APPENDIX L: HEXHAM SWAMP PLAN OF MANAGEMENT (HCRCMA, 2003)

Hexham Swamp Rehabilitation Project

Management Plan 2003 – 2007 *(post-opening of floodgates)*

PREFACE: HUNTER RIVER ESTUARY

… passing through the umbrageous parts of the forest, where lofty trees and low scrub interwoven into a thick veil that shut out the sunlight … many of the large trees we passed presented splendid specimens of the stag-horn fern, growing upon them, about fifty feet from the ground.

J Askew, describing the vegetation along the west bank of the Hunter River near the contemporary 'Travellers Rest' at Hexham (1857:296-7, in Albrecht G, 2000)

Albrecht (2000) further notes that "Between *Toorrnbing* Creek (Iron-Bark Creek) and Maitland the river runs close to many wetlands and swamps. The largest is *Burraghihnbihng* (Hexham swamp) while many other smaller lagoons are cut off from the river during dry times. Albrecht quotes Peter Cunningham's comments (1827:150-151):

The country back from the river consists of rising hills of inferior soil, with fertile flooded vine brushes, watered by lagoons communicating with the river. These lagoons swarm with the most delicious fish; and during the dry summers, when the water is low, the natives wade in and actually drag out cart-loads thereof, including immense eels.

Such descriptions of the richness and beauty of Hexham Swamp and surrounds compared with the reality of its degree of degradation in 1990, encouraged the (then) Hunter Catchment Management Trust to initiate a study of the Ironbark Creek catchment. In 1996 the Ironbark Creek Total Catchment Management Strategy was released to document this degradation and requirements for the Swamp's rehabilitation. The Hexham Swamp Rehabilitation Project was established to implement the key recommendation of the Strategy, a bold initiative to return tidal flows to one of the largest wetland complexes in coastal New South Wales. To again elicit such reactions as noted by Albrecht will indicate to all who have toiled on the Hexham Project that it has been a success.

Wetlands of the Hunter River estuary form part of a corridor of related natural areas in the Lower Hunter which extends from Stockton Bight to Mount Sugarloaf and beyond. The estuary's wetlands are of particular benefit on many levels, locally to internationally, as habitat for fish and crustaceans, migratory shorebirds, threatened species and ecological communities as well as open space for recreation and environmentally-based tourism, and an outdoor laboratory and demonstration site for education, training and research.

The Hunter-Central Rivers Catchment Management Authority's wetland rehabilitation project sites within the estuary (Kooragang Project: Ash Island, Tomago Wetlands and Stockton Sandspit; and Hexham Swamp) are of key conservation significance to the biodiversity of the corridor. These sites also provide unique opportunities for recreation, education, training and research that complement rather than duplicate related initiatives in the corridor. As such, the revised management plans for both CMA projects have been developed to be consistent with and complement all other conservation initiatives in the estuary in order to increase the overall benefits derived from the projects' activities.

Given the level of modifications made to the estuary to date, it is a tribute to the resilience and inherent productivity of estuarine ecosystems in general and to the Hunter estuary in particular that world-class natural areas continue to exist adjacent to globally significant industrial facilities. Preserving, conserving and restoring the remaining natural areas of the estuary are matters of urgency in developing the Hunter estuary as a model for management of wetlands in an industrialised and urbanised estuary.

EXECUTIVE SUMMARY

The Hexham Swamp Rehabilitation Project is a bold initiative to return tidal flows to one of the largest wetland complexes in coastal New South Wales. It originated from community concerns at the degraded state of the estuarine wetlands within Hexham Swamp since the installation of floodgates at the mouth of Ironbark Creek in the early 1970s. The (then) Hunter Catchment Management Trust (CMA) coordinated a study of Ironbark Creek catchment and in 1996 released the Ironbark Creek Total Catchment Management Strategy, in which the degree of degradation of the Swamp and requirements for its rehabilitation were fully documented.

The process for repair of the Swamp adopted by the CMA and continued by its successor, the Hunter-Central Rivers Catchment Management Authority (CMA) involves:

- securing government funding to assist with implementation of the Project;
- establishing a boundary for the Project based on extensive survey and tidal inundation modelling;
- purchasing most private grazing land and some public land within the Project area;
- acquiring 'easements to inundate' over some land on the edge of the Swamp;
- negotiating agreements with owners of infrastructure and facilities within the Swamp to ensure that these activities continue to function without detriment resulting from the Project, and that to the greatest extent possible, infrastructure does not adversely impact on the Project;
- carrying out protective works to infrastructure, facilities and land, where necessary;
- preparing an Environmental Impact Statement for submission with a development application;
- establishing a Project Committee to advise on Project implementation;
- monitoring ecological, hydrological and water quality parameters prior to alteration of the floodgates' operation to establish baseline conditions within the Swamp, and continuing this monitoring for several years after gate opening;
- keeping the community informed of progress with the Project and involved in Project activities, particularly residents of surrounding areas and Aboriginal traditional owners, and ensuring that their concerns are appropriately addressed;
- preparing a Management Plan to guide implementation of the Project;
- establishing and managing the lands as a protected area under a formal conservation agreement;
- subject to approval of the development application, increasing tidal flows into the Swamp through staged opening of the eight floodgates at the mouth of Ironbark Creek;
- managing land acquired with respect to feral animals and weeds, and erecting/ maintaining fences;

- re-establishing native vegetation through planting or natural regeneration;
- resolving the long-term ownership and management of land acquired for the Project.

The Project covers an area of almost 2,000 ha. Land identified as being within the Project area is currently owned by 47 individuals/organisations and a further seven organisations have interests in the Swamp. The CMA will acquire around 800 ha of private and public land as part of the Project, and proposes to transfer it to the management of the NSW Department of Environment and Conservation (DEC) (previously National Parks and Wildlife Service) in the future. Hexham Swamp Nature Reserve, managed by DEC, is adjacent to the land being acquired by the CMA and forms a significant part of the Project area. The remaining land within the Project area will be subject to 'easements to inundate' or other agreements with the landowners.

The Project is of a greater scale and complexity than other similar projects in New South Wales. Its successful completion presents an exciting challenge for the community and governments at all levels to demonstrate that difficult environmental issues can be tackled and resolved through cooperative effort.

The Hunter-Central Rivers Catchment Management Authority's wetland rehabilitation project sites within the Hunter estuary (Kooragang Project: Ash Island, Tomago Wetlands and Stockton Sandspit; and Hexham Swamp) are of key conservation significance to the biodiversity of a corridor which extends from Stockton Bight to Mount Sugarloaf and beyond. These sites also provide unique opportunities for recreation, education, training and research that complement rather than duplicate related initiatives in the corridor. As such, the revised management plans for both CMA projects have been developed to be consistent with and complement all other conservation initiatives in the estuary in order to increase the overall benefits derived from the projects' activities.

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1 INTRODUCTION

The abbreviations used in the Executive Summary are employed throughout the main document.

1.1 Background

The Swamp consists of an area of some 2,900 ha of freshwater and estuarine wetlands on the lower floodplain of the Hunter River. It comprises about a quarter of the catchment of Ironbark Creek (12,000 ha), which is the largest tidal creek in the Hunter River Estuary. A small area in the north-eastern corner of the Swamp drains into Purgatory Creek.

The Swamp is dominated by freshwater wetlands, with estuarine wetlands confined to small areas near Ironbark Creek. The proportion occupied by estuarine wetlands has decreased considerably in the last thirty years due to the restriction of tidal exchange which followed from construction and subsequent one-way operation of floodgates at the mouths of Ironbark Creek and Purgatory Creek.

The installation and operation of the floodgates has reduced flooding within the Swamp and has allowed cattle and horse grazing to expand. However, as large areas of mangroves and saltmarsh were replaced by meadow and reed communities (as a consequence of changes in hydrology and salinity), the area of nursery habitat for fish, prawns and other marine organisms was reduced. In addition, the number of waterbirds and other bird species have decreased markedly, and weeds and pest species such as alligator weed, pampas grass, water hyacinth, feral pigs and foxes have increased.

Reduced tidal exchange also resulted in oxidation of acid sulphate soils, lowering pH levels in several tributaries and raising soluble iron levels in the local waterways.

The deterioration of the Swamp is considered unacceptable by sections of the community and became even more poignant following the declaration in 1990 of the Hexham Swamp Nature Reserve, which covers about one-third (900 ha) of the Swamp.

In order to address problems such as those outlined above, the Ironbark Creek Total Catchment Management Committee (ICTCMC) was formed and released its Total Catchment Management Strategy in 1996 (ICTCMC 1996). This Strategy contained a list of recommendations divided into three Priority classes. Among the Priority 1 Recommendations were:

> "Improve tidal flows to reinstate and sustain healthy mangroves along the banks of Ironbark Creek, [and its tributaries] Fishery Creek and Shelley Creek";
>
> "Develop and implement appropriate floodgate and other management procedures, following proper evaluation, continue to exclude Hunter River flooding to the extent of the existing structures but allow rehabilitation of the Hexham Swamp estuarine ecosystem in the long term".

In response to these recommendations, the CMA commissioned WBM Oceanics Pty Ltd to prepare an EIS to evaluate the impacts of each of a range of options to modify the operation of the floodgates, including the "do-nothing" option. The EIS is being prepared. The final EIS will be based on a preferred option of floodgate opening/operation and protective works. This is the option on which this Management Plan is based and in turn this document will form part of the EIS.

The preferred option involves the eventual opening of all eight floodgates at the mouth of Ironbark Creek in such a manner that the highest tides are excluded (in order to minimise breeding of saltmarsh mosquito species in pools left behind during the highest tides – see Section 5.6), and the construction of low bunds to exclude tidal flows from some areas. The opening will be a staged process, commencing with a single gate opening followed by a monitoring period before the opening of additional floodgates. Subsequent gate openings will be subject to the results of monitoring of the previous stage. Should monitoring results indicate that further gate openings would be deleterious to the overall values of the area, or should safety be compromised, no further gates will be opened.

The gates will be fully operational as floodgates. That is, if there is any risk of flooding from the Hunter River at any time, the gates will be closed.

In addition to the EIS process, funding has been obtained from both the NSW and Federal Governments to implement the preferred option, covering an impact area of approximately 2,000 ha. A majority of the governments' grant funding has been provided for the purchase of private and some public land within the Project area.

The Federal funding has been provided on the basis that the land acquired with grant funding within the Project area is managed as an IUCN Category IV Protected Area (Habitat/Species Management). This is defined as an "area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species" (ANCA 1995). In the present case, the main form of intervention will be the opening of the floodgates to re-establish a tidal regime within the Swamp. A full description of Category IV is provided in Appendix D.

One implication of the adoption of Category IV is that cattle grazing operations will cease to be managed on a commercial basis. However, cattle grazing may continue as a tool to manage excessive vegetation growth and weed infestations within the Project area (see Section 5.6).

A further requirement of Federal funding is that a conservation agreement be entered into with NPWS or another organisation, such as the Nature Conservation Trust, to ensure that the use and management of the acquired land is appropriate to meet the Objectives of Management set down by the IUCN for a Category IV Protected Area.

1.2 Values

The Project area has a number of existing positive values that are subject to a number of threats. Existing values and threats are listed in Table 1-1. Further detail is provided in the Action Management Plans of Section 5.

There are several *potential* values that the Project area used to provide before the installation of the floodgates. These include the enhancement of habitat for migratory birds, and for estuarine and marine fish, many species of which are of importance to both recreational and commercial fisheries. It is expected that these values can be re-established to a large extent using suitable management techniques, particularly the staged opening of the floodgates. Unfortunately, the re-establishment of these potential values will be accompanied by some deleterious consequences. Nevertheless, a comparison of the benefits (advantages) and costs (disadvantages) of opening the floodgates indicated that the total benefits outweigh the costs (WBM Oceanics Australia, in prep.). The benefits and costs of opening the gates are listed in Table 1-2. Greater detail on the issues surrounding the values, threats, benefits, and costs is provided in the Management Action Plans of Section 5. These Plans also outline how the costs associated with the Project could be minimised.

Table 1-1 Existing Values and Threats

Values	Threats
Environmental • The Project area contains the majority of the regional freshwater reed and sedge wetland habitat (Section 5.5); • The Project area contains a number of species listed under the Threatened Species Conservation Act 1995 (Section 5.5); • The Project area provides some estuarine wetland habitat for migratory birds including those listed under the CAMBA and JAMBA agreements (Section 5.5); • The Project area represents an important link between natural areas to the west and south of Hexham Swamp and the Kooragang Wetland Rehabilitation Project area and Kooragang Nature Reserve to the east (Section 2.2) • The Project area provides a buffer from incompatible land use to the Ramsar-listed Kooragang Nature Reserve and Shortland Wetlands which comprise the Hunter Estuary Wetlands Ramsar site (Sections 1.6 and 2.2) Social • The Project area represents a major open space of regional significance, with recreational and educational use (Planning and Environment Commission 1978) (Sections 5.8 and 5.9) Economic • The Project area is an important flood storage area for flood waters from the Hunter River (Section 5.1) (Note: Also provides social and environmental values); • Some areas of the Project area provide grazing opportunities for domestic stock, particularly in times of drought (Section 2.1)	Environmental • The habitats within the Swamp have changed considerably in the past 30 years since the construction of the floodgates. Although future change is likely to slow down, it will be ongoing as sedimentation from the catchment continues. The large area presently occupied by reed swamp (dominated by *Phragmites australis*) reduces the habitat diversity within the Swamp. Common Reed swamp has little value as wildlife habitat, particularly for migratory birds and waterbirds (NPWS 1996) (Section 5.5); • Poor water quality due to poor quality and volume of stormwater run-off from the catchment (Section 5.3); • Poor water quality due to stagnation and oxidation of acid sulphate soils diminishes the value of the habitat (Section 5.3); • Presence of weeds and animal pests. These species pose a threat through their capacity to predate or out-compete native species (Section 5.6); • Accumulated sediment is choking some creek channels, thus affecting aquatic habitats (Section 5.4); • Grazing by domestic stock has altered the structure and composition of the vegetation and trampling has caused damage to surface soils and banks of waterways (Section 5.4 and 5.6); • Increased urban development on the edge of the Swamp could exacerbate already poor stormwater quality entering the Swamp.

Table 1-2 Benefits and Costs of Opening the Floodgates

Benefits	Costs
• Increased tidal inundation will increase habitat diversity. Presently, the majority of the Project area is covered by Common Reed swamp. Increased tidal inundation will restore several communities presently degraded, such as saltmarsh and mangrove forest (Section 5.5); • Increased tidal inundation will provide substantially greater habitat to estuarine species, such as migratory birds (including CAMBA and JAMBA listed species); • Increased tidal inundation will enhance fisheries in the Lower Hunter and beyond by providing nursery habitat for fish and crustaceans (prawns). Re-establishment of mangrove and saltmarsh areas within the Swamp should increase productive habitat areas within the Hunter River catchment by about 20 % of present areas. This could lead to a similar increase in the commercial fish catch in some areas; • Increased tidal inundation will help reduce the oxidation of acid sulphate soils (Section 5.3); • Increased tidal flushing will improve water quality (Section 5.3); • Increased tidal flows will improve flushing of accumulated sediment in the creek channels (Section 5.4); • Increased tidal influence will reduce the competitive advantages of weeds and pests (Section 5.6); • The Project will provide educational and research opportunities to study the rehabilitation process (Section 5.9); • The Project will provide additional opportunities for tourism and recreation (Section 5.8)	• Increased inundation will cause the replacement of freshwater species and habitat types (including some species listed under the *TSC Act 1995*) by salt tolerant species/habitats (Section 5.5); • Increased tidal inundation may provide additional opportunities for mosquito breeding (Section 5.6); • Increased tidal inundation will be deleterious to cattle grazing and hobby farms. Beef cattle farms will cease to be operated on a primarily commercial basis, although some grazing will continue on the periphery of the Project area (also see Section 5.6); • Increased tidal inundation may restrict access to existing infrastructure (Section 5.8); • Increased tidal inundation may increase community fear of flooding (Section 5.1); • Additional requirements for a modified floodgate opening regime will increase recurrent management costs (Section 5.2)

1.3 This Management Plan

This Management Plan covers a five-year time period (2003-2007) and outlines how the funding secured to date will be spent on the Project and proposes additional actions that have been identified by the Project Committee for longer-term management as part of the Hunter Estuary wetlands complex. Sections of the Plan outline the policies and objectives of the Project, existing and proposed management structures, and management actions to be taken by the CMA to implement the Project and recommended future actions.

As noted previously, a Draft Management Plan was prepared by WBM Oceanics to cover the five-year period 2000-2004. The original Action Plans were revised in early 2001 by the Project Committee.

This Plan supersedes the 2000-2004 Draft Management Plan and incorporates new information and has been expanded to include issues and activities that have arisen since 1999 (eg. as a result of legislative changes). The 2003-2007 Plan has retained the format and structure of the 2000-2004 Plan.

The Plan will be subject to review throughout its life. The eight-year period encompassed by the two plans covers the four years before and after the first proposed gate opening (scheduled for 2004). This period is of crucial importance to the Project, as it provides an important opportunity for monitoring the behaviour of a number of ecological and physical parameters, before floodgate opening, to establish baseline conditions, and following commencement of increased floodgate opening. Future actions, such as the opening of all floodgates, will then be reviewed on the basis of the results obtained during the monitoring period.

The Plan was written in accordance with some of the principles of the ISO 14001 International Standard (Environmental management systems - Specification with guidance for use). The Standard provides for the implementation of a management system that involves continuous review and improvement. These principles are to be reflected in the policy, planning, implementation, documentation and corrective action stages of the Project. While some of the detailed requirements of the Standard are beyond the scope of this Management Plan, these can be added at a later stage in the form of Appendices or as separate documents.

The Plan was prepared in consultation with a range of stakeholders (see Section 3). It followed on directly from the draft EIS process, which in itself involved extensive community consultation, such as public meetings, direct approaches to stakeholders (including all affected landholders), and a Value Management workshop. This workshop involved the identification and agreement of project objectives, a review of the draft EIS, identification of alternatives, identification of the preferred option, development of issues and watch-points in relation to the preferred option, and agreement on the content and scope of action plans. The Plan was revised by the Project Committee which also comprises a broad range of stakeholders (refer to Section 3).

The Commonwealth and New South Wales Governments have contributed significant funds towards the Project. A condition of Commonwealth funding was that CMA prepare a management plan that clearly establishes how the land acquired with grant funds will be managed to achieve the desired nature conservation outcomes. Finalisation of this Plan is not dependent on completion of the EIS, however it incorporates data and strategies developed during EIS preparation.

The draft EIS is being reviewed and updated to include extensive additional survey and tidal inundation modelling. The EIS is due for completion in 2004, and will be submitted with a development application for determination under the *Environmental Planning & Assessment Act 1979*.

1.4 Policy Statement and Objectives

1.4.1 Policy Statement

The following Policy Statement has been developed to guide the Project.

Recognising:

- that Hexham Swamp is a vital component of the natural environment of the Hunter Region and has a special role in relation to the regional way of life;
- that Hexham Swamp is unique within the region and its ecological characteristics have intrinsic values;
- that Hexham Swamp plays a critical role in the management of water resources, the functioning of the lower Hunter River catchment and the health of the estuary;
- that Hexham Swamp provides an important link in the natural corridor extending from the coast at Newcastle Bight, through Kooragang Nature Reserve and Wetland Rehabilitation Project area, to the forested Sugarloaf Range and Watagan Mountains;
- that steps must be taken to stop the degradation and destruction of Hexham Swamp while recognising that there will be ongoing human uses of this area that must be managed for long-term ecological sustainability;
- that we have the technical capacity to repair this wetland area and such rehabilitation is an integral part of managing this region in the long-term interests of the environment, the economy and our way of life;
- that effective management of Hexham Swamp requires cooperation between Government and the community; and
- that Federal, State and Local legislation, regulations and policies are to be complied with.

The Aim of the Project is to conserve, repair and continuously improve Hexham Swamp for nature conservation, while ensuring that the floodgates remain operational for their intended and current purpose of flood mitigation as it relates to Hunter River floods.

This Policy is to be communicated to all involved in the management of the Project, and should be available to the public.

1.4.2 Objectives

A number of broad objectives for the management of the Project were identified in the 2000-2004 Management Plan. They were reviewed and amended by the Project Committee in 2001. The revised objectives are listed below.

The paramount objective is that the floodgates are closed during Hunter River floods. Otherwise, nature conservation objectives have priority over those relating to other aspects of the Swamp (eg. recreation, education, and fisheries).

Nature conservation objectives

The highest priority nature conservation objective is to increase habitat diversity by restoring estuarine habitats within the Project area. Other conservation objectives are to:

- Improve habitat for estuarine fauna (waterbirds, migratory birds) and aquatic fauna (fish, amphibians, crustaceans, and invertebrates);
- Integrate the Project area into the regional protected natural area network;
- Control weeds and pests;
- Improve quality levels of water flowing from Hexham Swamp;
- Increase flushing of small tributaries which have become stagnant and restore creek beds;
- Encourage research into the optimal management of the Swamp.

Other objectives

The highest priority non-conservation objective is to ensure that the floodgates close during Hunter River floods. Other non-conservation objectives are to:

- Maintain infrastructure access in consultation with utilities;
- Enhance opportunities for passive recreation and nature appreciation;
- Encourage the use of Hexham Swamp for educational purposes;
- Protect archaeological and European heritage values, should these become apparent;
- Promote the Hunter Estuary as a centre of excellence in sustainable wetland management.

Objectives for day-to-day management are outlined in the Management Action Plans of Section 5.

1.5 Relationship with Legislation and Other Policies

The Project is subject to a variety of legislation and policies. Those of particular relevance are listed in

Table 1-3. All legislation and policies will be complied with, including new legislation enacted during the life of this Plan.

Of particular relevance is the NSW Wetlands Management Policy (DLWC 1996). It was issued by the NSW Government as one of the component policies of the State Rivers and Estuaries Policy. “The goal of the NSW Wetland Management Policy is the ecologically sustainable use, management and conservation of wetlands in NSW for the benefit of present and future generations” (DLWC 1996, p17). Among the nine principles which were adopted for the sustainable management of wetlands were several which are of direct relevance to the Project, including:

- Principle 2: Land use and management practices that maintain or rehabilitate wetland habitats and processes will be encouraged;
- Principle 6: Natural wetlands should not be destroyed, but when social or economic imperatives require it, the rehabilitation or construction of a wetland should be required;
- Principle 7: Degraded wetlands and their habitats and processes will be actively rehabilitated as far as practical;
- Principle 8: Wetlands of regional or national significance will be conserved (particularly if a Ramsar nomination is sought);
- Principle 9: The adoption of a stewardship ethos and cooperative action between land and water owners and managers, government authorities, non-government agencies and the general community is necessary for effective wetlands management.

The Project conforms to these principles. With respect to Principle 8, it should be noted that a Ramsar nomination will be pursued for Hexham Swamp in the future. This will complement the 1984 Ramsar listing of Kooragang Nature Reserve and the expansion in 2002 of this listing to include the Shortland Wetlands.

The Wetland Action Plan, which is prepared as a requirement of the NSW Wetlands Management Policy, mentions the Project as a key achievement for wetland management in NSW.

Table 1-3 Legislative and Policy Framework

Legislation or Policy	Purpose
New South Wales	
Catchment Management Authorities Act 2003	Provides for the establishment of Catchment Management Authorities and to devolve to them certain natural resources management issues in their regions
Crown Lands Act 1989	Provides a regime for the ownership and management of Crown Land
Drainage Act 1939	Enables landowners to join together to carry out drainage works, or works to mitigate the effects of floods or tides
Environmental Planning and Assessment Act 1979	Establishes process and requirements for assessment of development consents
Fisheries Management Act 1994 (Amended 2001)	Establishes responsibility for management and protection of marine, estuarine and freshwater fish and mangroves
Hunter Valley Flood Mitigation Act 1956 (repealed and most provisions incorporated into the Water Management Act 2000)	Provides for flood mitigation and streambank stabilisation activities to be carried out in the Hunter Valley
Local Government Act 1993 (Amended 2000)	Allows Local Government to undertake a range of functions and responsibilities
National Parks and Wildlife Service Act 1974 (Amended 2001)	Provides a framework for managing national parks and reserves as well as providing mechanisms to conserve and manage cultural and natural heritage
Native Vegetation Conservation Act 1997	Provides for the protection of native vegetation except mangroves
Noxious Weeds Act 1993	Provides for the control and removal of noxious weeds
Occupational Health and Safety Act 2000	Provides for health, welfare, and safety in the workplace
Pipelines Act 1967	Provides for the construction, operation and maintenance of pipelines; and for purposes connected therewith
Protection of the Environment Operations Act 1997	Provides for the prevention of environmental degradation, involving pollution prevention, cleaner production, reduction to harmless levels of discharge, recycling, and progressive environmental improvements
Public Health Act 1991	Relates to the maintenance of proper standards of health for the public (eg in relation to mosquito borne diseases)
Rivers and Foreshores Improvement Act 1948	Regulates the excavation and removal of material from land within 40 m of a water body
Fire Brigades Act 1989	Provides for the protection of persons and property from fire and hazardous incidents
Soil Conservation Act 1938	Protects sensitive areas from tree removal
State Emergency and Rescue Management Act 1989	Provides for the management of State emergency and rescue operations (eg in relation to floods)
Threatened Species Conservation Act 1995	Establishes a process for classifying and protecting endangered species and critical habitats

Water Act 1912	Provides for water rights, water and drainage, drainage promotion, and artesian wells
Water Management Act 2000 (Amended 2002 and 2004)	Provides for the management of water resources, including administrative process to manage surface and subsurface water (incl. wetlands), and Hunter Valley Flood Mitigation activities
Floodplain Management Policy	Provides for the reduction of flooding impacts and flood liability by flood mitigation works and measures, and by effective planning and development controls
NSW Wetlands Management Policy	Provides for the wise use, best management practice and rehabilitation of wetlands
State Environmental Planning Policy 14	Provides for the protection of coastal wetlands
State Environmental Planning Policy 71	Provides for the coordinated planning of coastal lands
Commonwealth	
Environmental Protection and Biodiversity Conservation Act 1999	Provides for protection of the environment, especially relating to national environmental significance and Australia's international environmental responsibilities
Wetlands Policy of the Commonwealth Government of Australia	To conserve, repair, and manage wetlands wisely

1.6 Relationship with the Hexham Swamp Nature Reserve

Approximately one third of the study area is composed of the Hexham Swamp Nature Reserve, which is administered by NPWS under the *National Parks and Wildlife Act 1974*. The *National Parks and Wildlife Amendment Act 2001* describes the purpose of nature reserves: "to identify, protect and conserve areas containing outstanding, unique or representative ecosystems, species, communities or natural phenomena". The *Amendment Act* states that "a nature reserve is to be managed in accordance with the following principles:

(a) the conservation of biodiversity, the maintenance of ecosystem function, the protection of geological and geomorphological features and natural phenomena,

(b) the conservation of places, objects, features and landscapes of cultural value,

(c) the promotion of public appreciation, enjoyment and understanding of the nature reserve's natural and cultural values,

(d) provision for appropriate research and monitoring."

The Hexham Swamp Nature Reserve was dedicated in 1990. The Plan of Management for the Hexham Swamp Nature Reserve (NPWS 1998) states that, in addition to general objectives of management, two specific objectives for the Hexham Swamp Nature Reserve are (NPWS 1998, p11):

- To protect, and where necessary improve the ecological condition of, the freshwater wetlands and estuarine wetlands of Hexham Swamp Nature Reserve so as to maintain and promote the population numbers and species diversity of waterfowl and migratory waders, particularly those recognised as endangered.

- To encourage, both on the two nature reserves and on adjacent lands and in conjunction with local educational, research and community organisations, educational and research programs into the values and the management of estuarine and freshwater wetlands where these are compatible with the first and second specific objectives.

The Plan of Management for the Hexham Swamp Nature Reserve outlines various policies to achieve these objectives, including the manipulation of the floodgates to increase the habitat diversity within the Swamp and the limiting of the extent of common reed *(Phragmites australis)*, which has taken over large areas of the Nature Reserve. The intent of the Project is compatible with the objectives for the Hexham Swamp Nature Reserve.

2 LOCATION AND HISTORY

2.1 Location and Land Use

Hexham Swamp is located on a back plain on the true right bank of the Hunter River, approximately 10 kilometres upstream of the centre of Newcastle (Figure 2-1). With the Hunter River as its north-eastern boundary, the Swamp is contained on its southern and western sides by hills, large parts of which are the subject of ongoing development. The hills surrounding the south-eastern corner of the Swamp, including the suburbs of Wallsend and Shortland, have been developed since last century and have experienced some open-cut coal mining activity in the past.

The Swamp consists of two major parts which are hydrologically separated from one another by the abandoned Richmond - Pelaw Main railway embankment. The area to the north-west of this embankment is drained by Purgatory Creek, a tributary of the Hunter River. The area south-east of the embankment is drained by a number of small streams such as Fishery and Shelley Creeks, tributaries of Ironbark Creek which itself drains into the Hunter River. Other waterways include Wentworth Creek which discharges into the Swamp.

Apart from a number of infrastructure easements which cross the Swamp, the two main land uses within the Swamp have been conservation and grazing. The focus for conservation is the Hexham Swamp Nature Reserve, which covers the north-western part of the Swamp. It represents a valuable link in the regional conservation network, as described in the next Section. Grazing has focussed on a small number of commercial beef cattle operations in the southern and south-western parts of the Swamp, particularly when other areas within the region experience drought conditions. The wetland sections of these properties have been acquired by the CMA as part of the Project and cattle grazing is being phased out from this land (see Section 5.6).

Other minor land uses near the margin of the Project area include small hobby farms (horses), residential (backyard) use, and some recreational usage (sports grounds, airstrip, and The Wetland Centre - see Section 2.2).

The Project area includes all of the Swamp to the south-east of the Richmond - Pelaw Main railway embankment, covering an area of almost 2,000 ha.

2.2 Position in Regional Protected Natural Area Network

The Swamp is part of a wetland complex that is recognised at national and international scales for its importance in the conservation of migratory birds, with over 4,800 migratory shorebirds recorded in 2000 (Straw 2000). The Hunter Estuary is listed on the Interim List of the Register of the National Estate, which reflects its value as waterbird habitat.

The Swamp has an important ecological connection between Kooragang Nature Reserve and Ash Island to the east, Shortland Wetlands and Newcastle Wetland Reserve to the south-east, and forested hills to the west. However, infrastructure such as the Great Northern Railway line and the Pacific Highway disrupt the continuity of the linkage to some extent, particularly for the movement of terrestrial fauna across these landscapes.

To the south-west of the Swamp a link may also be provided by the Blue Gum Hills Regional Park, which surrounds a former colliery between Minmi and Maryland. This

Regional Park could significantly enhance the conservation value of Hexham Swamp, by providing controls over the quality of catchment run-off, in addition to habitat extension.

2.3 Aboriginal Land Use

A review of the archaeological investigations which have been carried out in and around Hexham Swamp is provided in EJE Townplanning (1998) and Umwelt (2003). Detailed research at Woodberry Swamp (Kuskie 1994) and at Black Hill (Silcox & Ruig 1995) has revealed the existence of substantial amounts of sub-surface evidence of Aboriginal occupation on elevated surfaces around the margins of Hexham Swamp. While the Swamp would have undoubtedly been a focus for resource procurement, it has been demonstrated that Aboriginal settlement in the wetlands area was likely to be widespread and intensive along the higher and more well-drained margins.

The Project area falls within the jurisdiction of the Awabakal Local Aboriginal Land Council (ALALC) was consulted as part of the Umwelt Aboriginal Cultural Heritage Assessment. The ALALC and traditional owners of the Swamp area have indicated their support for the proposed rehabilitation project and are keen to become actively involved in works and monitoring of ecological and habitat changes.

2.4 European Settlement

Most early European use of the area was agricultural, based on the relatively fertile soils found on the floodplain. With continuing development of the area in the first 50 years of the 20th century, a number of projects had a significant effect on the Swamp. These included:

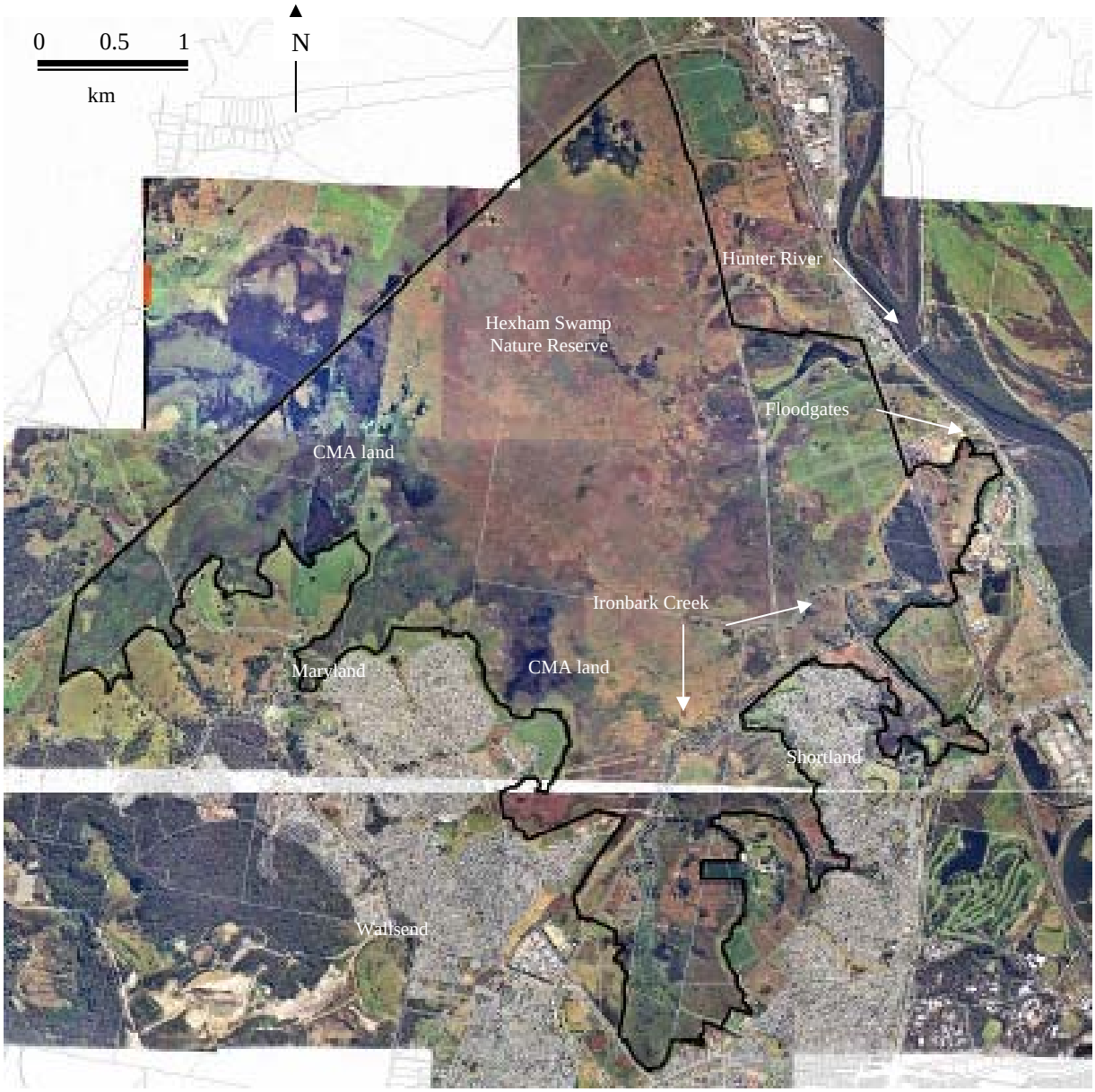
- The Great Northern Railway Line and its associated levee (1857) (Ericsson (1990);
- The Newcastle water supply pipeline including a levee and service track (1923);
- The Richmond and Pelaw Main Colliery railway through the north-east of the Swamp;
- Ironbark Creek floodgates (1970-1971);
- Urban and industrial development in the basin, including an airstrip for light aircraft (1972), a sewage treatment works and a major refuse dump with associated drainage and leachate ponds (1972) (Ericsson (1990);
- High voltage electricity transmission towers and a service track (1982-1983) (Ericsson (1990);
- The Pacific Highway and various other road works around the Swamp;
- Development of the catchment for housing, mining, and other landuses.

Earthworks associated with early developments changed the hydrology of the Swamp by cutting the tidal channels to the Hunter River in the east. Changes to the hydrology elsewhere in the Hunter River estuary due to reclamations and filling of estuarine channels in Kooragang Island and the former Platts Channel areas may also have affected the hydrology by increasing tidal intrusion into the Swamp.

The inflow of tidal water was restricted by the construction of levees along the Hunter River and the installation of floodgates near the mouth of Ironbark Creek in 1970. As a result, the area of tidally flushed wetlands has decreased substantially within Hexham Swamp allowing considerably greater use of the wetlands for seasonal grazing from spring to autumn.

The closure of the floodgates has been controversial from the outset, with adverse environmental conditions developing shortly after closure of the floodgates (DPW 1972). The Total Catchment Management Strategy (ICTCMC 1996) and the EIS for the modification of the floodgate operation (WBM Oceanics Australia in preparation) are but the latest expressions of the need to address the deleterious environmental conditions in the Swamp.

Figure 2-1 Map Showing Location of the Project



3 MANAGEMENT STRUCTURE

3.1 Structure

The Project is managed by the CMA. Up until July 1999, the Project was reported to community and agency members through the Ironbark Creek TCM Committee (ICTCMC), a subcommittee of the CMA. Advice from the ICTCMC was provided to the CMA, which implemented appropriate actions to advance the Project.

With the allocation of significant funding from the Federal and State Governments, a specific Project Committee was established in July 1999. This Committee contains all members of the ICTCMC and in addition, representatives from the Federal funding body, Environment Australia, NSW Wetland Advisory Committee and Kooragang Wetland Rehabilitation Project (see Appendix E).

The Project Committee's role includes:

- developing and reviewing this Management Plan;
- advising CMA on the Project by providing information and recommendations;
- overseeing management of the land acquired for the Project;
- monitoring management effectiveness;
- providing other groups and the community with accurate information on the Project;
- reviewing and endorsing all reports prior to their release to Environment Australia and others.

The CMA will remain responsible for management of the Project, and for any public announcements or other media contact relating to the Project.

It is anticipated that the long-term management of land acquired by CMA in the Swamp will be transferred to NPWS at some future time, subject to appropriate resources being allocated for effective management. It is envisaged that this transfer will not take place until all capital works associated with the Project are completed (eg. bunding).

Whilst NPWS has indicated that the acquired land would be added to the adjacent Hexham Swamp Nature Reserve, the final mix of reserve categories across the entire Project area may include nature reserve, state conservation area, regional park, or other appropriate designation to reflect the specific conservation or recreational/educational values of different areas.

A Management Action Plan has been formulated to guide resolution of this issue (refer to Section 5 1).

3.2 Reporting

3.2.1 Project Performance

Project performance will be measured by the extent to which the objectives are achieved. This will be largely conducted through the monitoring programs which have been developed and implemented as detailed in the Management Action Plans of Section 5. A successful performance would be indicated by, for example, an increased number of migratory birds recorded (both in terms of species and abundance) or the increased extent of mangrove and saltmarsh species in the Swamp.

In order to measure the overall performance of the Project, all measures available will be evaluated. Apart from the measures in the monitoring programs specified in Section 5.6, this would also include management performance measures such as the achievement of objectives within or to financial and/or time budgets.

A report outlining achievement of objectives, hindrances to achievements, and proposed corrective action (including resetting of objectives and targets) will be prepared annually from the end of 2004. The context in which objectives and targets will be reset will depend on the management structure in place at the time. The current management structure is outlined above. Annual reports will be publicly available, with opportunities for comment.

The CMA is responsible for monitoring project performance, with input from the Project Committee, until an alternative management structure has been finalised (see above).

4 FUNDING AND INDICATIVE BUDGET

Funding has been secured from the Commonwealth Government's Natural Heritage Trust (NHT), administered by Environment Australia, and the State of New South Wales through the Department of Infrastructure, Planning and Natural Resources (DIPNR). Table 4-1 lists the sources and amounts of these contributions. An indicative budget for the Project is presented in Table 4-2.

Table 4-1 Funding

Funding source	Total $
Federal Government (NHT)	2,400,000
NSW Government	2,700,000
CMA	540,000
In-kind (various contributors)	400,000
Total	**$6,040,000**

Table 4-2 Indicative Budget

Item	Total Budget $
Land Acquisition / Easements to Inundate	
Land purchases	2,900,000
Associated costs (legal, survey, valuation, negotiation)	835,000
Easements to Inundate	302,000
Marsden Street bund / drainage	250,000
Sub-Total	*$4,287,000*
Rehabilitation and Works	
Works to infrastructure	250,000
Bank stabilisation / sediment removal	200,000
Property fencing	50,000
Reporting / advertising / community consultation	68,000
Revegetation	20,000
EIS / Management Plan	320,000
Monitoring / data collection	345,000
Project management	400,000
Land management	100,000
Sub-Total	*$1,751,300*
Total	**$6,040,000**

4.1 Strategy for Land Acquisition

The area to be acquired for the Project has been determined on the basis of tidal inundation modelling, which in turn has been based on extensive surveys of Hexham Swamp. Private land holdings (grazing and hobby farm land) which will be inundated (whether partly or wholly) when all eight floodgates have been opened has been acquired from landowners on a voluntary basis. Land owned by NCC is being purchased (operational land) or transferred (community land) to the CMA. In addition, 'easements to inundate' are being acquired over other public land and private land, or other agreements entered into. Table 4-3 lists the land parcels involved.

Table 4-3 Land within Project area

Property	Owner
	Private Landholdings acquired by CMA and residual holdings (former owners shown in brackets)
DP 1044935 / 10	CMA (Dan)
DP 1044935 / 11	Dan, P
DP 998893 / 455	CMA (Searles)
DP 1024373 / 21	CMA (Searles)
DP 1024373 / 22	Searles, J & F
DP 836450 / 21	CMA (Gumb)
DP 1048213 / 1	Comerford, P & Yore, P
DP 1048213 / 2	CMA (Comerford & Yore)
DP 1023342 / 302	CMA (Priestley)
DP 1037030 / 12	CMA (Toyera P/L)
DP 1037030 /11	Toyera P/L
DP 864756 / 28	Watts, S (12 ha to be acquired by CMA)
DP 1037228 / 23	Marmulla, W (24 ha to be acquired by CMA)
DP 517366 / 211	Morris, C & S (0.9 ha to be acquired by CMA)
DP 199322 / 1,2,3,4,5 DP 584500 / 2 DP 742036 / 1,2 DP 126319 / 1	CMA (Hartin)
	Public Land
DP 599877 / 24 DP 1043133 / 3	Newcastle City Council (whole or part of lots to be acquired by CMA)
DP 755232 / 54 DP 218633 / 45	Newcastle City Council (community land – to be transferred to CMA)
DP 340105 / B DP 246123 / 12 DP 253998 / 28 DP 593379 / 107 DP 594894 / 11	Newcastle City Council ('easements to inundate')
DP 90465 / 1	State of NSW – Hexham Swamp Nature Reserve Dedicated as Nature Reserve 23/2/90 (Govt Gazette Fol.1518)
DP 725084 / 129	State of NSW – Hexham Swamp Nature Reserve
Crown Reservations along Ironbark Creek	Crown (control to be transferred to CMA)
Reserve for Wharf	Crown (control to be transferred to CMA)

Property	Owner
	Other Land (all subject to 'easements to inundate' or other agreement)
DP 832198 / 210	Hunter Water Corporation
DP 608814 / 1	
DP 408005 / 1	
DP 535220 / 2	
DP 400052 / A	
DP 339943 / A,B	
DP 805274 / 1	
DP 611441 / 1	
DP 611518 / 2	
Book 2432 No 699	
DP 606506 / 102	Williams, F, O'Rourke, W & Young, L
DP 599877 / 25	Newcastle Wallsend Coal Co
DP 584500 / 1	Metalcorp Limited
DP 998816 / 421	
DP 593732 / 51	Totalizer Agency Board of NSW
DP 593732 / 52	Tacon, I & R
DP 350274 / A	Puliuvea, S
DP 350274 / B	Lambkin, S
DP 16703 / 20	Cook, D
DP 16703 / 23	Cook, K
DP 590003 / 62	Waugh, R
DP 573628 / 74	Bradley, R & K
DP 524581 / 441	Docherty, G & I
DP 709247 / 325	Shields, N & K
DP 500143 / 1	Dunn, C &B
DP 635127 / 11	James, J & M
DP 407614 / D	Hancock, P & L
DP 708599 / 2412	Powell, G
DP 663814/ 35	Murray, D & K
DP 529512 / 1	Horacek, D & K
DP 529512 / 2	Hughes, D
DP 659461 / 25	Denton, L
DP 517002 / 262	McFayden, D & P
DP 16703 / 27	Hollube, E
DP 16703 / 28	Carpenter, W & R
DP 16703 / 29	Palmer, E & D
DP 16703 / 30	Flannery, R & P
DP 716666 / 2	Johnston, J & S
DP 592513 / 322	Bartlett, G
DP 502669 / 1	Whittaker, L
DP 233520 / 5	Shortland Wetlands Centre Ltd
DP 561496 / 9	
DP 755232 / 58,59,60, 61,62,63,64,66, 67,68, 127	Broadcast Australia (formerly NTL)
DP 184589 / 94	
AC 14928-83	
DP 570856 / 1100	The Trustees of the Roman Catholic Church for the Diocese of Maitland and Newcastle
DP 184589 / 98,99	
DP 570856 / 1101	Rhodes, T
DP 625053 / 12	Sierra Sun (NSW) Pty Limited
DP 627724 / 22	
DP 867471 / 200	Unimin Australia Limited
	Other organisations (subject to agreements)
Power transmission lines	TransGrid Energy Australia
Main Northern Railway line	Rail Infrastructure Corporation
Roads	RTA
Easement to drain water	NSW Land and Housing Corporation

5 MANAGEMENT ACTION PLANS

The following Management Action Plans have been prepared on the basis that the opening of the floodgates will be staged, with the first floodgate to be fully opened in early 2004. The Management Action Plans below have been prepared to cover a minimum of four years beyond the first gate opening, which would extend to December 2007 at the latest. The HSRP will update Action Plans before the expiry of this Plan, if required.

The issues that are to be managed during the period 2003-2007 are outlined below in ten Action Plans.

Estimated costs indicated in Action Plans are for the duration of this Management Plan (2003-07) and do not include expenditures prior to 2003.

5.1 Land Acquisition, Planning and Future Management

5.1.1 Current Status

5.1.1.1 Land Acquisition

The Hexham Project involves the purchase of freehold title and easements to inundate over private and public land within the Project area. Also, formal agreements and consents are being signed with other owners. The CMA has negotiated agreements with most landowners and the majority of land identified for purchase has been acquired. Negotiations are continuing with owners of land over which easements to inundate are required.

5.1.1.2 Planning

Approval to implement the Hexham Project, that is, to increase tidal inundation, is required under Parts IV and V of the *Environmental Planning & Assessment Act 1979*. NCC is the consent authority for Part IV and the Minister for Natural Resources for Part V.

State Environmental Planning Policy No 14 (Coastal Wetlands) triggers the requirement for the CMA to prepare an Environmental Impact Statement (EIS). State Environmental Planning Policy No 71 (Coastal Development) has recently been introduced. The implications for the Hexham Project of SEPP 71 are unclear at this stage, however they will be clarified prior to completion of the EIS.

5.1.1.3 Future Management

The CMA manages the Project and will continue to do so in the short-medium term. Long-term management of the land acquired by the CMA has yet to be resolved, however NPWS has indicated that it will take on this responsibility at some time in the future, subject to appropriate resources being allocated for effective management.

5.1.2 Problems

The land acquisition process is time consuming so that delays in finalising purchases could prevent CMA from accessing all available Commonwealth funds. In addition, careful identification of all affected land is essential to ensure that appropriate arrangements are entered into with owners.

Preparation of the EIS has involved complex tidal inundation modelling and extensive investigation of environmental issues.

Preliminary discussions have been held with NPWS, however detailed negotiations may indicate that 'appropriate resources' are not available for NPWS to take on long-term management of Project land.

5.1.3 Action Required

Objectives for management, actions required, timing and budget are tabulated in Table 5-1.

Table 5-1 Land Acquisition, Planning and Future Management Action Plan

Phase	Nature of Action Required	Responsible	Timing
Objective 1	**To acquire ownership, easements to inundate or consents for all land within the Project area.**		
Initial Action	Undertake all actions (valuations, surveys, preparation of DAs/ subdivision, legal) to purchase rural and residential land freehold title and easements to inundate from private and other landowners.	CMA	Ongoing, complete by 12/05
	Negotiate consents to inundation, where formal easements are not required.	CMA	Ongoing, complete by 12/05
Monitoring	Carry out title searches to ensure all affected properties are identified and appropriate action initiated.	CMA	Ongoing
Corrective Action	Initiate purchase/consent procedures if additional properties identified.	CMA	As soon as possible
	Regularly review progress to ensure acquisitions proceed as rapidly as possible.		Ongoing
Objective 2	**To obtain approval to implement the Project.**		
Initial Action	Obtain advice from the Commonwealth Government (Environment Australia) regarding Referral under the *Environmental Protection and Biodiversity Conservation Act 1999.*	CMA	As soon as possible
	Obtain Director General's Requirements from the Department of Infrastructure, Planning and Natural Resources, and hold a Planning Focus.	CMA	As soon as possible
	Finalise EIS to address all issues relevant to the Project and submit with a DA to NCC for assessment and approval under the *EP&A Act* (or to the Minister for Urban and Transport Planning should SEPP 71 be triggered).	CMA, WBM	As soon as possible
Monitoring	A program to track progress to be developed and implemented.	CMA, WBM	As soon as possible
Corrective Action	Changes to planning approaches to be made, if identified.	CMA, WBM	As required
Objective 3	**To establish a structure for long-term management of the Project area.**		
Initial Action	Initiate discussions with key stakeholders to develop a structure for long-term management.	CMA, Project Committee, NPWS, TWC, ALALC	As soon as possible
Monitoring	Review progress in light of implementation of rehabilitation objectives.	CMA, Project Committee	As required
Corrective Action	Discussions may need to be more vigorously encouraged if achievement of rehabilitation objectives is proceeding in advance of establishing a long-term management structure.	CMA, Project Committee	As required

5.2 Flood Risk and Floodgate Operation

5.2.1 Current Status

5.2.1.1 Hydrology

The Swamp is a major flood storage on the south bank of the Hunter River. It is located in the south-eastern portion of the Hunter Valley and lies approximately 15 km upstream from the mouth of the Hunter River. The majority of the Swamp is drained by Ironbark Creek, but a small section of the northern corner is drained by Purgatory Creek which discharges underneath the Great Northern Railway and New England Highway into the Hunter River through floodgates just upstream of the Hexham Road Bridge. Two small flap valve structures in the Hexham area also restrict water exchanges between the Swamp and the Hunter River.

The hydrology of the Swamp is influenced by local urban developments on its periphery and general development in the Lower Hunter Valley.

The hydrology of the catchments draining to the Swamp has been modified by the encroachment of urban areas. This is particularly so with respect to the quantity, quality and time distribution of runoff. The urban catchments contribute increased runoff by virtue of the increased impervious areas, and tend to provide a shorter response time by comparison with the natural conditions. Thus, although urban developments are above the level of major Hunter River floods, they may be affected by localised flooding and stormwater drainage (ICTCMC 1996).

5.2.1.2 Floodgates

Levee banks were constructed along the Hunter River and floodgates were installed near the mouth of Ironbark Creek during 1970-71 in order to mitigate the effects of floods in the Swamp area by the exclusion of small and medium floods (DPW 1972; Lawson and Treloar 1995). The following information on the operation of the floodgates is largely quoted from Lawson and Treloar (1995).

The floodgates consist of eight 2.13 x 2.13 m box culverts (invert level of -1.0 m AHD) each with a heavy, hinged flap gate on the Hunter River side. The hinged floodgates allow flow to pass through the culverts out of the Swamp. When water levels rise on the Swamp side of the gates to a level higher than the water level in the Hunter River, the water level difference across the gates forces the gates open and water flows out of the Swamp. If the Hunter River water level is higher than the Swamp water level, the gates close, preventing flow from entering the Swamp from the Hunter River.

The hinge point of each individual gate may be raised which opens a gap at the base of the flap which then permits flow from the river to the Swamp. Seven of the eight gates are presently closed to tidal flows, whilst one is raised approximately 0.30 m. This opening allows a small amount of tidal flow to enter the Swamp area when Hunter River water levels exceed Ironbark Creek levels. This flow is insufficient to inundate any land adjacent to the Creek.

Under low-flow conditions, when the system is tidally dominated, the present gate configuration allows much more outflow from the Swamp than inflow. Outflow can occur through all of the gates whilst inflow can only occur through the one partially lifted gate.

Under these low inflow conditions, the average water level in the Swamp is closer to the low tide level in the Hunter River than the mean water level.

During flood conditions, floodwaters from the Hunter River are prevented from entering the Swamp by the floodgates and levee system. Similarly, if Hunter River levels are higher than those in the Swamp, then floodwaters are prevented from flowing from the Swamp into the Hunter River. Floodwaters from the Hunter River will overtop the levee system when flood levels are above about 1.8 m AHD.

The primary effects resulting from the construction and present operation of one-way floodgates and levee banks at the mouth of Ironbark Creek are:

- lowering of the water table behind the gates to below mean water (during dry conditions);
- restricted saline waters entering the Swamp area;
- stagnation of water behind the floodgates.

In order to protect and enhance the values of the Project area, the floodgates are to be opened in a staged process.

The floodgates are managed as a component of the Hunter Valley Flood Mitigation Scheme by the Department of Infrastructure, Planning and Natural Resources. The gate presently opened 0.30 m is manually opened and closed, when required, using a truck-mounted winch. The Department is responsible for ensuring the floodgates are closed at all times in the event of a Hunter River rise.

5.2.2 Problems

There is some community concern regarding the issue of flooding in Ironbark Creek and the Swamp. Adding to this are the community's concerns about the impact of the Project (which involves the staged opening of the floodgates) on the existing flooding regime.

Specifically, there is a perception that the opening of the gates and subsequent tidal inundation of the Swamp will result in a significant loss in floodplain storage for local Ironbark Creek flood events. While numerical modelling has predicted that these impacts will be negligible, there remains a degree of scepticism in these results. Figure 5-1 shows the extent of the tidal inundation anticipated with eight gates opened, using the existing modelling.

There are community fears that the Project will worsen the impact of flood events in the Wallsend-Plattsburg and Jesmond-Birmingham Gardens areas. It is an imperative of the Project that the flooding issue is managed properly, based on adequate data and modelling. NCC has completed a floodplain management study for the Wallsend-Plattsburg area and proposes carrying out a similar study of the Jesmond-Birmingham Gardens area (Dark Creek catchment).

An additional perceived risk is that people may be harmed by the floodgates during in and out moving tides (eg. by being caught in a gate). However, no such case has ever been reported for the Lower Hunter, even though there are approximately 300 floodgates in this region (Austin Randall - DoL, pers. comm.). Based on this experience, this risk is likely to be low.

5.2.3 Action Required

Objectives for management, actions required, timing and budget are tabulated in Table 5-2.

Table 5-2 Flood Risk and Floodgate Operation Action Plan

Phase	Nature of Action Required	Responsible	Timing
Objective 4	**To ensure that the Project does not result in tangible increases in flood damages in the Swamp and the Ironbark Creek catchment.**		
Initial Action	Continue current operation of the floodgates until the first gate is fully opened. Operation of the gate will be manual involving manual closing of the gate during King tides (to minimise the breeding of mosquitoes - see Weeds and Pests Action Management Plan) and during flood warning periods, with subsequent manual re-opening of the gate.	DIPNR in liaison with CMA	Management ongoing
	Maintain water level gauges at several locations in the Swamp and on the downstream side of floodgates.	CMA in liaison with DIPNR	Baseline monitoring in place. Continue until gates opened (initially automatic stations then manual monitoring).
	Provide data on downstream boundary conditions for catchment flood models in support of NCC's program of floodplain management plan development.	CMA, WBM, NCC	As required
	A public education campaign will be developed to provide factual information to the community about perceived flooding risks associated with the opening of the floodgates.	CMA, Project Committee, WBM, NCC	Initiate at least 6 months before first gate opening
Monitoring	The program to monitor water levels under existing conditions and following the gate opening will be continued. Current monitoring procedures are outlined in Section 6.1.3 of the Hexham Swamp Rehabilitation Project EIS (WBM, 2005).	CMA	In progress
Corrective Action	None.		
Objective 5	**To minimise the risk of physical harm arising from the movement of tides through the floodgates.**		
Initial Action	A strategy will be prepared to identify risks and propose actions to minimise them. The need for warning signs and booms up/downstream and around the floodgates will be investigated during strategy development. It will include a protocol for documenting incidences.	CMA, DIPNR	Completed when first gate is lifted
Monitoring	The incidence of accidents is to be monitored.	CMA, DIPNR, TWC	Initiate at least 6 months before first gate opening
Corrective Action	Should accidents arise, strategies will be reviewed and amended, as necessary.	CMA, DIPNR, TWC	As required

5.3 Tidal Inundation

5.3.1 Current Status

Currently, there is only minor tidal inundation into the Swamp due to the present operation of the floodgates. With the staged opening of the gates, the area inundated will increase progressively as more gates are opened over time.

5.3.2 Problems

The hydrological impacts of any gate opening option will dictate the impacts on a range of other issues including fisheries, flora, water quality, soils and groundwater, as well as social and economic issues. Hence, an accurate prediction of the expected changes to the hydrological regime of the Swamp is critical to an understanding of the impacts and benefits to the associated issues. The primary change will be the increased degree of tidal flushing of the Swamp and saltwater inundation of parts of the Swamp.

The highly complex nature of the hydrological regime of the Swamp limits the accuracy of the predictions of saltwater inundation. These limitations are due to:

- the mixing of ponded freshwater and tidal inflows;
- the wide range of tidal conditions (ie. tidal range and salinity of water) that could occur in the Hunter River;
- the influence of factors such as wind dispersion;
- the inaccuracies in survey data available for hydraulic modelling;
- assumptions used in hydraulic modelling for shallow water bodies;
- the coarseness of the current hydraulic modelling.

As well, it needs to be understood that while gate opening will result in increased salinity of the water body, there will be significant spatial and temporal variations in this salinity. The degree of impact can vary over the entire Swamp area, depending on the option chosen, the season and phase of the tide. Hence, it is not possible to simply describe those areas to be impacted and those that are not.

All of the above factors make it difficult to accurately define the extent of influence of saltwater inundation following gate opening.

5.3.3 Action Required

Objectives for management, actions required, timing and budget are tabulated in Table 5-3.

Table 5-3 Tidal Inundation Plan

Phase	Nature of Action Required	Responsible	Timing
Objective 6	**To ensure that tidal inundation resulting from opening of the floodgates does not impact on land which is not managed by the Project or which has not been made available for tidal inundation.**		
Initial Action	A detailed 2D model of the study area has been developed using actual survey data of the Swamp. Following one gate opening, calibrate the model to simulate one gate opening. This will result in a model with a high degree of confidence of prediction for the opening of two gates. Once two gates have been opened, the model should be re-calibrated and verified. This will provide a high degree of confidence for the opening of four gates and an improved level of confidence for eight gates open. Hence, as the gates are progressively opened and the calibration is improved, the level of prediction will also be improved.	CMA, WBM, in liaison with DIPNR	In progress
Monitoring	In order to calibrate the model, the current monitoring program will be continued. (The monitoring program is outlined in Section 6.1.3 of the Hexham Swamp Rehabilitation Project EIS (WBM, 2005)).	CMA	Follows above
Corrective Action	The results of the monitoring program would be used to re-calibrate the model.	CMA, WBM	Follows above
Objective 7	**To ensure that the appropriate gate-opening regime is applied for a given rehabilitation objective such as will be formulated from time-to-time during the life of the Project.**		
Initial Action	Use the 2D model outlined under Objective 6 to predict the tidal inundation patterns and behaviour of various gate opening scenarios and tidal conditions in the Hunter River.	CMA, WBM, DIPNR	Initiate at least 3 months before gate opening
Monitoring	As for Objective 6.	CMA, WBM, DIPNR	Follows above
Corrective Action	As for Objective 6.	CMA, WBM, DIPNR	Follows above

5.4 Water Quality

5.4.1 Current Status

5.4.1.1 General

Numerous water quality studies have been performed in the Swamp and Ironbark Creek, all of which have been undertaken since the installation of the floodgates in 1970/71 (WBM Oceanics Australia, in prep).

It is apparent from the available water quality data for the Swamp and Ironbark Creek that the freshwater/brackish system is significantly eutrophied, with elevated nutrient levels and high primary growth (free and attached algae) occurring. The dissolved oxygen concentrations in the creek are highly variable, with concentrations upstream of the floodgates regularly below the ANZECC (1992) criterion. Water quality in the Hunter River appears to be better, with more normal dissolved oxygen concentrations, lower nutrients and pH. Suspended solids and turbidity appear to be slightly higher in the Hunter River than the Swamp, as the floodgates create water ponding and allow sediment settling to occur. Inputs of aluminium and/or soluble iron would also assist in the flocculation and settlement of suspended solids upstream of the floodgates.

5.4.1.2 Acid Sulphate Soils

The Beresfield 1:25,000 Acid Sulphate Risk map (CMA and DLWC 1993) shows the probability of encountering acid-sulphate soils in the study area. The Swamp lies almost entirely within an area described as having "high probability of occurrence of acid-sulphate soil materials within the soil profile".

However, additional studies and soil profile testing carried out in relation to acid sulphate soils obtained different results (Robert Carr and Associates 1998). The results indicate generally high oxidisable sulphur levels below the water table, though many samples were buffered by carbonate derived from shell fragments. Buffering capacity varied with depth and location, which may be associated with a variable carbonate content distribution within the soils. Samples from above the water table generally had a low oxidisable sulphur content, indicating oxidation in the past. The results of these studies indicate that, in general, the soils in the Swamp are neither actual nor potential acid sulphate soils.

However, areas with marine mud deposits at shallow depth have been shown to contain very high oxidisable sulphur levels, indicating that site specific analyses would need to be carried out for any proposed soil disturbance (eg. for the construction of levees). These areas appear to be localised around the Ironbark Creek area.

A geotechnical investigation was carried out by Robert Carr and Associates Pty Ltd (1999) on behalf of the Hunter Water Corporation for the proposed replacement of the Chichester pipeline across the Swamp from Tarro to Shortland.

The results of detailed acid sulphate soil (ASS) testing along the existing pipeline indicates that the soils along the majority of the route are potential ASS. This implies that the soils have a potential for acid generation if disturbed or if groundwater levels are lowered. The results of specific testing along the pipeline suggest that the occurrence of potential acid sulphate soils is more widespread than that indicated by previous testing.

The best practice is to avoid disturbance of the potential acid sulphate soils. Where excavation or disturbance is required it needs to be managed to contain and treat leachate produced from the soils, and the soil will require neutralisation. Typically this involves the application of lime in secure bund enclosures with monitoring to determine when the soil's acid generating capacity has been neutralised.

5.4.2 Problems

5.4.2.1 Eutrophication in the Swamp

Water quality data indicate that the Swamp and Ironbark Creek are currently significantly eutrophied, with elevated nutrient levels and high primary growth (free and attached algae) occurring and low dissolved oxygen levels. Such conditions discourage the establishment of desirable aquatic biological communities, thus affecting nature conservation and fisheries values. Recreational and aesthetic values are also affected.

While the opening of the floodgates is expected to improve the water quality of Ironbark Creek in the long term, in the short term there may be deleterious impacts arising from acid run-off (as exposed soils are inundated), decomposing vegetation (due to the contact of freshwater vegetation with saline tidal water), and potentially contamination from the Astra Street landfill at Shortland (due to increased water levels).

It is expected that acid drainage and vegetation die-back are short-term phenomena. The amount of acid within the Swamp is likely to be small and it is, moreover, finite. Seawater has a greater buffering capacity than freshwater, thus mitigating to some degree any impacts of acid drainage from exposed acid sulphate soils. The inundation of the soils by tidal water will prevent further oxidation of the soils.

Vegetation which is killed by tidal inundation is likely to be replaced by salt-tolerant saltmarsh or mangrove vegetation in the long term.

Potential impacts on water quality due to leachate from the Astra Street landfill site cannot be estimated at this time.

5.4.2.2 Acid Sulphate Soils

Tidal inundation will significantly reduce the potential of acid sulphate soils to generate acid by raising the groundwater table and providing a more static groundwater level. This will limit the depth of potential pyrite oxidation and restrict fluctuations in groundwater levels associated with climate. The other beneficial effect of tidal inundation is the buffering component of saline soils associated with carbon dioxide and bicarbonate ions which tends to maintain a pH within the slightly alkaline range (7.5 – 8.5).

The risk of an initial acid discharge into the Hunter River following the onset of tidal flushing is considered to be low. Some minor localised acid discharge may occur associated with spatial variation in acid generating potential and buffering capacity of the surface soils, however this is highly likely to be buffered by the saline waters and diluted by non-acidic discharge.

No soil excavation is intended at present, however soil disturbance for the construction of bunds or during any dredging may cause some release of acid drainage, resulting in local impacts.

5.4.2.3 Catchment Influences

Deleterious water quality conditions in the Swamp are also promoted by high nutrient run-off from the catchment. Some areas of the catchment contain urban and industrial development, which (without control) can introduce large loads of nutrients and sediment in addition to other pollutants (metals, oils, grease, litter, etc.). Pasture and other rural areas can also contribute significant nutrient and pollutant loads to downstream catchments, unless rural best management practices are implemented (management of stock access to waterways, contour banking, retention of riparian vegetation in drainage lines, etc.).

5.4.3 Action Required

Objectives for management, actions required, timing and budget are tabulated in Table 5-4.

Table 5-4 Water Quality Action Plan

Phase	Nature of Action Required	Responsible	Timing
Objective 8	**To ensure that, in the short term, water quality does not deteriorate to unacceptable levels as a result of the gate opening, and that it improves in the long term.**		
Initial Action	To minimise the intensity and extent of water quality deterioration due to the gate opening, the opening process will be staged, starting with a single gate.	CMA in liaison with DIPNR	Following approval of EIS
	Water quality objectives/criteria will be set which, if exceeded, will trigger a corrective response. Development of these objectives will take account of the Newcastle Stormwater Management Plan (NCC 1999) and the Interim Environmental Objectives for the Hunter Catchment (EPA 1999).	CMA, Project Committee, in liaison with EPA	Completed when first gate is lifted
Monitoring	A program to monitor water quality within the Project area has been developed and is in operation. The current water quality monitoring program is described in Section 6.2.3 of the Hexham Swamp Rehabilitation Project EIS (WBM, 2005).	CMA, Project Committee	In progress
Corrective Action	If water quality monitoring indicates unacceptable conditions arise as a result of the single gate opening, a strategy will be developed, and implemented if necessary, which would result in the mitigation of adverse water quality conditions. For example, vegetation could be mowed and removed from the projected impact area prior to further gate opening, thus minimising the amount of decomposing vegetation within the water body.	CMA, Project Committee	Completed when first gate is lifted
	A strategy can also be formulated to avoid adverse conditions beyond a single gate opening.	CMA, Project Committee	Complete prior to further gate opening
Objective 9	**To prevent adverse acid sulphate soil drainage resulting from construction works.**		
Initial Action	Acid sulphate potential of soils to be disturbed will be investigated and results compared with criteria listed in NSW ASSMAC (1998). Soil disturbance would occur, for example, during construction works for bunds or sediment removal from creeks.	CMA, in liaison with DIPNR	Complete prior to any soil disturbance
Corrective Action	Liming, relocation, disturbance to be limited during low tides or other corrective action to be taken if criteria are exceeded.	CMA	Complete prior to any soil disturbance or next high tide
Objective 10	**To encourage ecologically sustainable land and water management within the Ironbark Creek catchment.**		
Initial Action	The cooperation of catchment landholders and other land and water managers will be enlisted to manage the catchment in an ecologically sustainable manner. Several actions are specified in the Newcastle Stormwater Management Plan (NCC 1999).	CMA, Project Committee, NCMF, DIPNR, NCC	In progress
	If dredging is required, the quality of sediment to be dredged will be assessed prior to dredging and potential water quality impacts will be mitigated wherever practicable.	CMA in liaison with DIPNR	Sediment assessment completed as part of EIS
	Incoming water quality objectives/criteria are to be set which, if exceeded, will trigger a corrective response.	CMA in liaison with EPA	Completed when first gate is lifted
Monitoring	A monitoring program has been developed to monitor the quality of water entering and within the Project area (see above – Objective 8).	CMA, Project Committee	In progress
Corrective	The source of the pollution problem will be determined and catchment	Project Committee to	As required

Action	management adjusted, where possible.	liaise with EPA, NCMF, DIPNR and NCC	

5.5 Creek Erosion and Sedimentation

5.5.1 Current Status

5.5.1.1 Erosion

ICTCMC (1996) reviewed the extent of creek bank erosion in the Swamp. Erosion was evident at several locations, primarily in areas where:

- Native vegetation has been cleared to grass pasture;
- Cattle have accessed the creek banks;
- Fill has been placed along the banks to form bunds;
- Concentration of run off has occurred through low fill embankments associated with tracks and easements or drains.

The susceptibility to erosion of the surface soils in the Swamp is considered to be low on the basis of soil properties, vegetative cover and very low surface gradients. The Swamp is periodically inundated with significant run off of surface waters occurring to the drainage paths. Under these general sheet flow conditions the erosion hazard appears to be slight, however under concentrated flows the risk of erosion is high.

Some localised sheet and rill erosion is occurring along the margins of the Swamp where urbanisation has resulted in increased and concentrated run off. The erosion appears to be predominantly occurring along the foot slopes of the surrounding residual soil hillside areas. The boundary between the hillside areas and the low gradient swamp areas is generally marked by a sharp break of slope, suggesting past erosion from estuarine processes.

5.5.1.2 Sedimentation

The areas surrounding the Swamp comprise residual clay soils and weathered rock associated with the Tomago Coal Measures. These clay soils are highly susceptible to sheet and rill erosion particularly where the topsoil has been removed or disturbed. Sediment derived from this erosion eventually impacts on the Swamp as it is transported downstream.

ICTCMC (1996) noted that an estimated 8,500 tonnes of sediment is delivered to the Swamp annually from the catchment, although the load is variable, depending on climatic variation and development activities. The output to the Hunter River is only 400 tonnes/year, indicating that substantial amounts of sediment are trapped in the Swamp.

5.5.2 Problems

5.5.2.1 Erosion

The banks along Ironbark Creek and to a lesser extent Fishery and Shelley Creeks are currently undergoing localised erosion and regression. Tidal inundation will result in increased ebb tidal velocities along the channel areas with the extent of the influence depending on the number of tidal gates opened. In the short term this could result in an increase in the rate of bank erosion due to:

- Increased groundwater seepage from creek banks associated with raising of the groundwater table;

- Minor scour effects associated with tidal flows;
- Concentration of tidal over-bank flows at low points along the creeks;
- Gradual death of salt intolerant vegetation such as grasses.

Acceptable limits to erosion would need to be established. These limits will depend on the area affected, the volume of soil involved and the nature of the erosion (slumping, undercutting, gully erosion, etc.). Monitoring of erosion and rehabilitation would be conducted as a cooperative effort by the Project Committee, DIPNR and landowners.

In the long term, the re-establishment of native vegetation such as mangroves will have a beneficial effect on creek bank stability. Once native vegetation is established, the rate of erosion is likely to be significantly less than that presently occurring, particularly when stock grazing of creek banks ceases.

5.5.2.2 Sedimentation

ICTCMC (1996) noted that the Swamp acts as an efficient sediment trap with the annual volume of sediment input greatly in excess of output into the Hunter River. Sedimentation of the drainage paths and creeks is being promoted by the sediment surplus and the low-flow conditions induced by current floodgate operation. It will result in gradual sedimentation of the waterways if existing conditions remain.

The opening of the gates will promote tidal flushing of suspended sediments and reduce the risk of sedimentation along the waterways. Increasing the tidal influence is also expected to scour away some of the sediment which has accumulated in the last 30 years since the construction of the floodgates. However in terms of the total sediment input into the Swamp, tidal inundation is unlikely to significantly increase the volume of sediment discharge into the Hunter River, as the bulk of the sediment load entering the Swamp is derived from surrounding urban areas which are generally located about 0.5 km or more from the area of maximum tidal inundation.

5.5.3 Action Required

Objectives for management, actions required, timing and budget are tabulated in Table 5-5.

Table 5-5 Creek Erosion and Sedimentation Action Plan

Phase	Nature of Action Required	Responsible	Timing
Objective 11	**To ensure that erosion resulting from the Project remains within acceptable limits.**		
Initial Action	To minimise the intensity and extent of creek bank erosion, the opening process will be staged, starting with a single gate.	CMA, DIPNR	Initiate when first gate is lifted
	Criteria will be set which, if exceeded, would trigger a corrective response.	CMA, DIPNR	Completed when first gate is lifted
Monitoring	A program to monitor the incidence of erosion in the Swamp will be developed.	CMA in cooperation with DIPNR	Completed when first gate is lifted
	A program to monitor the incidence of erosion in the Swamp will be implemented and sites significantly eroded will be registered.	CMA, DIPNR	Initiate when first gate is lifted
Corrective Action	Sites with significant erosion to be rehabilitated.	CMA in cooperation with DIPNR and landowners	Initiate upon registration
Objective 12	**To ensure that there are no sedimentary obstructions to flow within the waterways.**		
Initial Action	The cooperation of catchment landholders and other land and water managers will be enlisted to minimise the sediment load from the catchment.	Project Committee in liaison with NCMF, DIPNR, NCC	Ongoing
Monitoring	A program to monitor the sedimentation of waterways to be developed.	CMA in cooperation with DIPNR	Completed when first gate is lifted
	A program to monitor the sedimentation of waterways to be implemented.	CMA in cooperation with DIPNR	Initiate when first gate is lifted
Corrective Action	If sediment blockages are identified, remove where appropriate.	CMA in cooperation with DIPNR	As required

5.6 Habitat Management

5.6.1 Current Status

5.6.1.1 Vegetation

Several studies of the vegetation of the Swamp have been conducted in the past. WBM Oceanics Australia (in prep.) provides a review of these studies together with an updated vegetation map and vegetation descriptions based on previous studies, new aerial photography interpretation (flown in 1994), and minor field survey work.

A total of eight communities were delineated. A brief description of each community is presented in Appendix C. This Appendix also includes a map showing the location and extent of the vegetation communities, digitised from the colour aerial photography of 1994.

An examination of regional vegetation surveys indicates that none of the vegetation communities presently encountered within the Swamp can be considered to be rare or threatened. The Swamp is mapped as SEPP14 Wetland No.840 and is large in area by regional standards.

A survey of the non-tidal wetlands of the Lower Hunter floodplain by Pressey (1981) indicated that the Swamp represented approximately 37% of the total non-tidal wetland area within the floodplain. Based on its extent, Pressey considered the Swamp to be an "outstanding" wetland in a regional context. Vegetation communities well represented within the Swamp included Common Reed (*Phragmites australis*), Cumbungi (*Typha orientalis*), and reeds *Schoenoplectus littoralis* and *Bolboschoenus caldwellii*.

The area covered by mangroves is currently, and has always been, small by regional standards. According to measurements by Williams *et al* (1998), the total mangrove area in the Hunter River estuary (excluding Hexham Swamp) was 1,711 ha in 1994. Given a current total area of 31.88 ha of mangrove within the Swamp, the proportion of the mangrove resource within the Swamp represents 1.8% of that within the Hunter River estuary.

Historically, the proportion of the Lower Hunter's saltmarsh contained within Hexham Swamp has been much higher than that of its mangroves. Of a total of 2,449.55 ha of saltmarsh in the Lower Hunter in 1966, 646.55 ha (26.4%) was located within the Swamp. The loss of virtually all saltmarsh in Hexham Swamp since then has therefore contributed considerably to the loss of saltmarsh in the Lower Hunter. Loss of saltmarsh has, however, also occurred due to developments elsewhere, as well as due to an expansion of mangroves into saltmarsh (Williams, pers. comm.).

A recent study showed that in 1938, Hexham contained 903.1 ha of saltmarsh, and 865.5 ha of freshwater wetland (not including Phragmites reed). Only 363.9 ha of the area were taken up by agriculture (Morrison 2001). Currently (2000) there is 5.9 ha of saltmarsh and 575 ha of freshwater swamp. The common reed (*Phragmites australis*) has increased in the Swamp by 2,862% with total cover of this reed at 885.7 ha in 2000 (Morrison 2001).

One plant species found in Hexham Swamp, *Zannichellia palustris*, is listed as Endangered (Schedule 1) under the NSW *Threatened Species Conservation Act 1995*. The species is not currently listed under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999*.

The species is an aquatic halophyte that occurs in eutrophic lakes, rivers and estuarine areas in Europe and North America, where it occasionally requires control. It was first recorded in Australia near Murray Bridge in South Australia in 1887. Since 1971 it has been recorded in the Canoe Channel (connecting The Wetlands Centre (TWC) to Ironbark Creek), as well as near the Minmi Road bridge across Ironbark Creek, Black Creek at Cessnock, ponds on Kooragang Island, and from near Belmont (Winning, 1996; Winning, 1996b). Its occurrence in the Lower Hunter has been known since the 1970s (S Jacobs, *pers.comm.*).

Given its worldwide distribution and its relatively recent discovery within the Hunter region, it is not clear whether the species is a recent introduction, possibly brought in on ballast water, or an indigenous species to NSW with a restricted range (Greenwood, 2001).

5.6.1.2 Fauna

A large number of studies have been conducted on the fauna of the Swamp. A review of these studies, augmented by brief field confirmations, is presented in WBM Oceanics Australia (in prep.). A concise version of this review is provided below.

Habitats

There are currently two broad habitat types (containing a range of micro-habitat types) within the Swamp:

- Channel habitat, comprised of Ironbark Creek and its major tributaries; and
- Wetland habitat, comprised of the shallow, seasonally inundated freshwater wetland areas of the Swamp, bordered by dry land.

The current absence of tidal inundation in shallow wetland areas precludes the use of these areas by estuarine macroinvertebrates and fish. Consequently, these groups are limited to (predominantly deep) channel habitats. Overall, the Swamp's catchment can be considered to have low habitat values for estuarine fauna at local to regional scales as:

- heavy siltation, Phragmites infestation and lack of tidal inundation has resulted in a reduction in the area of shallow brackish waters;
- all creeks have steep banks and are relatively deep (except the Canoe Channel), and therefore have limited structural diversity and habitat value;
- the presence of a narrow fringe of mangrove pneumatophores along some banks would provide a suitable habitat to some macroinvertebrates. However, the small area and poor condition of these mangroves limits their use by estuarine fauna;
- the channel habitat is well represented elsewhere in the Hunter River (eg. Moscheto Creek, Throsby Creek, areas around Fullerton Cove); and
- poor water quality (due to occasionally excessive nutrient levels) limits the value of Ironbark Creek as a viable estuarine habitat.

The Swamp's catchment can be considered to have moderate habitat value for freshwater macroinvertebrate and fish fauna at local to regional scales as:

- habitat diversity can be considered as moderate, as both channel and wetland habitats are available to these groups;
- structural diversity of the channel habitat is relatively low, comprised almost entirely of only a single micro-habitat (i.e. deep channels with a thin mangrove fringe). None of the creeks contain shallow protected areas, aquatic vegetation or riffle

sequences, reducing their habitat value. Some upstream sections of Ironbark Creek contain shallow waters, although these areas are degraded and suffer from high levels of weed infestation, litter and urban run-off;

- structural habitat diversity of the wetland habitat is relatively low, comprised almost entirely of grasslands and reeds;
- the available habitat types are well represented elsewhere in the Hunter region, but to a far lesser extent than those in the Swamp's catchment (eg. Beresfield, Thornton etc.);
- the available wetland areas are in relatively good condition; and
- poor water quality (due to occasionally excessive nutrient levels) limits the value of Ironbark Creek channel as a freshwater habitat.

Fish and Crustaceans

Overall, a total of 25 families comprising 60 species have been recorded from above the Ironbark Creek floodgates (WBM Oceanics Australia, in prep.). Of these, 45 were primary estuarine/saltwater species, 13 were catadromous species and 2 were primary freshwater species, according to classifications in Merrick and Schmida (1984), Grant (1985), Hutchins and Swainston (1986), Allen (1989) and Wager (1993). Twenty-four species are commercially important fish species.

Bull mullet (*Mugil cephalus)* were the most abundant commercial species (10% of catch), followed by yellow-finned bream (*Acanthopagrus australis*; 3%) and flat-tailed mullet (*Liza argentea*; 0.3%) (Shepherd, 1994). The numerical dominance of freshwater fish led Shepherd (1994) to conclude that the Ironbark Creek was essentially a freshwater creek system.

While a number of saltwater species can and do pass through the partially opened floodgates at Ironbark Creek, the abundances of many species, particularly the adult stages of most commercial species appear to be limited within the Ironbark Creek catchment compared with similar sized but non-gated creeks elsewhere within the region (Shepherd, 1994). These results demonstrate that Ironbark Creek is essentially not utilised currently by adult commercial saltwater fish, which is consistent with results obtained by McGregor (1979).

Shepherd (1994) undertook an investigation of the distribution and abundance of prawns (Family Penaeidea) over a one-year period at Ironbark Creek, and recorded three species of commercial importance (*Metapenaeus bennettae, M. macleayi* and *Penaeus plebejus*). A fourth commercially important prawn species (*Penaeus esculentus*) and the blue-swimmer crab (*Portunus pelagicus*) have also been recorded in Ironbark Creek by NSW Fisheries (unpublished data in DLWC, 1996). Shepherd (1994) demonstrated that the school prawn (*M. macleayi*) was by far the most abundant of the prawn species in Ironbark Creek, consistent with McGregor (1979) and NSW Fisheries (unpublished data in DLWC, 1996).

The juveniles of all prawn species occur at very low abundances in the study area, possibly due to the absence of good quality nursery habitat (McGregor 1979, Shepherd 1994). All prawn species recorded at Ironbark Creek utilise shallow coastal estuaries and rivers during their juvenile stage (Kailola *et al.,* 1993), and are more abundant in areas with high seagrass cover (Coles and Lee Long, 1984; Halliday, 1995). The absence of seagrass at Ironbark Creek may partly explain the rarity of juveniles in this creek.

The fish and crustacean assemblages in the study area have the following ecological values:

- the fish assemblages that occur in the study area are not unique, but rather representative of assemblages that are typical in slightly brackish to fresh waters. All fish recorded are relatively common and widespread throughout New South Wales.
- no endangered species, populations, ecological communities, or vulnerable species as currently listed under Schedules 4 and 5 of the *Fisheries Management Act 1994*, have been recorded, or likely to occur in the study area;
- the Purple-spotted Gudgeon (*Morgunda adspersa*), which is classified as Restricted by the Australian Society of Fish Biologists, has been recorded from Ironbark Creek. This classification was given due to serious decline in distribution and abundance of this species in the Murray-Darling Drainage, particularly in South Australia (Extinct) and Victoria (Presumed Extinct) (Wager, 1993). Electrophoretic studies (South Australian Department of Fisheries, cited in (Wager, 1993)) indicate that the Murray-Darling stock is considerably different from east coast stocks, and therefore warrants classification as a separate taxon (species). For this reason, IUCN and ANCA (now Environment Australia (EA)) only classify the Murray-Darling stock as Endangered (EA) and Critical (IUCN), and does not apply to east coast stocks (Wager, 1993), which are considered as relatively common.
- no species (but see *Morgunda adspersa*) listed as Endangered, Threatened, Potentially Threatened, Critical or Vulnerable by the EA (Wager, 1993) or the IUCN have been recorded, or are likely to occur, within the study area.;
- provides a functional nursery habitat for a range of economically important species; and
- many species (eg. *Pseudomugil signifier, Hypseleotris compressa, H. galii*) prey on mosquito larvae, restricting adult mosquito population sizes.

Ironbark Creek presently has low fisheries values at local, regional and state scales as:

- there are few aquatic habitat types of direct fisheries value in Ironbark Creek;
- mangroves, which constitute one of the most important micro-habitat types to commercial fisheries species, cover only a small area of Ironbark Creek catchment and are highly degraded;
- water quality is typically poor and unsuitable for many species of fisheries importance;
- the habitat types of fisheries value (channels with a thin mangrove fringe) are well represented in the Hunter River, throughout NSW and elsewhere in eastern Australia;
- the abundance of commercially important prawn species in Ironbark Creek is relatively low. Ironbark Creek is not directly fished for prawns, however it is likely that the prawns that do use this catchment would form a minor part of the commercial prawn catch for the Hunter River, and possibly other areas along the NSW and Queensland coasts;
- with the exception of Sea Mullet, Ironbark Creek does not presently support significant juvenile and adult populations of commercially important fish.

Macroinvertebrate

The aquatic macroinvertebrate assemblages of Ironbark Creek have been investigated in several studies, as reviewed by WBM Oceanics Australia (in prep.). Most of these have concentrated on species of direct fisheries value.

The aquatic macroinvertebrate assemblages are comprised of freshwater and estuarine species. Both freshwater and estuarine organisms typically co-occur throughout the creek, from areas adjacent to the floodgates to areas upstream of the Chichester pipeline. This result suggests that the composition of aquatic (estuarine and freshwater) macroinvertebrates does not follow a strong salinity gradient, at least along the length of the creek investigated by previous surveys.

Unfortunately there are few available data on the composition, distribution and/or abundance of macroinvertebrates that inhabit the shallow wetland areas. Preliminary observations made by WBM Oceanics Australia (in prep.) recorded a range of freshwater insects which are typical of shallow freshwater wetland areas.

CMA engaged Bio-Analysis in 2002 to conduct a study into benthic invertebrates in the Swamp as part of the overall before/after floodgate opening study. A pilot study was completed that identified benthic macroinvertebrates to species level. Analysis of data collected showed that although there was some overlap between communities found in Hexham and at two reference sites, communities in Hexham generally are made up more of species that indicate degraded sites and that are tolerant of poorer water quality (Roberts 2002). This study is to continue in association with other studies into the effects on the Swamp of modifying floodgate operation.

The benthic macroinvertebrate assemblages in the study area are not unique, but representative of the types of assemblages that are typical in slightly brackish to fresh waters. Almost all macroinvertebrate families recorded in this study have been recorded elsewhere in the Hunter River system (eg. Chessman *et al.*, 1997, Shepherd, 1994), and are widespread and common throughout temperate Australia (Williams, 1980; Hutchings, 1984; Dakin and Bennett, 1987).

Installation of the floodgates has in turn resulted in a macroinvertebrate assemblage which is of low to moderate conservation value. However, they do form an important part of the diet of many fish species that inhabit Ironbark Creek, its tributaries and the adjacent wetlands.

Birds

A total of 188 species of birds have been previously recorded from the NPWS Atlas grid square in which the Swamp is located. This species diversity represents 142 genera from 55 families.

Approximately 17% (32 species) of the avifauna recorded with the NPWS Atlas areas containing the Swamp, are heavily dependent on freshwater and brackish wetland systems (eg. open water, saltmarsh, shallow seasonal freshwater swamps, wet reed communities, ponded pastures) to complete their life cycle. The majority of the species recorded for the NPWS Atlas search area that are listed under the NSW *Threatened Species Conservation Act 1995* are species that are heavily dependent on wetland environments that are of high habitat value and integrity.

The Swamp is considered to be of regional importance for large numbers of birds, particularly waterfowl (NPWS, 1981), supporting approximately 45% of remaining Hunter wetlands habitat for Black Swan *(Cygnus atratus)*, Pacific Black Duck *(Anas superciliosa)*,

Australasian Shoveler *(Anas rhynchotis)*, Grey Teal *(Anas gracilis)* and Chestnut Teal *(Anas castanea*) (DPW,1988). In excess of 10,000 waterfowl were recorded on the Swamp during the 1970s, however numbers have declined since then possibly due to flood mitigation works and the increase in dominance of Common Reed over large tracts of the Swamp (NPWS, 1996a).

A number of bird species recorded from the general area are listed under the *Threatened Species Conservation Act 1995* (TSC Act). Species potentially occurring within the Swamp include Black-necked Stork (*Ephippiorhynchus asiaticus*) (listed as Endangered), Magpie Goose *(Anseranas semipalmata)*, Black Bittern *(Ixobrychus flavicollis)*, Australasian Bittern (*Botaurus poiciloptilus*), Painted Snipe *(Rostratula benghalensis)*, Comb-crested Jacana *(Irediparra gallinacea)* Blue-billed Duck (*Oxyura australis*) and Freckled Duck (*Stictonetta naevosa*) (all of which are listed as Vulnerable).

Sixteen of the species recorded at or near the Swamp have also been listed in either the *Agreement between the Government of Australia and the Government of The Peoples Republic of China for the protection of migratory birds and their environment 1976* (CAMBA) and/or the *Agreement between the Government of Australia and the Government of Japan for the protection of migratory birds in danger of extinction and their environment 1974* (JAMBA).

However, a review conducted by Kingsford and Levy (1996) indicated that a number of migratory waders previously recorded for the Lower Hunter have either not been recorded anymore since 1986 or their numbers have significantly declined. Changes to the estuarine islands of the Hunter River, and loss of saltmarsh and freshwater wetlands (including changes in the Swamp would have contributed to this trend (Geering, 1995; Kingsford and Levy, 1996; WBM Oceanics Australia, in prep.).

Herpetofauna

The NPWS Atlas grid square in which Hexham Swamp is located, together with records from previous studies within the area indicate that thirteen reptile species representing, eleven genera and five families are known or likely to occur within the Swamp (see WBM Oceanics Australia, in prep.). ICTCMC (1996) lists twelve species for the Ironbark Creek catchment including one species (Blind Snake, *Ramphotyphlops nigrescens*), which is not included in the summary above, and which may occur within Hexham Swamp.

Those species with strong wetland affinities include Eastern Long-necked Tortoise (*Chelodina longicollis)*, Black-bellied Swamp Snake (*Hemiaspis signata)* and the Red-bellied Black Snake (*Pseudechis porphyriacus)*. The Eastern Long-necked Tortoise inhabits permanent water bodies from lakes to billabongs and the slower moving sections of waterways. Both snake species feed principally on frogs with reptiles and small mammals also taken, either as encountered and/or sought during declines in frog populations (Wilson and Knowles, 1988).

Eleven species of amphibians (four genera and two families) have been recorded from the Swamp (WBM Oceanics Australia, in prep.). An additional three species have been recorded within the NPWS Atlas grid square in which Hexham Swamp is located. One species, the Green and Golden Bell Frog (*Litoria aurea*), is listed as Endangered under the *TSC Act 1995*.

Markwell (1984) identified eleven frog species at the Swamp (including the Green and Golden Bell Frog) which represents approximately 30% of the frog species likely to occur within the Hunter region (Markwell 1984). The study also noted that the operation of the Ironbark Creek floodgates may have produced beneficial conditions for the expansion of

frog distribution in the south-east of the swamp as a result of changes from saline to freshwater conditions and subsequent vegetation community changes (eg. saltmarsh to reed swamps). However, there was a notable absence of frogs within the central sector of the Swamp, east of the Pelaw Main railway line which corresponded with an extensive area of wetland dominated by *Phragmites australis*. Only one species, the Green and Golden Bell Frog, was recorded from this community, and then only along the margins.

Recent surveys by Hamer (1998) and Winning (2002) failed to locate the Green and Golden Bell Frog in the Swamp, although it has been observed on the margin of the Swamp at the former Astra Street waste disposal site and at the '2HD pond' near Sandgate (C Reiher, SOFAR letter of 18/9/01). The decline of this species in the Swamp may be related to the presence of the introduced Mosquito Fish (*Gambusia holbrooki*). This species is an adaptable, fecund species which has been implicated in the decline of local populations of native frogs and fish in general (NPWS Draft Threat Abatement Plan: Predation by *Gambusia holbrooki*, 2002; Morgan and Buttermer, 1996; Arthington, 1989).

Mammals

Ten species, including two native species (Northern Brown Bandicoot *Isoodon macrourus* and Water-rat *Hydromys chrysogaster*), have been recorded from studies within the Swamp, although 26 species of mammals (twelve genera, twelve families) have been recorded from the NPWS Atlas grid square in which Hexham Swamp is located. A complete list of mammal species is provided in WBM Oceanics Australia (in prep.).

There is a relatively small number of mammals of the region which are dependent on wetland environments for their existence. Of the species known or likely to occur in the Swamp, only the Water-rat (*Hydromys chrysogaster)* and Swamp Rat (*Rattus lutreolus)* are considered to be dependent or heavily reliant on inundated or damp environments. The Common Planigale (*Planigale maculata*), known from areas adjacent to the Swamp, is often found in forested habitats near water.

Of the species identified in the NPWS Atlas search and those recorded from studies within the Swamp, five species are listed as Vulnerable under the *TSC Act 1995*. These are the Koala (*Phascolarctos cinereus*), Squirrel Glider (*Petaurus norfolcensis*), Little Bentwing-bat (*Miniopterus australis*), Common Bentwing-bat (*Miniopterus schreibersii*) and Greater Broad-nosed Bat (*Scoteanax rueppellii*). It is however unlikely that Koalas and Squirrel Gliders would occur within the Swamp itself.

5.6.2 Problems

The Swamp's catchment currently contains a diverse number of native plant and animal communities. It is expected that the opening of the floodgates will change the assemblages and distribution of these communities. The extent to which such changes may occur will be dependent on the degree of tidal flushing which is determined by the number of tidal gates opened.

The main impacts of the opening of the floodgates are listed below:

- A single gate opening would affect a small area near the floodgates presently covered with degraded saltmarsh, mangroves, Common Reed, and She-oak.

  Initial inundation by saline waters will result in the death of salt-sensitive vegetation. Short-term impacts of vegetation decomposition may include increased nutrient levels and the lowering of dissolved oxygen levels in water to levels lower than that required for aquatic fauna to survive, and increased levels of erosion and turbidity. In the longer

term, salt intolerant vegetation will be replaced by salt tolerant vegetation, and any exposed banks will be revegetated by salt tolerant species.

One species, the Horned Pondweed *Zannichellia palustris* is listed as an Endangered species under the *Threatened Species Conservation Act 1995*. Its habitat is likely to be affected by floodgate opening;

- The floodgates currently restrict tidal exchange and flushing of Ironbark Creek. As a consequence, water quality is generally poor and the diversity and abundance of aquatic fauna (fish, crustaceans, macroinvertebrates) is severely reduced (Shepherd, 1994; Roberts, 2002). The opening of the floodgates should improve water quality conditions and available habitat for aquatic fauna thereby making these ecological communities more viable and improving fisheries resources;

- The opening of the floodgates will improve the quality and extent of habitat for a range of common and threatened bird species, including migratory waders and wetland birds. However, species typically associated with freshwater environments (including species such as the Vulnerable-listed Australasian Bittern) may have their habitat (Common Reed community) markedly reduced in the opening of all eight floodgates. Few species will be affected by the single gate opening;

- The opening of the floodgates would result in a reduction in habitat for reptiles and frogs;

- Few mammals, with the exception of microbat species which forage over the Swamp, as well as the water rat and swamp rat, will be directly affected by the opening of the floodgates.

Rehabilitation of the Project area will also involve the removal of cattle and other domestic stock from the Swamp in order to allow the regeneration of natural vegetation. Removal of grazing pressure is, however, likely to increase the incidence of weeds. Grazing regimes using cattle or other stock may, therefore, need to be employed to control weed infestations in selected areas, subject to careful monitoring of the impacts of cattle

5.6.3 Action Required

Objectives for management, actions required, responsibilities, timing and budget are tabulated in Table 5-6.

Table 5-6 Habitat Management Action Plan

Priorities	Nature of Action Required	Responsibility	Timing
Objective 13	**To restore tidal habitats, while minimising deleterious impacts on rare or threatened species and, where possible, improve conditions for these species or their habitats (including freshwater habitat).**		
Initial Action	A single gate will be opened initially to allow sufficient time for monitoring of changes to ecological parameters.	CMA in liaison with DIPNR	Following approval of EIS
	Develop and implement a program of revegetating areas on the margins of wetland areas within the Project area.	CMA, Project Committee, ALALC, Community	In progress
	Research will be conducted into the habitat requirements of rare and threatened species, where this information does not already exist.	CMA, Project Committee	Commence immediately
Monitoring	A monitoring program has been developed to measure the ecological characteristics once the first gate is opened. The monitoring program includes baseline survey of the Swamp and will continue after increased floodgate opening. The current monitoring program is detailed in Section 6.4.3 (vegetation) and Section 6.5.3 (fauna) of the Hexham Swamp Rehabilitation Project EIS (WBM, 2005).	CMA, Project Committee	In progress
Corrective Action	Depending on the results of research and monitoring, alterations may be required to the operation of the floodgates in order to modify the tidal regime. Other corrective action may include increased revegetation (seeding and/or planting), active introduction of suitable fauna species, creation of special purpose habitat for significant species (eg. by excluding threatening processes such as Mosquito Fish from frog habitats), translocation of salt intolerant species to suitable new habitat, re-instatement of grazing regimes in selected areas to control weed growth, or manipulation of habitats using techniques developed through research.	CMA, Project Committee in liaison with NPWS and NSWF	Post-monitoring

5.7 Pest and Weed Management

5.7.1 Current Status

5.7.1.1 Weed Species

WBM (in prep.) listed 12 major weed species in the Ironbark Creek catchment, including four listed as noxious plants in the Newcastle local government area (Blackberry, Alligator Weed, Pampas Grass and Water Hyacinth). Public Authorities are required under the *Noxious Weeds Act 1993* to control noxious plants on the lands they manage.

Some weed species are sufficiently aggressive that they out-compete native plants and become an economic liability for councils and other control authorities. Three noxious weed species common in the Swamp area are Pampas Grass (*Cortaderia selloana*), Alligator Weed (*Alternanthera philoxeroides*) and Water Hyacinth (*Eichhornia crassipes*). These are briefly described below.

Control of noxious weeds on CMA land is outlined in the Project pest plant and animal control plan produced in 2002.

Alligator Weed

Alligator Weed was first sighted in the Swamp in 1979, in a drain below the Shortland Wastewater Treatment Plant where it responded well to the influx of nutrient-enriched effluent.(Le Messurier, 1981). In 1981, pockets of Alligator Weed were found in an unformed suburban drainage canal off Watkins Street, Elermore Vale and on an adjoining embankment. Also in 1981, Alligator Weed was found in a recently planted turf lawn at a home in Andretta Avenue, Elermore Vale. This infestation was unrelated to earlier infestations. In 1988, infestations of Alligator Weed were found spreading along Ironbark Creek downstream from Minmi Road, also in nutrient-rich waters. Herbicide applications have been applied in an attempt to prevent its spread in this location. Other major infestations occur in Dark Creek and the adjoining land. In 1992, new outbreaks were detected north of Fishery Creek on the western side of the water pipeline. It is likely that this infestation was spread to the swamp by cattle frequenting infestations along Fishery Creek. In early 1993, a further outbreak was confirmed in a suburban lawn at Maryland. It is also present within TWC (Le Messurier, pers. comm.)

More recently, Alligator Weed has been found along the disused railway line on both CMA and Service land. The incidences of Alligator Weed here are being controlled in a joint operation by NPWS and CMA.

Pampas Grass

Infestations of the perennial Pampas Grass occur in various locations along the southern and eastern edges of the Swamp. An extensive spraying effort by NCC has decreased the infestation considerably. An on-going campaign for many years will be necessary to kill regeneration by seedlings in areas which used to be extensively infested, such as around the Shortland garbage dump and around The Wetland Centre. There is also a large infestation around the 2HD radio masts.

Water Hyacinth

During the operations of the former Newcastle Regional Abattoir the presence of Water Hyacinth was considered beneficial in being able to remove large quantities of nutrients from the waterways receiving abattoir effluent. A campaign undertaken in 1988 by the owners of this land, now a residential area, have controlled Water Hyacinth in the wetlands alongside the Great Northern Railway Line.

A survey of Water Hyacinth was undertaken in the Swamp and surrounding land during early 2002. This survey showed that there were extensive infestations of the weed throughout the Project area and on surrounding land, especially to the north of the disused railway line.

Other environmental weeds include species such as the Rush *Juncus acutus*, Kikuyu *(Pennisetum clandestinum)*, Blackberry *(Rubus vulgare)*, Fennel *(Foeniculum vulgare)*, Castor Oil Plant *(Ricinus communis)*, Stinking Roger *(Tagetes vulgare)*, Wild Tobacco Tree *(Solanum mauritianum)*. Most of these are abundant only in small areas near the margins of the Swamp, except for *Juncus acutus*, which occurs throughout the degraded saltmarsh areas, particularly in the southern part of the HSRP area.

5.7.1.2 Exotic Pest Species

A number of exotic animals are found within the Swamp, many of which can be considered to be pest species. These include domestic stock and pets and feral animals.

Cattle and horses are kept in fenced paddocks along the western and southern edges of the Swamp. However, stock are also known to break out of fenced areas and are routinely roaming the Swamp, causing physical damage to the Swamp.

Domestic pets pose a problem in the area in the form of feral dogs and cats, the impact of which is difficult to quantify. However, there is no doubt that feral cats have the potential to severely effect small mammal and bird populations.

Non-domestic (feral) animals found in the Swamp include Pig *(Sus scofa)*, Fox *(Vulpes vulpes)*, Rabbit *(Oryctolagus cuniculus)*, Hares *(Lepus capensis)*, Black European Rat *(Rattus rattus)*, Brown Rat *(Rattus nomegicus)*, Indian Mynah *(Acridotheres tristis)*, Starling *(Sturnus vulgaris)*, and English Sparrow *(Passer domesticus)*. These fauna cause physical damage and/or compete with native fauna for resources.

Pigs and Foxes in particular are causing widespread damage. Foxes have a major impact on the fauna populations at The Wetland Centre through predation of native bird and other animal species, in some cases on threatened or endangered species. Whilst foxes in local area may be temporarily excluded through fencing and poisoning, the gap is soon filled from free roaming animals from the fringes or body of the Swamp. Foxes are listed as a Key Threatening Process under the *TSC Act 1995*.

In addition to these species, the Swamp is also populated by large numbers of Mosquito Fish *(Gambusia affinis)*, a fish species which is a major predator of mosquito larvae, but also of native frogs and fish larvae and juveniles. It is listed as a Key Threatening Process under the *TSC Act 1995* (see also below).

Carp are also a problem in the Swamp due to the physical damage they cause to river systems. They also affect native fish species through competition for resources. It is

envisaged that once the floodgates are opened, the habitat available to Carp will be very small and their populations should naturally decline.

With the exception of Carp and Mosquito Fish, control of pest animal species is outlined in the Project pest plant and animal control plan produced in 2002.

5.7.1.3 Mosquitoes

WBM Oceanics Australia (in prep.) provides a summary of mosquito sampling results until 1998. The Project has been monitoring mosquito populations in the Swamp since the 2000-01 season. This work is now being undertaken by the University of Sydney. From the results it is evident that the Common Banded Mosquito (*Culex annulirostis*) is now the predominant pest species breeding in the Ironbark Creek catchment.

Despite the loss of significant tidal ventilation in Ironbark Creek and salt water intrusion into the Swamp, the current mosquito breeding sources are variable and include former tidal channels and mudflats off Ironbark Creek and Fishery Creek. The continuity and free-flowing characteristics of the channels have been obstructed over the past 20 years by natural earth blocks and the accumulation of debris.

The major inputs of water to these hollows arise from periods of sustained rainfall or overtopping of levees caused by floods.

Water may stand for many weeks in some of the deeper ponds and allow breeding and larval development of mosquitoes. Common Banded Mosquitoes *(Culex annulirostris)* and the Common Australian Anopheline *(Anopheles annulipes)* have been found breeding in some of the grassy pools. The Saltmarsh and Hexham Grey Mosquitoes *(Ochlerotatus vigilax* and *Ochlerotatus alternans)* also breed in some of the shallow temporary pools of the old mudflats fringed by the remains of mangroves. Here the pools become brackish due to the remnant salt content of the substrate. A lack of drainage in these areas ensures a continuum of mosquito breeding.

Former tidal channels, now vegetated and holding semi-permanent water following rainfall, are also breeding sources. Larvae of the Common Banded Mosquito have been isolated from these pools. These sources occur east of the water supply pipeline and previously supported populations of the Saltmarsh Mosquito.

In addition, sources include freshwater swamps, shallow water or water-logged areas located on the fringe of the Swamp. Here the water may be temporary or permanent. These are distinct depressions vegetated by weeds and other plants and allow breeding of the Common Banded Mosquito. The breeding of the Common Banded Mosquito and the Saltwater Culex *(Culex sitiens)* has been detected in enormous numbers in the eutrophic waters of Fishery Creek beneath the water pipeline crossing.

From time to time algae blooms and weed build-up caused by high nutrient levels have allowed mosquito breeding to go unchecked in waters normally frequented by larvivorous fish. Dry season flow conditions may also give rise to high nutrient conditions.

In regard to predation, the most prolific populations of vertebrate and invertebrate predators occur in the major ponds at TWC. Here the Mosquito Fish (*Gambusia affinis)* shares its habitat with other naturally-occurring insect predators. In addition, both the larvae of Scotch Grey Mosquito and beetles of the Dytiscidae family have been observed feeding on pest mosquito larvae in the Swamp (Le Messurier, pers.comm.).

Mosquito Fish occur in large numbers in most of the fringe waterholes such as those located on both sides of Leneghans Drive and in lesser numbers in the isolated waterholes along the northern end of the Chichester pipeline, however, these fish alone will not remove the pest mosquito problem.

5.7.2 Problems

5.7.2.1 Weeds and Exotic Pests

The replacement of large areas of mangroves and saltmarsh with meadow and reed communities following the construction of the floodgates, has allowed a number of pests and weeds to thrive in the Swamp.

There are numerous weed species in the Swamp area, with the greatest infestations occurring in the fields and paddocks around urbanised areas, transport corridors, industrial sites. The weeds threaten the ecological values of the Swamp by displacing native plant species and the animals dependent on native species, as well as occupying habitats for migratory birds and waterfowl.

Increased tidal inundation within the Swamp caused by the opening of the floodgates would reduce freshwater environments, and is therefore likely to reduce the occurrence of the majority of exotic plant species that are dependent on freshwater environments. Although species such as Water Hyacinth and Alligator Weed are able to tolerate slightly saline conditions, growth would be significantly reduced. However, increased tidal exchange may result in the transport of viable propagules elsewhere. Increased tidal inundation and salinity levels may also increase the suitability of conditions for the introduced Rush *Juncus acutus*. This species is currently a major problem for the Kooragang Wetland Rehabilitation Project, located a short distance from the Project area.

The exotic animal species present in the study area include livestock, domestic, and feral animals. Livestock (cattle and horses) have caused environmental degradation to the Swamp through damage to native vegetation, nutrient enrichment of soils and waterways, soil compaction, bank erosion, and the spreading of weeds. Domestic and feral animals such as cats, dogs, and foxes (which are listed as a Key Threatening Process under Schedule 3 of the TSC Act 1995) have the potential to predate on the wide range of native animals in the Swamp including mammals, birds, reptiles, frogs, and invertebrates. Feral animals such as pigs, rabbits and hares cause soil erosion, and pigs also cause further environmental degradation through soil compaction, the muddying and eutrophication of waterways, and through predation on other animals including wetland birds. Other exotic animals present in the the Swamp catchment such as the Black European and Brown Rats, and birds including Indian Mynahs, Starlings, and Sparrows, compete with and often displace native animals.

Increased tidal inundation within the Swamp would reduce freshwater environments, and is therefore likely to reduce the occurrence of exotic animals including pigs, rabbits, hares, foxes, feral cats and dogs, livestock, rats and birds, all of which generally prefer freshwater environments.

The introduced Mosquito Fish *Gambusia holbrooki* was introduced into Australia to prey on mosquito larvae. While currently present in the Swamp, the opening of the floodgates is likely to increase the area available for the Mosquito Fish. This would have a beneficial impact on the population of mosquito larvae (by preying), thus mitigating the health risk posed by increased mosquitoes. Unfortunately, Mosquito Fish also preys on the larvae of a number of native frogs and fish species, including the endangered Green and Golden Bell Frog *(Litoria aurea)*. Mosquito fish also compete with native estuarine and freshwater fish.

As a result, Mosquito Fish has been listed as a Key Threatening Process under Schedule 3 of the *TSC Act 1995*. Careful management may be required where special purpose frog habitat is considered.

5.7.2.2 Mosquitoes

The Swamp provides habitat for at least 25 species of mosquitoes (WBM in prep., University of Sydney, 2002). Some of these mosquito species such as the Common Banded Mosquito and the Saltmarsh Mosquito are potential vectors of viruses. The opening of the floodgates and regular tidal inundation may increase the potential breeding habitat of mosquitoes, resulting in an increased incidence of mosquitoes. Apart from nuisance caused by mosquitoes, they may also represent a health risk to the residential areas surrounding the Swamp through transmission of arboviruses such as Ross River Fever.

The CMA is presently working in conjunction with other organisations in the Lower Hunter on the management of mosquitoes.

5.7.3 Action Required

Objectives for management, actions required, responsibilities, timing and budget are tabulated in Table 5-7.

Table 5-7 Pest and Weed Management Action Plan

Priorities	Nature of Action Required	Responsibility	Timing
Objective 14	**To ensure that exotic plant and animal species do not threaten the ecological values of the Swamp.**		
Initial Action	A weed management strategy has been developed and is being implemented. One option to control weeds is to use a domestic stock-grazing regime in those areas currently grazed by such animals. This would require the design and implementation of a grazing trial program as part of the overall weed control program as well as the fencing off of areas sensitive to stock (eg. creek banks). Other weed control options include physical removal of plants (pulling by hand or backhoe [for *Juncus acutus*]) or chemical control.	CMA in liaison with Project Committee, NPWS, RLPB, NCC, DIPNR, TWC	Implementation ongoing
	A feral animal management strategy has been developed and is being implemented. Options for control of Foxes and Pigs include baiting and trapping.	CMA in liaison with Project Committee NPWS, RLPB, NCC, TWC	Implementation ongoing
Monitoring	The above control programs includes a monitoring program designed to evaluate the incidence of weed or pest species or damage from these species.	CMA in liaison with Project Committee, NPWS, RLPB, NCC, DLWC, TWC	
Corrective Action	Control measures may need to be adjusted if criteria are continuously exceeded.	CMA in liaison with Project Committee, NPWS, RLPB, NCC, DLWC, TWC	As required
Objective 15	**To ensure that human health and comfort levels are not compromised as a result of the potential additional mosquito presence caused by the opening of the floodgates.**		
Initial Action	Adjust the operation of the floodgates to prevent the creation of tidal breeding pools by restricting the influence of the highest tides. This action will require monitoring to determine the exact operation required to achieve this aim (see Section 5.4).	CMA in liaison with DIPNR	Initiate when the first gate is lifted
	A management regime will be developed based on the Integrated Mosquito Management Plan (IMMP).	CMA, KWRP, NCC, PSC, UniN	Completed when the first gate is lifted

Priorities	Nature of Action Required	Responsibility	Timing
Monitoring	A program has been developed to monitor the incidence of mosquito breeding in the Swamp and other estuarine wetlands. Baseline data are being collected prior to increased floodgate opening. Existing mosquito monitoring program is described in Section 6.6.4 of the Hexham Swamp Rehabilitation Project EIS (WBM, 2005).	CMA, KWRP, NCC, PSC, UniN, UniS	In progress
Corrective Action	If monitoring indicates significant increase in mosquito breeding in the Swamp, actions as detailed in the IMMP will be taken.	CMA, KWRP, NCC, PSC	As required

5.8 Fire

5.8.1 Current Status

Reed communities such as those which currently dominate the Swamp typically have high fuel loads and provide conditions suitable for very high fire intensities (NPWS 1997). Despite these characteristics, the Swamp does not appear to have been affected greatly by fire. Records from NPWS and NSW Fire Brigades of fires in the Swamp extending back to 1990 indicate that the majority of recorded fires were small spot fires.

Only two events over this time period could be considered to have had a significant impact, with both of these occurring in the eastern corner of the site. These events occurred in April 1991 and March 1993. The 1991 event affected areas on both sides of Ironbark Creek, while the 1993 event was limited to its eastern side. It is likely that both of these events would have had a significant effect on the remaining mangrove and saltmarsh communities found on the site.

5.8.2 Problems

Although the proposed tidal inundation should diminish fire hazard in the future, the potential for large-scale fires remains in the short term. In the longer term, there will still be areas which are not regularly tidally inundated and which will, therefore, still be subject to wild fires. Fire will remain an issue to be managed properly to avoid damage to life and property and to ensure that desired habitat management outcomes are achieved.

5.8.3 Action Required

Objectives for management, actions required, timing and budget are tabulated in Table 5-8.

Table 5-8 Fire Management Action Plan

Priorities	Nature of Action Required	Responsibility	Timing
Objective 16	**To minimise the risk of fire damage to life and property and to ensure that desired habitat management outcomes are achieved.**		
Initial Action	A fire management plan to be developed and implemented. The fire management plan to outline fire hazards within the Project area, methods and advantages for fire fighting and suppression (particularly near the HSRP area boundaries and near fire sensitive communities such as mangroves and saltmarsh).	CMA, NPWS, Fire Brigade	As soon as possible
Monitoring	Fuel load to be monitored, particularly near the edges of the Project area, in urban areas, and in areas of strategic wildfire advantage.	CMA, NPWS, NCC	Ongoing
Corrective Action	Reduce high fuel load by slashing or other appropriate methods	CMA, NPWS, NCC	Determined by monitoring outcomes

5.9 Access and Infrastructure

5.9.1 Current Status and Problems

5.9.1.1 Existing Infrastructure

The Project area is traversed by a number of infrastructures, including the Main Northern Rail Line, the Chichester Water Pipeline, the TransGrid powerline, and the Maryland to Shortland (wastewater) Rising Main. Access to most of these developments needs to be maintained for servicing purposes.

The Main Northern Rail Line is highly unlikely to be impacted by tidal inundation due to the proposed modification of the floodgate operation. The lowest point along the 6.5 km section from the Kooragang Branch Line South Fork to the Hexham Bridge across the Hunter River is 2.0 m ASL, which is well above the 1.6 m ASL level at which the floodgates would be closed.

Local floods from the Ironbark Creek catchment would present the only flooding threat (if any) to the railway line which would be affected by changing the operation of the floodgates. However, modelling indicates that it would be highly unlikely that such floods alone would cause flooding of the railway.

The Chichester Water Pipeline may be replaced in the future. Several options are available and re-routing of the pipe may be involved. The pipeline is serviced from an access track under which culverts allow movement of water. As long as the current pipeline is operated, the access track and culverts will be required. Opening of all eight floodgates is not expected to adversely affect the pipeline, however some increased inundation of the access track may occur, requiring filling of depressions and generally raising its height.

The TransGrid powerline runs from Shortland along Ironbark Creek towards Wallsend. The foundations of the pylons are on bedrock, at a distance of up to 30 m below ground. The ground level around the pylons is approximately 1 m above the surrounding area. Thus, while the lower parts of the pylons may be flooded from time to time, there will be no danger of the pylons toppling over due to loss of soil strength through saturation. Periodic inundation of the lower parts of the powerline is not considered to be an issue. However, access to the powerline may need minor upgrading.

The Maryland to Shortland (wastewater) Rising Main is underground, and access is not expected to be required for some time.

Radio masts adjacent to Ironbark Creek floodgates and near Wallsend cemetery require damp ground to function, however permanent inundation with saline water is not desired. The masts adjacent to the floodgates may require protection from tidal inundation by a low bund. The Wallsend masts are beyond any tidal influence and do not require further protection at this time.

CMA will continue to work with infrastructure owners to ensure the Project does not have negative impacts on their operations and that to the greatest extent possible, infrastructure does not adversely impact on achievement of the Project objectives.

5.9.1.2 Habitat Management

Access and minor infrastructure may also be required from time-to-time for habitat management purposes. Access may, for example, include access to cattle which are used for weed control, or access for fire management.

This may require the construction of light tracks in and around the Project area. A light boat ramp may also require construction. Interference with ecological processes should be minimised when constructing and maintaining access.

5.9.1.3 Recreational and Tourism Access and Infrastructure

While the main aim for the Project is nature conservation, significant recreational and tourism opportunities are provided. Activities which are compatible with nature conservation include birdwatching, light boating (canoes), cycling, and walking. Most access required for these activities could coincide with that required for habitat management (see above). Some boardwalks, shelter, and other structures may, however, also be required.

5.9.2 Action Required

Objectives for management, actions required, timing and budget are tabulated in Table 5-9.

Table 5-9 Access and Infrastructure Action Plan

Phase	Nature of Action Required	Responsible	Timing
Objective 17	**To maintain access to infrastructure where required.**		
Initial Action	Agreements will be negotiated with infrastructure managers on maintenance of access.	CMA	In progress
	Access to be upgraded where necessary. Upgrading would involve the use of culverts and other measures to minimise the impact of upgrading on the values of the Project.	CMA, HWC, TransGrid, RIC	Completed when DA approved
Monitoring	A program for monitoring the condition of infrastructure access will be developed and implemented.	CMA, HWC, TransGrid, RIC	Complete program when first gate is lifted
Corrective Action	Access will be repaired if damaged or worn.	CMA, HWC, TransGrid, RIC	As required
Objective 18	**To provide access for habitat management which minimises deleterious impacts on ecological processes.**		
Initial Action	A plan showing required access for habitat management will be prepared.	CMA, NPWS, Project Committee	As soon as possible
	Access for habitat management to be dedicated/constructed.	CMA, NPWS	Completed when first gate is lifted
Monitoring	A program for monitoring the condition of habitat management access to be developed and implemented.	CMA, NPWS	Complete program when first gate is lifted
Corrective Action	Access to be repaired if damaged or worn.	CMA, NPWS	As required
Objective 19	**To provide access for recreational purposes which minimises deleterious impacts on ecological processes.**		
Initial Action	A plan showing required access for recreational purposes will be prepared.	CMA, NPWS, Project Committee	As soon as possible

	Access for recreational purposes to be dedicated/constructed.	CMA, NPWS	Completed when first gate is lifted
Monitoring	A program for monitoring the condition of recreational access to be developed and implemented.	CMA, NPWS	Complete program when first gate is lifted
Corrective Action	Access to be repaired if damaged or worn.	CMA, NPWS	As required

5.10 Community Education and Involvement and Research

5.10.1 Current Status

Concern with the status of the Swamp and the Ironbark Creek catchment has a history dating back to the installation of the floodgates. With the *Catchment Management Act 1989*, a framework for formal community involvement in Total Catchment Management (TCM) was introduced. In response, the Ironbark Creek TCM Committee (ICTCMC) was formed, consisting of members of State and Local Government, as well as community representatives. Public forums, brochure drops, field inspections, and information displays have been held since to increase community awareness of the issues and to seek community input. In addition, several overview studies were commissioned which were published in the Ironbark Creek TCM Strategy (ICTCMC 1996). The main recommendation from the Strategy was to re-open the floodgates at the mouth of Ironbark Creek.

An EIS for the gate opening was subsequently commissioned (WBM, in prep.), which involved further community consultation, including public meetings, one-to-one consultations for residents directly affected, and extensive consultation with Local and State Government.

5.10.2 Problems

The CMA and other environmental management agencies are limited in their capability to manage environmental resources without the cooperation of the wider community. For example, tree clearing, pollution (oil spills, dog faeces, littering), and the manner in which stormwater is managed in the catchment have important impacts on the ecological processes of the Swamp. Arson or other vandalism especially to the floodgates within the Swamp also compromise environmental values.

There is therefore a need to instil a sense of ownership and to educate the community about the Project area and its requirements.

Conversely, some sections of the community (eg. members of the Project Committee and TWC), already do feel a sense of ownership and need to have opportunities to be involved in the management of the Project area. Involving the community could have significant benefits for the Project, including free or low cost labour, expertise, financial assistance or other assistance in kind.

Field days, replanting programs, clean-up campaigns, and similar engagements would provide such opportunities for day-to-day management. Input into management plan updates and other public consultation processes would provide opportunities to be directly involved in the strategic management of the Project area. The creation of facilities for recreational activities such as birdwatching, canoeing, walking, cycling, and picnics would also provide opportunities for increasing the links between the Project and the community.

The community also should be informed about the perception that the opening of the gates and subsequent tidal inundation of the Swamp will result in a significant loss in floodplain storage for local Ironbark Creek flood events. As noted in the Flood Risk and Floodgate Operations Management Action Plan (Section 5.2), there is some concern among the community that the Project will cause additional flooding in developed areas. A community education program can assist in resolving such concern.

The Project provides a valuable opportunity for schools, universities and other institutions to conduct research and field excursions. Research outcomes could assist in improving the management of the Project, in a process which is similar to that which operates at the Kooragang Wetland Rehabilitation Project (KWRP).

5.10.3 Action Required

Objectives for management, actions required, timing and budget are tabulated in Table 5-10.

Table 5-10 Community Education and Involvement and Research Action Plan

Phase	Nature of Action Required	Responsible	Timing
Objective 20	**To encourage and maintain community interest in the Project through education and public awareness activities.**		
Initial Action	A community education and public awareness plan to be developed and implemented.	CMA, Project Committee	As soon as possible
	Communication strategies for the Project to be developed to complement other strategies, eg. Hunter Catchment Blueprint, Hunter Ramsar Communication Strategy.	CMA, Project Committee	As soon as possible
	Criteria to be set which would trigger corrective action if not met. Criteria could be based on the percentage of people surveyed who are aware of the issues, or who behave in an environmentally sustainable manner with respect to a particular issue.	CMA, Project Committee	Ongoing
Monitoring	A monitoring program to be developed and implemented to measure community awareness of issues related to the Project area.	CMA, Project Committee	Ongoing
Corrective Action	The community education plan and communications strategies to be adjusted if criteria are not met.	CMA, Project Committee	As required
Objective 21	**To involve the community in day-to-day and strategic management for the benefit of both the community and the Project.**		
Initial Action	A program for community involvement will be developed and implemented. The program will include targets and protocols for introducing and managing volunteers.	CMA, NPWS, Project Committee	As soon as possible
	Public comment to be sought on plans and publications, where appropriate.	CMA, Project Committee	As required
	A research program to be developed and proposals requested from appropriate institutions.	CMA, Project Committee	As required
Monitoring	Levels and types of community involvement to be monitored and compared with targets.		
Corrective Action	Where targets are not met, further action is required to ensure targets are met in future. Corrective action could include involving other sections of the community and using different methods to reach the community.	CMA, Project Committee	As required
Objective 22	**To develop facilities to support educational and recreational uses of the Project area.**		
Initial Action	An educational and recreational facilities development plan to be prepared and implemented.	CMA, NPWS, Project Committee, KWRP, TWC	Once land purchase has been finalised
Monitoring	Visitor numbers and activities are to be monitored.	CMA, NPWS	As required
Corrective Action	Visitor numbers may need to be encouraged, re-directed, or discouraged and/or recreational facilities may need expansion or modification.	CMA, NPWS	As required

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APPENDIX A: ABBREVIATIONS USED

Abbreviation	Full Name
AHD	Australia Height Datum
ANZECC	Australia and New Zealand Environment and Conservation Council
ASS	Acid Sulphate Soils
CAMBA	China-Australia Migratory Birds Agreement (1986)
DIPNR	Department of Infrastructure, Planning and Natural Resources
EIS	Environmental Impact Statement
EPA	NSW Environmental Protection Authority
CMA	Hunter-Central Rivers Catchment Management Authority
ICTCMC	Ironbark Creek Total Catchment Management Committee
IUCN	International Union for Nature and Natural Resources
JAMBA	Japan-Australia Migratory Birds Agreement (1974)
KWRP	Kooragang Wetland Rehabilitation Project
NCC	Newcastle City Council
NPWS	NSW National Parks and Wildlife Service
NSW ASSMAC	NSW Acid Sulphate Soil Management and Advisory Committee
NSWF	NSW Fisheries
Ramsar	Convention on Wetlands of International Importance Especially as Habitat for Water Birds
TSC Act 1995	Threatened Species Conservation Act 1995
TWC	The Wetlands Centre, Australia

APPENDIX B: GLOSSARY

AHD - Australia Height Datum	National survey datum corresponding approximately to mean sea level. Note that this is not Port Datum which is the datum usually referred to in tidal tables.
ASS - Acid Sulphate Soils	Soils containing iron sulphides, a chemical resulting from a chemical reaction between marine derived sulphate and terrestrial iron oxides and organic matter. It is typically found in low lying coastal soils formed within the past 10,000 years after the last major sea level rise. When iron sulphides are submerged in groundwater, the soils are said to be "potential ASS". When they are exposed to air, they are oxidised and result in the production of sulphuric acid, which is harmful to the environment. Exposed soils with iron sulphides are therefore "actual ASS".
Cost-Benefit Analysis	An economic analysis which weighs up the costs against the benefits of a particular proposal. If the costs outweigh the benefits the proposal should not go ahead. In general, if the benefits outweigh the costs it is desirable for the proposal to go ahead.
Endangered Species	A species which is likely to become extinct unless the circumstances and factors threatening its abundance, survival or evolutionary development cease to operate; or a species the numbers of which have been reduced to such a critical level, or the habitats of which have been so drastically reduced, that it is in danger of extinction.
Environmental Impact Statement	A document prepared under Part 4 or 5 of the Environmental Planning and Assessment Act 1979 which considers the likely impact of a proposed activity on the environment. The factors which must be considered are specified 1994 Regulations.
Estuary	A narrow sea arm or embayment at the mouth of a river, up which the tides penetrate twice daily.
Floodgates	Structures placed in waterways designed to stop floodwaters. If floodgates are placed in tidal waterways they can also be used to stop tidal flows.
Hydraulic	The term given to the study of water flow in rivers, estuaries, and coastal systems.
Hydrology	The term given to the study of the rainfall-runoff process in catchments.
Pest	A troublesome or harmful animal species to humans.
Rehabilitation	The process involved in bringing
Swamp	An almost level closed, or almost closed depression with seasonal or permanent water table at or above the surface.
Tidal Inundation	Flooding of land by tidal water. For most tidally inundated land, this occurs twice daily, during high tide. However, high tides vary in height, depending on the position of the moon and other celestial bodies. On this basis, some areas are inundated only once a day, or even only once a month.
Threatened Species	An extinct, endangered, or vulnerable species (as under the TSC Act 1996)
Vulnerable Species	A species which is likely to become endangered within the next 25 years unless the circumstances and factors threatening its abundance, survival or evolutionary development cease to exist.
Weed	Any plant which grows in place where it is not wanted. Environmental weeds are weeds the growth of which is considered to be environmentally degrading. Plant species can be declared to be noxious under the Noxious Weeds Act 1993. Land owners have particular responsibilities associated with the control of noxious weeds.
Wetland	Any land where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and its surface.