. However, the effectiveness of the approach in improving the estuarine management and preservation of assets will have to wait until the plan is enacted to be properly assessed. Based on these preliminary evaluations, this report has presented a discussion on the participatory approach used in the LHEMP process, as well as a number of recommendations for future practice and research areas which warrant further research. It is hoped that the lessons learnt during this process may aid the later phases of the LHEMP implementation and allow others to undertake similar processes to improve estuarine management and regional sustainability.

7. ACKNOWLEDGEMENTS

The author would like to acknowledge that document has been written as part of the development of her PhD in water management and sustainable development, which is kindly funded by the General Sir John Monash Foundation, the CSIRO, Cemagref and the Fenner School of Environment and Society at the Australian National University (ANU); and supervised by Prof. Ian White (Fenner School-ANU), Dr. Pascal Perez (RSPAS-ANU/CIRAD, France), Prof. Alexis Tsoukiàs (LAMSADE-CNRS, France), Dr. Nils Ferrand (Cemagref, France) and Mr. Stewart Burn (CSIRO Land and Water).

8. REFERENCES

Ackermann, F., Eden, C. (2001) SODA and Mapping in Practice. In Rosenhead, J. and Mingers, J. (eds.) *Rational analysis for a problematic world revisited*. Wiley, Chichester, pp. 43-60.

ANZECC / ARMCANZ (2000) *Australian and New Zealand guidelines for fresh and marine water quality*, Australian and New Zealand Environment and Conservation Council, Department of Environment and Heritage, Canberra, Australia. Online [URL]: *www.deh.gov.au/water/quality/nwqms*

Billington, K. (2005) *River Murray Catchment Risk Assessment Project for Water Quality—Concepts and Method*, SA EPA, 88 pp. Online [URL]: *http://www.epa.sa.gov.au/pdfs/rm_concepts.pdf*

Daniell, K.A. (2007) *Summary Report: Community Workshop 1 for the Lower Hawkesbury Estuary Management Plan*. Available as Appendix A in: WBM Pty Ltd (2007) *Lower Hawkesbury Estuary Synthesis Report*, prepared for the Hornsby Shire Council, NSW, Australia.

Daniell, K.A., Ferrand, N. (2006) *Participatory Modelling for Water Resources Management and Planning,* D3.8.2, Aquastress IP, FP6, Europe.

Daniell, K.A., White, I., Ferrand, N., Tsoukiàs, A., Burn, S., Perez, P. (2006) *Towards an art and science of decision aiding for water management and planning: a participatory modelling process*. In: Proceedings of the 30th Hydrology & Water Resources Symposium [CD ROM], 4 – 7 December 2006, Hotel Grand Chancellor, Launceston, Tasmania. ISBN: 0-8582579-0-4

Everingham, P. (2005) *Upper South East Water Quality Risk Management Strategy*. South Australia. Department of Water, Land and Biodiversity Conservation.

Fleming, N.S. (2005) *Systems Based Planning and Information Networks for Sustainability*, EIANZ Conference 'Working on the Frontier – Environmental Sustainability in Practice', 29 March – 1 April 2005, Christchurch, New Zealand.

Fletcher, W.J., Chesson, J., Fisher M., Sainsbury, K.J., and Hundloe, T.J. (2004) *National ESD Reporting Framework: The 'How To' Guide for Aquaculture*. Version 1.1 FRDC, Canberra, Australia

HSC - Hornsby Shire Council (HSC) (2002) *Berowra Creek Estuary Management Study and Management Plan*. Online [URL]: *http://www.hornsby.nsw.gov.au/environment/index.cfm?NavigationID=1806*

HSC - Hornsby Shire Council (2004) *Community Sustainability Indicators Project*, Hornsby Earthwise. Online [URL]: *http://www.hornsby.nsw.gov.au/uploads/documents/CSIPExplanation.pdf*

HSC - Hornsby Shire Council (2006a) *Brooklyn Estuary Management Study*. Online [URL]: *http://www.hornsby.nsw.gov.au/uploads/documents/2006_Brooklyn_Estuary_Management_Study.pdf*

HSC - Hornsby Shire Council (2006b) *Q26/2006 Lower Hawkesbury Estuary Management Plan – Tender Document*, Water Catchments Team, Hornsby Shire Council, NSW, Australia.

Kimmerikong (2005) *Hawkesbury-Nepean River Estuary Management – Scoping Study – Final Report*, Kimmerikong Pty Ltd Natural Resource Management. Online [URL]: *http://www.hn.cma.nsw.gov.au/multiversions/2759/FileName/Scoping%20Study_HNEstuaryMan_Final%20Report_Nov05.pdf*

Mazri, C. (2007) *Apport méthodologique pour la structuration de processus de décision publique en contexte participatif.* PhD Thesis, Université Paris Dauphine, France.

DPI - NSW Department of Primary Industries (2006) *NSW Oyster Industry Sustainable Aquaculture Strategy, Public Consultation Document.* Online [URL]: *http://www.fisheries.nsw.gov.au/__data/assets/pdf_file/61704/OISAS-Public-Consultation.pdf*

SJB Planning (2005) *Hornsby Shire Waterways Review*, SJB Planning Pty Ltd, Sydney, Australia.

SKM - Sinclair Knight Merz (2004) *Monitoring, Evaluation and Reporting Framework for Gippsland NRM.* Report for the West Gippsland Catchment Management Authority. SKM Ref: WC02773, Melbourne.

SP AusNet (2006) Risk Management Framework. Online [URL]: *http://www.sp-ausnet.com.au/CA256FE40021EF93/Lookup/20060413RiskManagementFramework/$file/Risk%20Management%20Framework%20Version%201.0.pdf*

Standards Australia (2006) HB 203:2006, Environmental risk management—Principles and processes.

Standards Australia (2004a) AS/NZS 4360:2004, Risk Management.

Standards Australia (2004b) HB 436:2004, Risk Management Guidelines - Companion Handbook

WBM Pty Ltd (2007) *Lower Hawkesbury Estuary Synthesis Report*, prepared for the Hornsby Shire Council, NSW, Australia.

Wild River, S., Healy, S. (2006) *Guide to Environmental Risk Management*, CCH Australia Ltd., Sydney, Australia.

World Health Organisation (2003) Guidelines for Safe Recreational Environments—Volume 1 Coastal and Fresh Waters.

Umwelt Environmental Consultants (2006) Mt Arthur Coal Environmental Assessment for Proposed Exploration Adit. Online [URL]: *http://www.umwelt.com.au/mtarthurcoal-adit/*

APPENDIX A RISK TABLES

Lower Hawkesbury Estuary Management Plan Risk Tables ***Page 1***

Consequences Scale

Asset Category	*Consequence Level Description*				
	Insignificant 1	**Minor** 2	**Moderate** 3	**Major** 4	**Catastrophic** 5
Scenic amenity and national significance	Little to no impact, or short term (reversible) impacts, on scenic amenity Impacts have little to no community significance	Minor or medium-term impacts on scenic amenity (some reversible) Impacts have low community significance for the region and nation	Moderate or long-term impacts on scenic amenity (mostly irreversible) Impacts have some community significance for the region but little nationally	Major and permanent long-term impacts on scenic amenity Impacts have high community significance for the region and some nationally	Extreme and permanent long-term impacts on scenic amenity Impacts have high regional and national community significance
Functional and sustainable ecosystems	Little to no discernable effects on aquatic AND/OR terrestrial ecosystems or impact is so small to be considered trivial.	Aquatic AND/OR terrestrial ecosystem health temporarily compromised over a localised area. Possible minor changes in species abundance and community structure but these could be mistaken for being due to seasonal changes or natural variation. Recovery would likely occur within a short time frame.	Aquatic AND/OR terrestrial ecosystem health compromised in a localised area for a long time period OR temporarily over a wider area. May result in significant changes in native species abundance and community structure AND/OR major habitat loss AND/OR triggering of algal/nuisance species growth. Recovery may take several years.	Aquatic AND/OR terrestrial ecosystem health compromised over a wide area for a moderate term. May result in major changes in native species abundance and community structure AND/OR major habitat loss AND/OR triggering of algal/nuisance species growth. Recovery may take many years.	Aquatic AND/OR terrestrial ecosystem health severely compromised over a wide area and for a long term. May result in extensive losses of organisms and habitat with the potential for whole ecosystem destruction. Recovery may occur in the very long term or not at all.
Largely undeveloped natural catchments and surrounding lands	Little to no impact of development, or short term (reversible) impacts, on land-use patterns The quality and quantity of runoff remains unchanged (relative to normal variability patterns)	Minor or medium-term impacts of development on land-use patterns (some reversible) Possible minor changes to runoff quality AND/OR quantity outside normal variability	Moderate or long-term impacts of development on land-use patterns (mostly irreversible) Significant changes to runoff quality AND/OR quantity outside normal variability	Major and permanent long-term impacts of development on land-use patterns Major changes to runoff quality AND/OR quantity outside normal variability	Extreme and permanent long-term impacts of development on land-use patterns Extreme changes to runoff quality AND/OR quantity outside normal variability
Recreational opportunities	Little or no impact on recreational opportunities	Minor or medium-term impacts on some recreational opportunities, most activities remain unaffected	Moderate or long-term impacts on some recreational opportunities AND/OR minor impacts on most activities	Major and permanent long-term impacts on some recreational opportunities AND/OR moderate impacts on most activities	Severe and permanent damage to a large number of recreational opportunities
Sustainable economic industries	Little or no impact on resources, industries and activities of economic significance	Minor impacts on some resources, industries and activities of economic significance. Possible short-term losses of employment AND/OR financial hardship.	Moderate or long-term impacts on some resources, industries and activities of regional economic significance. Loss of employment AND/OR sustained financial hardship in some industries (potentially recoverable in the medium term).	Major impacts on some resources, industries and activities of regional AND national economic significance. Widespread employment losses AND/OR high industry financial losses (potentially recoverable in the long term).	Severe and permanent impacts on some resources, industries and activities of high national economic significance. Widespread employment losses AND/OR extreme financial losses (not recoverable in the long term) AND/OR total collapse of some industries.
Culture and heritage	Little or no impact on areas or items of cultural significance and traditional ways of life	Minor permanent impacts to some areas or items of local cultural significance AND/OR minor unwanted impacts on traditional ways of life	Permanent damage to some areas or items of local cultural significance AND/OR moderate unwanted impacts on traditional ways of life	Permanent damage to areas or items of local AND national cultural significance AND/OR major unwanted impacts on traditional ways of life	Widespread permanent damage to areas or items of national cultural significance AND/OR total decimation of traditional ways of life
Improving water quality that supports multiple uses	Insignificant impact on water quality and flora, fauna and habitatInsignificant impacts on optical properties, temperature, dissolved oxygen, nutrient levels and salinity outside of natural variabilityPresence of toxins and undesirable species (heavy metals, pesticides, bacteria, algae etc.) do not exceed water quality guidelines (i.e. ANZECC, WHO) anywhere in the estuary	Minor localised effects on water quality but without long-term impacts on aquatic ecosystems Minor localised impacts on optical properties, temperature, dissolved oxygen, nutrient levels and salinity outside of natural variabilityPresence of toxins and undesirable species (heavy metals, pesticides, bacteria, algae etc.) exceed water quality guidelines (i.e. ANZECC, WHO) in a few areas (such as at discharge points) but does not limit most estuary uses (fishing, oyster farming, recreation) in other areas	Significant localised effects but without longer-term impact on aquatic ecosystems, and short-term and localised effects on water quality that impacts some estuarine usesSignificant localised impacts on optical properties, temperature, dissolved oxygen, nutrient levels and salinity outside of natural variabilityPresence of toxins and undesirable species (heavy metals, pesticides, bacteria, algae etc.) exceed water quality guidelines (i.e. ANZECC, WHO) in a few areas that have short-term impacts on some estuary uses (fishing, oyster farming, recreation)	Damage to a moderate portion of the aquatic ecosystem resulting in moderate impacts on aquatic populations and habitats and long-term impact on water quality that impacts some estuarine usesSignificant widespread impacts on optical properties, temperature, dissolved oxygen, nutrient levels and salinity outside of natural variabilityPresence of toxins and undesirable species (heavy metals, pesticides, bacteria, algae etc.) exceed water quality guidelines (i.e. ANZECC, WHO) in most of the estuary that have major impacts AND/OR long-term effects on some estuary uses (fishing, oyster farming, recreation)	Damage to an extensive portion of aquatic ecosystem resulting in severe impacts on aquatic populations and habitats and long-term impacts on water quality and most estuarine usesExtreme widespread impacts on optical properties, temperature, dissolved oxygen, nutrient levels and salinity outside of natural variabilityPresence of toxins and undesirable species (heavy metals, pesticides, bacteria, algae etc.) exceed water quality guidelines (i.e. ANZECC, WHO) in most of the estuary that have devastating long-term impacts on some estuary uses (fishing, oyster farming, recreation)
Community value	Little to no impact on local communities and their well-being, heath, social equity, access to services and participation levels (in local activities, governance processes etc.)	Minor long-term AND/OR moderate short-term impacts (mostly repairable) on local communities and their well-being, health, social equity, access to services and participation levels (in local activities, governance processes etc.)	Significant long-term AND/OR major short-term (mostly repairable) impacts on local communities and their well-being, health, social equity, access to services and participation levels (in local activities, governance processes etc.)	Major long-term AND/OR devastating short-term (some repairable) impacts on local communities and their well-being, health, social equity, access to services and participation levels (in local activities, governance processes etc.)	Extreme and widespread devastating long-term impacts on all local communities and their well-being, health, social equity, access to services and participation levels (in local activities, governance processes etc.)
Governance, legal and media	Little or no impact on existing governance structures Low-level legal and regulatory issues Public concern limited to local complaints	Minor impacts on existing governance structures (minor changes required for improvement AND/OR small disagreements between governing agencies) Minor legal issues, non-compliances and breaches of regulations Minor, adverse local public or media attention and complaints	Moderate impacts on existing governance structures (significant changes required AND/OR disagreement between governing agencies) Serious breaches of regulations with possible investigation, report to authority with prosecution AND/OR moderate fine possible Significant adverse local public and media attention. Possible limited criticism from outside groups (NGOs, national media)	Major impacts on existing governance structures (major changes required AND/OR major disputes between governing agencies) Major breaches of regulations. Major litigation likely Significant adverse national media, public and NGO attention	Extreme impacts on existing governance structures (total breakdown of existing structures AND/OR irreconcilable disputes between governing agencies) Significant prosecution and fines. Very serious litigation including class action Serious international public and media outcry

Lower Hawkesbury Estuary Management Plan Risk Tables ***Page 2***

Likelihood Scale

	Likelihood Level Description				
	Rare	**Unlikely**	**Possible**	**Likely**	**Almost certain**
	1	**2**	**3**	**4**	**5**
Likelihood of risk **impacts** occurring	Occurs only in exceptional circumstances	Could occur but not expected	Could occur	Will probably occur in most circumstances	Is expected to occur in most circumstances

Risk Level Matrix

Likelihood Level Description	*Consequence Level Description*				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	H	H	V	E	E
Likely	M	H	H	V	E
Possible	L	M	H	V	V
Unlikely	L	L	M	H	V
Rare	L	L	M	H	H

LEGEND
E = Extreme risk; immediate action required
V = Very high risk; immediate senior management attention required
H = High risk; senior management attention required
M = Moderate risk; management responsibility must be specified
L = Low risk; manage by routine procedures

Uncertainty Scale

	Description of knowledge certainty				
Level of confidence	1	2	3	4	5
	Perception only, no information to support opinion	Perception based, some information on process but not directly relevant to local region, or information at a regional level has significant limitations	Limited information, information could relate to cause or effect, expert knowledge would lead to this outcome—may be some differences in opinion	Information available and could relate to cause or effect, process has been described and documented at a regional level, experts can verify this position	Information is available and represents the process, and relates to cause and effect, process has been described and documented at a regional level, experts readily agree on this position

Current risk management effectiveness

Rating	***Guide to effectiveness***
Excellent	Systems and processes exist to manage the risk and management accountability is assigned. The systems are well documented and the system is effective in mitigating the risk
Good	Systems and processes exist to manage the risk. Some improvement opportunities have been identified but not yet actioned
Satisfactory	Systems and processes exist to manage the risk. Recent changes in operations require confirmation that accountabilities are in place and understood and that the risk is being actively managed
Poor	The system and process for managing the risk has been subject to major change or is in the process of being implemented and its effectiveness cannot be confirmed
Unsatisfactory	No system exists or process exists to manage the risk

APPENDIX B WORKSHOP 2 AGENDA

Workshop 2 Agenda for the Lower Hawkesbury River Estuary Management Plan

Thursday 15th of February, 2007
9.30am – 3.30pm

Hornsby Shire Council, Council Chambers (Function Room 1)
296 Pacific Highway, Hornsby

9.30am	**Welcome and Project Background Update** (Peter Coad)
9.40am	**Workshop Agenda** (Philip Haines)
9.45am	**Personal Introductions** (Philip Haines) Everyone to introduce themselves to the group: name, where they are from.
9.50am	**Confirmation of Goals, Assets and Risks** (Philip Haines) – Seek general endorsement of the goals, the assets (values) and risks (issues), as identified at the first workshop and through the subsequent review of environmental and planning documentations.
10.20am	**Risk analysis method presentation** (Katherine Daniell) – The method to be used for analysis of the risks will be presented (looking at consequence and likelihood tables of risk impacts on estuarine assets, overall risk levels and uncertainties). An example risk will be used as a demonstration.
10.30am	**Morning Tea**
10.50am	**Analysis of risks** – (Katherine Daniell) As a large group, do the first risk as an example (Excessive Sedimentation) (30 minutes)
11.20am	**Separate participants into three groups –** Approximately 7 per group.
	Small group risk analyses (5 or 6 risks each) – each group to do the same first risk (WQ not meeting standards) as a validation, then separate risks for each group. Participants will assess each risk with respect to likelihood and consequence of occurrence (spend no more than 30 minutes per risk). For each risk, commence with brief discussion on sources / causes and potential impacts. We will then use the risks table to agree on likelihood, consequences, risk level, uncertainty and management effectiveness (Small groups facilitated by WBM staff).
12.50pm	**Lunch**
1.30pm	**Continuation of risk analysis** (small groups).
2.45pm	**Large group discussion** (Katherine Daniell) – Reporting back from small group analyses.
3.25pm	**Wrap-up and next process steps** (Peter Coad)
	Distribution of evaluation questionnaire
3.30pm	**Official workshop end** – Afternoon tea

APPENDIX C RISK SHEET

Risk Sheet No. ____ **Group Colour ______________**

For your group's list of risks, please complete the following questions and table. A separate sheet should be used for each risk.

What is the risk?

What are the sources/causes of this risk?

What are the main potential impacts of this risk?

Where, or to whom, will these impacts occur?

What are the current strategies used to manage this risk?

Please fill in the following table for this risk using the "Risk Table Sheets" provided:

Asset Category	***Consequence***	***Likelihood***	***Risk Level***	***Uncertainty***	***Management Effectiveness***	***Notes***
Scenic amenity and national significance						
Functional & sustainable ecosystems						
Largely undeveloped surrounding lands						
Recreational opportunities						
Sustainable economic industries						
Culture and heritage						
Water quality for multiple uses						
Community value						
Governance, legal and media*						

APPENDIX D WORKSHOP 2 EVALUATION QUESTIONNAIRE

Process evaluation: Workshop 2 for the Lower Hawkesbury River Estuary Management Plan

Thank you for participating in this workshop. To help evaluate and improve the effectiveness of this planning process, we would appreciate your help in answering this questionnaire about your thoughts and experiences related to this second workshop.

The responses will be used by the project team to improve future workshops and by researchers at the Australian National University to evaluate and compare the effectiveness of using participatory processes in Natural Resources Management. Please contact Katherine Daniell (ANU) or Philip Haines (WBM Oceanics Pty Ltd) if you have any enquiries related to this questionnaire or the project process.

Your Name and Affiliation ________________________________

1. What do you think were the objectives of this second workshop?

2. In your opinion, were these objectives satisfactorily achieved? If not, why not?

3. How was this workshop useful or valuable for you? (If it was not, please also state why.)

4. Is there anyone else you think should have participated in this workshop? Why?

5. How did today's activities help you to work with and relate to the other participants?

6. Please give your level of agreement with the following statements (tick the box).

The activities in today's workshop:	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
Helped me to get to know the other participants better.	☐	☐	☐	☐	☐
Helped me to share my views and opinions with others.	☐	☐	☐	☐	☐
Helped me to better structure my own thoughts	☐	☐	☐	☐	☐
Aided creativity and the creation of new thoughts or ideas.	☐	☐	☐	☐	☐

Please turn over

7. What are the most important things you have learnt throughout today's workshop?

8. Please give your level of support for the following questions (tick the box).

How much have you learnt about:	Nothing	A little bit	A fair bit	Quite a lot	A lot
The management of the estuary and its surrounding environment?	☐	☐	☐	☐	☐
Other participants in the group?	☐	☐	☐	☐	☐
Yourself (or your own opinions and practices)?	☐	☐	☐	☐	☐

9. Were you satisfied with the way the workshop was facilitated? ____________________

10. How do you think the facilitation of the workshop could have been improved?

11. Overall, what did you like about the workshop?

12. Overall, what did you dislike about the workshop?

13. Overall, how do you think the workshop could have been improved?

14. Do you have any other comments or questions about this workshop or the overall project?

Thank you very much for your time and participation.

APPENDIX E RISK SENSITIVITY ANALYSES SUMMARY TABLE

This table summarises the rankings of the 15 risks analysed in Workshop 2 under 33 scenarios as explained in Section 3.9.2. All columns in white have been ranked based on "risk level" values and those in yellow on their "knowledge uncertainty" (kc) or "management ineffectiveness" (me) values.

rank no.	log2 0	log2 kc	log2 me	log2 env5	log2 env10	log2 ce5	log2 ce10	log2 hist5	log2 hist10	log2 man5	log2 man10
1	5.	7.	5.	5.	5.	5.	5.	5.	5.	5.	5.
2	3.	6.	12.	8.	8.	3.	3.	3.	14.	8.	8.
3	8.	15.	10.	3.	3.	8.	8.	14.	3.	3.	3.
4	6.	5.	15.	6.	6.	6.	6.	12.	2.	6.	6.
5	12.	12.	8.	12.	12.	12.	12.	2.	13.	12.	12.
6	14.	10.	3.	9.	9.	14.	14.	13.	12.	9.	9.
7	9.	9.	13.	14.	14.	9.	9.	8.	9.	2.	2.
8	2.	11.	6.	13.	13.	2.	2.	6.	6.	14.	14.
9	13.	13.	2.	11.	11.	13.	13.	9.	4.	13.	13.
10	11.	14.	9.	2.	2.	11.	7.	4.	10.	4.	4.
11	4.	1.	14.	1.	1.	4.	11.	10.	8.	11.	11.
12	1.	3.	1.	4.	4.	7.	4.	11.	11.	1.	1.
13	7.	4.	4.	7.	7.	1.	1.	1.	1.	10.	10.
14	10.	8.	11.	10.	10.	10.	10.	7.	7.	7.	7.
15	15.	2.	7.	15.	15.	15.	15.	15.	15.	15.	15.

rank no.	cxl 0	cxl kc	cxl me	cxl env5	cxl env10	cxl ce5	cxl ce10	cxl hist5	cxl hist10	cxl man5	cxl man10
1	5.	7.	5.	5.	5.	3.	3.	3.	14.	5.	8.
2	3.	6.	12.	3.	8.	5.	5.	5.	13.	8.	5.
3	12.	15.	10.	8.	3.	8.	8.	14.	2.	3.	3.
4	8.	5.	15.	12.	12.	12.	12.	2.	3.	12.	12.
5	14.	12.	8.	6.	6.	14.	14.	12.	12.	6.	6.
6	2.	10.	3.	9.	9.	6.	6.	13.	5.	2.	9.
7	6.	9.	13.	14.	14.	9.	9.	6.	6.	9.	2.
8	9.	11.	6.	2.	2.	2.	2.	9.	10.	14.	14.
9	13.	13.	2.	11.	13.	11.	11.	10.	9.	13.	4.
10	11.	14.	9.	13.	1.	13.	13.	4.	4.	4.	13.
11	4.	1.	14.	1.	11.	4.	7.	11.	11.	11.	1.
12	1.	3.	1.	4.	4.	7.	4.	1.	1.	1.	11.
13	10.	4.	4.	7.	7.	1.	1.	7.	7.	10.	10.
14	7.	8.	11.	10.	10.	10.	10.	8.	8.	7.	7.
15	15.	2.	7.	15.	15.	15.	15.	15.	15.	15.	15.

rank no.	c+l 0	c+l kc	c+l me	c+l env5	c+l env10	c+l ce5	c+l ce10	c+l hist5	c+l hist10	c+l man5	c+l man10
1	3.	7.	5.	5.	5.	5.	5.	3.	14.	5.	5.
2	5.	6.	12.	3.	8.	3.	3.	14.	2.	8.	8.
3	12.	15.	10.	8.	3.	8.	8.	2.	13.	3.	3.
4	14.	5.	15.	12.	6.	6.	6.	13.	12.	12.	12.
5	2.	12.	8.	9.	12.	12.	12.	12.	3.	2.	2.
6	9.	10.	3.	6.	9.	14.	14.	9.	9.	9.	9.
7	13.	9.	13.	14.	14.	9.	9.	5.	10.	6.	6.
8	8.	11.	6.	2.	13.	2.	2.	6.	6.	14.	14.
9	6.	13.	2.	13.	11.	13.	13.	10.	5.	13.	4.
10	11.	14.	9.	11.	2.	11.	7.	11.	11.	4.	13.
11	1.	1.	14.	1.	1.	4.	11.	1.	1.	11.	11.
12	10.	3.	1.	4.	4.	7.	4.	4.	4.	1.	1.
13	4.	4.	4.	7.	7.	1.	1.	7.	7.	10.	10.
14	7.	8.	11.	10.	10.	10.	10.	8.	8.	7.	7.
15	15.	2.	7.	15.	15.	15.	15.	15.	15.	15.	15.

risk no.	rank max	rank min	rank max	rank min	
1.	10	13	11	12	*note also 12 Acceptable
2.	2	10	9	15	
3.	1	5	6	12	*note also max 1 T, likelihoods likely to be somewhat overrated compared to other risks
4.	9	12	13	13	
5.	1	9	1	4	
6.	4	9	2	8	
7.	10	14	1	15	
8.	1	14	5	14	
9.	5	9	7	10	
10.	7	14	3	6	
11.	9	12	8	14	
12.	3	6	2	5	*note also min 5 Tolerable
13.	4	10	7	9	*note also 9 Intolerable
14.	1	8	10	11	
15.	15	15	3	4	*note not properly completed

APPENDIX F WORKSHOP 3 AGENDA

Workshop 3 Agenda for the Lower Hawkesbury River Estuary Management Plan

Thursday 3rd of March, 2007
9.30am – 3.30pm

Hornsby Shire Council, Council Chambers (Function Room 1)
296 Pacific Highway, Hornsby

9.30am	**Welcome** (Peter Coad)
9.35am	**Workshop Agenda** (Philip Haines)
9.40am	**Personal Introductions** (Philip Haines) Everyone to introduce themselves to the group: name, where they are from plus in 10 words or less: an innovative of 'radical' strategy to address one of the risks to the estuary
9.50am	**Goals, Assets and Risks** (Philip Haines) – Presentation of goals, assets (values) and risks (issues), as identified at the first workshop, and supplemented through background investigations and the second stakeholder workshop.
10.10am	**Strategy mapping method presentation** (Katherine Daniell) – Explanation of how the individual cards can be organised in small groups to aid further exploration and elaboration of strategies to treat each of the risks.
10.20am	**Individual brainstorming of strategies and actions to treat risks** – Each participant will be given the opportunity to think of potential strategies and actions to manage the risks (2 minutes per risk). These will be written on individual cards. Creativity is strongly encouraged. Feasibility of strategies will be assessed in a later stage. On each card, please write along with the strategy or action: the risk number, your name and whether this card is linked to another one you have written.
11.00am	**Morning Tea**
11.20am	**Separate participants into small groups** – *About 4 groups of 4 – 5 participants each.*
	Small group strategy mapping (3 or 4 risks each) – Following method presentation.
12.50pm	**Lunch**
1.30pm	**Strategy mapping review** – Participants will have the opportunity to review and add additional information to the risk strategy maps from other groups.
2.00pm	**Strategy mapping refinement** - Small groups to reconvene and refine strategies based on input from other stakeholders. Potential responsibilities and indicators to monitor the effectiveness of strategies are to be specified.
3.00pm	**Reporting of strategies** – As a large group, individuals will report on one or two of the most effective strategies for each risk.
3.20pm	**Wrap-up and process for EMP completion** (Peter Coad / Philip Haines)
	Distribution of evaluation questionnaire
3.30pm	**Official workshop end** – Afternoon tea

APPENDIX G WORKSHOP 3 EVALUATION QUESTIONNAIRE

Process evaluation: Workshop 3 for the Lower Hawkesbury River Estuary Management Plan

Thank you for participating in this workshop. To help evaluate and improve the effectiveness of this planning process, we would appreciate your help in answering this questionnaire about your thoughts and experiences related to this third workshop and the overall planning process.

The responses will be used by the project team to improve future workshops and by researchers at the Australian National University to evaluate and compare the effectiveness of using participatory processes in Natural Resources Management. Please contact Katherine Daniell (ANU) or Philip Haines (WBM Oceanics Pty Ltd) if you have any enquiries related to this questionnaire or the project process.

Your Name and Affiliation ________________________________

1. What do you think were the objectives of this third workshop?

2. In your opinion, were these objectives satisfactorily achieved? If not, why not?

3. How was this workshop useful or valuable for you? (If it was not, please also state why.)

4. Is there anyone else you think should have participated in this workshop? Why?

5. How did today's activities help you to work with and relate to the other participants?

6. Please give your level of agreement with the following statements (tick the box).

The activities in today's workshop:	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
Helped me to get to know the other participants better.	☐	☐	☐	☐	☐
Helped me to share my views and opinions with others.	☐	☐	☐	☐	☐
Helped me to better structure my own thoughts	☐	☐	☐	☐	☐
Aided creativity and the creation of new thoughts or ideas.	☐	☐	☐	☐	☐

Please turn over

7. What are the most important things you have learnt throughout today's workshop?

8. Please give your level of support for the following questions (tick the box).

How much have you learnt about:	Nothing	A little bit	A fair bit	Quite a lot	A lot
The management of the estuary and its surrounding environment?	☐	☐	☐	☐	☐
Other participants in the group?	☐	☐	☐	☐	☐
Yourself (or your own opinions and practices)?	☐	☐	☐	☐	☐

9. Were you satisfied with the way the workshop was facilitated? ___________________

10. How do you think the facilitation of the workshop could have been improved?

11. Overall, what did you like about the workshop?

12. Overall, what did you dislike about the workshop?

13. Overall, how do you think the workshop could have been improved?

Questions relating to the overall Lower Hawkesbury Estuary Planning Process:

14. What motivated you most to take part in this planning process?

15. How do you think this process is helping to better manage the Estuary? (If it is not, please also state why.)

16. Do you understand and support the methods you used in these workshops to help create the LHEMP? (Please also state why or why not.)

17. Do you believe that your contribution to these workshops and planning process has been valued by the project team and other participants? (If it has not been, please also state why.)

18. Do you think the estuary management plan resulting from this process will be well accepted by the participants and outside stakeholder communities? Why?

19. Overall, how do you think this estuary planning process could be improved?

20. Do you have any other comments or questions about this workshop or the overall project?

Thank you very much for your time and participation.

APPENDIX C: PLANNING AND LEGISLATION REVIEW BY SJB

Environmental Planning and Assessment Act, 1979

The principal legislation establishing the planning framework in NSW is the *Environmental Planning and Assessment Act, 1979* (EPA Act). The *EPA Act* came into force on 1 September 1980 with the intention of implementing a system of land use control.

The key parts of relevance to the Study are outlined below.

Part 1 – Preliminary

Part 1 of the *EPA Act* identifies the objectives as:

(a) to encourage:

  (i) the 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,

  (ii) the promotion and co-ordination of the orderly and economic use and development of land,

  (iii) the protection, provision and co-ordination of communication and utility services,

  (iv) the provision of land for public purposes,

  (v) the provision and co-ordination of community services and facilities, and

  (vi) the protection of the environment, including the protection and conservation of native animals and plants, including threatened species, populations and ecological communities, and their habitats, and

  (vii) ecologically sustainable development, and

  (viii) the provision and maintenance of affordable housing, and

(b) to promote the sharing of the responsibility for environmental planning between the different levels of government in the State, and

(c) to provide increased opportunity for public involvement and participation in environmental planning and assessment.

Of particular relevance to the Study in Part 1 are Clauses 5A to 5D which require the following:

- in the administration of the *EPA Act* the likely affect the significant effect on threatened species, populations or ecological communities, or their habitats is to be taken into account and an assessment to be undertaken in accordance with any assessment guidelines under the *Fisheries Management Act, 1994* and the *Threatened Species Conservation Act, 1995*; and

- each planning authority must have regard to the register of critical habitat kept by the Director-General of National Parks and Wildlife under the *Threatened Species Conservation Act 1995*.

Part 3 – Environmental Planning Instruments

Part 3 of the Act introduced a three tier system of environmental planning instruments, being:

- State Environmental Planning Policies
- Regional Environmental Plans and
- Local Environmental Plans

Parts 3A to 5A – Approval Processes

Approval processes for "development" and "works" in NSW are provided for in Part 3A, Part 4, Part 5 and Part 5A of the *EPA Act*. The following provides an outline of the key provisions without the sections specifically repeated.

Briefly the processes are outlined as follows.

Part 3A – Major Infrastructure and Other Projects

Part 3A came into operation in August 2005 and applies to development that is declared to be a project to which the part applies. Sections 75A to 75 ZA address specific provisions. A project can be declared by:

(a) A State Environmental Planning Policy, or

(b) By order of the Minister published in the Government Gazette.

There are two types of development that may be declared:

(a) Major infrastructure or other development that in the opinion of the Minister is of state or regional environmental significance, or

(b) Old Part 5 activity approvals where the proponent is the determining authority and an EIS would have been required.

If a development is declared to be a project to which Part 3A applies it can also be declared 'critical infrastructure'. The Department has produced guidelines regarding Part 3A projects.

The Brooklyn – Dangar Island Priority Sewerage Scheme is an example of a development that had it been lodged after August 2005, it would have required approval under Part 3A. Otherwise Part 3A is unlikely to apply to the majority of development within the Study Area.

Part 4 – Development Assessment

This part of the *EPA Act 1979* lays out the legislative regime for what is commonly known as the standard process for lodgement and consideration of development applications. The relevant sections are found at s76 to s109B.

Essentially Part 4 processes apply where the local authority (Council) is the consent authority. The issue of permissibility is generally found in the Local Environment Plan (LEP) relevant to the Council. The controls for development of particular sites or use are found in Councils LEP and DCP.

The process of obtaining a Part 4 approval is open to any person with the consent of the owner of the land.

The majority of land based development within the Study Area will fall within Part 4 of the Act.

Section 79BA of the Act requires development within bushfire prone areas (with the exception of subdivision of land that could lawfully be used for residential or rural residential purposes or development for a special fire protection purpose) to comply with the specifications and requirements of *Planning for Bushfire Protection* and the Commissioner of the NSW Rural Fire Services to be consulted. Such provisions affect the majority of development within the Study Area.

Division 5 of Part 4 identifies the special procedures for integrated development, being development that requires a separate approval under other legislation.

Specific development such as subdivision may trigger integrated development provisions as a result the need for additional approvals under *Rural Fire Act 1997* for example.

A large proportion of development within the Study Area is integrated development as it is within 40m of a waterway and thus requiring a Controlled Activity Approval under the Water Management Act 2000 (WM Act 2000).

The Water Management Act 2000 replaced the Rivers and Foreshores Improvement Act 1948 (RFI Act 1948) on the 4 February 2008.

A Controlled Activity Approval (CAA) replaces the former Part 3A approval which was required under the Rivers and Foreshores Improvements Act 1948. A CAA is now required for works that are on 'Waterfront Land', this is via Part 3 of Chapter 3 of the WM Act 2000.

Waterfront Land is defined under the WM Act 2000 and is generally land that is within 40 metres from the top of the highest bank of a river, there are also similar provisions for lakes, estuaries and coastal waters.

A CAA is defined under the WM Act 2000 as activities carried out on waterfront land as follows:

'(a) the erection of a building or the carrying out of a work (within the meaning of the Environmental Planning and Assessment Act 1979), or

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

© 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.'

Transitional arrangements under the Water Management Act 2000 allow pending Das to be assessed under the RFI Act 1948, with the Part 3A permit upgraded to a 'Controlled Activity Approval' at the time of concurrence by the Department of Water and Energy.

Exemptions from the Water Management Act 2000 are defined in Clause 39A of the WM (General) Regulation 2004 and include exemptions for government authorities, with the exception of Landcom as follows:

'(2) Persons (excluding public authorities and local councils, but including Landcom) are exempt from section 344 (1) (a) of the Act in relation to the following controlled activities that they carry out in, on or under waterfront land:

(a) activities carried out in accordance with any lease, licence permit or other right in force under the Mining Act 1992, the Crown Lands Act 1989 or the Crown Lands (Continued Tenures) Act 1989,

(b) activities comprising the excavation of the bed of a river, lake or estuary for the purpose of facilitating the use of a water supply work,

(c) activities carried out pursuant to section 52 (Domestic and stock rights) of the Act,

(d) activities carried out, in accordance with a harvestable rights order, in connection with the construction or use of a dam on land within the harvestable rights area constituted by the order,

(e) activities carried out in connection with the construction or use of a work to which Part 2 of the Water Act 1912 applies in accordance with a licence issued under that Part in relation to that work,

(f) activities carried out in connection with the construction or use of a controlled work within the meaning of Part 8 of the Water Act 1912 in accordance with an approval issued under that Part in relation to that work,

(g) activities carried out in connection with:

(i) the erection of a dwelling house or dual occupancy building, or

(ii) the making of alterations or additions to an existing dwelling house or dual occupancy building, or

(iii) the provision of ancillary facilities for an existing dwelling house or dual occupancy building,

being activities that comprise exempt development or activities the subject of a development consent or complying development certificate issued under the Environmental Planning and Assessment Act 1979, but excluding any activity carried out in, on or over the bed of any river, lake or estuary,

(h) activities comprising nothing more than the removal of vegetation in circumstances that would otherwise be lawful,

(i) the carrying out of development in accordance with:

(i) Development Control Plan No 33—Rouse Hill Regional Centre, and

(ii) the Master Plan referred to in section 1.10 of that development control plan,

on the land bounded by Windsor Road, Commercial Road and Withers Road, Rouse Hill, comprising Lots 1–9, DP 270520, Lot 401, DP 1111687, Lots 304, 305, 307 and 309, DP 1107129, Lot 105, DP 1108407, and Lot 201, DP 1096167.'

A large proportion of development within the Study Area is 'waterfront land' as defined under the Water Management Act 2000 within 40m of a waterway and thus development on this land will require a 'Controlled Activity Approval' under the Water Management Act 2000 unless it meets the exemptions as outlined under clause 39A of the Water Management (General) Regulation 2004.

Part 5

Part 5 of the Act applies to an "activity" which is not subject to development control i.e. where a particular proposal does not require development consent under Part 4 of the *EPA Act 1979* but requires approval from a Minister of Public Authority, or is proposed to be carried out by a Minister or Public Authority. Part 5 only applies to those proposals which are permissible without requiring development consent.

Part 5 focuses on the obligation of the "determining authority" to consider the environmental impact of any "activity". A "determining authority" is the public authority which is proposing to carry out the activity and also any public authority which is required to approve an activity proposed by the person who wishes to carry out the activity.

Part 5 identifies the requirements and process for the determining authority in terms of when an Environmental Impact Statement (EIS) is required, the exhibition of the EIS, having regard to critical habitat, endangered fauna, vulnerable species, conservation agreements, plans of management, and joint management agreements and bio-banking agreements under the *Threatened Species Act, 1995*, consideration of representations made to the exhibition and where an Inquiry is required.

An example of a Part 5 application is if the Roads and Traffic Authority (RTA) sought to construct a new freeway as it would also be the determining authority.

Part 5A – Development by the Crown

The provisions of Part 5A prevail over Part 4 to the extent of an inconsistency between two parts. Essentially this part of the Act provides a legislative regime for consideration of Development Applications made by, or for and on behalf of, the Crown.

Other Parts of the EPA Act

The remaining parts of the EPA Act relate to:

- Part 6 – Implementation and Enforcement
- Part 7 – Finance
- Part 8 – Miscellaneous

Part 6 includes the Section 117 Ministerial Directions. The following Section 117 Directions are of some relevance to the Study.

- No.1.4 Oyster Aquaculture

  This direction applies to Priority Oyster Aquaculture Areas and other aquaculture outside these areas identified in the NSW Oyster Industry Sustainable Aquaculture Strategy 2006. Parts of the Lower Hawkesbury are identified as being priority oyster aquaculture areas. The direction applies when Council decides to prepare, or is directed by the Minister to prepare any draft LEP that proposes to change the land use which may result in impacts on the Priority Oyster Aquaculture Areas or any current oyster aquaculture lease in the national park estate or an incompatible use between the oyster aquaculture and other uses,

- No.2.1 Environmental Protection Zones

  This direction applies when Council prepares a draft LEP. The draft LEP is then required to include provisions that facilitate the protection and conservation of environmentally sensitive areas or land within an existing environmental protection zone or land that is otherwise identified for environmental protection purposes.

- No.2.2 – Coastal Protection

  Section 117 Direction No.2.2 – Coastal Protection is of relevance to part of the Study Area, in that applies to the coastal zone as defined in the *Coastal Protection Act, 1979*. This Direction applies when a Council prepares a draft LEP that creates, removes or alters a zone or a provision relating to land in the coastal zone.

  The Direction requires Council to consider and any LEP to be consistent with:

  (i) the manual relating to the management of the coastline for the purposes of section 733 of the Local Government Act 1993 [NSW Coastline Management Manual 1990], and

  (ii) the NSW Coastal Policy: A Sustainable Future for the New South Wales Coast 1997, and

  (iii) the Coastal Design Guidelines 2003.

- No.4.4 – Planning for Bushfire Protection

  Direction No. 4.4 applies to all Councils when they prepare a draft LEP that affect or is in proximity to land mapped as bushfire prone land.

- No.5.6 – Central Coast

  This direction applies to Gosford and Wyong Councils and requires any LEP to be prepared in accordance with the appropriate regional strategy (i.e. new Draft Regional Strategy).

Standard Instrument (Local Environmental Plans) Order 2006

The Standard Instrument (LEPs) Order 2006 was gazetted on 31 March 2006 and is part of a package of local planning reforms aimed at reducing the number of plans and improving the consistency in planning instruments. It was further amended on the 25th June 2008.

The Standard Instrument requires all draft principal LEPs to be prepared in accordance with the Standard Instrument and incorporate relevant mandatory provisions before they can be publicly exhibited and recommended for gazettal.

The Standard Instrument seeks to standardise the zones in Local Environmental Plans, identifying 34 standard zones for Councils to use when preparing new principal LEPs for the local government areas.

Of particular relevance to this study are the Waterways and Environmental Protection Zones being:

- W1 Natural Waterways

  This zone is generally intended for waterways that are to be protected due to their ecological and scenic values. A limited number of low impact uses that do not have an adverse effect on the natural value of the waterway can be permitted in this zone.

- W2 Recreational Waterways

  This zone is generally intended for waterways that are used primarily for recreational purposes such as boating, fishing and waterskiing, but which may have also have ecological, scenic or other values that require protection.

- W3 Working Waterways

  This zone is generally intended for waterways which are primarily used for shipping, port, transport and other working uses. The zone recognises that it may also be used for recreational uses.

- E1 National Parks and Nature Reserves

  This zone is generally intended to cover existing national parks and nature reserves. All uses currently authorised under the *National Parks and Wildlife Act, 1974* will continue to be permitted without consent within this zone.

- E2 Environmental Conservation

  This zone is generally intended to protect land that has high conservation value. A number of land uses considered to be inappropriate for this zone have been mandated as prohibited uses.

- E3 Environmental Management

  This zone is generally intended to be applied to land that has environmental or scenic values or hazard risk, but where a limited range of development including dwelling houses and other uses could be permitted. This zone might also be suitable as a transition between areas of high conservation value and other land uses such as rural or residential.

- E4 National Parks and Nature Reserves

  This zone is generally intended for land with special environmental or scenic values where residential development could be accommodated.

In relation to the application of the waterway zones, advice was received from the Department of Planning as part of another study, that indicated that land based zones may be applied to smaller waterways (such as streams and intermittent creeks). Waterway zones are generally intended for application to the waterways' channel and banks.

In terms of timeframes for the preparation of new comprehensive LEP's in accordance with the Standard Instrument, the Department has given Councils a variable timeframe between 3 and 5 years. Gosford and Warringah Councils has been directed to complete the preparation of the new LEP within 3 years i.e. by April 2009, whereas Hornsby has a 5 year timeframe (April 2011).

State Environmental Planning Policies (SEPPs)

SEPP 14 – Coastal Wetlands

SEPP 14 aims to ensure that the coastal wetlands are preserved and protected in the environmental and economic interests of the State. The Policy defines over 1300 areas along the NSW Coastline as wetlands.

The policy identifies that land clearing, levee construction, drainage work and filling requires development consent and that such development is 'designated development'. Therefore, development applications for such works are required to be accompanied by an Environmental Impact Statement (EIS). The policy identifies that the local council is the consent authority for such work.

SEPP 14 does not identify any coastal wetlands within the study area and therefore does not apply to the Study Area.

SEPP 19 – Bushland in Urban Areas

SEPP 19 is a broad SEPP which applies to the majority of urban areas throughout Sydney. The principle aim of the SEPP is to protect and preserve bushland in urban areas.

The SEPP places particular focus on the protection of bushland within open space zones and land adjoining open space zones by requiring consent for the clearing or disturbance of bushland and the preparation of plans of management for bushland or open space zones. The SEPP does not establish any specific controls or criteria in relation to protection of bushland.

The SEPP is a consideration for development adjoining open space zones which only occurs in isolated parts of the Study Area.

SEPP 26 – Littoral Rainforests

SEPP 26 aims to provide a mechanism for the consideration of applications for development that is likely to damage or destroy littoral rainforest areas with a view to the preservation of those areas in their natural state.

In areas identified by the Policy as Littoral Rainforests, or within 100m of such an area, a person cannot erect a building, carry out work, use land for any purpose, or subdivide it, disturb, change or alter any landform or disturb, remove, damage or destroy any native flora or other element of the landscape or dispose of or dump any liquid, gaseous or solid matter without development consent.

Furthermore, the policy identifies that such development is 'designated development' and therefore development applications for such works are required to be accompanied by an Environmental Impact Statement (EIS).

The policy identifies that the local council is the consent authority for such work (unless it is State Significant Development) and that consent cannot be granted without the concurrence of the Minister for Planning.

The policy applies to those areas shown on the SEPP 26 Maps but does not include areas dedicated or reserved under the National Parks and Wildlife Act 1974.

As there are no areas shown on the SEPP 26 Maps within the Study Area, SEPP 26 does not apply.

SEPP 35 – Maintenance Dredging of Tidal Waterways

The objective of SEPP 35 is to enable the maintenance dredging of tidal waterways by public authorities to be carried out in a timely, cost effective and environmentally responsible manner in response to changing conditions in those waterways.

The Policy aims to rationalise the planning controls applicable to maintenance dredging, ensure that all environmental impacts of maintenance dredging are assessed and ensure proper consultation with affected bodies is undertaken and the views such bodies considered.

Schedule 1 of the SEPP identifies land to which the SEPP does not apply. This includes land covered by Sydney Regional Environmental Plan No.20 – Hawkesbury – Nepean River (No.2 1997) (SREP 20). SREP 20 covers the entire study area and therefore SEPP 35 does not apply.

SEPP 44 – Koala Habitat Protection

SEPP 44 encourages the conservation and management of natural vegetation areas that provide habitat for koalas to ensure permanent free-living populations will be maintained over their present range.

Affected councils cannot approve development in an area affected by the policy without an investigation of core koala habitat.

The policy applies to the whole study area with the exception of areas dedicated or reserved under the National Parks and Wildlife Act 1974 or to land dedicated under the Forestry Act 1916 as a State forest or flora reserve.

SEPP 62 – Sustainable Aquaculture

The aims and objectives of SEPP 62 are to encourage sustainable aquaculture in NSW, making aquaculture permissible in areas where a comprehensive and integrated regional aquaculture strategy has been developed, establish minimum requirements for aquaculture development, establish an environmental assessment regime and application to the North Coast of NSW.

The Policy applies to pond or tank based aquaculture in the North Coast, Hunter and Central Coast Regions of NSW, i.e. it applies to the Gosford City local government area and therefore part of the Study Area. In relation to natural water-based aquaculture in the form of oyster aquaculture, the

Policy applies across the State. The area to which the Policy applies in relation to other forms of natural water based aquaculture is yet to be established.

SEPP 71 – Coastal Protection

SEPP 71 aims to protect and manage the natural, cultural, recreational and economic attributes of the New South Wales coast, protect and improve public access, protect and preserve Aboriginal heritage, visual amenity, beach environments and beach amenity, native coastal vegetation, the marine environment, rock platforms, and manage the coastal zone in accordance with the principles of ecologically sustainable development, ensure development is appropriate for the location, and encourage a strategic approach to coastal management.

This Policy establishes what development is significant coastal development, identifies the procedure for the determination of significant coastal development in terms of the referral process to the Director-General for comment, and identifies master plan requirements for certain development in the coastal zone.

The Policy applies to the area declared as the NSW Coastal Zone under the *Coastal Protection Act, 1979*. In November 2005, the NSW Coastal was extended to include the greater metropolitan region.

Within the Gosford local government area, the Coastal Zone affects northern banks of the Hawkesbury River, east of Mangrove Creek. The depth of this zoning on land varies from between 1 to 2km from the foreshore, depending on the location. Within the Hornsby local government area, only Dangar Island and Milsons Island are affected by the Coastal zone. No part of the Study Area within the Warringah local government area falls within the Coastal Zone.

The SEPP requires Council to refer to the Director General development within 100m below mean high water mark of the sea, a bay or estuary.

SEPP (Sydney Metropolitan Water Supply) 2004

This plan was gazetted on 24 December 2004 and applies to the whole of NSW.

This plan facilitates development for water supply infrastructure to enable deep water extraction from dams supplying water to the Sydney metropolitan area, allows investigation for groundwater availability, and allows development by the Sydney Catchment Authority under Part 5 of the *EPA Act 1979*.

SEPP (Major Projects) 2005

SEPP (Major Projects) 2005 was gazetted on 25 May 2005 and applies to the whole state.

The SEPP defines certain developments that are major projects under Part 3A of the *EPA Act 1979* and determined by the Minister for Planning. The SEPP also lists State Significant Sites. The policy repeals SEPP 34 and 38, as well as provisions in numerous other planning instruments, declarations and directions.

The SEPP aims to:

- identify development to which Part 3A of the *EPA Act 1979* applies;

- identify development that is critical infrastructure under Part 3A;
- facilitate the development, redevelopment or conservation of State Significant sites;
- facilitate service delivery outcomes for public services and the redevelopment of major sites for a public purpose or redevelopment of major sites where no longer appropriate or suitable for a public purpose ; and
- rationalise and clarify the provisions making the Minister the approval authority for state significant sites.

Schedule 2 of the SEPP identifies those specific sites to which the Part 3A of the *EPA Act 1979* apply. A Specific Site of particular relevance to this Study is 1 – Coastal Areas.

Coastal areas are identified as those areas within coastal zone as identified on the maps approved under the Coastal Protection Act, 1979. Currently, the Coastal Protection Act, 1979 only applies the Coastal Zone affects northern banks of the Hawkesbury River, east of Mangrove Creek within the Gosford local government area and Dangar Island within the Hornsby local government area.

Schedule 2 – 1 Coastal Areas identifies the following development within the coastal zone as being the subject of Part 3A of the EPA Act 1979:

- extractive industries, landfill, mining, marinas and other industries in the coastal zone or in sensitive coastal locations within the coastal zone (Sch. 2-1 cl.(1) (a) to (e)) and certain recreational or tourist facilities (Sch. 2-1 cl.(1)(f))
- buildings or structures greater than 13 metres in height in sensitive coastal locations in the Greater Metropolitan coastal zone, and the whole of the coastal zone for the rest of the State (Sch. 2-1 cl.(1)(g))
- certain subdivisions of land not connected to sewerage works (Sch. 2-1 cl.(1)(h))
- subdivision of land into more than 25 lots (or rural residential into 5 lots) if the land is wholly or partly in sensitive coastal locations for the Greater Metropolitan coastal zone and the whole of the coastal zone for the rest of the State. (Sch.2-1 cl.(1)(i)).

This clause does not apply to development, which under another environmental planning instrument requires the concurrence of the Minister or Director General, or identifies the Minister or Director General as the consent authority.

In the event of any inconsistency between this SEPP and another environmental planning instrument, this Policy prevails to the extent of any inconsistency.

SEPP (Infrastructure) 2007

SEPP (Infrastructure) 2007 was gazetted on the 1 January 2008 and was prepared to consolidate and update planning provisions relating to infrastructure and government land. The SEPP provides a consistent planning regime for infrastructure and the provision of services across NSW, along with providing for 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.

The SEPP:

- outlines planning processes for considering classes of public infrastructure and particular infrastructure projects
- exempts some minor public infrastructure from the need for an approval
- clarifies where new infrastructure can be located and provides for additional permissible uses on government land
- requires State agencies constructing infrastructure to consult local councils when a new infrastructure development is likely to affect existing local infrastructure or services.

SEPP (Infrastructure) 2007 repeals the following SEPP's relevant to Hornsby:

- State Environmental Planning Policy No 8—Surplus Public Land
- State Environmental Planning Policy No 9—Group Homes
- State Environmental Planning Policy No 11—Traffic Generating Developments
- State Environmental Planning Policy No 16—Tertiary Institutions
- State Environmental Planning Policy No 27—Prison Sites
- State Environmental Planning Policy No 35—Maintenance Dredging of Tidal Waterways
- State Environmental Planning Policy No 48—Major Putrescible Landfill Sites
- State Environmental Planning Policy No 54—Northside Storage Tunnel
- State Environmental Planning Policy No 63—Major Transport Projects
- State Environmental Planning Policy No 69—Major Electricity Supply Projects
- State Environmental Planning Policy No 72—Linear Telecommunications Development—Broadband
- State Environmental Planning Policy (ARTC Rail Infrastructure) 2004
- State Environmental Planning Policy (Sydney Metropolitan Water Supply) 2004

Division 25 of the SEPP relates to waterway or foreshore management activities. A definition of 'waterway or foreshore management activities' is contained within the SEPP and includes:

'(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.'

Section 129 of the SEPP identifies development which is permitted without consent and includes development for the purposes of waterway or foreshore management activities which may be carried out by or on behalf of a public authority without consent on any land. These activities include:

- construction works;
- routine maintenance works;
- emergency works, including works required as a result of flooding, storms or coastal erosion;
- environmental management works.

The clause also relates to development for the purpose of temporary works associated with drought relief which maybe be carried out by on behalf of a public authority without consent subject to certain criteria.

Regional Environmental Plans (REPs)

SREP 20 – Hawkesbury/Nepean River

The key REP applying to the Study Area is Sydney REP No 20 – Hawkesbury/Nepean River (SREP 20). SREP 20 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.

SREP 20 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 SREP 20 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 SREP 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 SREP 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.

Sydney Regional Environmental Plan No.6 – Gosford Coastal Areas

SREP 6 does not apply to land within the Study Area.

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

(c) 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

(d) 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.

The plan only applies to certain hydrological catchments, within the Sydney region. The REP does not apply to the Study Area.

Local Environmental Plans

Hornsby Shire Local Environmental Plan 1994 (HSLEP 1994)

The study area incorporates virtually the whole of the Hornsby Shire Council local government area.

The Hornsby Shire Local Environmental Plan 1994 (HSLEP 1994) is the comprehensive LEP for the Shire, providing a zoning framework and statutory controls. Under the HSLEP 1994, the majority of the immediate catchment area is zoned for either, National Parks and Nature Reserves, Environment Protection or Rural purposes.

The National Parks and Nature Reserves zone comprises the large areas of the Marramarra National Park, Ku-ring-gai National Park, Ku-ring-gai Chase National Park, Berowra Valley Regional Park, Muogamarra Nature Reserve and Long Island Nature Reserve.

Environment Protection zones within Hornsby comprise Wetlands (A), River Catchment (B), Tourist (C), Recreation (D) and River Settlements (E). The Environment Protection B – River Catchment zone is the predominant Environment Protection zone within the Catchment. The Environment Protection B zone dominates the western end of the study area between Singletons Mill and Wisemans Ferry and more southern regions around Canoelands and south of Forest Glen and Fiddletown

Along the river there are a number of river settlements. The larger of these being Brooklyn and Wisemans Ferry, comprise a variety of zones. Brooklyn includes various residential zones, business zones, open space zones, special uses and environmental protection zones. Whereas Wisemans Ferry given its smaller scale is limited to business, open space, special uses and environment protection zones.

The smaller more isolated river settlements of Berowra Waters, Dusthole Point, Neverfail Bay, Calabash Point, Coba Point, Marramarra Creek, Sunny Corner and Milsons Passage are zoned Environment Protection E (River Settlement) zone, which is a more restrictive zone, limiting development to bushfire hazard reduction (except ancillary buildings); communication facilities, demolition; dwelling-houses; group homes; utility installations and subdivision.

Notably Dangar Island is zoned Environmental Protection B – River Catchment zone.

Hornsby Council undertook a review of the planning controls applicable to the river settlements and foreshores within Hornsby Shire (SJB Planning 2006). The report recommends minor amendments to the zoning controls, permissible uses and development controls.

Parts 3 and 4 of the HSLEP 1994 identify the general and special controls for development.

Of particular relevance to the Study Area are Clauses 20 and 21 which relate to Waterways and Designated Development respectively.

Clause 20 stipulates that development consent is required for all development below Mean High Water Mark (MHWM), establishes the foreshore building line control and identifies flood prone land.

Clause 21 identifies that both reclamation and dredging within Sanbrook Inlet, Brooklyn Boat Harbour and Parsley Bay, or on land which is located within a distance of 20 metres below the mean high water mark of Dangar Island are declared to be designated development.

Also of particular relevance to the Study is that Council is also seeking to implement the key recommendations of the Waterways Review 2005 (see discussions in Section __ below) which included zoning the waterways, with one of four recommended waterways zonings reflecting the physical and environmental constraints of the area.

Gosford Planning Scheme Ordinance and Interim Development Order

The study area includes a significant part of the Gosford Council local government area, namely being the Mangrove Creek, Mooney Mooney Creek, Mullett Creek and Patonga Creek catchments.

The Gosford Planning Scheme Ordinance and Gosford Interim Development Order are the key planning instruments for the Gosford local government area, providing the zoning framework and statutory controls.

That area of the study area located within the Gosford local government area is largely comprised of the Brisbane Water National Park, Popran National Park and Dharug National Park and the Broken Bay Sport and Recreation Centre.

The study area includes a number of settlements along the area, which include Patonga, Little Wobby, Mooney Mooney and Cheero Point, Bar Point, Marlow, Wendoree Park, Spencer, Greengorve, Lower Mangrove, Mangrove Creek.

Gosford Planning Scheme Ordinance

The Gosford Planning Scheme Ordinance (GPSO) was gazetted on 24 May 1968. Since 1968 the GPSO has been amended by a variety of Interim Development Orders and some 462 Local Environmental Plans, the bulk of which were site specific.

While, the GPSO originally provided the zoning framework for the whole local government area, with a variety of zones including non-urban, residential, business, industrial, special uses, open space, national parks and restricted development, these days (given the abovementioned amending IDOs and LEPs), the GPSO really only applies to the Open Space and Residential zones.

Under the GPSO, the bulk of the study area was originally zoned a mix of 1(a) and 1(c) Non-Urban, 5(a) Special Uses – Water Supply or 6(a) Open Space in the case of the Brisbane Waters National Park or 6(b) Open Space Special Purposes – Forestry or Native Flora Preservation. This is no longer the case with a number of zones amended under the IDO (see below).

Notably, the settlements of Patonga and Mooney Mooney are zoned under the PSO a mix of 2© Residential, Special Uses and Open Space zones.

Specific Clauses within the GPSO of relevance to the Study are Clause 37 – Foreshore Building Line;

Clause 45CD – Exempt Development; Clause 45 CE – Complying Development; and Clause 49 – Development on bed of lakes, rivers etc. Schedules 10 and 11 outline the criteria for Exempt and Complying Development respectively.

Gosford Interim Development Order

The Gosford Interim Development Order (IDO) was gazetted on 30 March 1979.

The IDO suspended all zonings under the GPSO of non-urban areas. The large tracts of land around Mangrove Creek and Mooney Mooney Creek were rezoned to a mix of either 5(a) Special Uses – Water Supply, 6(a) Open Space – Recreation for the Dharug National Park (west of Mangrove Creek) or 7(a) Rural Conservation. The areas around Peats Ridge and Narara were generally rezoned 1(a) Rural Agriculture and 7(b) Rural Scenic Protection.

The river settlements of Cheero Point, Bar Point and Spencer are typically zoned either 7(c5) Rural Scenic Protection – Tourist or 7(c6) Rural Scenic Protection – Residential. Further west of Spencer isolated strips of river frontage are zoned 7(a) Rural Conservation.

Specific Clauses within the IDO of relevance to the Study are Clause 10 – General Concurrence (for development in the 7(d) and (7(e) zones, Clause 13 – Foreshore Building Lines, Clause 38 – Development on bed of lakes, rivers etc and Clauses 40B and C relating to Exempt and Complying Development.

Other Gosford LEPs

As identified above, there are some 462 Local Environmental Plans, the majority of which are site specific, some of which affect sites within the Study Area.

Warringah Local Environmental Plan 2000

The Study Area incorporates Cowan Creek catchment, the eastern half of which is located within the Warringah Council local government area.

The Warringah Local Environmental Plan 2000 (WLEP 2000) is the comprehensive LEP for the Warringah local government area, providing the development framework and statutory controls. Notably, the WLEP 2000 does not zone land throughout the local government area. Area based development is controlled through locality statements.

Unlike other LEPs, the WLEP 2000 does not use broad local government wide or theme based objectives. It controls issues by area based objectives in the form of desired future character statements. The locality statements identify the “desired future character” of each area, landuses and respective development controls, such as housing density, building height, setbacks, landscaped open space and heritage items.

The Cowan Creek Catchment Locality Statement applies to the study area and is divided into seven sub-localities being Cottage Point, Booralie Road, Terry Hills Village, Myoora Road, McCarrs Creek Road, Ku-ring –gai Chase National Park and Mona Vale Road North. The majority of the locality is covered by the Ku-ring-gai Chase National Park locality statement.

Clauses of the LEP of relevance to the Study include Clause 44 – Pollutants, Clause 76 – Management of stormwater and Clause 77 – Erosion and sedimentation.

Development Control Plans

Gosford Council

Gosford Council has approximately 174 Development Control Plans (DCPs) that are either zone based, issue based, land use or locality based plans. The key DCPs relevant to the study are DCP 089 – Scenic Quality, DCP 125 Coastal Frontage, DCP 148 – Complying Development Conditions and DCP 165 – Water Cycle Management.

DCP 089 – Scenic Quality

Development Control Plan No. 89 – Scenic Quality was adopted in November 1996 and aims to provide more detail with regard to the management of the scenic quality of Gosford. The DCP applies to all land within the Gosford local government area and is required to be taken into consideration by Council when assessing any development application or rezoning application.

The objectives of the DCP are:

- *to provide a detailed assessment of Gosford's landscape character which highlights the diversity between and within landscape units;*
- *to detail the components of that landscape character;*
- *to provide a comparative ranking of the landscapes; and*
- *to develop appropriate guidelines for the management of the landscape character.*

The principles of the DCP are:

- protection of vegetated ridgelines and upper slopes;
- new development to have required to character of area both built and natural;
- retention of non-urban breaks between urban areas;
- ensuring built environment does not dominate landscape features in non-urban areas; and
- highlighting quality of particular areas.

The DCP divides the whole of Gosford local government area into a set of geographical units. The Upper Hawkesbury and Lower Hawkesbury Geographical Units are the main units applying to the Study Area, with the Broken Bay unit applying to the Patonga Beach area. Within each Geographical Unit, the area is divided into landscape units, which are then given a level of significance (i.e. state, regional or local).

The Upper Hawkesbury Geographical Unit covers the landscape units of Wisemans Ferry to Spencer, Mangrove Creek, Propran Creek and Dharug. The Lower Hawkesbury Geographical Unit includes the landscape units of Spencer to Berowra Creek, Mooney Mooney Creek, Mullet Creek and Brooklyn Estuary. The Patonga Creek Catchment falls within the Patonga Beach Land-Units landscape unit contained within the Broken Bay Geographical Unit.

Development Control Plan No. 125 – Coastal Frontage

DCP 125 came into effect on 27 January 2000 and provides more detailed guidelines for the development of the land having regard to minimising the risks associated with building on land which has frontage to a coastal beach or cliff.

The DCP applies to all land within the City of Gosford which is affected by the coastal processes of beach and/or cliff erosion, namely, the section of coastline from Forresters Beach to Patonga. The

DCP therefore only applies to a small section of the Study Area being part of the Patonga Creek catchment.

The objectives of the DCP are:

(a) to minimise the risk to life and property associated with development and building on land which has a coastal beach and/or cliff frontage.

(b) to provide guidelines for the development of land within the coastal frontage area

Development Control Plan No. 148 – Complying Development Conditions

DCP 148 outlines the conditions for Complying Development.

Development Control Plan No. 165 – Water Cycle Management

DCP 165 Water Cycle Management came into effect on 1 October 2003 and aims to make provision for water efficiency in development to minimise the impact on the natural water cycle. The DCP addresses issues such as rainfall runoff, erosion and sedimentation control, nutrient control, on-site stormwater detention and flood mitigation.

The DCP applies to all land within the Gosford local government area and is required to be taken into consideration by Council when assessing any development application for residential development.

Hornsby Council

Hornsby Shire Council has some thirty (30) Development Control Plans (DCPs) that are either zone based, issue or relating to a particular land use and locality or area based plans.

The key DCPs applying to the Study Area were recently reviewed as part of the Hornsby Council "River Settlements and Foreshores Review" (SJB Planning 2006). The Review recommended a number of amendments to the DCPs including revised controls, revised guidelines, the introduction of character statements and general amendments to improve consistency between other DCPs.

The key DCPs of relevance to this Study are outlined below.

Brooklyn DCP (1996)

The Brooklyn DCP is an area based DCP which sets broad planning strategies and controls associated with different forms of land based development. The general controls are identified as a series of elements, each element with objectives, performance criteria and prescriptive measures.

The planning strategies cover the issues of the aquatic environment, traffic and parking, services, tourism and heritage.

General controls are divided into residential precincts, environmental protection precincts, business precincts, town centre and open space precincts. Key development controls include minimum lot size, site coverage, floor space ratio, landscaped area, height, setbacks, foreshore controls and parking.

The DCP also includes general strategies, objectives and controls for more generic issues including flora and fauna, environment protection, soil and water management, drainage control, heritage, contributions, fire hazard, waste minimisation, acoustics, urban streams, land sensitivity, effluent disposal and crime prevention.

The DCP also provides masterplans for the key recreation areas of McKell Park, Brooklyn Park, Saltpan Reserve and the Old Dairy Site.

Dangar Island DCP (1994)

This DCP adopts a similar area based approach to the Brooklyn DCP, providing general controls associated with land based development for Dangar Island. The objectives of the DCP are:

- to provide measures to protect the natural and built environment;
- to protect the amenity and scenic qualities of the area; and
- to maintain the low density character of Dangar Island.

The general controls are identified as a series of elements, each element with objectives, performance criteria and prescriptive measures. The elements include density, design, height, setbacks, views, sunlight and privacy, soil and water management, landscaping, environment protection, waterway structures, heritage, energy efficiency, urban streams, land sensitivity, acoustics, effluent disposal and crime prevention.

River Settlements DCP (2003)

This DCP applies to Dusthole Point, Neverfail Bay, Calabash Point, Coba Point, Marramarra Creek, Sunny Corner and Milsons Passage. Again, this DCP adopts a similar approach to the Brooklyn and Dangar Island DCP's.

The objectives of the DCP are:

- to provide a detailed planning strategy for River Settlements;
- to provide development guidelines to protect the natural and built environment;
- to protect the amenity and scenic qualities of the area; and
- to maintain the low density character of the settlements.

Again, the general controls are identified as a series of elements, each element with objectives, performance criteria and prescriptive measures. The elements include density, design, height, setbacks, views, sunlight and privacy, waterway structures, heritage, energy efficiency and services, acoustic, landscaping, effluent disposal, land sensitivity, topography, soil and water management, flora and fauna protection, urban streams, bushfire hazard, crime prevention and wast minimisation and management.

Rural Lands DCP (2001)

This DCP covers a wide geographical area of the Hornsby Shire, being the rural areas of the Shire. The objectives of the DCP are:

- to provide land use direction for the rural area;
- to provide measures to protect the natural and built environment;
- to enhance the established character of the rural areas; and
- to ensure development relates to site conditions.

The DCP provides broad strategies including environmental and population strategies that recognise environmental constraints to population growth and development, with more specific masterplans style controls for the various rural villages.

The DCP provides strategies and controls for specific rural landuses in addition to general controls which are identified as a series of elements, each element with objectives performance criteria and prescriptive measures. The elements include dwelling design, setbacks, soil and water management, drainage control, urban streams, effluent disposal, flora and fauna protection, visual amenity, landscaping, fences and gates, heritage, fire hazard, air quality, contributions, energy efficiency, crime prevention, waste minimisation and management, satellite dishes, tennis courts and patios.

Sustainable Water DCP

The Sustainable Water DCP aims to achieve the implementation of sustainable water practices into the management of development in the Hornsby Shire, and applies to all development under the Hornsby LEP 1994.

The DCP is divided into a strategy element and set of control elements, the strategy element outlining Council's actions to achieve sustainable water practices and the control elements applying to development using objectives, performance criteria and prescriptive measures. Such control elements include site planning, construction. Materials and design, topography, water courses, soil dispersibility, soil landscapes, native plant communities, bushland, fauna habitat, operations and maintenance and land sensitivity.

Exempt and Complying Development DCP

This DCP applies to all land within the Hornsby Shire Council area and provides the procedures for exempt and complying development and minor Council works.

Parts 2 and 3 of the DCP utilise a set of parameters to establish the areas in which exempt and complying development are permitted throughout the Shire. Specific controls then identify what is deemed to be exempt development and complying development.

The Exempt Development provisions identified in Part 2 apply to the majority of land within the study area.

The Part 3 Complying Development provisions do not apply to the majority of the Study Area, with the exception of parts of Brooklyn and Wisemans Ferry, as Part 3B identifies that Complying Development does not apply to Environmentally Sensitive Areas which are defined as:

- land affected by the floodline identified on the HSLEP zoning maps;

- below MHWM;
- containing Acid Sulphate Soils;
- having a slope greater than 20%;
- within 40m of bushland;
- within 40m of a watercourse; and
- land with a moderate to high bushfire hazard.

Furthermore, Part 3 Complying Development provisions do not apply to the Environmental Protection A, B, C or D zones.

Warringah Council

There are no DCPs within the Warringah Council of any specific relevance to the Study Area. The only DCP that Warringah Council has relates to notification procedures and mobile phone towers.

Other Important Studies/Documents

Metropolitan Strategy – City of Cities, A Plan for Sydney's Future

The NSW Government released the Metropolitan Strategy in December 2005. The strategy is a broad framework to secure Sydney's place in the global economy by promoting and managing growth.

The Metropolitan Strategy identifies that it applies to the wider Sydney region including Hornsby, Warringah and Gosford local government areas. Given the geographical area that the Metropolitan Strategy covers, including some 43 local government areas, the Strategy is arranged into ten subregions.

The three local government areas to which the Study relates are each located within separate subregions under the Strategy. Hornsby is located in the North subregion, Warringah in the North East subregion and Gosford in the Central Coast sub region. Notably, the Strategy identifies the Central Coast subregion is the subject of a separate regional strategy being Central Coast Regional Strategy (which is discussed in Section 7.2 below).

The Metropolitan Strategy is a strategic document made up of seven (7) strategies. The seven (7) strategies are:

- Economy and Employment
- Centres and Corridors
- Housing
- Transport
- Environment and Resources

- Parks and Public Places
- Implementation and Governance

Key objectives and actions have been identified for each of the seven (7) strategies.

Of particular relevance to this matter are the Environment and Resources Strategies, which identify key environment and resource objectives as:

- E1 Establish targets for Sustainable Growth
- E2 Protect Sydney's Natural Environment
- E3 Achieve Sustainable Use of Natural Resources
- E4 Protect Valuable Rural Activities and Resource Lands

Strategy E2 – Protect Sydney's Natural Environment is of particular relevance as it namely aimed at improving the health of waterways, coasts and estuaries. The Strategy identifies the following initiatives in relation to improving the health of waterways, coasts and estuaries:

- embed stormwater and catchment objectives and targets into local planning instruments
- undertake stream mapping to identify regionally significant riparian corridors important for protection of aquatic and terrestrial biodiversity values and include in local planning instrument;
- promote water sensitive urban design and improve stormwater management by ensuring development is consistent with strategic stormwater management plans;
- implement environmental flows to improve waterway health as outlined in the Metropolitan Water Plan;
- improve coastal protection and foreshore access by updating and applying the Coastal Policy/Coastal SEPP provisions directly into the Local Environmental Plans (LEPs);
- Work with the Catchment Management Authorities and local communities to link waterway health initiatives with urban renewal through provision of open space, better urban design and coordinated stormwater planning.

The Study seeks to develop catchment objectives and targets suitable/readily adopted into the local planning instruments for the Lower Hawkesbury Catchment.

Central Coast Regional Strategy

The NSW Government released the Central Coast Regional Strategy on the 26 June 2008. The Strategy applies to the local government areas of Gosford and Wyong.

The Central Coast Strategy identifies nine (9) strategies as being:

- Centres and Housing
- Economy and Employment

- Transport
- Environment, Heritage, Recreation and Natural Resources
- Natural Hazards
- Water
- Regional Infrastructure
- Regional Transport
- Implementation
- Monitoring, Review and Governance

Each Strategy identifies a set of desired outcomes and actions. The outcomes and actions of Environment and Resources Strategy, Natural Hazards and Water are of particular relevance to this study.

Desired outcomes include:

- requiring councils to implement the relevant policies actions and management plans including those formulated in line with the NSW Government's NSW estuary management manual and NSW coastline management manual (1990), and Floodplain development manual: the management of fl ood liable land (Department of Natural Resources 2005);
- requiring council environmental planning instruments to incorporate the principle of integrated water cycle management;
- requiring councils to implement the relevant policies within relevant catchment management authorities' catchment action plans ensuring;
- to accommodate existing and future water needs, without compromising the health of the Region's rivers, estuaries and lakes and to implement natural resource management legislation requirements, e.g. the Water Management Act 2000.
- developing a Regional Conservation Plan that identifies and protects State and regional biodiversity values, including buffers to these areas, and provides certainty for development;
- focusing future population growth in existing urban areas, areas identified as a part of comprehensive LEP reviews and suitable areas within the North Wyong Shire Structure Plan Area;
- requiring councils to implement the relevant policies and actions contained within management plans formulated in line with the State Government's Estuary Management, Coastline Management and Floodplain Development manuals, identifying agricultural land that requires protection from inappropriate development;
- requiring council environmental planning instruments to incorporate the principle of Integrated Water Cycle Management;
- requiring councils to implement the relevant policies within both Catchment Management Authorities' Catchment Action Plans;

- ensuring new development incorporates water sensitive urban design (WSUD) and minimising water demand;
- implementing the Building and Sustainability Index (BASIX) tool to reduce water and energy use by residential development; and
- investigating measures such as dual reticulation (separate drinking and grey water systems) in new developments.

The actions include:

- The Department of Primary Industries, in partnership with the Department of Planning, to undertake mapping of regionally significant activities, including agriculture, mining, petroleum uses, extractive industry and special uses, to identify rural activities and resource lands for preservation.
- The Department of Planning and Wyong Council to work with the NSW Mine Subsidence Board and Department of Primary Industries to ensure future development in Wyong Shire takes account of current and potential future mining issues.
- Require LEPs to appropriately zone land with high State or regional environmental, agricultural, resource, vegetation, habitat, waterways, wetland or coastline values.
- Require LEPs to appropriately zone land of high landscape value (including scenic and cultural landscapes).
- Councils, through preparation of LEPs, to incorporate appropriate land use buffers around environmentally sensitive, rural and resource lands.
- The Department of Environment and Conservation, working with the Department of Planning and councils, to prepare a Regional Conservation Plan that:
- identifies regional conservation priorities for incorporation into public and private conservation initiatives (such as biobanking)
- identifies offset mechanisms which secure the biodiversity values of the priority regional conservation areas in perpetuity
- provides more certainty for both development and conservation outcomes.
- The Department of Planning, the Department of Environment and Conservation and councils to work towards biocertification of LEPs, where appropriate.
- Ensure LEPs facilitate conservation of Aboriginal and non-Aboriginal heritage.
- Ensure LEPs do not rezone rural and resource lands for urban purposes or rural residential uses unless agreement is first reached regarding the value of these resources.
- Incorporate provisions to control the offsite impacts of development – in particular the export of pollutants and high flows – in local development standards and policies.

- Ensure LEPs and other strategies implement the NSW Coastal Policy, the NSW Rivers and Estuaries Policy, the NSW Flood Prone Land Policy and plans prepared in accordance with these documents.

- Protect the health of the Central Coast's waterways, coasts and estuaries and lakes by integrating relevant objectives and targets from the Hunter-Central Rivers and Hawkesbury Nepean Catchment Action Plans, Stormwater Management Plans and Estuary Management Plans (including both the Tuggerah Lakes Estuary Plan and the Brisbane Water Estuary Management Plan, when completed) into local planning.

- Implement key initiatives and guidelines including Action for Air, Industrial Noise Policy, Noise and Vibration Guidelines and Environmental Criteria for Road Traffic Noise.

- Integrate the aims and objectives of the NSW Waste Avoidance and Recovery Strategy through local development standards and policies.

- Develop, in consultation with relevant Aboriginal community groups and councils, a guide to Aboriginal involvement in the development assessment process. Also:

    - an agreed methodology for Aboriginal cultural heritage assessments to be undertaken

    - guidelines to inform the planning process as well as the issuing of approvals under the National Parks and Wildlife Act 1979.

In terms of the implementation of the desired outcomes and actions identified in the strategy, as part of the Government's state wide planning reforms, Gosford Council is required to prepare a new principal LEP within 5 years. The Minister for Planning will issue a Direction under Section 117 of the Environmental Planning and Assessment Act, 1979 that will require all LEPs to be consistent with the Central Coast Strategy.

The Strategy is proposed to be reviewed by the Department of Planning every five years in partnership with the Central Coast Regional Coordination Management Group, to ensure that it remains responsive and up to date.

Waterways Review (2005)

In 2005, Hornsby Council commissioned a review of the planning controls that apply to the waterways within the Hornsby local government area, to determine the most appropriate local planning regime to manage the competing environmental, social and economic pressures on the waterway.

The review examined the current circumstances associated with the waterway within the Hornsby local government area and included a capability assessment. The review also considered legislative and governance issues associated with administering the waterways, current practices in planning for the waterways and made recommendations for amending the current planning controls.

The key recommendations included:

- zoning the waterways, with one of four recommended waterways zonings reflecting the physical and environmental constraints of the area;

- listing permissible development;
- prohibiting reclamation;
- prohibiting seawalls below MHWM; and
- information on the existing environmental context and desired future character for inclusion in the Brooklyn, River Settlements, Dangar Island and Rural Lands DCPs.

Council is currently seeking to implement the findings of the Review. This may include the preparation of a stand-alone LEP or the incorporation of planning controls into Council's comprehensive LEP and DCP. Discussions are currently occurring with the Department of Planning regarding the progression of the Review findings.

Hawkesbury – Nepean Draft Catchment Action Plan 2006-2015

The Hawkesbury-Nepean Draft Catchment Action Plan (CAP) is the mechanism to direct and produce natural resource investment by the Hawkesbury-Nepean Catchment Management Authority (CMA). It provides a 10 year strategic direction, identifying priorities for incentives programs to better target activities to improve environmental outcomes and investment return.

The CAP has three themes being river health, biodiversity and soil and land.

Hornsby Tourism Provisions – Planning Review 2003

This document reviews the significance and value of tourism to the Hornsby Shire and recommends strategies and actions.

In relation to land use planning constraints the document notes that the Hornsby Shire generally contains highly sensitive natural environments and extreme care needs to be exercised in considering land use proposals that directly impact on the integrity and values of natural areas. The report notes that:

- the topography and waterways define the River Settlements, including Brooklyn;
- that it is a fragile river environment;
- any future development needs to be sensitive to the existing visual character (small in scale) and the environmental limitations of this riverine/bushland environment;
- in some cases, such as Berowra Waters, current visitation numbers during peak periods appear to be at capacity;
- a number of local industries depend on maintenance of water quality; and
- the Hawkesbury River and its foreshores are highly sensitive natural environments and their value as a magnet for tourists relies on their natural attributes being conserved as much as possible.

Planning for Bushfire Protection 2006

Planning for Bush Fire Protection 2006 is a revised NSW Rural Fire Service (RFS) publication updating the previous 2001 guide. The guide outlines the required bush fire protection measures for development applications located on land that has been designated as bush fire prone.

Planning for Bushfire 2006 provides a guide for councils, fire authorities, developers, planning consultants, building practitioners and home owners. It provides the necessary planning considerations when developing areas for residential use in residential, rural-residential, rural and urban areas when development sites are in close proximity to areas likely to be affected by bushfire events. The document outlines the bushfire planning matters which need to be considered at various stages of the planning process.

This document is complimented by each of the Councils Bushfire Prone Maps, which identify those areas of the respective local government area prone to bushfires.

The majority of the Study Area is identified as being within bushfire prone areas, comprising Category 1 Vegetation or requiring Vegetation Buffers of 100m and 30m.

NSW Coastal Policy (1997)

The 1997 NSW Coastal Policy responds to the fundamental challenge to provide for population growth and economic development without placing the natural, cultural, spiritual and heritage values of the coastal environment at risk. To achieve this, the Policy has a strong integrating philosophy based on the principles of ecologically sustainable development (ESD).

The Policy addresses a number of key coastal themes including:

- Population growth in terms of physical locations and absolute limits;
- Coastal water quality issues, especially in estuaries;
- Disturbance of acid sulfate soils;
- Establishing an adequate, comprehensive and representative system of reserves;
- Better integration of the range of government agencies and community organisations involved in coastal planning and management;
- Indigenous and European cultural heritage; and integration of the principles of ESD into coastal zone management and decision making.

The policy applies to all new developments and publicly owned lands in urban areas covered by the coastal zone as defined under the NSW Coastal Protection Act 1979. The only area of the Lower Hawkesbury estuary that falls within the coastal zone is the foreshore from the eastern bank of Mangrove Creek to the eastern bank of Patonga Creek within Gosford local government area.

The management of the coastal zone is the responsibility of a range of government agencies, local councils and the community. The Policy provides a framework for the balanced and coordinated management of the coast's unique physical, ecological, cultural and economic attributes.

Implementing the Policy is a complex task. Many state agencies, local councils and different stakeholders are committed to carrying out the 138 Strategic Actions contained in the Policy. The NSW Coastal Council oversees the implementation of the Policy and reports annually to the NSW Parliament on progress made towards its implementation.

The Coastal Policy is structured into two broad parts. Part A outlines the principles and themes which guide the Policy, while Part B details the goals, objectives and strategic actions.

In 1997, the Minister for Planning re-issued a Direction under Section 117 of the Environmental Planning and Assessment Act 1979 for all local councils in the coastal zone regarding the Coastal Policy 1997. In preparing a draft Local Environmental Plan (LEP), the Direction requires councils to a) include provisions that give effect to and are consistent with the NSW Coastal Policy 1997; and b) they should not alter, create or remove existing zonings unless a Local Environmental Study for the draft LEP has been prepared and considered by council.

Coastal Design Guidelines for NSW (2003)

The Coastal Design Guidelines for NSW were released in March 2003 and were prepared with reference to the NSW Government's Coastal Policy 1997. The Guidelines provide a best practice framework for ensuring that design reflects the character of different places and how urban design helps new development to be more responsive to community expectations and local conditions. The coastal design guidelines are based on the principles of ecologically sustainable development (ESD).

Other Important Legislation

The Water Management Act 2000

The Water Management Act 2000 seeks to promote the integrated and sustainable management of the States waters for the benefit of both present and future generations.

Key features of the *Water Management Act* include, outlining statutory rights for environmental water, providing for the development of statutory water plans and development of a water trading system.

Most of the Act's provisions commenced on 1 January 2001, but some provisions relating to harvestable rights, access licences, approvals and the Water Investment Trust are not yet in force.

The Water Management Act 2000 replaced the Rivers and Foreshores Improvement Act 1948 (RFI Act 1948) on the 4 February 2008. The Water Management Act 2000 seeks to promote the integrated and sustainable management of the States waters for the benefit of both present and future generations.

The Water Management Act 2000 also contains provisions for approvals of 'controlled activities' and should be consulted in relation to estuary management options. A Controlled Activity Approval (CAA) replaces the former Part 3A approval which was required under the Rivers and Foreshores Improvements Act 1948. A CAA is now required for works that are on 'Waterfront Land', this is via Part 3 of Chapter 3 of the Water Management Act 2000.

A CAA is defined under the Water Management Act 2000 as activities carried out on waterfront land as follows:

(a) the erection of a building or the carrying out of a work (within the meaning of the *Environmental Planning and Assessment Act 1979*), 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.'

Waterfront Land is defined under the Water Management Act 2000 and is generally land that is within 40 metres from the top of the highest bank of a river, there are also similar provisions for lakes, estuaries and coastal waters.

Transitional arrangements under the Water Management Act 2000 allow pending DAs to be assessed under the RFI Act 1948, with the Part 3A permit upgraded to a 'Controlled Activity Approval' at the time of concurrence by the Department of Water and Energy.

Exemptions from the Water Management Act 2000 are defined in Clause 39A of the Water Management (General) Regulation 2004 and include exemptions for government authorities, with the exception of Landcom.

A large proportion of development within the Study Area is 'waterfront land' as defined under the Water Management Act 2000 within 40m of a waterway and thus, dependent on the list of exemptions contained under Clause 39A of the Water Management (General Regulation) 2004, development on this land will require a Controlled Activity Approval under the Water Management Act 2000 (WM Act 2000).

The National Parks and Wildlife Act 1974

The National Parks and Wildlife Act 1974 (NSW) (NP&W Act) established the NSW National Parks and Wildlife Service (NPWS – Now integrated into the Department of Environment and Conservation).

Under the Act, the Director-General considers and investigates proposals for additions to any national park, historic site, state recreation area, nature reserve, state game reserve, karst (limestone) conservation reserve, regional park or Aboriginal area.

Division 1 of the Act describes land, which may be reserved, and this includes crown lands reserved under the Crown Lands Act.

Under the *National Parks and Wildlife Act 1974*, the National Parks and Wildlife Service protects native aquatic macrophytes and riparian vegetation on lands under its control. Freshwater plants scheduled under the *Threatened Species Conservation Act 1995* are afforded greater protection.

The *National Parks and Wildlife Act 1974* requires that a Plan of Management be prepared for each National Park. A Plan of Management is a legal document, which outlines how a National Park will be managed in the years ahead.

The Coastal Protection Act 1979

The principal objection of the *Coastal Protection Act 1979* is to protect the coastal environment of the State for the benefit of both present and future generations.

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, and
- 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, and
- recognising the social and economic benefits of a sustainable coastal environment,
- promote public pedestrian access, acquisition to promote the protection, enhancement, maintenance and restoration;
- recognising the role of the community, as a partner with government and
- 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.

The land to which the *Coastal Protection Act, 1979* applies is identified generally as the “coastal zone” and is delineated on maps approved by the Minister for Planning. As identified in relation to SEPP 71, the *Coastal Protection Act, 1979,* applies to northern banks of the Hawkesbury River, east of Mangrove Creek to the eastern bank of Patonga Creek within the Gosford local government area and Dangar Island and Milson Island within the Hornsby local government area. No part of the Study Area within the Warringah local government area falls within the Coastal Zone.

Part 3 of the *Coastal Protection Act, 1979* provides for general supervision of the use, occupation and development of the coastal zone. This includes a requirement for public authorities to gain concurrence from the Minister before any development is carried out or consent is given for the use, occupation or development of the coastal zone, that is otherwise not the subject of the provisions of an environmental planning instrument (other than a SEPP).

Part 4A provides for the preparation of coastal management plans by local councils.

Part 4B of the *Coastal Protection Act, 1979* modifies the common law doctrine of erosion and accretion in relation to foreshore land. Under this doctrine, the position of any boundaries defined by reference to the mean high water mark are not fixed, but migrate in accordance with gradual, natural and imperceptible movements in the position of the mean high water mark. The Act requires that any mean high water mark property boundary determination involving an increase in the area of land on the landward side of the boundary will only be allowed if it can be established that the trend of accretion will be indefinitely sustained through natural means, and that no public access to a beach, headland or waterway will, or is likely to be, restricted or denied.

Part 5 outlines the penalties for offences against the *Coastal Protection Act, 1979*.

Local Government Act 1993

The Local Government Act1993 (LG Act) defines the powers, duties and functions of all local councils in New South Wales.

The LG Act is divided into chapters. The key chapters of relevance to the Study are outlined below.

Chapter 2 identifies the purposes of the LG Act as follows:

(a) to provide the legal framework for an effective, efficient, environmentally responsible and open system of local government in New South Wales,

(b) to regulate the relationships between the people and bodies comprising the system of local government in New South Wales,

(c) to encourage and assist the effective participation of local communities in the affairs of local government,

(d) to give councils:

  (i) the ability to provide goods, services and facilities, and to carry out activities, appropriate to the current and future needs of local communities and of the wider public

  (ii) the responsibility for administering some regulatory systems under this Act

  (iii) a role in the management, improvement and development of the resources of their areas,

(e) to require councils, councillors and council employees to have regard to the principles of ecologically sustainable development in carrying out their responsibilities.

Chapter 3 identifies the Councils charter. One Charter of particular relevance to the Study is “to properly manage, develop, protect, restore, enhance and conserve the environment of the area for which it is responsible, in a manner that is consistent with and promotes the principles of ecologically sustainable development”.

Chapter 5 identifies the function of Council under the Act. This Chapter also identifies other legislation under which a Council is conferred other functions. Such legislation includes:

- *Environmental Planning and Assessment Act, 1979*
- *Protection of the Environment Operations Act, 1997*
- *Coastal Protection Act, 1979*

Chapter 6 identifies the service functions of a Council, the following of which are of relevance to the Study:

- environment conservation, protection and improvement services and facilities;
- waste removal, treatment and disposal services and facilities;
- pest eradication and control services and facilities;

- water, sewerage and drainage works and facilities; and
- stormwater drainage and flood prevention, protection and mitigation services and facilities.

Chapter 6 also outlines the requirements in relation to the classification, use and management of public land, including the process of the preparation of plans of management for public land including those areas of public land which comprise “critical habitat” designated under the *Threatened Species Conservation Act, 1995* or *Fisheries Management Act 1994*.

Chapters 7 and 8 relate to the regulatory and ancillary functions of Council.

Chapters 9 to 15 relate to the establishment of Councils, election of Councillors, staffing, operations, accountability, honesty and disclosure of interests and financials.

Chapter 16 relates to offences, which include water, sewerage and drainage offences, including offences within Catchment districts and Chapter 17 relates to Enforcement.

Fisheries Management Act, 1994

The general objective of the Fisheries Management Act 1994 is to conserve, develop and share the fishery resources of the State for the benefit of present and future generations.

As well as providing authorisation and permits for aquaculture, recreational and commercial fishing activities, the Act also lists threatened marine species, populations and ecological communities.

The *Fisheries Management Act* specifies that a public authority authorising or carrying out of dredging or reclamation work or interrupting fish passage must give notice of the proposed work to the Minister of Fisheries and consider any matters raised.

The main provisions of this legislation that relate to Estuary Management works are:

- Habitat Protection Plans – which allow for the gazettal of management plans for the protection of specific aquatic habitats;
- Dredging and Reclamation Plans – which allows for the control and regulation of dredging and reclamation works, which may be harmful to fish and fish habitat. It establishes requirements to obtain a permit from or to consult with NSW Fisheries (now known as the Department of Primary Industries).
- Protection of mangroves and certain other marine vegetation, which requires permits to be obtained for the regulation of damage to or removal of certain marine vegetation including seagrass.

Of particular relevance to the Estuary Management Plan are provisions within the Act relating to the preparation of Habitat Protection Plans. Fish Habitat Protection Plans describe potential threats to fish habitat and recommend actions to mitigate the effects of potentially damaging activities.

The Fisheries Management Act also protects fish species listed as endangered or vulnerable.

Threatened Species Conservation Act 1995

The Act provides for the identification, conservation and recovery of threatened species and their populations and communities. It also aims to reduce the threats faced by those species. Unless a licence has been obtained under the *National Parks and Wildlife Act 1974* or the *Threatened Species Conservation Act 1995*, or approval under the EPA Act, it is an offence under the *National Parks and Wildlife Act* to harm any animal or plant that is a threatened species, population or ecological community (NPWA s.118(1)(b)).

Threatened species, populations and communities are listed as endangered or vulnerable in Schedules 1 and 2 respectively.

Protection of the Environment Operations Act 1999

The *Protection of the Environment Operations Act* replaces the *Clean Air Act 1961*, *Clean Waters Act 1970, Noise Control Act 1975, Pollution Control Act 1970, Environmental Offences and Penalties Act 1989* and regulatory provisions of the *Waste Minimisation Act 1995*.

The Act makes it an offence to pollute the environment without an environment protection licence issued by the Environment Protection Authority (now the Department of Environment and Conservation).

Schedule 1 lists activities, which require an EPA licence. The schedule includes dredging works and extractive industries, however the definitions of both of these activities require quantities of more than 30,000m^3 per year before they fall under the Act. If the sediment to be dredged were classified as hazardous or industrial waste, the activity would require an environment protection licence.

Catchment Management Authorities Act 2003

The *Catchment Management Authorities Act* establishes 13 Catchment Management Authorities across NSW. The Catchment Management Authorities replace the Catchment Management Boards and Trusts set up under the repealed *Catchment Management Act*. The Hawkesbury Nepean Catchment Management Authority will cover the Brooklyn Estuary. Certain natural resource management functions are devolved to the Catchment Management Authorities. This includes the preparation of a draft Catchment Action Plan as soon as practicable for approval by the Minister under Part 4 of the Act.

The Act also repeals the *Catchment Management Act 1989* and to amends various Acts consequentially.

It is expected that the Draft Catchment Action Plan will be based on the Hawkesbury Nepean Catchment Blueprint prepared by Hawkesbury-Nepean Catchment Management Board.

Natural Resource Commission Act 2003

The Act created an independent Natural Resources Commission to make recommendations on natural resource management standards and targets, audit the performance of the catchment management authorities (CMAs), report on the achievement of targets, and carry out inquiries.

Native Vegetation Act 2003

The Native Vegetation Act 2003 (NV Act 2003) regulates the clearing of native vegetation on all land in NSW, except for land listed in Schedule 1 of the Act.

Schedule 1 of the Act excludes:

- any land reserved or acquired for National Parks under the *National Parks and Wildlife Act, 1974*;
- any land affected by an interim heritage order or listing on the State Heritage Register;
- any land that is critical habitat, being habitat declared under Part 3 of the *Threatened Species Conservation Act 1995* or under Division 3 of Part 7A of the *Fisheries Management Act 1994;*
- any land reserved or acquired for State Forestry purposes;
- any urban land (residential, business or industrial land under any EPI);
- the whole of the Hornsby and Warringah local government areas, amongst others.

In view of this, the NV Act 2003 appears to only apply to the Rural and Conservation zoned within the Gosford local government area.

The objectives of this Act are:

- to provide for, encourage and promote the management of native vegetation on a regional basis in the social, economic and environmental interests of the State, and
- to prevent broadscale clearing unless it improves or maintains environmental outcomes, and
- to protect native vegetation of high conservation value having regard to its contribution to such matters as water quality, biodiversity, or the prevention of salinity or land degradation, and
- to improve the condition of existing native vegetation, particularly where it has high conservation value, and
- to encourage the revegetation of land, and the rehabilitation of land, with appropriate native vegetation,
- in accordance with the principles of ecologically sustainable development.

The NV Act repealed the *Native Vegetation Conservation Act 1997*, provides definitions of native vegetation, clearing, native remnant vegetation, regrowth, protected regrowth and routine agricultural management activities.

Notably the NV Act requires consent for clearing to be either as part of a development consent issued in accordance with the NV Act or via a Property Vegetation Plan (PVP). PVPs are negotiated agreements between a landholder and the Minister for Natural Resources (or a Catchment Management Authority if the Minister has delegated this role to the CMA).

PVPs run with the land and the *Environmental Planning and Assessment Regulation 2000* has been amended to provide that PVPs are included on planning (or zoning) certificates under Section 148 of the EPA Act 1979. Councils are only required to include a statement about the PVP on the planning certificate if notified of the existence of the PVP by the person or body who approved the PVP.

APPENDIX D: GUIDELINES FOR ESTUARY ASSET PROTECTION

To ensure guidelines for estuary asset protection are implemented within the Lower Hawkesbury the following criteria are to be used when assessing future activities or proposals (DECC, 2007) by consent authorities and managers of foreshore infrastructure:

- **Sustainability**: the option is consistent with the principles of ecologically sustainable development and other relevant principles referred to in the NSW Coastal Policy 1997;
- **Consistency with goals**: the option promotes achievement of reducing risks to estuary assets;
- **Likely impacts**: the social economic and environmental benefits and impacts are acceptable to state, council and the community;
- **Planning framework:** the option is consistent with relevant policies and plans at the state, regional, catchment and local levels;
- **Public domain:** the option protects or enhances the public domain, particularly the public's right to access, use and enjoy foreshore reserves, beaches and waterways;
- **Cultural:** the option respects and promotes the cultural, social or spiritual value of the coastal environment;
- **Acceptable risk:** the level of risk to life, property and the environment is acceptable;
- **Cost-Benefit:** the cost-benefit of the option is positive, and superior to alternate options;
- **Financial:** the option can be adequately financed, both initially and in the long term;
- **Legal & regulatory:** the option is compatible with legal and regulatory constraints, including land tenure issues and approvals by Commonwealth and State Agencies;
- **Community support:** the community understands and supports the option.

The guidelines for protection of estuary assets are consolidated from documents that are listed below. Further information can be obtained from these documents which in many instances offer further information on the implementation of these guidelines:

- NSW DPI (1998) "Habitat Protection Plan No.3- The Hawkesbury- Nepean River System." September 1998, NSW DPI Fisheries;
- DECC (2007) "Environmental Action for Marinas, Boatsheds and Slipways". June 2007, Department of Environment and Climate Change;
- DECC (2008) "Coastal Management Manual, Volume-1" 2008 in press. Department of Environment and Climate Change;
- NSW Government (2006) "NSW Oyster Industry- Sustainable Aquaculture Strategy" 2006, NSW Government; and
- HSC (2008) "Hornsby Shire Council- Rivers Settlements and Foreshores Review" 2008, Hornsby Shire Council.
- NSW Government (2004) Managing Urban Stormwater- Soils and Construction. Landcom
- ASSMAC (1998) Acid Sulfate Soil Manual. Acid Sulfate Soil Management Advisory Committee

- HSC (2007) Onsite Sewage Management Strategy, Hornsby Shire Council

D.1 Cumulative impacts

Source: NSW DPI (1998)

With regard to environmental consequences, specific works, activities or proposals must not be considered in isolation. Even if a single action is judged as likely to cause little damage, the cumulative impacts of this action plus all likely future actions arising from it need consideration. Such a consideration is particularly important where a work, activity or proposal is likely to set a precedent or create a need/opportunity for additional facilities, or where a development is proposed in stages. Cumulative impacts need to be considered at all steps in the design, planning, development and ongoing management process.

D.2 Pollution

Source: NSW DPI (1998), HSC (2008), NSW Government (2004)

The application of current best management practice in relation to pollution control needs to ensure the protection of estuary assets identified within this management plan (refer Section 3.1.1).

Approval authorities should ensure that any area liable to be affected by water pollution as a result of a particular proposal is investigated and/or mapped (with respect to any habitats present) before the event. The extent of such investigation should depend on the scale of the proposal, and take into account natural spatial and temporal variability.

Any further development of the Hawkesbury-Nepean catchment should only occur if accompanied by adequate provisions for habitat conservation. Such provisions include (but are not limited to) the following:

- the maintenance of natural creek channels and wetlands;
- the preservation of the maximum amount of native vegetation possible, particularly riparian vegetation;
- the avoidance of flood-prone land where levee banks might be needed;
- the preservation of fish passage;
- systems for treating stormwater (such as gross pollutant traps, sedimentation ponds and artificial wetlands);
- measures that minimise sediment escape during clearing and construction;
- the adoption of Australian New Zealand Environment and Conservation Council (ANZECC) guidelines (including both biological and physicochemical factors) as water quality goals for all immediate receiving waters;
- appropriate monitoring of habitats liable to be affected.

D.3 Climate change impacts

Source: CSIRO (2007), QLD (2008)

Projected changes to the climate in the Hawkesbury Nepean climate include increases in average temperature and changes to rainfall patterns. However, the most significant changes are likely to include extreme weather events. To reduce future risk, planning decisions should be made with reference to projected climate change. Changes specific to the Hawkesbury catchment are discussed in (CSIRO 2007). Of particular interest to the estuary is a reduction in freshwater flows.

Vulnerability and assessment mapping for the Hawkesbury Nepean Estuary is currently being undertaken by the Sydney Coastal Councils Group (SCCG). The mapping is expected to be available by 2009. Vulnerabilities mapped are expected to include:

- Land areas vulnerable to adverse health effects associated with extreme heat events;
- Land areas vulnerable to the effects of sea-level rise, storm, and storm surge impacts;
- Land areas vulnerable to significant runoff;
- Land areas vulnerable to significant bushfire; and
- Land areas associated with ecological systems and natural resources that are more or less resilient to the effects of climate change.

Once available, this mapping should be referred to for planning and assessment purposes. Note that the project is in collaboration with the Australian Greenhouse Office, CSIRO and the University of the Sunshine Coast. Given the nature of this area of research, the mapping is likely to be continually adapted as knowledge and understanding improves with time.

D.4 Erosion and sedimentation

Source: NSW Government (2008)

The application of current best management practice in relation to erosion and sediment control needs to ensure the protection of all habitats, including those in saltwater wetlands and creeks.

D.5 Reclamation

Source: HRC (1998)

Reclamation is work that involves the filling or draining of submerged land for the purpose of reclaiming the land, or the filling of submerged land for the purpose of supporting a building or structure (such as a bridge) being erected over the land. The Waterway Review recommends the prohibition of reclamation (PLN328/05 Hornsby Shire Waterways Review). This document will inform the preparation of Hornsby Councils comprehensive Local Environmental Plan. Further, reclamation is considered to be inconsistent with the principles of Crown Land Management (Crown Lands Act 1989-Sect 11) which states “(b) that the natural resources of Crown Land (including water, soil, flora, fauna and scenic quality) be conserved wherever possible and (e) that, where appropriate, Crown land should be used and managed in such a way that both the land and its resources are sustained in perpetuity”. The prohibition of reclamation of foreshore areas is considered necessary due to the reduction in estuarine open space, reduction in intertidal and benthic habitats and alterations to natural hydrologic regimes essential for maintenance of estuarine character and function.

D.6 Dredging and extraction

Source: HRC (1998)

Proposals for extensive navigation dredging of the Hawkesbury and the estuarine reaches of its tributaries should generally not be permitted, but should not be categorically prohibited.

In recognition of the damage already done to habitats within the Hawkesbury-Nepean system, no new extractive operations should be permitted between the shores or banks of any river or stream draining to the Hawkesbury Estuary, or on land within 50 metres of the Estuary.

Dredging may be approved for an essential public purpose (e.g. navigation) or environmental rehabilitation. However, effort should be made not to interfere with existing fish habitat corridors and sensitive/threatened habitats such as mangrove seagrass and saltmarshes.

D.7 Construction and management of foreshore infrastructure

Source: DECC 2007

General (seawalls, jetties, bridges, culverts, ramps and pontoons)

The conservation and enhancement of aquatic habitat should be taken into account in determining the location of such structures. These structures are to be prohibited, which require removal within the vicinity of seagrass, saltmarsh and mangrove communities.

Structures should not compromise existing habitat corridors of seagrasses, mangroves, macroalgae, reeds or ribbonweed.

Structures should not significantly alter natural sediment transport, wave, current or flow patterns, or impede fish passage.

Structures should be designed to maximise their habitat value to aquatic flora and fauna. Surfaces that provide sheltering sites for fish should be used where feasible.

Within the estuary, berthing facilities located where it is too deep or turbid for plants to grow on the sea bed should utilise pontoons in preference to fixed walkways. Pontoon sides provide hard substrate that remains just below the surface, where conditions for macroalgal growth are optimised.

Wharf and jetty pylons made of timber should not be treated with toxic chemicals (e.g. for marine borers). Alternatives include using concrete pylons and protecting untreated timber with a polyvinyl (plastic) wrap. These alternatives favour attached macroalgae and invertebrates, and hence provide for better aquatic habitat without weakening the structure.

Marinas and Jetties

Best practice standards for marinas and jetties include:

- Bund and cover fuel dispensing facilities and regularly inspect and maintain fuel tanks, bowsers, nozzles and hoses to ensure they are not leaking.
- Ensure first flush catchment system is of sufficient capacity and is regularly maintained
- Boat owners are to discouraged from discharging bilge water
- Provide pumpout facilities for public and private use and encourage their use
- Encourage boat owners to take steps to avoid polluting waters when washing their boats
- Place spill clean-up kits at likely spill locations and train all staff in their use
- Connect cutting and sanding machines to dust extractors- collect dust close to source
- Carry out outboard motor tests in tanks located in bunded and covered areas
- Carry-out all spray-painting inside a booth that complies with Australian Standards.

Slipway and Hardstand

Best practice standards for slipways and hardstands include:

- Ensure all slipways, hardstands and works areas are graded, bunded and are fitted with catch drains to collect waste water and chemical spills;
- Carry out all work above catch drains;
- Keep slipway work areas clean at all times. Ensure the area is cleaned up before leaving the site;
- Ensure sumps and pits are clean at all times. Ensure area is cleaned up before leaving the site;
- Ensure sumps and pits are clean and pumps are operating on their float switches; and
- Ensure operators have an Environmentally Hazardous Chemicals license if dealing with any organic wastes, including tributylin.

Waste storage and Hazardous materials

Best practice standards for waste storage and hazardous materials include:

- Store hazardous materials, including fuel, oils and chemicals, in correctly segregated, bunded and covered areas;
- Ensure all containers have lids on and are in good condition;
- Ensure wastes (solid and liquid) are sent to facilities that can lawfully take them;
- Develop an emergency response procedure for chemical spills and train staff on how to prevent and manage spills; and
- Regularly check the integrity of underground storage tanks.

Boatsheds

In order to maintain boatsheds as modest structures and for their intended use for the storage of boats and other maritime goods the following controls should be considered:

- Given there are no setbacks imposed on boatsheds from the waterway, activities such as boat washdown, engine maintenance, antifoul paint removal, etc have the potential to directly impact the river system. Hence, the boatshed design should incorporate best management practices and accommodate materials for the containment, collection and off site disposal of waste and other products produced by boat maintenance activities. Onsite treatment and disposal of products associated with boat maintenance is not to be encouraged due to the risk its presents and issues of resourcing for Council compliance staff to routinely inspect and ensure these devices are operating adequately.

- Ancillary landscape modifications such as paved areas, terracing and boat maintenance structures, such as dinghy storage racks should be incorporated within a $30m^2$ footprint of the Boatshed.

- Where more than two permanent berths for boats of 8m length or greater are proposed, sewage pumpout facilities should be incorporated into the boatshed design.

Seawalls

Design and construction of seawalls within the Hornsby Shire Local Government area is controlled by the River settlements and Foreshore DCP. Guidelines for seawall designs that assist with protecting estuary assets include the following design elements:

- Seawalls should reflect a slope that is commensurate with the surrounding natural landscape and should minimise wave reflection so as not to transfer bed and bank instability by wave action problems onto adjacent properties. Vertical walls have the greatest reflectance and are therefore to be discouraged;

- Seawalls should be constructed of sandstone and not mortared nor constructed of solid masonry or poured in-situ concrete construction. Mortar is only to be used for the addition of ecological features (such as shelves, pools and horizontal shelves);

- Seawalls (including the 'toe') should not extend below the mean high water mark without written authority from Department of Crown Lands. Where vertical walls are permitted they should be contained entirely within private property boundaries and not be located on the boundary of, on or within Crown Land (as defined by the Mean High Water Mark);

- New Seawalls should take account of the levels and layout of adjoining sites and aim to achieve integration between adjoining sites;

- Seawall design should incorporate provisions that maximise habitat by the addition of small horizontal shelf, pools, crevices, etc.;

- It should be demonstrated that a bed and bank instability issue exists and hence a seawall is required. Other options for bed and bank stability need consideration, such as bank stabilisation from vegetation;

- The seawall is not to be used as part of any reclamation of any natural (or near-natural) foreshore area. Also, material is not to be dredged from the estuary for purpose of providing material to backfill a seawall;

- The seawall should not impede any public right of access; and should be a minimum height to protect against:
  - The range of natural variations in the height of adjacent waters;
  - Any enhanced wave action due to water craft allowed in the area;
  - Potential consequences of climate change resulting in increased storm surge, sea level rise and wave action; and
  - Not restrict planting of riparian vegetation or impede the potential for estuarine vegetation for recolonisation. Incorporation of estuarine vegetation (eg mangrove, saltmarsh, etc) into seawall design is to be encouraged.

Construction of elevated platforms, such as boardwalks over the wall or estuary is not to be encouraged, and are prohibited to extend beyond the Mean High Water Mark. Elevated platforms that prohibit light attenuation are prohibited.

D.8 Construction and operation of aquaculture facilities

Source: NSW DPI (1998)

New intensive aquaculture activities (e.g. fish farms) should not be permitted over or within seagrass beds, mangroves, macroalgae, reeds, ribbonweed or other native attached macrophytes. Cages or similar fish holding facilities should only be placed where there is adequate flushing and sufficient water depth.

New extensive aquaculture activities (e.g. oyster leases) should not be permitted over Posidonia seagrass beds, or be allowed to compromise existing habitat corridors of seagrasses, mangroves, macroalgae, reeds or ribbonweed.

Aquaculture facilities such as grow-out ponds or hatcheries should not release effluent into any freshwater water body, wetland, river or stream, or into groundwater. Effluent should be stored, recycled or irrigated in accordance with DECC and Local government guidelines and current best practice.

Aquaculture facilities should not release effluent into the estuary.

Aquaculture of species not native to the Hawkesbury-Nepean catchment should not be authorised unless stringent escape prevention measures are employed.

Provisions contained within the New South Wales Oyster Industry Sustainable Aquaculture Strategy (OISAS) to protect the water quality within Priority Harvest Areas should be considered. In particular, appropriate methods for onsite sewerage disposal that minimise risk of river settlements influencing the category of the aquaculture harvest area is to be considered. Specifically, planning instruments should refer directly to the OISAS strategy which provides planning guidance and a regulatory framework for aquaculture within the Hornsby Local Government Area.

D.9 Acid sulfate soils

Source: ASSMAC (1998)

The exposure or disturbance of potential or actual acid sulfate soils should not be allowed during the construction, installation, operation or maintenance of foreshore infrastructure.

D.10 Clearing of vegetation

Source: NSW DPI (1998)

Native vegetation (including trees, shrubs and grasses) should be retained wherever possible, particularly where it is within 50 metres of a water body, wetland, river or stream (as measured from the top of the bank or shore): Native forest, woodland, bush or scrub should not be cleared or otherwise damaged.

Stock access should be managed to ensure the minimum impact on riparian and estuarine vegetation.

Exotic riparian vegetation should be replaced with locally native species, and bare areas be replanted.

Aquatic weeds should be controlled as much as possible, using best practice control and disposal methods.

D.11 Removal of snags, boulders or rock

Source: NSW DPI (1998)

Snags, boulders or rock should not be removed from any waters. Where their removal is essential, the material that must be removed should be re-oriented in line with the flow, or relocated to a nearby area of water in consultation with DPI Fisheries, in order to minimise any loss of fish habitat.

D.12 Fishing

Source: NSW DPI (1998)

Commercial and recreational fishers should use methods that minimise damage to fish habitat or fish stocks. Methods that cause excessive damage should be phased out. In particular, commercial trawler operators should use by-catch reduction devices when appropriate and recreational fishers should avoid damaging fish habitats.

The design and construction of new causeways or culverts, or modifications to existing ones, should allow for fish passage and adequate water flows.

D.13 Water regulation

Source: NSW DPI (1998)

Natural stream flows (both the quantity and seasonality of flows) should be retained where possible. If not possible, then a regime of environmental flows should be provided in consultation with DPI Fisheries.

The direct effects of water abstraction and impoundments, along with the indirect effects of groundwater extraction, should always be considered in relation to the maintenance/provision of stream flows.

D.14 Boating

Source: NSW DPI (1998)

The removal or damaging of seagrass and most types of macroalgae requires a permit under the Fisheries Management Act 1994. Removal of seagrass habitat for additional moorings is to be prohibited.

To assist the re-establishment of riparian vegetation along denuded banks, "no wash zones" should be considered for those river sections where the loss of riparian vegetation is severe. Within a given area, such a zone would only be needed until regeneration was successful.

D.15 Effluent disposal

Source: NSW Government (2006), HSC (2007)

Consideration should be given towards ensuring new river settlements minimise their potential risk towards contributing to adverse water quality through inefficient or inappropriate on-site disposal mechanisms. To achieve such risk reduction, particularly in Priority Oyster Areas, best practise onsite sewage management is to be used. This requires the sustainable disposal of household wastewater in such a manner that meets NSW Health requirements and relevant Australian Standards.

APPENDIX E: RISK ASSESSMENT RESULTS FOR ALL STRATEGIES

For a quick reference to the risk assessment process, refer to the following summary tables. The first table for each of the risks outlines the Primary strategies for that risk. The colour coding in the column headed "risk reduction potential" is a guide to the effectiveness of strategies. Very High rated strategies (coloured red) are the most effective strategies, with orange and yellow coding indicating High and Medium rated strategies (respectively). Those strategies that are not colour coded were not short-listed. Also some of the medium (yellow) strategies were not short listed.

Risk 1: Risk of inappropriate or unsustainable development

Table 1.1 Primary strategies addressing Risk 1

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score – likelihood	Aggregated risk reduction score – consequence	Risk Reduction Potential
1a	Conduct assessments to determine the carrying capacity of land areas (based on water, air, biodiversity and land capabilities) and limits for sustainable development within the entire catchment.	Research	0.07	5.0%	0.03	5.0%	2, 6, 8, 10, 11, 12, 16	0.29	0.28	0.08
1b	Collect information to inform amendments to planning controls based on the assessment of land capability, estuary carrying capacity (future population and development within the catchment) and ecological assessments.	Research	0. n14	10.0%	0.03	5.0%	2, 3, 6, 8, 10, 12	0.39	0.16	0.062
1c	State Government to reconsider regional strategies based on outcomes of sustainability and land capability assessments.	Planning	0.07	5.0%	0.03	5.0%	2, 8	0.18	0.04	0.01
1d	Determine sustainable limits for recreational activities (types, numbers and locations) and the requirements for existing/new facilities and access to achieve sustainable limits on foreshores and waterways of the estuary (ie, suitable locations, unsustainable locations requiring removal, locations requiring restoration, new sustainable locations).	Research	0.07	5.0%	0.03	5.0%	3, 6 ,7, 8	0.28	0.17	0.05

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score – likelihood	Aggregated risk reduction score – consequence	Risk Reduction Potential
1e	Review waterway access locations and requirements to consider all stakeholder needs with recommendations from the review informing appropriate Planning and Works Programs.	Research	0.07	5.0%	0.03	5.0%	2, 3, 7, 8	0.19	0.05	0.01
1f	Develop and implement an Estuary Processes and Issues Checklist (EPIC) and integrate the checklist into councils planning controls. (The checklist is required to be completed and submitted with DA documentation. The checklist will require applicants and council planners to assess the likely impacts of Das upon the natural processes, estuary values and sustainability of the Lower Hawkesbury Estuary).	Research	0.10	7.5%	0.03	5.0%	2, 3, 4, 8, 10 , 12, 13	0.29	0.09	0.03
1g	Ensure planning instruments incorporate best practise: sediment, erosion and stormwater controls (eg construction controls plans and WSUD); use of water reduction devices and maximal permeable surfaces, landscaped area calculations: protection of native vegetation; sewage management (eg low risk OSSMs); restriction of landscaping and gardens to endemic species; energy efficient design and ESD.	Planning	0.14	10.0%	0.03	5.0%	2, 3, 6, 7, 8, 12, 13, 14	0.50	0.11	0.06
1h	Not used									
1i	Ensure suitable controls are contained within planning instruments for the design of foreshore development including recreational facilities to maintain the estuary shoreline in as natural state as possible and minimises potential for bank erosion	Planning	0.07	5.0%	0.03	5.0%	3, 4, 8	0.22	0.05	0.01
1j	Incorporate appropriate provision in planning instruments to require all Marinas to provide accessible pumpout facilities as a component of their licence to operate in the Lower Hawkesbury.	Planning	0.07	5.0%	0.03	5.0%	2, 7, 12	0.15	0.07	0.01
1k	Incorporate provisions within planning controls to require all new dwellings or major alterations and additions to existing dwellings in the vicinity of priority oyster harvest areas to consider installation of pumpout sewage systems, where feasible.	Planning	0.07	5.0%	0.03	5.0%	2, 12	0.12	0.05	0.01
1l	Encourage conservation of native vegetation on private land	Education	0.03	2.0%	0.03	5.0%	6, 13	0.09	0.04	0.00

Table 1.2 Secondary strategies addressing Risk 1

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
2a	0.07	5.0%	0.02	4.0%	Risk 2
2c	0.03	2.0%	0.02	3.0%	Risk 2
6a	0.07	5.0%	0.02	3.0%	Risk 6
6b	0.01	1.0%	0.02	3.0%	Risk 6
2d	0.04	3.0%	0.02	3.0%	Risk 2
2b	0.01	1.0%	0.02	3.0%	Risk 2
7a	0.01	1.0%	0.02	3.0%	Risk 7
12ll	0.01	1.0%	0.02	3.0%	Risk 12
10b	0.03	2.0%	0.02	3.0%	Risk 10
6c	0.03	2.0%	0.02	3.0%	Risk 6
7b	0.10	7.5%	0.03	5.0%	Risk 7
6d	0.02	1.5%	0.02	3.0%	Risk 6
7g	0.01	1.0%			Risk 7
12aa	0.02	1.5%	0.02	3.0%	Risk 12
10a	0.01	1.0%	0.02	3.0%	Risk 10

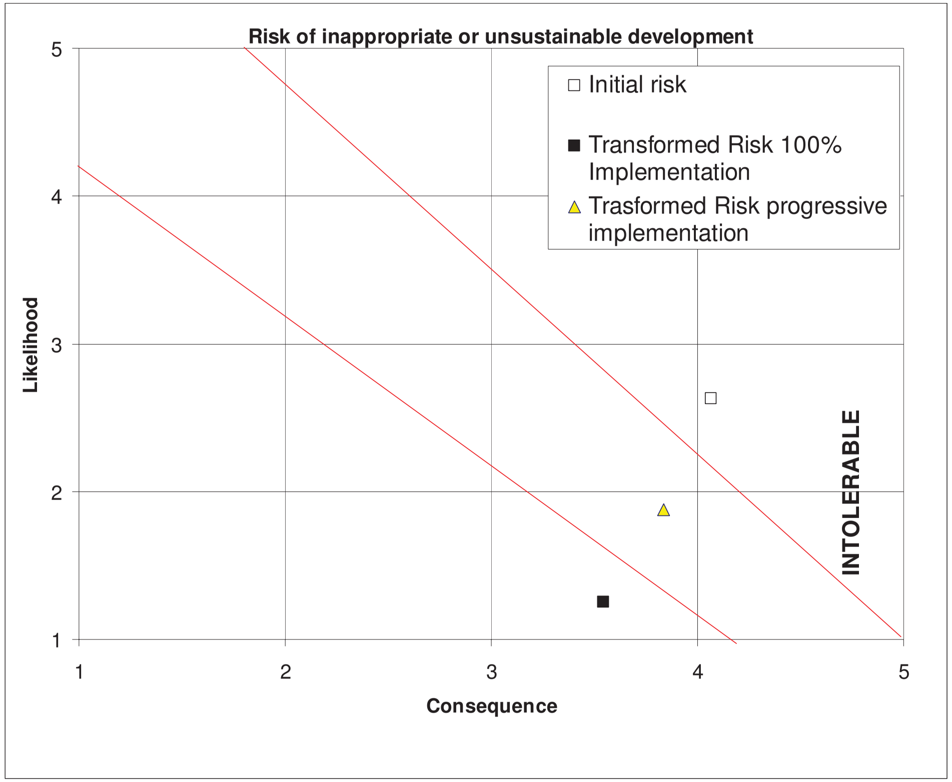


Figure 1.1: Risk Reduction Potential for Risk 1

Risk 2: Risk of over-exploiting or degrading the estuary's biodiversity and other assets

Table 2.1 Primary strategies addressing Risk 2

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
2a	Undertake an audit of planning compliance to review the effectiveness of development conditions to protect estuary assets and achieve sustainability. (eg an audit of the types of development being approved for consistency with sustainable growth limits and estuary asset protection goals).	Planning	0.04	3.0%	0.00	0.8%	1,3,6,8,12	0.24	0.06	0.014
2b	Define and map minimum buffer widths for riparian/foreshore vegetation in relevant planning documents (LEPs, DCPs etc) to protect estuary assets and account for landward migration of habitat due to sea level rise.	Planning	0.04	3.0%	0.02	4.0%	1,3,6,10	0.22	0.05	0.011
2c	In all Development Control Plans, information on the existing environmental context and desired future character is to be included in order to provide a more complete strategic approach.	Planning	0.01	0.8%	0.00	0.8%	1,8	0.05	0.03	0.001
2d	During the review of plans of management for all parks and reserves (both national and council managed), ensure estuary assets are preserved (including habitat values for native animals, animals listed under the TSC Act 1995, prescribed burning and bushfire suppression undertaken according to park/reserve fire management plan, etc).	Research	0.03	2.0%	0.00	0.8%	3,6,14	0.22	0.07	0.014
2e	Develop a strategy for sustainable recreation across the Lower Hawkesbury, which states the sustainability of locations, facilities and access based upon recreational survey and other data.	Research	0.03	2.0%	0.00	0.8%	3,4,7	0.49	0.17	0.084
2f	Prohibit reclamation activities in all planning instruments.	Planning	0.01	0.8%	0.00	0.8%	1,3,8	0.07	0.01	0.001
2g	Liaise with the Metropolitan LALC and other indigenous groups to assess if the current level of management of aboriginal sites around the estuary is appropriate.	Planning	0.01	0.8%	0.00	0.8%	6,8	0.06	0.03	0.002
2h	Prepare management plans for commercial and recreational fishing (based upon the findings of commercial and recreational fishing surveys and research into fishing impacts) which outline fishing parameters to sustain fish stocks and aquatic habitats (including zones appropriate to various fishing amounts (bag limits) and practices, use of bycatch devices and non-target species avoidance techniques). The plan needs also to address potential issues with visiting commercial fishers.	Planning	0.03	2.0%	0.02	2.5%		0.03	0.02	0.000
2i	Ensure commercial fishers minimise the catch of non-target species, the incidental catch of non-utilised species, marine mammals, reptiles, seabirds and impacts on associated or dependent species using such measures as mesh or gear modifications, closed areas and bycatch reduction devices.	Compliance	0.03	2.0%	0.02	2.5%	7	0.03	0.04	0.001

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
2j	Enforce compliance of recreational fishers with regulations on bag limits, minimum fish sizes etc	Compliance	0.01	0.8%	0.01	1.5%	3,7	0.04	0.04	0.002
2k	Educate all commercial fishers on methods to minimise the catch of non-target species, the incidental catch of non-utilised species, marine mammals, reptiles, seabirds and impacts on associated or dependent species. Such methods include mesh or gear modifications, closed areas and bycatch reduction devices.	Education	0.03	2.0%	0.02	2.5%	7	0.03	0.04	0.001
2l	Educate commercial fishers to ensure they understand the immediate action required to mitigate impacts on protected or endangered species from their trawling operations	Education	0.00	0.3%	0.01	1.5%	7	0.01	0.03	0.000
2m	Identify significant seagrass beds on NSW Maritime boat charts and stickers and undertake education program to promote protection of seagrass	Education	0.03	2.0%	0.00	0.8%	15	0.04	0.04	0.002
2n	Riparian zones in priority agricultural areas fenced to prevent access of livestock to estuary, protect and encourage rehabilitation of riparian vegetation.	Capital works	0.03	2.0%	0.00	0.8%	6,14	0.11	0.06	0.007
2o	Undertake comprehensive of mapping of the extent and condition of riparian habitats (including mangroves, saltmarsh and wetland species) in the Lower Hawkesbury and review periodically	Research	0.01	0.8%	0.01	1.5%	16,5	0.08	0.08	0.006
2p	Improve native vegetation condition through revegetation of priority areas (based on habitat mapping)	Capital works	0.01	0.8%	0.01	1.5%	6,13	0.03	0.05	0.001
2q	Expand bush regeneration programs and conservation programs for specific priority species	Capital works	0.00	0.3%	0.01	1.5%	6,13	0.03	0.05	0.001
2r	Provide incentives to landholders to conserve significant habitats and native vegetation identified on private land (e.g. through property vegetation plans and voluntary conservation agreements)	Capital works	0.01	0.8%	0.00	0.8%	6,13	0.07	0.02	0.001
2s	Initiate a program for the removal of rubbish (including derelict boats) from riparian areas. The clean up program should focus on larger items such as derelict boats and dumped construction materials, with input and assistance from industry groups and volunteers.	Capital works	0.00	0.3%	0.02	2.5%	15	0.03	0.09	0.003
2t	Identify, protect, enhance and rehabilitate sites of Indigenous cultural significance, in collaboration with local indigenous groups (e.g. middens subject to erosion)	Capital works	0.01	0.8%	0.01	1.5%	N/A	0.01	0.01	0.000
2u	Identify, protect, enhance and rehabilitate sites of European heritage significance, in collaboration with local historical societies.	Capital works	0.01	0.8%	0.01	1.5%	N/A	0.01	0.01	0.000

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
2v	Employ a River Keeper for the Lower Hawkesbury estuary, to assist in compliance, education and on-ground works (eg boat speeds and zones, seagrass protection, effluent discharges, littering, fishing, foreshore habitat protection, foreshore and waterway activities).	Capital works	0.04	3.0%	0.02	4.0%	3,6,7,8,12,13,15	0.22	0.23	0.051
2w	Install marker buoys and warnings around seagrass habitats to deter boaters from accessing and damaging these habitats	Capital works	0.03	2.0%	0.00	0.8%	15	0.04	0.04	0.002
2x	Encourage the development and implementation of selective fishing gear, trawl practises/equipment and by-catch reduction devices amongst commercial fishers and researchers	Research	0.01	0.8%	0.01	1.5%	7	0.02	0.03	0.001

Table 2.2 Secondary strategies addressing Risk 2

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
1b	0.04	2.5%	0.00	0.8%	Risk 1
1f	0.01	2.5%	0.00	0.8%	Risk 1
1c	0.03	0.3%	0.00	0.8%	Risk 1
1g	0.04	0.3%	0.01	1.5%	Risk 1
6a	0.03	0.8%	0.00	0.8%	Risk 6
6b	0.01	0.3%	0.00	0.8%	Risk 6
1d	0.03	0.3%	0.00	0.8%	Risk 1
7a	0.03	0.3%	0.00	0.8%	Risk 7
7b	0.01	1.5%	0.01	1.5%	Risk 7
7c	0.03	2.0%	0.00	0.8%	Risk 7
7d	0.00	0.6%	0.00	0.8%	Risk 7
7e	0.03	0.6%	0.00	0.8%	Risk 7
7f	0.03	0.3%	0.00	0.8%	Risk 7

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
7g	0.01	0.6%	0.01	1.5%	Risk 7
7h	0.00	0.6%	0.01	1.0%	Risk 7
7j	0.01	0.6%	0.01	1.0%	
1i	0.01	0.6%	0.01	1.0%	Risk 1
1j	0.00	2.0%	0.02	2.5%	Risk 1
1a	0.01	0.6%	0.00	0.8%	Risk 1
3a	0.01	0.6%	0.01	1.5%	Risk 3
3c	0.04	0.3%	0.00	0.8%	Risk 3
5c	0.03	0.6%	0.01	1.5%	Risk 5
5d	0.01	0.3%	0.01	1.5%	Risk 5
5e	0.01	0.6%	0.01	1.5%	Risk 5
6a	0.01	0.6%	0.00	0.8%	Risk 6
6b	0.00	0.3%	0.00	0.8%	Risk 6
6c	0.00	0.3%	0.00	0.8%	Risk 6

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
6d	0.00	0.3%	0.00	0.8%	Risk 6
10b	0.01	0.6%	0.00	0.8%	Risk 10
10c	0.00	0.3%	0.00	0.5%	Risk 10
10d	0.01	0.6%	0.00	0.8%	Risk 10
11d	0.01	0.6%	0.01	1.5%	Risk 11
11b	0.01	0.6%	0.00	0.8%	Risk 11
11e	0.00	0.3%	0.00	0.8%	Risk 11
11f	0.01	0.6%	0.01	1.5%	Risk 11
11a	0.01	0.6%	0.00	0.8%	Risk 11
12r	0.00	0.3%	0.00	0.8%	Risk 12
12t	0.00	0.3%	0.00	0.8%	Risk 12
12v	0.00	0.3%	0.00	0.8%	Risk 12
12w	0.01	0.8%	0.01	1.5%	Risk 12
12x	0.00	0.3%	0.01	2.0%	Risk 12
12dd	0.00	0.3%	0.00	0.8%	Risk 12
12ff	0.01	0.6%	0.01	1.5%	Risk 12
12hh	0.01	0.6%	0.01	1.5%	Risk 12
12jj	0.01	0.8%	0.01	1.5%	Risk 12
13a	0.00	0.3%	0.01	1.5%	Risk 13
13b	0.00	0.3%	0.01	1.5%	Risk 13
14c	0.00	0.2%	0.01	2.0%	Risk 14

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
15a	0.01	0.6%	0.00	0.8%	Risk 15
15b	0.00	0.3%	0.00	0.8%	Risk 15
15d	0.00	0.3%	0.00	0.8%	Risk 15
15e	0.00	0.3%	0.00	0.8%	Risk 15
15j	0.00	0.3%	0.00	0.8%	Risk 15
16b	0.01	0.6%	0.01	1.5%	Risk 16
16d	0.01	0.6%	0.01	1.5%	Risk 16
16e	0.01	0.6%	0.01	1.5%	Risk 16
16f	0.00	0.3%	0.00	0.8%	Risk 16
16g	0.01	0.5%	0.01	1.5%	Risk 16

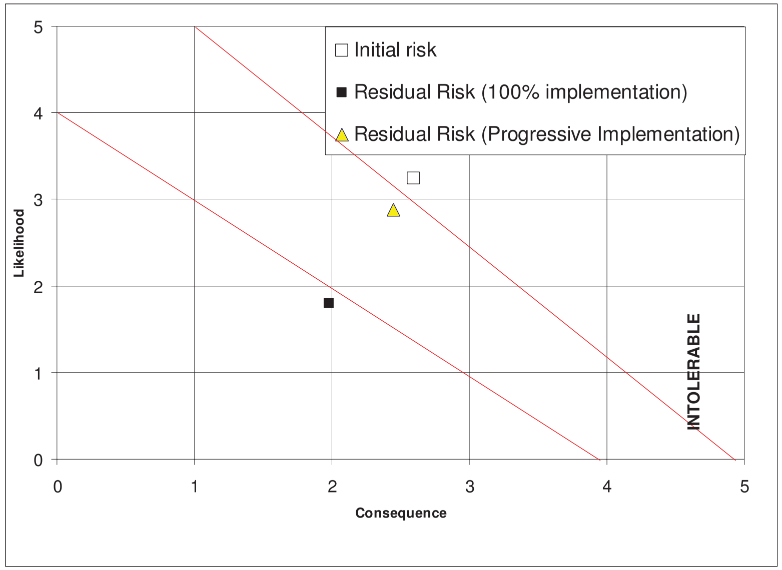


Figure 2.1 Risk Reduction Potential for Risk 2

Risk 3: Risk of inappropriate or excessive foreshore access and activities

Table 3.1 Primary strategies addressing Risk 3

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
3a	Restrict foreshore access in areas of high environmental sensitivity	Compliance	0.06	5.5%	0.01	6.5%	2,4,6	0.13	0.05	0.006
3c	Rehabilitate recreational areas on the foreshore and implement Foreshore Annual Maintenance Program	Capital works	0.02	2.0%	0.01	6.5%	2, 14	0.09	0.02	0.002

Table 3.2 Secondary strategies addressing Risk 3

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
1b	0.04	3.3%	0.00	2.0%	Risk 1
1f	0.04	3.3%	0.00	2.0%	Risk 1
1g	0.05	4.5%	0.00	2.0%	Risk 1
1e	0.05	4.5%	0.01	5.0%	Risk 1
1i	0.05	4.5%	0.00	2.0%	Risk 1
1d	0.05	4.5%	0.01	5.0%	Risk 1
2a	0.04	3.3%	0.00	2.0%	Risk 2
2d	0.05	4.5%	0.01	5.0%	Risk 2
2b	0.04	3.3%	0.00	2.0%	Risk 2
2e	0.05	4.5%	0.01	5.0%	Risk 2
2f	0.05	4.5%	0.00	2.0%	Risk 2
2j	0.02	2.0%	0.01	4.0%	Risk 2
2v	0.04	3.3%	0.01	4.0%	Risk 2
4a	0.04	3.3%	0.01	4.0%	Risk 4
5a	0.04	3.3%	0.01	4.0%	Risk 5
6a	0.04	3.3%	0.00	2.0%	Risk 6
7b	0.04	3.3%	0.00	2.0%	Risk 7
12a	0.05	4.5%	0.01	5.0%	Risk 12
12cc	0.04	3.3%	0.01	4.0%	Risk 12
15b	0.04	3.3%	0.01	3.5%	Risk 15
15d	0.04	3.3%	0.01	3.5%	Risk 15
15f	0.04	3.3%	0.01	3.5%	Risk 15
16c	0.05	4.5%	0.01	5.0%	Risk 16
16f	0.04	3.3%	0.01	3.5%	Risk 16

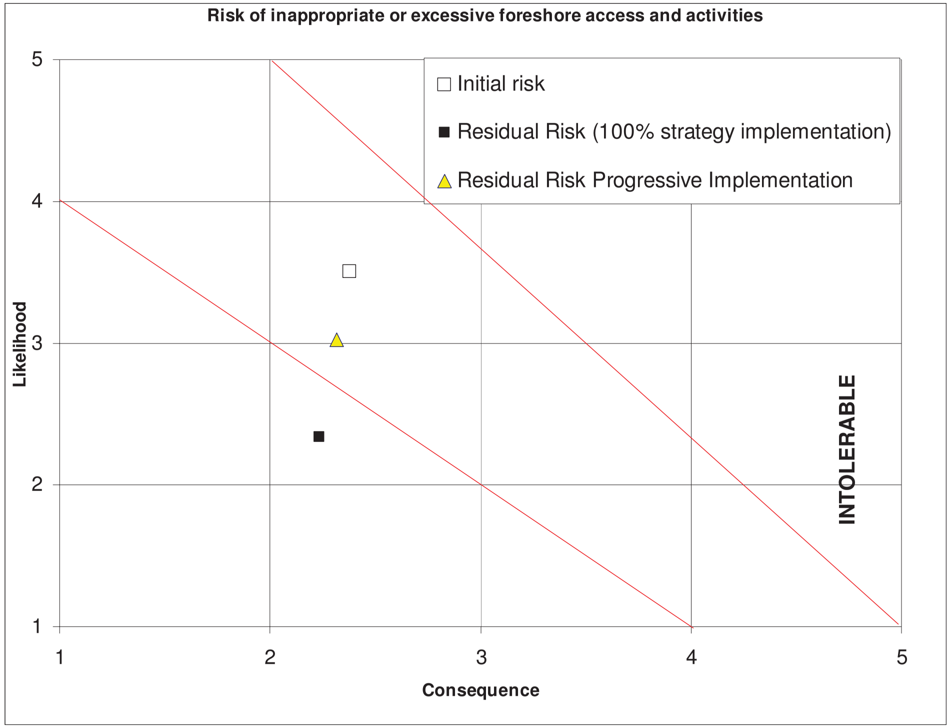


Figure 3.1 Risk Reduction Potential for Risk 3

Risk 4: Risk of inadequate facilities to support foreshore and waterway access and activities

Table 4.1 Primary strategies addressing Risk 4

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
4a	Ensure adequate waste disposal facilities for people aboard boats and recreational fishers on land. This includes installation/provision of approved bins on hire boats, commercial fishing boats, moored boats and trailable boats, and supporting waste services on land.	Capital works	0.13	15.0%	0.05	20.0%	3,7,12	0.18	0.11	0.020
4b	Initiate planning of the Lower Hawkesbury section of the Great Hawkesbury Walk.	Capital works	0.04	5.0%	0.01	5.0%	15	0.06	0.05	0.003

Table 4.2 Secondary strategies addressing Risk 4

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
1f	0.09	10.0%	0.01	5.0%	Risk 1
1h	0.09	10.0%	0.01	5.0%	Risk 1
2e	0.36	40.0%	0.11	40.0%	Risk 2
3a	0.04	5.0%	0.01	5.0%	Risk 3
12m	0.13	15.0%	0.05	20.0%	Risk 12

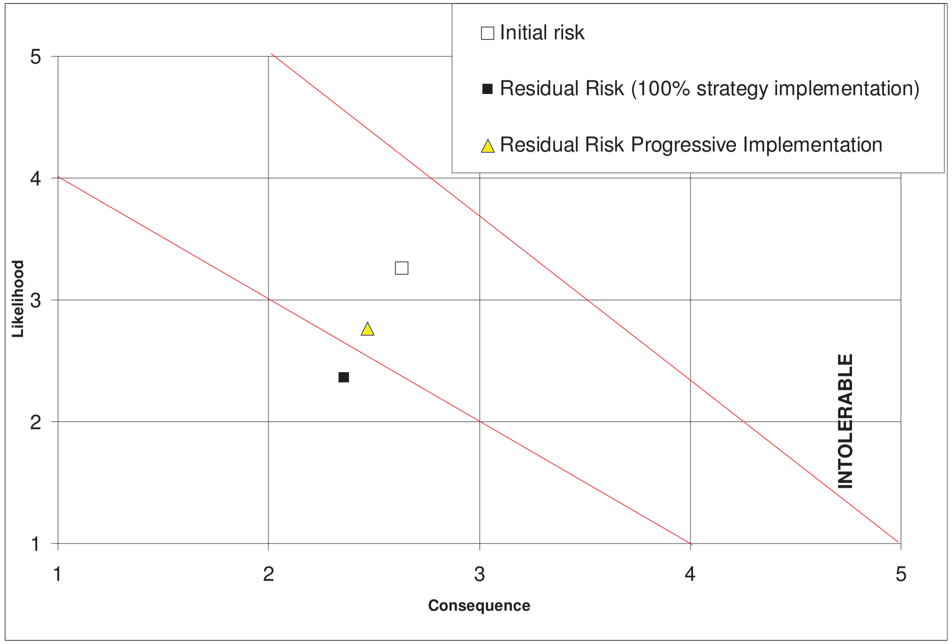


Figure 4.1 Risk Reduction Potential for Risk 4

Risk 5: Risk of inadequate monitoring to measure effectiveness of EMP

Table 5.1 Primary strategies addressing Risk 5

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
5a	Establish a regular monitoring program to monitor the impacts of recreation at various locations and times of year (such as peak periods), to ensure ongoing sustainability of such locations.	Research	0.10	10.0%	0.04	10.0%	3,7,16	0.18	0.10	0.019
5b	Establish and implement one recreational water quality monitoring program (such as Beach/Streamwatch by EPA) for the entire Lower Hawkesbury.	Research	0.10	10.0%	0.04	10.0%	12,16	0.12	0.07	0.008
5c	Undertake periodic mapping of aquatic habitats (including the extent and condition of benthic, intertidal zone, water column and water surface habitats) throughout the Lower Hawkesbury	Research	0.10	10.0%	0.04	10.0%	2,16	0.14	0.06	0.009
5d	Develop key biological indicators and establish a biological monitoring program for aquatic and riparian habitats	Research	0.10	10.0%	0.04	10.0%	2	0.11	0.04	0.005
5e	Develop a comprehensive ecosystem health water quality monitoring program across the Lower Hawkesbury	Research	0.10	10.0%	0.04	10.0%	2,12	0.11	0.04	0.005
5f	Determine a set of parameters to indicate the progress in implementation of the EMP and to measure/indicate the effectiveness of actions in achieving EMP goals and protecting estuarine health.	Research	0.05	5.0%	0.02	5.0%	8	0.06	0.04	0.003
5g	Ensure monitoring programs are given a high priority to enable measurement of the effectiveness of the EMP.	Research	0.05	5.0%	0.02	5.0%	16	0.06	0.04	0.002

Table 5.2 Secondary strategies addressing Risk 5

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
2o	0.05	10.0%	0.04	10.0%	Risk 2
8b	0.05	5.0%	0.02	5.0%	Risk 8
8c	0.05	5.0%	0.02	5.0%	Risk 8

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
10d	0.05	5.0%	0.02	5.0%	Risk 10
12hh	0.10	10.0%	0.04	10.0%	Risk 12
12kk	0.05	5.0%	0.02	5.0%	Risk 12

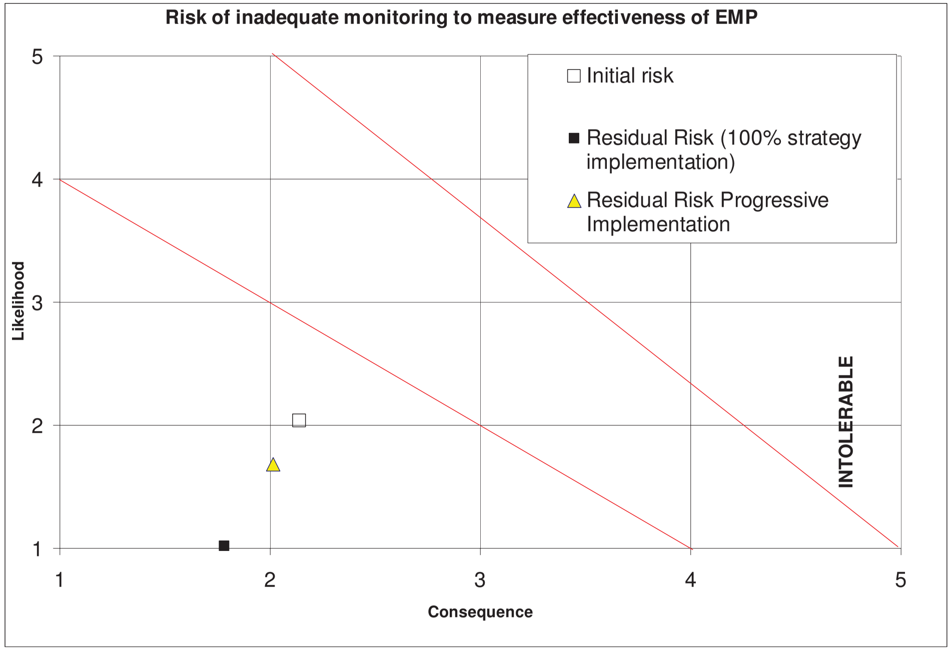


Figure 5.1 Risk Reduction Potential for Risk 5

Risk 6: Risk of inappropriate land management practices

Table 6.1 Primary strategies addressing Risk 6

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
6a	Minimise clearing of vegetation on privately owned land via new LEP template (eg Clause 5.9) and existing biodiversity strategy	Planning	0.09	7.0%	0.05	7.5%	1,2,3,14	0.23	0.08	0.019
6b	State government to develop stronger deterrents for failure to comply with planning controls and regulations	Planning	0.04	3.0%	0.01	1.0%	1,2,8,12,14	0.08	0.03	0.003
6c	Enhance compliance with development consent conditions (sediment erosion controls, stormwater controls, permeable surface area, water reduction devices, urban design, vegetation removal etc). Increase and enforce penalties for non-compliance and unauthorised development (including renovations etc)	Planning	0.04	3.0%	0.01	1.0%	1,2,12,14	0.07	0.02	0.001
6d	Increase compliance with development consent conditions (such as for maintenance of stormwater devices, permeable surface area, water reduction devices, urban design, vegetation removal etc) over the long term (ie, in the years after completion of a development) to ensure such conditions continue to be met	Compliance	0.07	5.0%	0.04	5.5%	1,2,12,14	0.10	0.05	0.005
6e	Increase the number of rural residential and smaller area landholders (less than 100 ha) attending management training for rural residential block and small farm management. The education should increase awareness of rural impacts on the estuarine environment, and provide solutions to manage such impacts.	Education	0.07	5.0%	0.04	5.5%	11,12	0.09	0.05	0.004
6f	Increase the area of non-urban land managed within its capability	Education	0.07	5.0%	0.04	5.5%	11,12	0.09	0.05	0.004
6g	Implement education strategy for commercial and industrial sectors of the catchment to increase awareness of their impact on estuarine environment, and provide solutions to mitigate such impacts	Education	0.04	3.0%	0.02	3.5%	8,11,12	0.07	0.04	0.003
6h	Educate residents as to best practise catchment management (fertilisers, chemicals, pesticides, threat of weeds to bushland, and encourage the removal of exotic species and replacement with suitable indigenous plants, domestic animals)	Education	0.04	3.0%	0.02	3.5%	12,13,15	0.07	0.07	0.005

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
6i	Provide incentives for the establishment of riparian filters to treat run-off from areas which may generate potentially high pollutant loads in runoff (eg, livestock, turf farms etc)	Capital/On-ground works	0.01	1.0%	0.01	1.0%	12,14	0.01	0.01	0.000
6j	Undertake soil conservation works such as fencing, gully control structures, track/trail, fire trails and rural road stabilisation and revegetation to reduce soil erosion	Capital/On-ground works	0.01	1.0%	0.01	1.0%	12,14	0.01	0.01	0.000

Table 6.2 Secondary strategies addressing Risk 6

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
1b	0.09	7.0%	0.01	1.0%	Risk 1
1g	0.09	7.0%	0.01	1.0%	Risk 1
1k	0.04	3.0%	0.01	1.0%	Risk 1
1a	0.09	6.5%	0.05	7.5%	Risk 1
1d	0.07	5.0%	0.04	5.5%	Risk 1
2a	0.07	5.0%	0.01	1.0%	Risk 2
2d	0.09	6.5%	0.05	7.5%	Risk 2
2b	0.04	3.0%	0.01	1.0%	Risk 2
2g	0.04	3.0%	0.02	3.5%	Risk 2
2n	0.01	1.0%	0.05	7.5%	Risk 2
2p	0.01	1.0%	0.02	3.5%	Risk 2
2q	0.01	1.0%	0.02	3.5%	Risk 2
2r	0.04	3.0%	0.01	1.0%	Risk 2
2v	0.01	1.0%	0.02	3.5%	Risk 2
3a	0.01	1.0%	0.01	2.0%	Risk 3
10a	0.01	1.0%	0.01	2.0%	Risk 10
12o	0.04	3.0%	0.02	3.5%	Risk 12
12s	0.01	1.0%	0.01	2.0%	Risk 12
12w	0.01	1.0%	0.02	3.5%	Risk 12
15a	0.03	2.0%	0.01	2.0%	Risk 15
15b	0.03	2.0%	0.01	2.0%	Risk 15

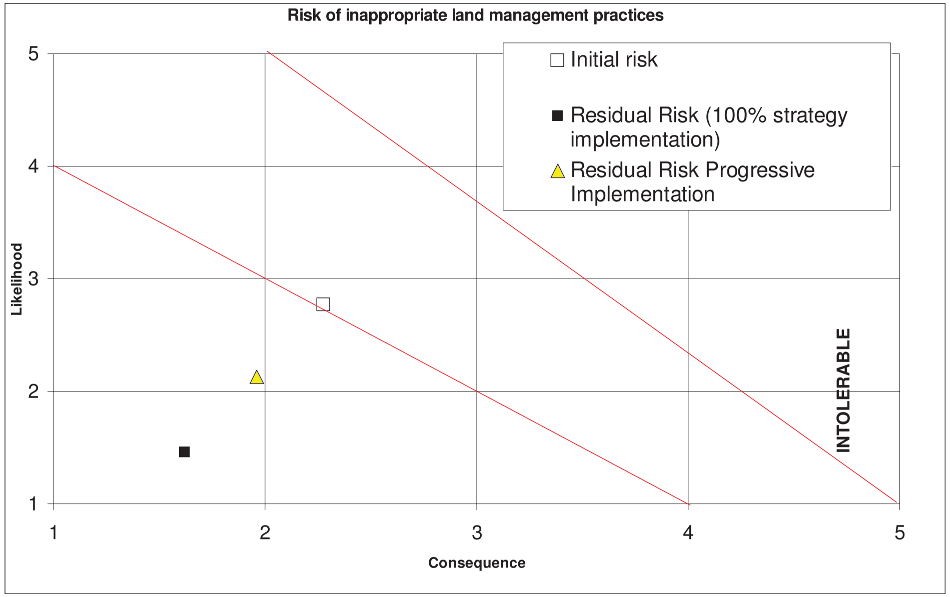


Figure 6.1 Risk Reduction Potential for Risk 6

Risk 7: Risk of inappropriate or excessive waterway access and activities

Table 7.1 Primary strategies addressing Risk 7

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
7a	Investigate which zoning, in accordance with LEP standard instrument, offers greatest protection to Big Bay and Marramarra Creek and incorporate into new LEP	Planning	0.03	3.0%	0.01	0.5%	2	0.06	0.01	0.001
7b	Use recommendations made in the Hornsby Shire Waterways Review (SJB, 2006) to inform waterway zoning in new LEP for the Lower Hawkesbury	Planning	0.05	5.0%	0.01	0.5%	2,8,12	0.11	0.07	0.008
7c	Update existing boating maps (boat and PWC speeds, access, and vessel size limits in various zones) for the entire Lower Hawkesbury to reflect findings of bank erosion studies, significant aquatic and riparian habitats, priority harvest area requirements, and other relevant environmental studies	Education	0.07	7.5%	0.07	7.0%	2,12,13	0.11	0.09	0.010
7d	Implement exclusion zones for recreational/private boating in specific oyster harvest area to protect sanitary water quality, using appropriate methods	Planning	0.03	3.0%	0.03	2.5%	2,12	0.03	0.03	0.001
7e	Investigate innovative methods to restrict the numbers of boats or the size of vessels in areas of high environmental sensitivity/significance.	Planning	0.03	3.0%	0.03	2.5%	2	0.06	0.03	0.002
7f	Ensure no net increase in existing moorings/berthings is permitted throughout the Lower Hawkesbury. Only permit additional berthings in marinas where they replace existing swing moorings.	Planning	0.05	5.0%	0.01	0.5%	2	0.07	0.01	0.001
7g	Progressively relocate or modify moorings considered to have a high environmental impact or are located in areas of high environmental significance or sensitivity.	Planning	0.00	0.5%	0.05	5.0%	1,2,12,14	0.04	0.09	0.003
7h	Dredging of existing navigation channels is supported subject to appropriate environmental approvals	Planning	0.03	3.0%	0.03	2.5%	2,12	0.03	0.03	0.001
7i	Enhance compliance activities and enforcement of penalties for all waterway regulations and consider increasing deterrents for non compliance with regulations (boat speed zones, effluent discharges, seagrass protection, littering, permanent occupation of boats, illegal overnight mooring of boats etc)	Compliance	0.00	0.5%	0.03	2.5%	12,15	0.02	0.06	0.001

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
7j	Develop and implement a program for auditing boats for methods used to contain waste from boat maintenance, effluent discharge practises, rubbish disposal, oil discharge from bilge pumps and all other environmental issues associated with boat usage. This could reasonably be combined with NSW Maritime audits of moorings.	Compliance	0.05	5.0%	0.05	5.0%	2,15	0.07	0.10	0.007
7k	Develop a "River Code" which outlines acceptable boating activities/behaviour (focussing on environmental impacts) and includes updated boating maps. The "River Code" could incorporate existing NSW Maritime and other brochures relating to the environment and appropriate behaviour (boat speeds etc). Options for distribution of "River Code" should be considered (eg, stickers, with licence applications, broad advertising etc)	Education	0.03	3.0%	0.03	2.5%		0.03	0.03	0.001

Table 7.1 Secondary strategies addressing Risk 7

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
1g	0.02	2.3%	0.02	1.5%	Risk 1
1e	0.03	3.0%	0.01	0.5%	Risk 1
1i	0.03	3.0%	0.03	2.5%	Risk 1
1d	0.07	7.5%	0.07	7.0%	Risk 1
2e	0.05	5.0%	0.05	5.0%	Risk 2
2x	0.00	0.5%	0.03	2.5%	Risk 2
2j	0.00	0.5%	0.03	2.5%	Risk 2
2k	0.00	0.5%	0.03	2.5%	Risk 2
2l	0.00	0.5%	0.03	2.5%	Risk 2
2v	0.07	7.5%	0.07	7.0%	Risk 2
2x	0.00	0.5%	0.03	2.5%	Risk 2
4a	0.00	0.5%	0.05	5.0%	Risk 4
5a	0.03	3.0%	0.03	2.5%	Risk 5
12a	0.03	3.0%	0.03	2.5%	Risk 12
12b	0.03	3.0%	0.03	2.5%	Risk 12
12x	0.03	3.0%	0.03	2.5%	Risk 12
12ll	0.00	0.5%	0.03	2.5%	Risk 12
12ll	0.00	0.5%	0.02	1.5%	Risk 12
15b	0.03	3.0%	0.03	2.5%	Risk 15
15d	0.03	3.0%	0.03	2.5%	Risk 15
15f	0.02	2.3%	0.02	1.5%	Risk 15
16c	0.03	3.0%	0.03	2.5%	Risk 16
16e	0.03	3.0%	0.03	2.5%	Risk 16
16f	0.03	3.0%	0.03	2.5%	Risk 16

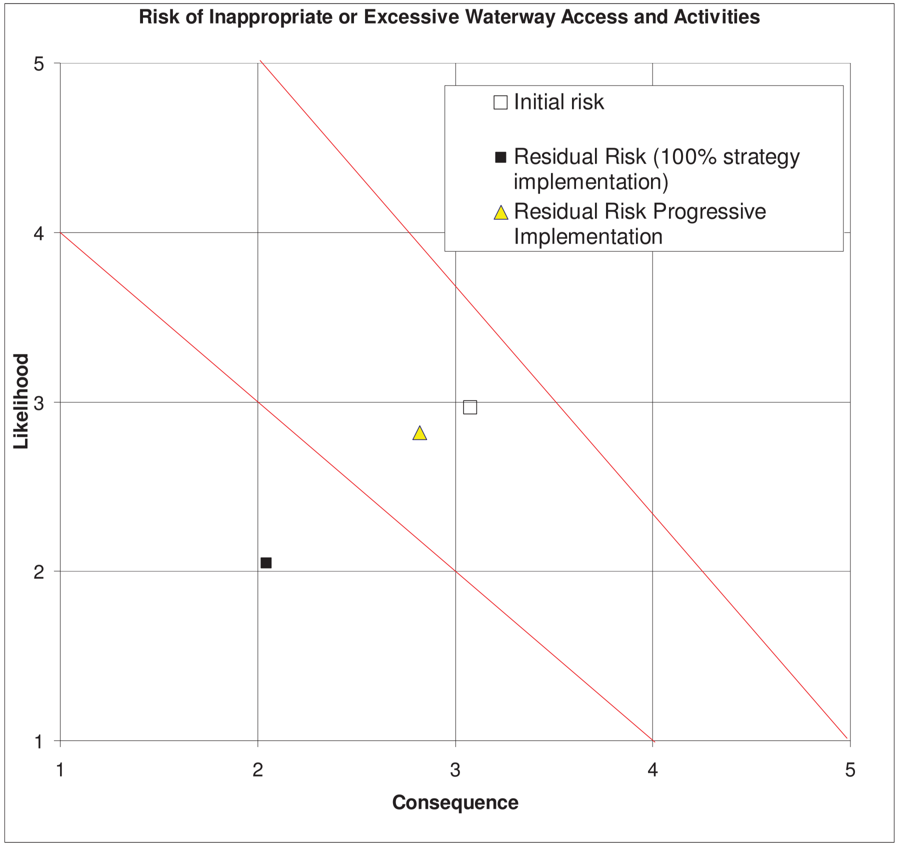


Figure 7.1 Risk Reduction Potential for Risk 7

Risk 8 Risk of inadequate or dysfunctional management mechanisms

Table 8.1 Primary strategies addressing Risk 8

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
8a	Transfer the management of Kangaroo Point pumpout to an appropriate State government agency	Planning	0.01	1.5%	0.01	1.5%	12	0.01	0.01	0.000
8b	Provide an annual progress report which gives a review of monitoring data, progress in implementing EMP actions and outlines the status of estuarine health	Research	0.02	4.0%	0.02	4.0%	5,9	0.24	0.09	0.022
8c	Undertake an independent review and update of the EMP every three years to continually improve performance in meeting the EMP objectives and protecting estuarine health	Research	0.02	4.0%	0.02	4.0%	5,9	0.24	0.09	0.022
8d	Provide a forum for discussion about issues relating to the estuary and EMP progress	Education	0.04	6.0%	0.03	5.5%	9,15	0.11	0.12	0.014
8e	Establish an MOU for data sharing (e.g. between SWC, NSW Food Authority, HSC, HNCMA, GSC, PC etc). Compile and manage a supporting database for the MOU for all monitoring data for the Lower Hawkesbury.	Research	0.02	3.5%	0.02	4.0%	N/A	0.02	0.02	0.000

Table 8.2 Secondary strategies addressing Risk 8

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
1b	0.02	3.5%	0.02	4.0%	Risk 1
1f	0.02	3.5%	0.02	4.0%	Risk 1
1c	0.01	1.5%	0.01	1.5%	Risk 1
1g	0.02	3.5%	0.02	4.0%	Risk 1
1e	0.01	1.5%	0.00	0.5%	Risk 1
1i	0.01	1.5%	0.01	1.5%	Risk 1
1a	0.02	3.5%	0.02	4.0%	Risk 1
1d	0.02	3.5%	0.02	4.0%	Risk 1
2a	0.02	3.5%	0.02	4.0%	Risk 1

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
2c	0.01	1.5%	0.01	1.5%	Risk 2
2f	0.01	1.0%	0.00	0.5%	Risk 2
2g	0.01	1.5%	0.00	0.5%	Risk 2
2v	0.02	3.5%	0.02	4.0%	Risk 2
5f	0.01	1.5%	0.02	4.0%	Risk 5
6b	0.01	1.5%			
6g	0.01	1.0%	0.01	1.5%	Risk 6
7b	0.06	9.5%	0.06	9.5%	Risk 7
9a	0.04	6.0%	0.03	5.5%	Risk 9
9b	0.02	3.5%	0.02	4.0%	Risk 9

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequenc e Risk Reduction (%)	Refer for Details
9c	0.04	6.0%	0.03	5.5%	Risk 9
9e	0.04	6.0%	0.03	5.5%	Risk 9
10b	0.01	1.5%	0.01	1.5%	Risk 10
12e	0.01	1.5%	0.01	1.5%	Risk 12
12g	0.01	1.5%	0.01	1.5%	Risk 12
12j	0.01	1.5%	0.00	0.5%	Risk 12
12k	0.01	1.5%	0.01	1.5%	Risk 12
12p	0.01	1.5%	0.01	1.5%	Risk 12
12t	0.01	1.5%	0.01	1.5%	Risk 12
12w	0.01	1.5%	0.01	1.5%	Risk 12
16a	0.01	1.0%	0.00	0.5%	Risk 16

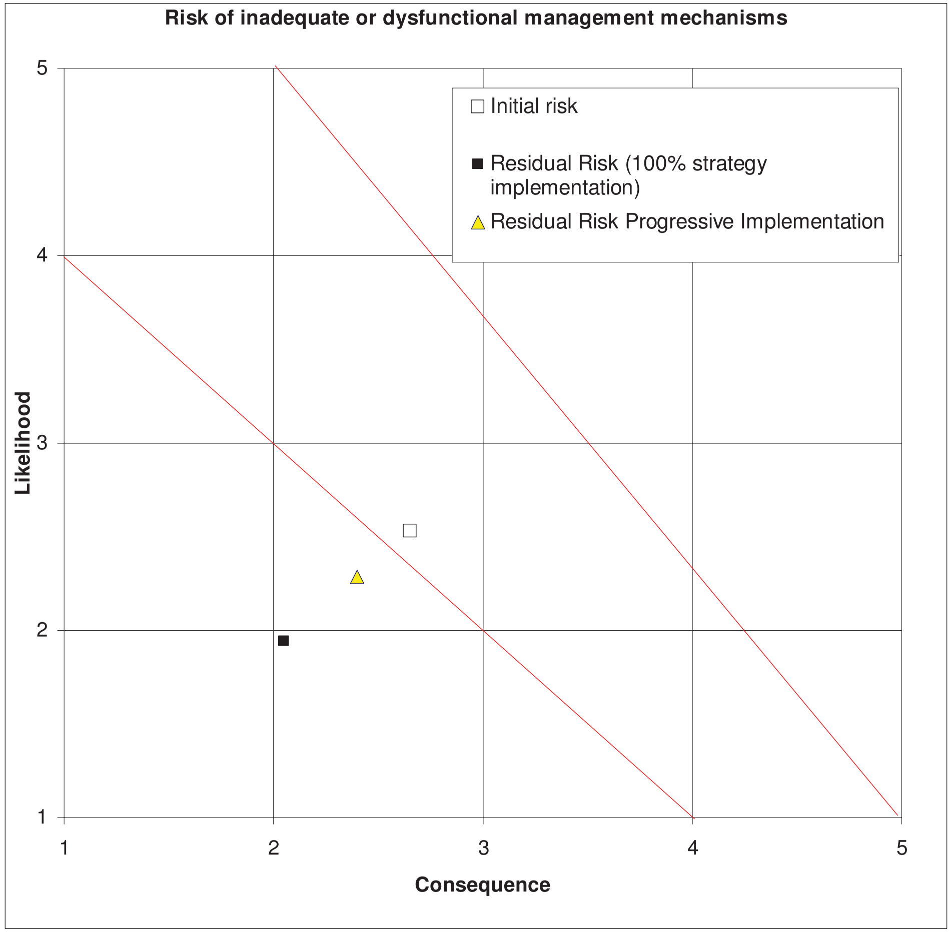


Figure 8.1 Risk Reduction Potential for Risk 8

Risk 9 Risk of not meeting EMP objectives within designated timeframes

Table 9.1 Primary strategies addressing Risk 9

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
9a	Liaise with relevant state agencies to ensure integration of EMP actions into their relevant planning instruments/management plans/strategy activities (eg HNCMA's Catchment Action Plan, DPI Fisheries Sustainable Oyster Aquaculture Strategy etc)	Planning	0.24	15.0%	0.06	12.0%	8	0.28	0.09	0.026
9b	Submit the EMP to appropriate Minister for gazettal by the NSW Government	Planning	0.32	20.0%	0.06	12.0%	8	0.34	0.08	0.029
9c	Establish a Lower Hawkesbury estuary management committee to be facilitated by HNCMA which incorporates Pittwater, Gosford, Hornsby Councils for a coordinated approach to estuary management.	Planning	0.24	15.0%	0.06	12.0%	8	0.28	0.09	0.026
9d	Investigate possibilities for involving universities, the CSIRO and/or other research organisations in research programs that implement actions within this plan (eg habitat mapping, biological monitoring program, etc.)	Research	0.06	4.0%	0.06	12.0%	16	0.08	0.08	0.006
9e	Lobby NSW Government to appoint an Estuary Manager for entire Lower Hawkesbury, to administer and update existing management plans and access State, Federal and private industry funding sources, and to develop a Hawkesbury estuary management plan.	Capital/On-ground works	0.29	18.0%	0.06	12.0%	8	0.30	0.07	0.021

Table 9.2 Secondary strategies addressing Risk 9

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
8b	0.16	10.0%	0.05	10.0%	Risk 8
8c	0.16	10.0%	0.05	10.0%	Risk 8
8d	0.06	4.0%	0.05	10.0%	Risk 8
16a	0.06	4.0%	0.05	10.0%	Risk 16

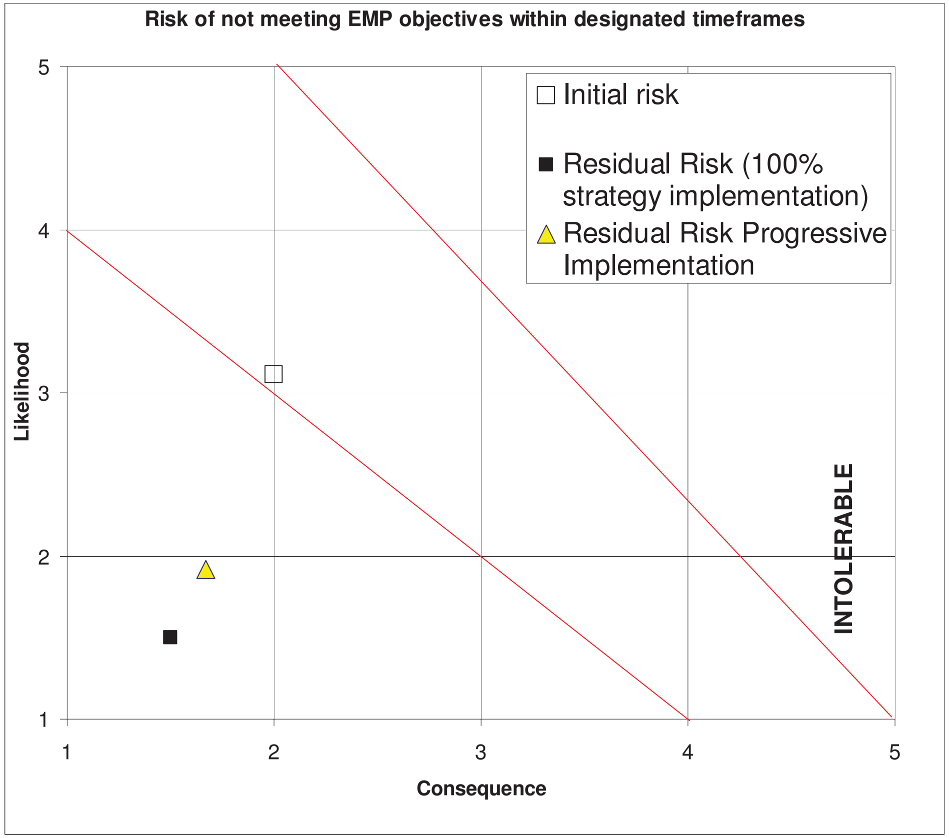


Figure 9.1 Risk reduction potential for Risk 9

Risk 10 Risk of climate change

Table 10.1 Primary strategies addressing Risk 10

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
10a	Incorporate Climate Change Strategy to mitigate local climate change impacts into planning instruments/ management plans/ strategy activities (ie with tools such as vulnerability maps)	Research	0.12	20.0%	0.09	10.0%	1, 6, 16	0.17	0.16	**0.027**
10b	Improve the understanding of local impacts which may arise from climate change (eg produce vulnerability maps) and the management responses to such impacts (changes to infrastructure, planning provisions etc)	Planning	0.12	20.0%	0.09	10.0%	1, 2, 8	0.16	0.12	**0.020**
10c	Through the estuary management program, investigate novel actions to reduce carbon emissions / aim toward carbon neutrality in undertaking estuary management tasks (eg, planting of trees to offset boat use when sampling, etc)	Research	0.06	10.0%	0.14	15.0%	2	0.06	0.15	**0.009**
10d	Develop a set of biological indicators (eg, food chain or structural biota) which will assist in measuring climate change impacts	Research	0.06	10.0%	0.09	10.0%	2, 5	0.12	0.12	**0.014**

Table 10.2 Secondary strategies addressing Risk 10

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
1b	0.06	**10.0%**	0.09	**10.0%**	**Risk 1**
1f	0.03	**5.0%**	0.09	**10.0%**	**Risk 1**
2b	0.09	**15.0%**	0.09	**10.0%**	**Risk 2**
3b	0.03	**5.0%**	0.14	**15.0%**	**Risk 3**
1a	0.03	**5.0%**	0.09	**10.0%**	**Risk 1**

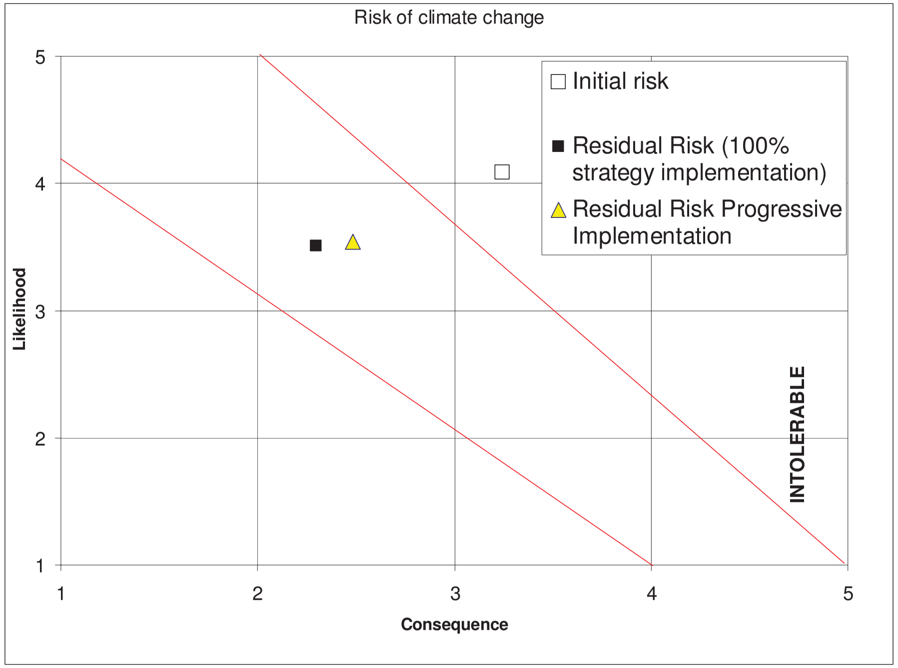


Figure 10.1 Risk Reduction Potential for Risk 10

Risk 11 Risk of regulated freshwater inflows

Table 11.1 Primary strategies addressing Risk 11

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
11a	Continue to lobby for reuse of water from STPs, to reduce freshwater demands in catchment	Research	0.12	15.0%	0.05	15.0%	2,12,16	0.15	0.09	0.014
11b	Regulate surface and ground water extraction (through licences etc) based upon assessment of required environmental flows.	Planning	0.15	20.0%	0.05	15.0%	2,12	0.16	0.06	0.010
11c	Develop and implement a plan of management to maintain sustainable environmental flows as a component of total water cycle management (based upon studies and modelling of sustainable flows).	Planning	0.05	7.0%	0.02	6.0%	N/A	0.05	0.02	0.001
11d	Increase the uptake of water and energy reduction devices through greater planning controls, incentives, free water reduction audits for homes/businesses etc	Planning	0.15	20.0%	0.05	15.0%	2	0.16	0.06	0.010
11e	Implement re-use options (such as dual reticulation, drinking water or other system) for treated effluent from STPs and their reticulation systems (eg sewer mining)	Planning	0.04	5.0%	0.02	6.0%	2	0.04	0.03	0.001
11f	Undertake a comprehensive environmental flows investigation for all tributaries to the Lower Hawkesbury. This should include determining groundwater and surface water extraction rates/volumes, contributions from all sources (urban runoff, STPs), and ecological flow requirements.	Capital works	0.05	7.0%	0.05	15.0%	2,12	0.06	0.10	0.006

Table 11.2 Secondary strategies addressing Risk 11

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
1a	0.02	3.0%	0.01	3.0%	Risk 1
6e	0.02	3.0%	0.01	3.0%	Risk 6
6f	0.02	3.0%	0.01	3.0%	Risk 6
6g	0.02	3.0%	0.01	3.0%	Risk 6

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
12w	0.02	3.0%	0.01	4.0%	Risk 12
12ee	0.02	3.0%	0.01	4.0%	Risk 12
12x	0.02	3.0%	0.01	4.0%	Risk 12
16g	0.04	5.0%	0.01	4.0%	Risk 16

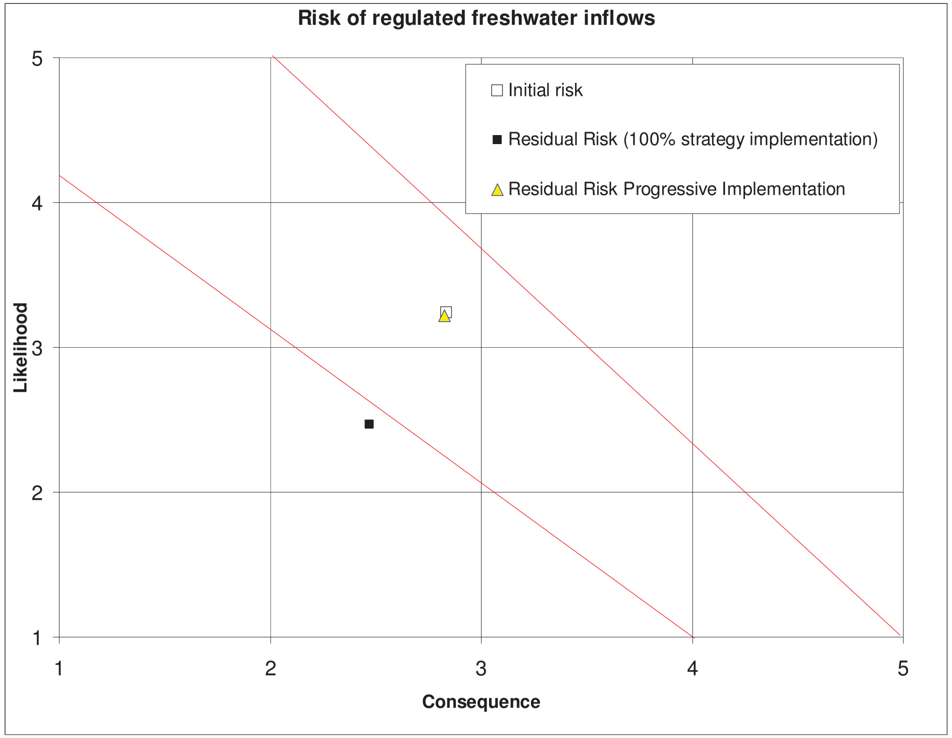


Figure 11.1 Risk Reduction Potential for Risk 11

Risk 12: Risk of water quality and sediment quality not meeting relevant environmental and human health standards

Table 12.1 Primary strategies addressing Risk 12

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
12a	Ensure fishing practises and oyster growing practises avoid artificially attracting large numbers of birds into oyster harvest zones	Planning	0.02	1.0%	0.01	1.0%	7	0.05	0.04	0.002
12b	Declare all waterway areas in the Lower Hawkesbury as a 'no discharge zone'	Planning	0.05	2.5%	0.01	1.0%	7	0.07	0.04	0.003
12c	Extend regulations for holding tanks to both grey and black water for recreational and commercial vessels.	Planning	0.05	2.5%	0.01	1.0%	7	0.07	0.04	0.003
12d	Lobby State government to increase deterrents for effluent discharges and other forms of pollution from vessels using the waterways.	Planning	0.02	1.0%	0.01	1.0%	7	0.02	0.04	0.001
12e	Prepare and implement a strategy for pumpouts across the Lower Hawkesbury Estuary (eg public use of commercial pumpouts, installation of additional public pumpouts etc)	Planning	0.05	2.5%	0.01	1.0%	8	0.06	0.02	0.001
12f	Provide incentives to install oil absorbent devices within bilge water holding tanks for all moored and berthed vessels.	Planning	0.05	2.5%	0.01	1.0%	15	0.06	0.05	0.003
12g	Review Emergency Spill Management Action Plans to ensure they are adequate to protect estuarine assets for all LGAs with Lower Hawkesbury waterway	Planning	0.02	1.0%	0.03	2.5%	8	0.03	0.04	0.001
12h	Provide incentives (eg grants or services) for a routine pumpout service to riverside settlements	Planning	0.05	2.5%	0.01	1.0%	1	0.06	0.03	0.002
12i	Develop a sewage management strategy for riverside settements as part of the 'Sanitary Surveys' undertaken by NSW Food Authority with consideration given to eliminating sewage leaching to the estuary.	Planning	0.05	2.5%	0.01	1.0%	N/A	0.05	0.01	0.001
12j	Encourage Sydney Water to consider an assessment of alternatives for management of sewage at Brooklyn, including effluent reuse.	Planning	0.01	0.8%	0.01	1.0%	8	0.02	0.02	0.000
12k	Ensure use of correct procedures for advising of algal blooms and marine pests (caulerpa, stingers etc) occurrence (such as through RACC)	Compliance	0.00	0.3%	0.03	2.5%	8	0.01	0.04	0.001
12l	Ensure compliance of correct waste disposal from Marinas and vessels	Compliance	0.02	1.0%	0.01	1.0%	7	0.02	0.03	0.001

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
12m	Ensure all boating facilities (marinas, slipways, private boat sheds, ferries, boat ramps etc) have containment areas for boat operation and maintenance (especially anti-foul paints, fuel storage tanks) and use best practise methods for mitigating environ	Compliance	0.05	2.5%	0.01	1.0%	3,4	0.18	0.07	0.012
12n	All Councils within the catchment to conduct Emergency spill management as per relevant Emergency Action Plan	Compliance	0.02	1.0%	0.03	2.5%	N/A	0.02	0.03	0.001
12o	Ensure all onsite septic systems throughout the catchment are audited for efficient operation and recommendations of audits enacted. Enforce penalties where correct operation and outcomes of audit are not enacted.	Compliance	0.05	2.5%	0.01	1.0%	6	0.09	0.04	0.003
12p	Sydney Water to continue to inform Councils and appropriate estuary users when STP's begin bypassing.	Compliance	0.00	0.3%	0.03	2.5%	8	0.01	0.04	0.001
12q	Implement a program to audit private sewer connections (such as NSW Government's former "pipechecks" program) and ensure audit recommendations are enacted	Compliance	0.01	0.8%	0.01	1.0%	15	0.02	0.03	0.001
12r	Reconsider licence conditions upon EPA licence renewals to reduce load of pollutant discharged	Compliance	0.01	0.8%	0.01	1.0%	2	0.02	0.02	0.000
12s	Ensure compliance with greywater reuse policy (ie, DWE and Council Policies)	Compliance	0.01	0.8%	0.01	1.0%	6	0.03	0.03	0.001
12t	Audit commercial and industrial areas with regard to mitigating impacts on estuarine assets.	Compliance	0.02	1.0%	0.03	2.5%	2,8	0.03	0.05	0.001
12u	Promote the use of oil absorbent devices for the removal of fuels and oils from bilge water	Education	0.02	1.0%	0.01	1.0%	N/A	0.02	0.01	0.000
12v	Provide information to residents to improve management of on-site sewage disposal, particularly in proximity to oyster harvesting areas, and on alternative disposal methods.	Education	0.02	1.0%	0.03	2.5%	2,15	0.05	0.11	0.006
12aa	Provide education to increase community acceptance of recycled water from STPs, and collection and re-use of stormwater, etc as per the STWCMS	Education	0.01	0.8%	0.01	1.0%	1	0.03	0.03	0.001
12bb	Investigate increasing wet weather capacity of STPs in catchment to ensure no bypassing during wet weather	Capital works	0.05	2.5%	0.01	1.0%	N/A	0.05	0.01	0.001
12y	Eliminate all sources of sewer overflows (including pumping stations, mushrooms, sewer chokes) in both dry and wet weather throughout the Lower Hawkesbury catchment.	Capital works	0.05	2.5%	0.01	1.0%	N/A	0.05	0.01	0.001

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
12z	Continue to upgrade STP effluent quality to minimise pollutant loads and enable greater re-use	Capital works	0.05	2.5%	0.01	1.0%	N/A	0.05	0.01	0.001
12cc	Install appropriate sewage disposal at public facilities located near waterways in the parks, reserves and foreshore recreational areas	Capital works	0.02	1.0%	0.01	1.0%	3	0.06	0.02	0.001
12w	Apply best practise stormwater management and asset management for stormwater infrastructure through preparation, implementation and regular review of stormwater management plans across the Lower Hawkesbury catchment.	Capital works	0.05	2.5%	0.01	1.0%	2,6,8,11	0.10	0.07	0.007
12bb	Ensure that all state-owned road and rail infrastructure within the catchment has adequate stormwater management for water quality and flows	Capital works	0.02	1.0%	0.01	1.0%	11	0.04	0.03	0.001
12x	Consider end of pipe treatment for all direct stormwater outlets to the estuary	Capital works	0.02	1.0%	0.01	1.0%	2,11,14	0.06	0.05	0.003
12dd	Investigate, and implement as appropriate, solid waste, green waste and recyclables collection for Riverside Settlements	Capital works	0.02	1.0%	0.01	1.0%	2,13,15	0.05	0.07	0.003
12ff	Ensure use of low residue herbicides and adopt practices to minimise input to the waterway	Capital works	0.02	1.0%	0.01	1.0%	2	0.03	0.02	0.001
12gg	Improve management of leachate and runoff from waste disposal sites	Capital works	0.02	1.0%	0.01	1.0%	N/A	0.02	0.01	0.000
12hh	Undertake remote and real time environmental monitoring for the Lower Hawkesbury (eg chlorophyll-a probes, wind speed probes, salinity, flow meters, satellite data), and make data available to the public.	Research	0.05	2.5%	0.04	3.3%	2,5,13,16	0.19	0.13	0.025
12ii	Investigate opportunities for allowing flushing under the causeway at Sandbrook Inlet	Research	0.00	0.3%	0.03	2.5%	14,16	0.04	0.10	0.005

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
12jj	Determine sources of sediment contamination and impacts of contaminants on estuarine health, through sediment and water quality testing across the Lower Hawkesbury	Research	0.02	1.0%	0.03	2.5%	2,16	0.06	0.08	0.004
12kk	Establish an ongoing sediment monitoring program for the estuary concentrating on areas of known heavy metal contamination or boat maintenance services.	Research	0.02	1.0%	0.03	2.5%	5,16	0.08	0.09	0.007
12ll	Complete mapping of stormwater drainage system in all areas of the Lower Hawkesbury catchment and ensure maps are regularly updated	Research	0.02	1.0%	0.03	2.5%	16	0.02	0.03	0.001

Table 12.2 Secondary strategies addressing Risk 12

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
1b	0.02	1.0%	0.01	1.0%	Risk 1
1f	0.02	1.0%	0.01	1.0%	Risk 1
1g	0.05	2.5%	0.01	1.0%	Risk 1
1j	0.05	2.5%	0.01	1.0%	Risk 1
1k	0.05	2.5%	0.01	1.0%	Risk 1
1a	0.02	1.0%	0.03	2.5%	Risk 1
2a	0.05	2.5%	0.01	1.0%	Risk 2
2v	0.02	1.0%	0.03	2.5%	Risk 2
4a	0.02	1.0%	0.01	1.0%	Risk 4
5b	0.02	1.0%	0.03	2.5%	Risk 5
5e	0.06	3.5%	0.06	4.3%	Risk 5
6b	0.02	1.0%	0.01	1.0%	Risk 6
6c	0.02	1.0%	0.01	1.0%	Risk 6

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
6d	0.02	1.0%	0.01	1.0%	Risk 6
6e	0.01	0.8%	0.01	1.0%	Risk 6
6f	0.02	1.0%	0.01	1.0%	Risk 6
6g	0.02	1.0%	0.01	1.0%	Risk 6
6h	0.02	1.0%	0.01	1.0%	Risk 6
6i	0.04	2.0%	0.01	1.0%	Risk 6
6j	0.04	2.0%	0.01	1.0%	Risk 6
7b	0.02	1.0%	0.00		
7c	0.02	1.0%	0.01	1.0%	Risk 7
7d	0.02	1.0%	0.01	1.0%	Risk 7
7g	0.02	1.0%	0.01	1.0%	Risk 7
7h	0.01	0.8%	0.01	1.0%	Risk 7
7i	0.01	0.5%	0.01	1.0%	Risk 7

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
8a	0.02	1.0%	0.01	1.0%	Risk 8
11b	0.05	2.5%	0.04	3.3%	Risk 11
11f	0.05	2.5%	0.01	1.0%	Risk 11
11a	0.05	2.5%	0.04	3.3%	Risk 11
15b	0.02	1.0%	0.03	2.5%	Risk 15
15d	0.02	1.0%	0.01	1.0%	Risk 15

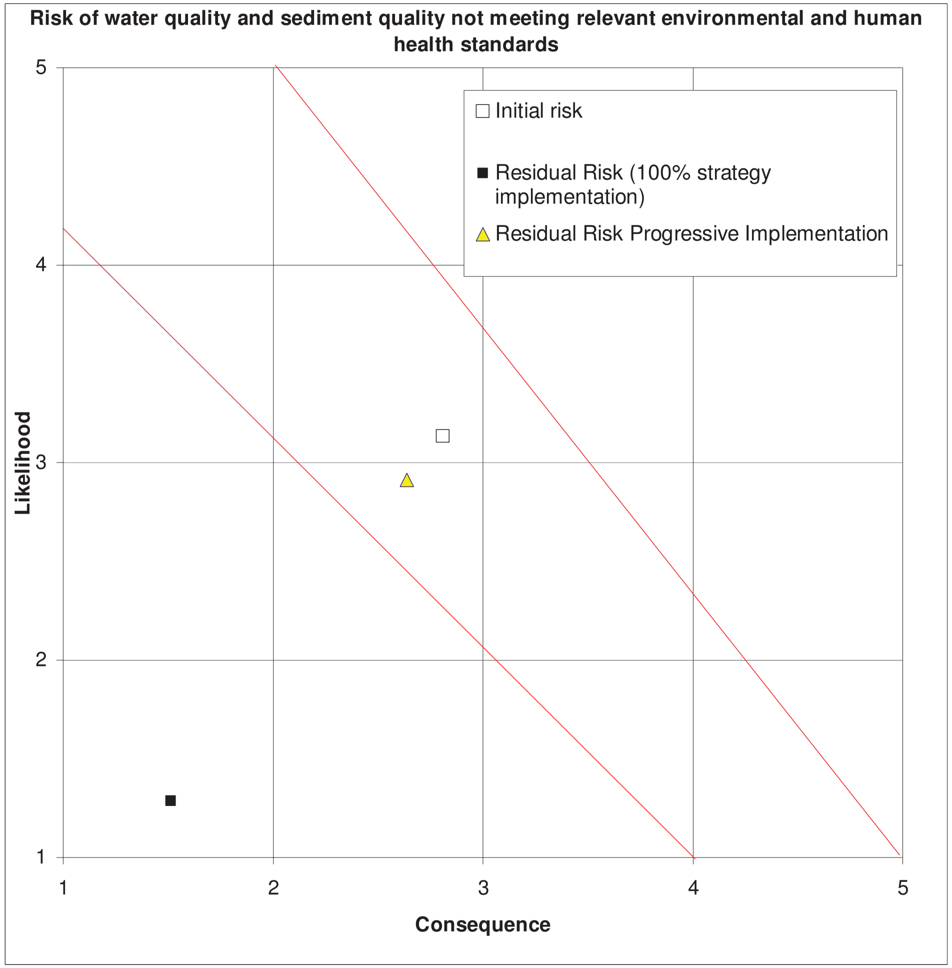


Figure 12.1 Risk Reduction Potential for risk 12

Risk 13 Risk of introduced pests, weeds and disease

Table 13.1 Primary strategies addressing Risk 13

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
13a	Enhance weed management programs across catchment, particularly in estuarine vegetation	Capital works	0.10	25.0%	0.07	25.0%	2,15	0.12	0.11	0.014
13b	Enhance existing pest eradication programs, particularly in estuarine habitats	Capital works	0.10	25.0%	0.07	25.0%	2,15	0.12	0.11	0.014

Table 13.2 Secondary strategies addressing Risk 13

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
1f	0.01	3.0%	0.01	2.0%	Risk 1
1g	0.01	3.0%	0.01	2.0%	Risk 1
1b	0.02	5.0%	0.01	2.0%	Risk 1
2p	0.01	2.0%	0.01	5.0%	Risk 2
2q	0.01	2.0%	0.01	5.0%	Risk 2
2r	0.02	5.0%	0.01	2.0%	Risk 2
2v	0.01	2.0%	0.01	2.0%	Risk 2
6h	0.02	4.0%	0.01	5.0%	Risk 6
7c	0.01	3.0%	0.01	4.0%	Risk 7
12dd	0.02	4.0%	0.01	4.0%	Risk 12
12hh	0.02	4.0%	0.01	4.0%	Risk 12
14c	0.04	10.0%	0.03	10.0%	Risk 14
15c	0.01	3.0%	0.01	3.0%	Risk 15

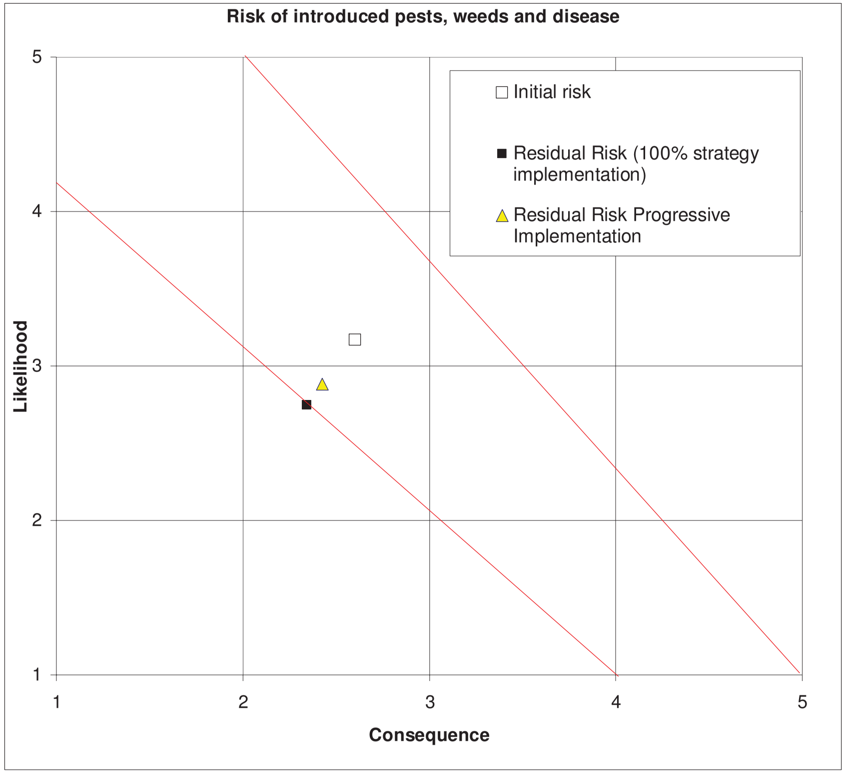


Figure 13.1 Risk Reduction Potential for Risk 13

Risk 14 Risk of excessive sedimentation (human induced)

Table 14.1 Primary strategies addressing Risk 14

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
14a	Investigate the potential for increased sedimentation as a result of bushfires and prescribed burning	Research	0.03	5.0%	0.01	4.0%	16	0.05	0.04	0.002
14b	Determine sedimentation rates for the estuary as required.	Research	0.02	3.0%	0.01	4.0%	16	0.04	0.03	0.001
14c	Prepare and implement creek rehabilitation plans to restore and maintain native vegetation in the riparian zone	Capital/On-ground works	0.07	14.0%	0.04	15.0%	2,13	0.12	0.07	0.009

Table 14.2 Secondary strategies addressing Risk 14

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
1g	0.07	14.0%	0.01	4.0%	Risk 1
2d	0.07	12.5%	0.01	4.0%	Risk 2
2n	0.07	12.5%	0.01	4.0%	Risk 2
3c	0.03	5.0%	0.01	4.0%	Risk 3
6a	0.03	5.0%	0.01	3.0%	Risk 6
6b	0.02	3.0%	0.01	3.0%	Risk 6
6c	0.03	5.0%	0.01	3.0%	Risk 6
6d	0.03	5.0%	0.01	3.0%	Risk 6
7g	0.01	2.0%	0.02	10.0%	Risk 7
7h	0.01	2.0%	0.04	15.0%	Risk 7
12x	0.01	2.0%	0.01	3.0%	Risk 12
12ii	0.01	2.0%	0.04	15.0%	Risk 12
16f	0.02	3.0%	0.01	3.0%	Risk 16
16g	0.03	5.0%	0.01	3.0%	Risk 16

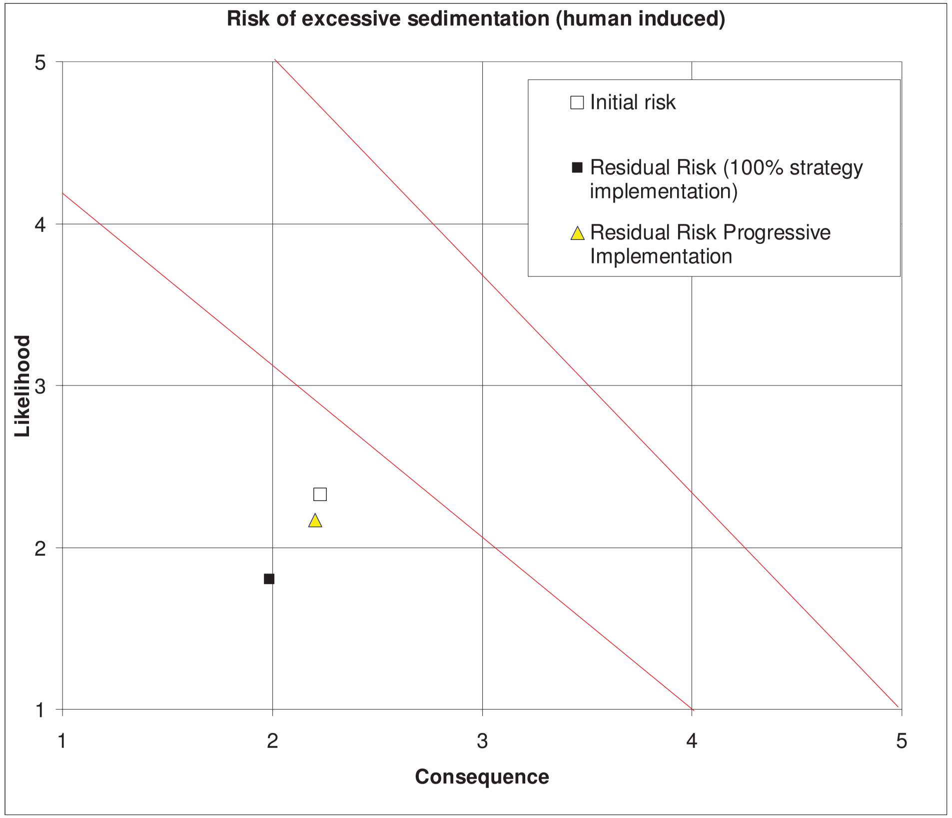


Figure 14.1 Risk Reduction Potential for Risk 14

Risk 15 Risk of residents and users lacking passion, awareness and appreciation of the estuary

Table 15.1 Primary strategies addressing Risk 15

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
15a	Consider a "Residents Pack" which outlines the estuary values, regional significance, ways to preserve such values, and includes existing brochures (from Councils, DPI Fisheries, NSW Maritime, NPWS etc) on stormwater, endemic plantings, bushcare, boating maps, seagrass maps, aquatic weeds, etc	Education	0.05	9.0%	0.14	9.0%	2,6	0.09	0.15	0.013
15b	Encourage vigilance in reporting non compliance with regulations and environmental conditions/degradation (eg, sediment erosion controls, OSSMs, vegetation removal/destruction, stormwater control and maintenance, recreational activities etc) and pollution incidents (e.g. algal blooms, oils spills, chemical spills etc) to appropriate authorities (e.g., "river hood watch program")	Education	0.03	5.0%	0.08	5.0%	2,3,6,7,12	0.14	0.16	0.022
15c	Encourage local residents to participate in conservation and bush regeneration schemes	Education	0.03	5.0%	0.08	5.0%	13	0.04	0.08	0.003
15d	Educate recreational users/general visitors about estuary values and the estuarine system, recreational impacts, and actions they may take to reduce impacts on priority areas (seagrass, harvest areas, recreational swimming) in the estuary (e.g. signage, boating stickers, brochures etc)	Education	0.03	5.0%	0.08	5.0%	2,3,12,7	0.12	0.12	0.014
15e	Provide a general understanding and appreciation of Aboriginal culture and occupation of the Lower Hawkesbury, within the parks, reserves and other foreshore recreational areas, with appropriate brochures, signage and interpretation programs.	Education	0.03	5.0%	0.08	5.0%	2	0.03	0.08	0.003
15f	Participate in community events to highlight unique values of estuary and promote estuary management program	Education	0.01	2.5%	0.04	2.5%	3,7	0.07	0.06	0.004
15g	Provide information about the estuary on the Internet through all local councils' home pages, and promote the estuaries website (www.estuary.hornsby.nsw.gov.au) and links between Councils websites for Lower Hawkesbury.	Education	0.01	2.5%	0.04	2.5%	N/A	0.01	0.04	0.001
15h	Develop a schools estuarine education program, which includes a resource kit and practical experience in bush regeneration work, water quality monitoring and other tasks	Education	0.03	5.0%	0.08	5.0%	N/A	0.03	0.08	0.002

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
15i	Investigate program of guided tours to promote education about the estuary	Education	0.03	5.0%	0.08	5.0%	N/A	0.03	0.08	0.002
15j	Provide interpretive / heritage signage at strategic locations to explain key features, waterways and estuary significance	Capital/On-ground works	0.03	5.0%	0.08	5.0%	2	0.03	0.08	0.003

Table 15.2 Secondary strategies addressing Risk 15

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
2m	0.01	2.5%	0.04	2.5%	Risk 2
2s	0.03	5.0%	0.08	5.0%	Risk 2
2v	0.03	5.0%	0.08	5.0%	Risk 2
2w	0.01	2.5%	0.04	2.5%	Risk 2
4b	0.01	2.5%	0.04	2.5%	Risk 4
6h	0.01	2.5%	0.04	2.5%	Risk 6
7i	0.01	2.5%	0.04	2.5%	Risk 7
7j	0.01	2.5%	0.04	2.5%	Risk 7
8d	0.01	2.5%	0.04	2.5%	Risk 8
9d	0.01	2.5%	0.04	2.5%	Risk 11
12ll	0.01	2.5%	0.04	2.5%	Risk 12
12q	0.01	1.0%	0.02	1.0%	Risk 12
12v	0.03	5.0%	0.08	5.0%	Risk 12
12dd	0.01	2.5%	0.04	2.5%	Risk 12
13a	0.01	2.5%	0.04	2.5%	Risk 13
13b	0.01	2.5%	0.04	2.5%	Risk 13

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
16b	0.01	2.5%	0.04	2.5%	Risk 16

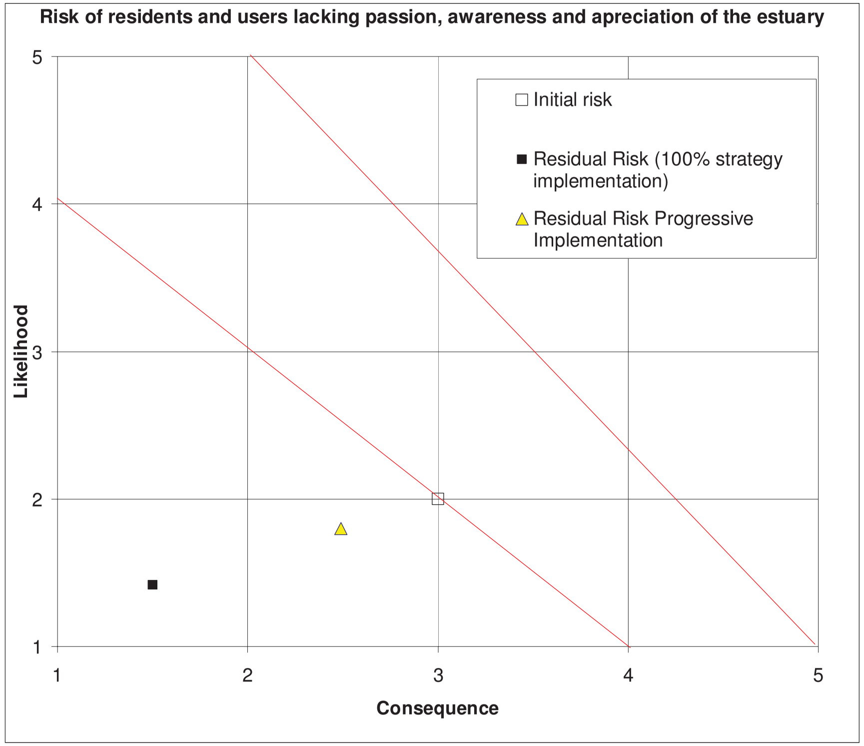


Figure 15.1 Risk Reduction Potential for Risk 15

Risk 16 Risk of insufficient research

Table 16.1 Primary strategies addressing Risk 16

Strategy #	Strategy	Category	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Other risks addressed	Aggregated risk reduction score - likelihood	Aggregated risk reduction score - consequence	Risk Reduction Potential
16a	Establish MOU's (Memorandums of Understanding) between Council and universities and other research organisations to encourage research into the estuary	Planning	0.01	3.0%	0.02	2.5%	8,9	0.08	0.07	0.006
16b	Develop a catchment and estuarine model to illustrate the interactions between the estuary and catchment influences	Research	0.03	6.0%	0.04	5.0%	2,15	0.05	0.08	0.004
16c	Undertake periodic surveys of the types, numbers and locations of various recreational activities on all foreshores and waterways of the Lower Hawkesbury.	Research	0.02	3.5%	0.04	5.0%	3,7	0.10	0.07	0.007
16d	Undertake periodic survey of recreational and commercial fishers to determine volumes, species and locations of fish caught across the entire Hawkesbury Estuary	Research	0.02	3.5%	0.04	5.0%	2	0.03	0.04	0.001
16e	Undertake research into the impact of catch numbers, trawl methods (such as otter boards) and other influences on the long term sustainability of all fish species (target and non-target) in the Hawkesbury Estuary	Research	0.03	6.0%	0.04	5.0%	2,7	0.06	0.07	0.005
16f	Undertake a study to identify locations of bank erosion in the estuary and determine the causes of such erosion (e.g., wind waves, boat wake) and remediate as required	Research	0.03	6.0%	0.04	5.0%	2,3,7,14	0.11	0.08	0.009
16g	Determine physical processes (hydrodynamics) of the estuary using in stream flow gauges, bathymetric survey etc	Research	0.03	6.0%	0.04	5.0%	2,11,14	0.10	0.07	0.007

Table 16.2 Secondary strategies addressing Risk 16

Strategy #	Likelihood Risk Reduction	Likelihood Risk Reduction (%)	Consequence Risk Reduction	Consequence Risk Reduction (%)	Refer for Details
1a	0.03	6.0%	0.04	5.0%	Risk 1
2o	0.01	3.0%	0.04	5.0%	Risk 2
5a	0.01	3.0%	0.04	5.0%	Risk 5
5b	0.01	3.0%	0.04	5.0%	Risk 5
5c	0.01	3.0%	0.02	2.5%	Risk 5
5g	0.01	2.0%	0.02	2.5%	Risk 5
9d	0.01	3.0%	0.02	2.5%	Risk 9
10a	0.03	6.0%	0.04	5.0%	Risk 10
11a	0.03	6.0%	0.04	5.0%	Risk 11
12hh	0.02	3.5%	0.04	5.0%	Risk 12
12ii	0.03	6.0%	0.04	5.0%	Risk 12
12jj	0.03	6.0%	0.04	5.0%	Risk 12
12kk	0.01	2.0%	0.04	5.0%	Risk 12
12ll	0.01	1.5%	0.02	3.0%	Risk 12
14a	0.03	6.0%	0.03	4.0%	Risk 14
14b	0.03	6.0%	0.02	3.0%	Risk 14

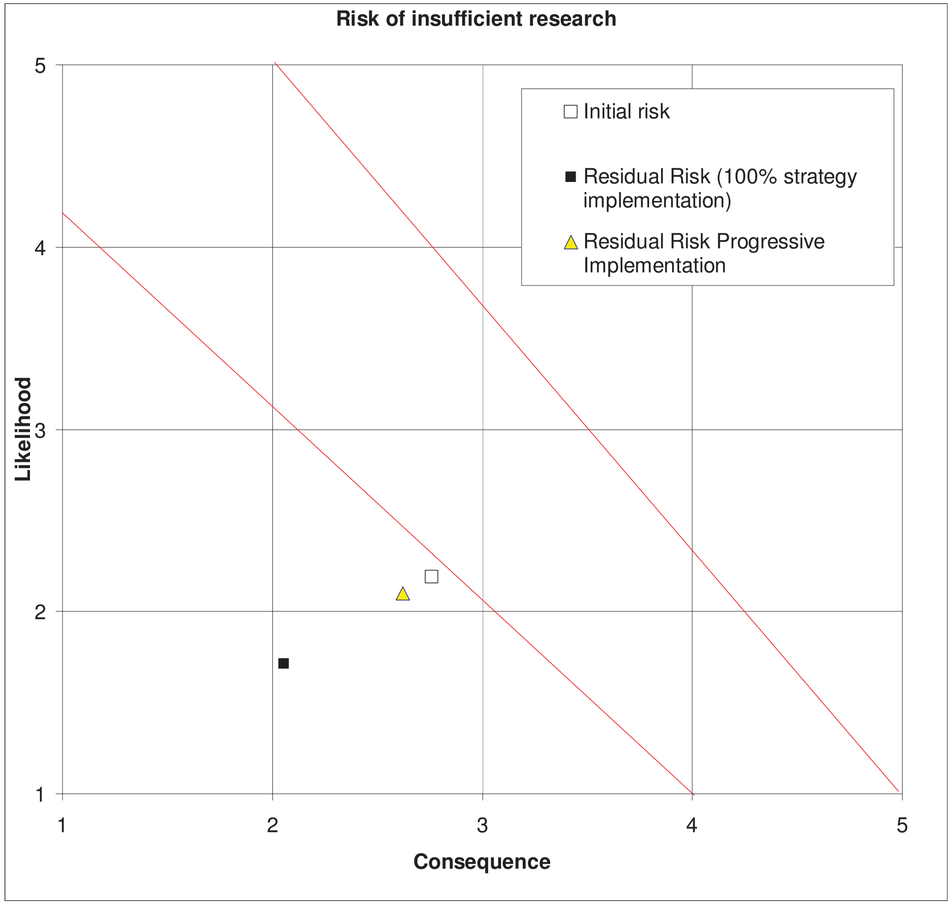


Figure 16.1 Risk Reduction Potential for Risk 16

APPENDIX F: TERMS OF REFERENCE FOR LOWER HAWKESBURY ESTUARY MANAGEMENT COMMITTEE

1. Name

- The name of the committee shall be the "Lower Hawkesbury Estuary Management Committee".
- This is a committee of Hornsby Shire Council. Hornsby Shire Council is the lead agency in the preparation and implementation of the Lower Hawkesbury Estuary Management Plan.

2. Membership

- The committee will be convened by a Chairperson who is a Councillor of Hornsby Shire Council.
- A Vice Chairperson who is a Councillor of Hornsby Shire Council.
- Membership on the committee is offered to community, commercial and government representatives. Membership will be offered to:
  - Department of Environment and Climate Change
  - NSW Maritime
  - NSW DPI Fisheries
  - Sydney Water Corporation
  - Gosford City Council
  - Hornsby Shire Council
  - NSW National Parks and Wildlife Service
  - NSW Environment Protection Authority
  - Hawkesbury Nepean Catchment Management Authority
  - Residents of Riverside Settlements
  - Commercial Fishing representation
  - Oyster Farming representation
  - Boating associations
  - Recreational Fishing Clubs
- Membership selection will be determined according to the following procedure;
  - Advertisement within local papers inviting community and commercial representatives
  - Government representation will be sought via letter request to the agencies nominated above.
  - Initial membership to establish the Lower Hawkesbury Estuary Management Committee will be determined by the Appointed Chair and Vice Chairperson in consultation with Manager-Water Catchments and Team Leader- Estuary Management
  - Commercial and community membership selection will be based on;

    - Knowledge; of the Estuary and issues influencing natural resource management
    - Involvement; in the preparation of the Lower Hawkesbury Estuary Management Plan
    - Representation; involvement and representation of local community and commercial groups
    - Willingness; to attend meetings as required and be actively involved in projects that arise from the committee

- Membership on the Lower Hawkesbury Estuary Management Committee will be for a period of 3 years. At the completion of the 3 year of membership community and commercial membership positions will be readvertised.

3. Quorum

- The quorum of the committee will be half the membership plus one member.

4. Chairperson

- The Chairperson shall be a Councilor appointed by Hornsby Shire Council:
- In the absence of the appointed Chairperson, the Vice Chairperson shall convene the meeting.
- In the absence of the Chairperson and the Vice Chairperson, the Team Leader - Estuary Management shall convene the meeting.

5. Absences

- Should any member be absent from a meeting, a person nominated by the absentee can be substituted.

6. Observers

- Observer status may be granted to other persons attending Lower Hawkesbury Estuary Management Committee meetings as deemed appropriate (via general consensus) by the Lower Hawkesbury Estuary Management Committee.

7. Review of the Terms of Reference

- The Terms of Reference shall be in place until the Lower Hawkesbury Estuary Management Plan has been completed. The Terms of Reference will be reviewed every 3 years to coincide with membership readvertisement. Hornsby Shire Council shall reserve the right to alter the Terms of reference at any stage.

8. Agenda

- The Chairperson shall cause an agenda and related papers to be circulated to committee members at least one week prior to the scheduled meeting date;

- The Chairperson shall be assisted in administration of the committee by Hornsby Shire Council's Water Catchments Team; and
- At least two meetings shall be scheduled per financial year.

9. Minutes and Reports

- The Chairperson shall arrange for the minutes of each meeting to be taken, circulated before the next meeting and confirmed at the next meeting; and
- The Chairperson shall ensure that the confirmed minutes of each committee meeting are placed within Councils record management system.

10. Purpose of the Committee

- The Lower Hawkesbury Estuary Management Committee is responsible for overseeing the implementation of actions and strategies as contained within the Lower Hawkesbury Estuary Management Plan.
- The committee does not have delegation under s377 of the Local Government Act, 1993 and does not formally exercise Council's powers and functions. Hence, the committee cannot make decisions on behalf of Council. The committee can make recommendations with regard to estuary management matters to Council following due process.

11. Vacancy

- In the event of a casual vacancy occurring, a new committee member may be appointed by Council;
- Any committee member who has three or more consecutive absences, without achieving leave of absence, is to be asked to show cause why they should remain a member of the committee; and
- Recruitment of new or replacement members will involve calling for nominations and the determination of the nominations will be made by the Lower Hawkesbury Estuary Management Committee in conjunction with Hornsby Shire Council.
- In the event of a death of a committee member, nominations for a person who fulfills the role of the deceased shall be called.

12. Completion of the Lower Hawkesbury Estuary Management Plan

- Upon completion of the Lower Hawkesbury Estuary Management Plan this committee and functions thereof will be terminated.



Hawkesbury estuary program

www.estuary.hornsby.nsw.gov.au

HORNSBY SHIRE COUNCIL

Hornsby Shire Council
296 Pacific Highway
Hornsby NSW 2077

Telephone: 9847 6666
8.30am – 5.00pm Monday to Friday

www.hornsby.nsw.gov.au