A Vision for the Waterway Corridor

"A sustainable, biologically diverse, stable, naturally functioning waterway corridor providing:

- an accessible environment
- a healthy environment
- a recreational environment
- a safe environment
- a valuable environment; and
- a well managed environment

for all of its users now, and well into the future."

Toongabbie Creek Waterways Maintenance and Rehabilitation Masterplan

Background to Masterplan Preparation.

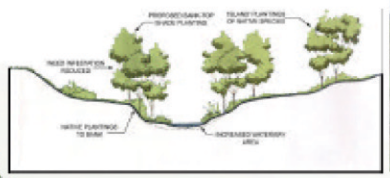
Parramatta City Council has adopted a Waterways management strategy, entitled *"Rivers of Opportunity"*, which outlines a range of goals and objectives for Council's Waterways. In conjunction with a number of other strategic planning documents the Toongabbie Creek Waterways Maintenance and Rehabilitation Masterplan has been prepared to establish and prioritise a range of management activities planned to improve and rehabilitate the condition of the waterway corridor.

The management activities have been established having regard to the historic and current stream form and function of the waterway corridor, and current best practice in waterway management.

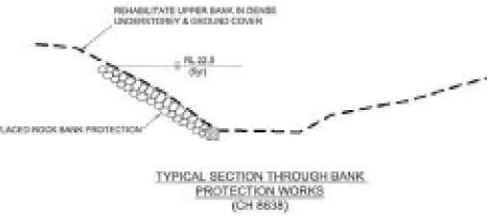
The activities also respond to a *"Vision for the Waterway Corridor"* developed through a process of consultation with Councillors, key stakeholders and interested waterway corridor users.

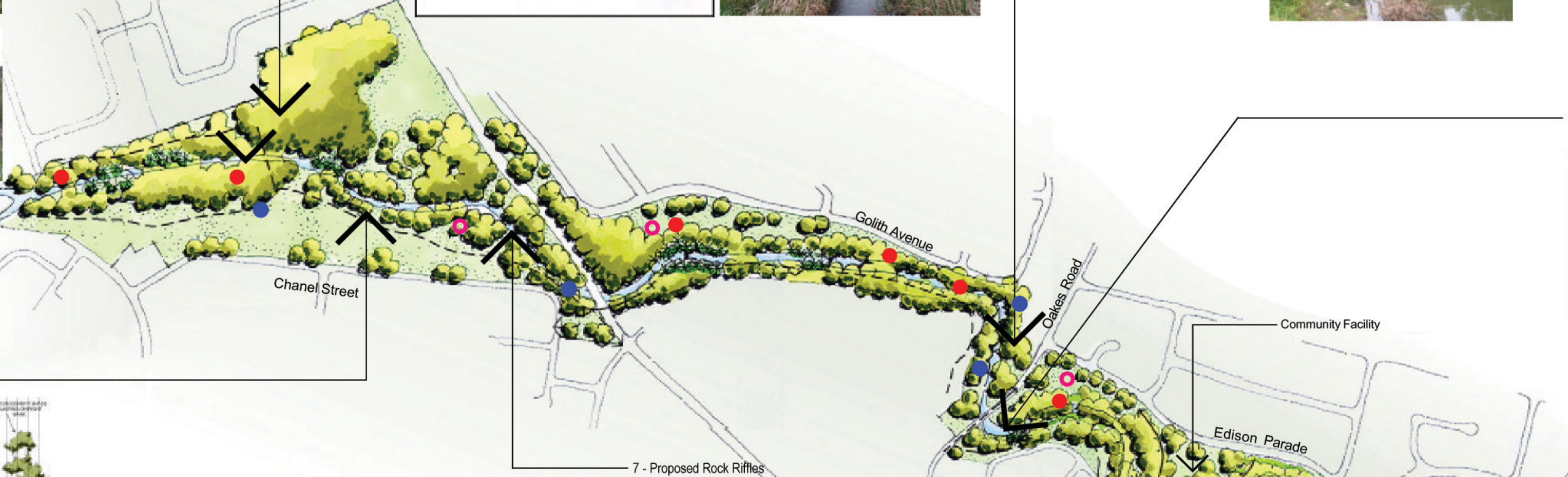
1 - Sedimentation Removal

2 - Shade Tree Planting

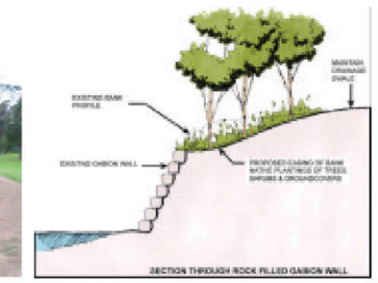


3 - Rock Bank Protection

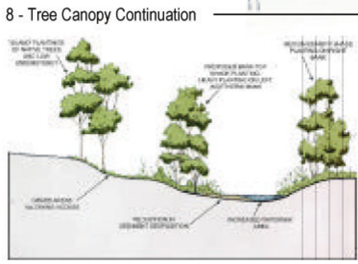




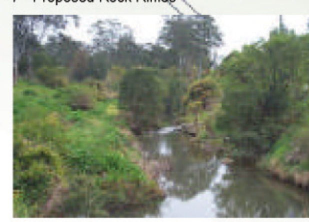
6 - Oakes Road Revegetation

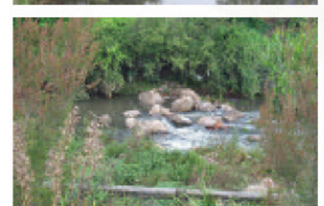


8 - Tree Canopy Continuation

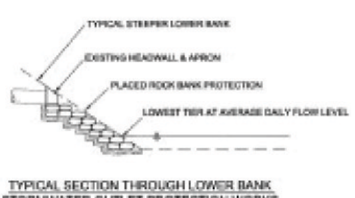


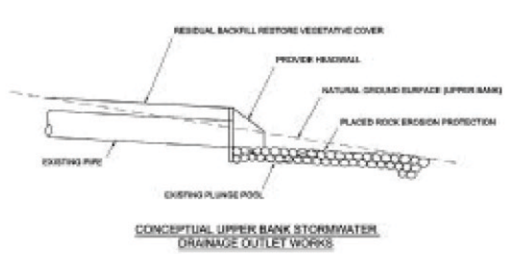
7 - Proposed Rock Riffles





4 - Upgrade to Stormwater Outlets - refer to legend





5 - Vegetation Rehabilitation

Key Maintenance & Rehabilitation Actions

1 - Sedimentation Removal
2 - Shade Tree Planting
3 - Rock Bank Protection
4 - Upgrade to Stormwater Outlets
5 - Vegetation Rehabilitation
6 - Oakes Road Revegetation
7 - Proposed Rock Riffles
8 - Tree Canopy Continuation

Legend

- Interpretive Opportunities
- Drainage Outlets
- Existing Playgrounds
- Future proposed Bike Paths (concept only)
- Existing Bike Path

0 50 100 150 200 250 300 350 400 450 500 m

EDAW

t o o n g a b b i e c r e e k

Maintenance and Rehabilitation Masterplan

Patterson Britton & Partners Pty Ltd

PARRAMATTA CITY COUNCIL
UPPER PARRAMATTA RIVER CATCHMENT TRUST

UPPER TOONGABBIE CREEK:
CREEK MAINTENANCE AND REHABILITATION MASTERPLAN

VOLUME 1

Issue No. 2
AUGUST 2002

PARRAMATTA CITY COUNCIL
UPPER PARRAMATTA RIVER CATCHMENT TRUST

Upper Toongabbie Creek:
Creek Maintenance and Rehabilitation Masterplan

VOLUME 1

Issue No. 2
AUGUST 2002

Document Amendment and Approval Record

Issue	Description of Amendment	Prepared by [date]	Verified by [date]	Approved by [date]
1	Draft	AG (11.6.02)	AG (11.6.02)	
2	Final	AG (6.8.02)	AG (6.8.02)	

Note: This document is preliminary unless it is approved by a principal of Patterson Britton & Partners.

Document Reference: rp4082ag_ec020805final(vol 1)
Time and Date Printed: 11:31 AM 24 August, 2005

Table of Contents

List of Tables

Page No.

1 INTRODUCTION

1.1 Waterways of Parramatta

Parramatta is nestled at the foot of the hills district 24km from Sydney CBD. The city and its suburbs cover an area of 61 square kilometres. These hills, and the valley below, make up part of the catchment of the Parramatta River. The waters of the Upper Parramatta River Catchment begins in our roads and gutters and ends up flowing into numerous creeks such as Coopers, Quarry Branch, Finlaysons, Greystanes, Pendle Hill and Toongabbie Creeks.

The creeks that make up the Duck and the Lower Parramatta River Catchments also eventually flow into Parramatta River. This includes Vineyard, Subiaco, Clay Cliff and Brickfield Creeks. The only exception is the Lane Cove Catchment, comprising Terrys Creek and Devlins Creek, which make their way to Lane Cover River. In total there is approximately 65km of natural creeks or 13.4km of open channel that form the lifeblood of our catchment.

Parramatta River and its associated creeks has been a significant landmark since early Aboriginal inhabitance, through the early periods of European settlement, to the present day. Over this time the waterways have been impacted by many factors including pollution, introduced weeds, erosion, changes to water flow and many other physical disturbances. All facets of modern civilization have impacted on the waterways from development, industry, pollution, recreation, stormwater runoff, sewer overflows, boating and simple things we do every day such as driving the car or walking the dog.

In more recent times there have been activities to reduce this decline including revegetation, weeding and the construction of pollution control devices to reduce the amount of litter and other pollutants finding their way into the waterway system. Despite these recent efforts, it is now recognised that creeks and waterways are becoming an endangered and threatened system, much like the native flora and fauna that once inhabited them.

1.2 Managing our Waterways

Parramatta City Council has developed a Management Plan that links its desired vision and outcomes directly to the projects and actions it undertakes. This is achieved by determining:

⇒ Desired long term goals on what condition we want our waterways to be in;
⇒ Key issues impacting on waterways;
⇒ Achievable and realistic outcomes in the next 4 years.

To implement these 4 year outcomes and address the complex and interrelated issues associated with managing waterways, Parramatta City Council has developed a Strategy and Plan, titled 'Rivers of Opportunity', which sets out both where we want to be in 2020 and how we are going to get there. For each waterway issue Council is developing masterplans, forward works programs and targeted actions to address them.

Council Management Plan

COUNCIL VISION:
Paramatta city – The City at the centre of Sydney. The best Place to live, work, visit and invest.

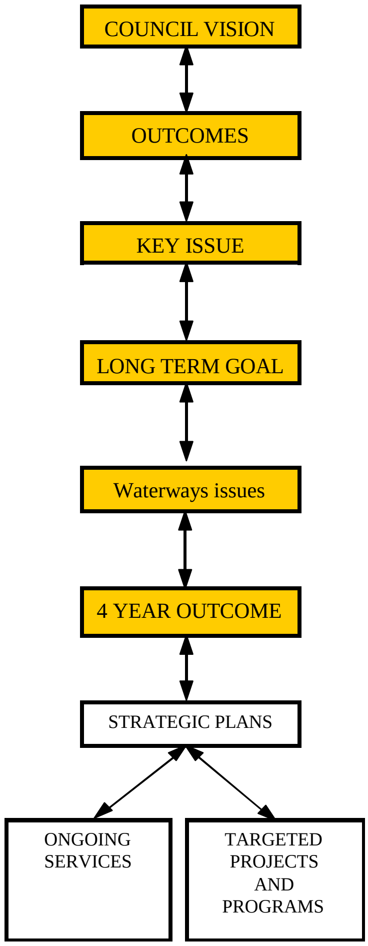
STRATEGIC OUTCOME:
Natural City: Parramatta city will protect and enhance its environment. Think globally and act locally

KEY ISSUE:
Waterways

OUR LONG TERM GOAL FOR WATERWAYS:
Waterways have a sustainable biologically diverse natural function while balancing the needs of human activities

WATERWAYS ISSUES:
Water Quality
Stream Management
Flood Management

4 YEAR OUTCOMES:
Water quality will not decline
The health of streams will improve
Properties affected by flooding will be reduced

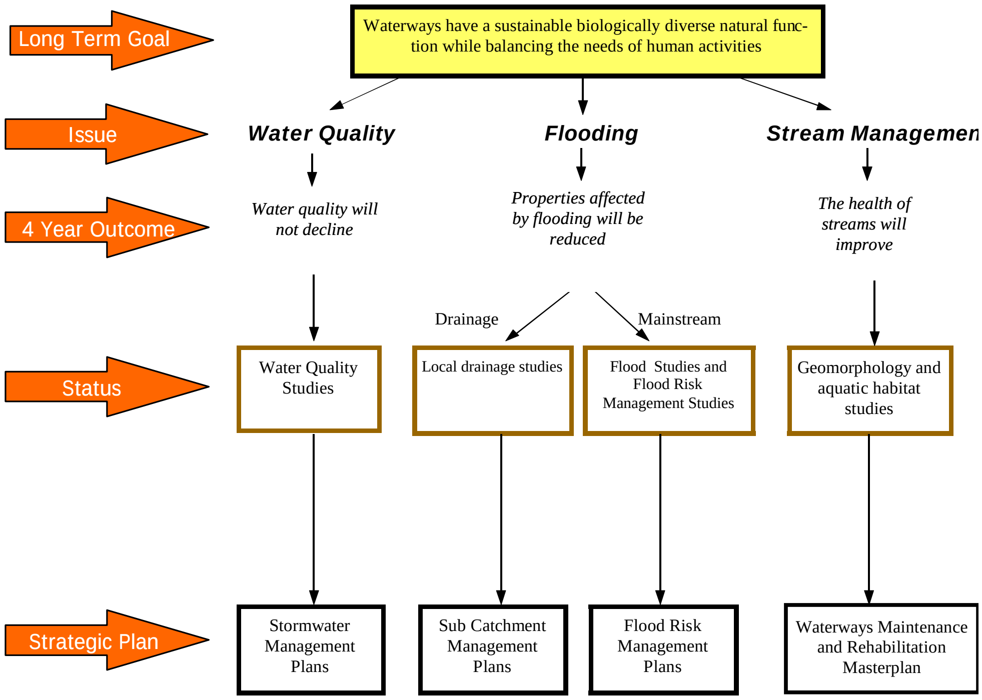


1.3 Strategic Planning for our Waterways

In order to deliver the 4 year outcomes several strategic planning documents are required. These include:

- Stormwater Management Plans;
- Waterways Maintenance and Rehabilitation Masterplans;
- Floodplain Risk Management Plans;
- Sub-Catchment Management Plans *(drainage)*.

Each of these plans is prepared for specific areas. The Plans assist in determining specific actions, priorities and their benefits to both the community and natural environment. They will set us down the path of developing a comprehensive and coordinated approach to the management of our waterways for the future.



1.4 Maintenance and Rehabilitation Masterplans

Despite the numerous plans that already exist there is still extensive work required to update this information and ensure that the entire Local Government area is covered. While there has been significant progress in planning for water quality and flooding there is still extensive work required before Council has adequate planning of all stream corridors. To address this Council will be developing Maintenance and Rehabilitation Masterplans for all of its waterways.

The Maintenance and Rehabilitation Masterplans identify:

- A vision for the specific waterway corridor
- What the waterways were once like
- Their current status
- Future opportunities and current constraints in improving them
- Detailed recommendations of works required

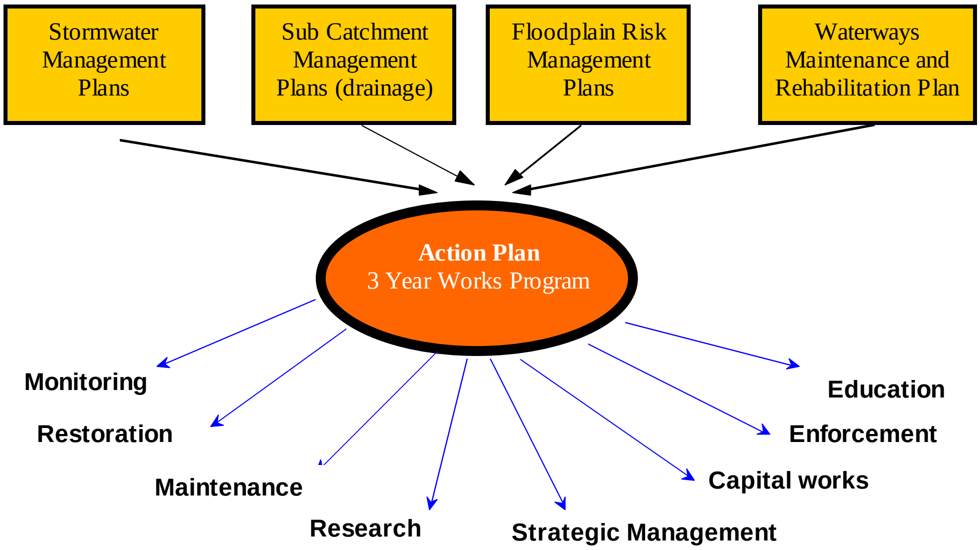
Actions that will form a part of these Maintenance and Rehabilitation Masterplans include:

- Noxious weed control program
- Willow removal program
- Riparian restoration
- Removal of blockages
- Bank erosion protection

Each of the actions related to waterways recommended in the above management plans are then combined into a single Action Plan. This Action Plan is used to determine the priority works and actions to be undertaken across Council based on the limited resources available. The Action Plan includes the recommended actions, estimated budgets, areas of responsibility, priority and type of action. This may include activities such as:

- Capital works
- Education
- Research
- Planning
- Maintenance needs

The *Action Plan* is not fixed and changes each year as new information is collected and more detailed investigations are undertaken. These will then be implemented either through Council's ongoing services or through targeted projects.


Stormwater Management Plans
Sub Catchment Management Plans (drainage)
Floodplain Risk Management Plans
Waterways Maintenance and Rehabilitation Plan
Action Plan
3 Year Works Program
Monitoring
Restoration
Maintenance
Research
Strategic Management
Capital works
Enforcement
Education

2 GUIDING PRINCIPLES TO STREAM MANAGEMENT

2.1 Legislative Policy Framework

Council's Waterways Maintenance and Rehabilitation Masterplans are prepared and implemented within a broad legislative and policy framework.

A broad description of relevant Commonwealth, State and Local Government legislation, policy documentation and environmental planning instruments as they apply in the waterway and riparian corridor management context, is provided in **Table 2.1**.

Table 2.1 Legislative and Policy Framework Review

Legislation or Policy Title	Description Summary	Effects on Maintenance and Rehabilitation Activities in Waterway Corridors
COMMONWEALTH (LEGISLATION)		
Environment Protection and Biodiversity Conservation Act 1999	The objects of this Act are, among others: “Ÿ to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance” and “Ÿ to promote ecological sustainable development through the conservation and ecologically sustainable use of natural resources”.	A Commonwealth Act supporting Ecologically Sustainable Development *(ESD)*, providing a significant overlap with NSW State Legislation such as the Environmental Planning & Assessment Act 1979 and the Threatened Species Conservation Act 1995. Future activities in waterway corridors should be undertaken within a framework of ESD.
COMMONWEALTH (POLICIES)		
National Strategy for Ecologically Sustainable Development (1992)	A National Strategy which has as its principal goal: “Development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.” A core objective of the Strategy, among others, is: “Ÿ to protect biological diversity and maintain essential ecological processes and life support systems.”	The National Strategy is implemented at the local level through the application of State and Local Government Legislation and Policies. Future activities in waterway corridors should be undertaken within a framework of ESD.
National Strategy for the Conservation of Australia’s Biological Diversity	This National Strategy provides the framework for protecting Australia’s Biodiversity. The Strategy’s stated aim is “to bridge the gap between current activities and those measures necessary to ensure effective identification, conservation and ecologically sustainable use of Australia’s biological diversity.”	The National Strategy supports programs such as native vegetation protection and management, feral weed and pest control and management of threatened species habitat, among others. These are activities which may form part of waterways maintenance and rehabilitation Masterplans.

Table 2.1 Legislative and Policy Framework Review (cont'd)

Legislation or Policy Title	Description Summary	Effects on Maintenance and Rehabilitation Activities in Waterway Corridors
Wetlands Policy of the Commonwealth Government of Australia	This policy provides strategies to ensure that the activities of the Government promote the conservation, ecologically sustainable use and enhancement, where possible, of wetlands functions. Among others, those strategies include: "Involving the Australian people in wetlands management" and "working in partnership with State/Territory and Local Governments".	The policy seeks to promote and support local government efforts in wetlands conservation and management, through encouragement of the preparation of local wetlands policies. Such local policies may form part of future waterway maintenance and rehabilitation Masterplans.
Local Agenda 21	In 1992, at a UN conference on environment and development, Agenda 21 was endorsed, and set out how both developed and developing countries could work towards sustainable development. Local authorities were one of the groups recognised as being fundamental in working towards sustainable development *(and hence "Local" Agenda 21)*. At the local level in Australia, the 1997 "Newcastle Declaration" (*made at an international conference focussing on the challenge of sustainability for local government)* clarified and re-stated the commitment of local government in Australia to Agenda 21 and sustainable development.	The application of the principles of Local Agenda 21 during the preparation and implementation of waterway maintenance and rehabilitation Masterplans will ensure application within a framework of ESD. Stakeholder and Focus Group meetings are proposed so as involve the community through the development of specific "*Visions*" for each of Council's waterways.
STATE (LEGISLATION)		
Catchment Management Act 1989	This is an Act to implement the total catchment management of natural resources. The Act promotes the sustainable use of natural resources and seeks to provide for, among others, stable soil and protective vegetation cover within water catchments.	The Act and its accompanying Regulation support total catchment management practices through the establishment of Catchment Management Boards.

Table 2.1 Legislative and Policy Framework Review (cont'd)

Legislation or Policy Title	Description Summary	Effects on Maintenance and Rehabilitation Activities in Waterway Corridors
Environmental Planning & Assessment Act, 1979	This Act and its accompanying Regulation are the primary legislation for landuse planning in NSW. The Act encourages, among other things: • the "*proper management, development and conservation of natural and artificial resources*"; • the "*protection of the environment, including the protection and conservation of native animals and plants, including threatened species, populations and ecological communities, and their habitats*"; and • "*ecological sustainable development*".	The Act ensures that future activities in the waterway corridors are undertaken within a framework of ESD, and that future maintenance and rehabilitation activities are permissible within each landuse zone within which the waterway corridor lies, and that the environmental impact of any activity or work has been properly assessed.
Fisheries Management Act 1994	This Act aims to "*conserve develop and share the fishery resources of the State for the benefit of present and future generations*". Among other things, the Act aims to "*conserve threatened species, populations and ecological communities of fish and marine vegetation*" and "*to promote ecologically sustainable development*"..	This Act will ensure that any future activities in the waterway corridors will maintain and enhance aquatic habitat.
Local Government Act 1993	This is an Act to guide the operation of Local Government. It requires Councils among other things, "*to carry out activities, appropriate to the current and future needs of local communities …..*". The Act directs Councils to prepare plans of management for, among others, community land. Where community land is categorised as a "*natural area*", and is further categorised as a "*watercourse*", specific directions are made as to the core management objectives. Where land is categorised as a "*natural area*" the core management objectives include:	The Council's management of its waterways, and in particular the preparation of waterways Maintenance and Rehabilitation Masterplans, is driven through compliance with this Act.

Table 2.1 Legislative and Policy Framework Review (cont'd)

Legislation or Policy Title	Description Summary	Effects on Maintenance and Rehabilitation Activities in Waterway Corridors
Local Government Act 1993 *(cont'd)*	• to "*conserve biodiversity and maintain ecosystem function*"; • to "*maintain the land,..., in its natural state and setting*"; • to "*provide for the restoration and regeneration of the land …..*". Where land is further categorised as a "*watercourse*" the core management objectives also include: • to "*manage watercourses so as to protect the biodiversity and ecological values of the instream environment, particularly in relation to water quality and water flows*"; • to "*manage watercourses so as to protect the riparian environment, particularly in relation to riparian vegetation and habitats and bank stability*"; • to "*restore degraded watercourses*"; and • to "*promote community education and community access to and use of the watercourse*".	
Noxious Weeds Act 1993	This act aims to ensure appropriate measures for the control of noxious weeds throughout NSW, and requires control of weed species listed under various schedules.	As a landowner, Council has an obligation to control noxious weeds along waterway corridors. This applies in particular to any works where Alligator Weed and Salvinia *(W1 listed weed species)* is likely to be disturbed.
Protection of the Environment Administration Act 1991	The principal objective of this Act is to constitute the Environment Protection Authority and to provide for the integrated administration of environmental protection. The Act requires that regard be had to the need for ecologically sustainable development.	This Act ensures that future activities within waterway corridors are undertaken within a framework of ESD.

Table 2.1 Legislative and Policy Framework Review (cont'd)

Legislation or Policy Title	Description Summary	Effects on Maintenance and Rehabilitation Activities in Waterway Corridors
Protection of the Environment Operations Act 1997	This Act has as one of its objectives, among other things, to "*protect, restore and enhance the quality of the environment in New South Wales having regard to the need to maintain ecologically sustainable development*". The Act consolidates a range of key pollution control legislation under a single Act *(eg. the Clean Waters Act 1970; the Environmental Offences and Penalties Act 1989)*. The Clean Waters Regulations, 1972 now refer to matters contained in this Act. These Regulations enable the classification of waters in NSW and regulate the permissible discharge of pollutants to those waters.	Parts of this Act regulate the discharge of pollutants into waterways in NSW.
Rivers and Foreshores Improvement Act 1948	This Act makes provisions for the protection and improvement of protected waters *(ie. most rivers, lakes, lagoons and estuaries)* and the associated beds, banks shores and land within 40 metres of the water body. Other than Part 3A of this Act, the provisions of the Act have been amalgamated into the Water Management Act 2000.	Although Part 3A of this Act does not apply to Council *(s. 22H)*, Council may choose to refer any future works which interferes with the bed and banks of waterways to the technical advisors at DLWC for review and comment. Work subject to a development application will be referred to DLWC for review, and the issuing of a permit under Part 3A of this Act.
Soil Conservation Act 1938	This Act makes provision for the conservation of soil resources and for the mitigation of soil erosion.	A landowner may be directed under the provisions of this Act to undertake remedial works to reduce an erosion hazard. Should the bed or banks of any waterway be identified as such a hazard, Council, as a landowner, may be directed to carry out such works. The Masterplans will identify appropriate works.
Threatened Species Conservation Act 1995	An Act to conserve threatened species, populations and ecological communities. Among other things, the objects of this Act include:	Where any activities, proposed to be carried out in the Masterplans, are located within or adjacent to an endangered species or critical habitat, compliance with this Act may require the preparation of an eight part test to assess likely impacts and if necessary, the preparation of a Species Impact Statement, or may require the provision of alternative conservation measures.

Table 2.1 Legislative and Policy Framework Review (cont'd)

Legislation or Policy Title	Description Summary	Effects on Maintenance and Rehabilitation Activities in Waterway Corridors
Threatened Species Conservation Act 1995 *(cont'd)*	• to "*conserve biological diversity and promote ecologically sustainable development*" and • to "*protect the critical habitat of those threatened species, populations and ecological communities that are endangered*".	
Water Management Act 2000	This Act progressively replaces the Water Act 1912 and provides for "*the protection, conservation and ecologically sustainable development of the water sources of the state*". The Act sets out water management principles which include: • *"water sources, floodplains and dependant ecosystems (including groundwaters and wetlands) should be protected and restored and, where possible, land should not be degraded*"; and • "*habitats animals and plants that benefit from water or are potentially affected by managed activities should be protected and* (*in the case of habitats) restored"*.	This Act ensures that future activities in the waterway corridors are undertaken within a framework of ESD.
STATE (POLICY)		
Flood Prone Land Policy	The primary objective of the policy is "*to reduce the impact of flooding and flood liability on individual owners and occupiers of floodprone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible*". The policy provides for among other things: "*….. the need to consider ways of maintaining and enhancing the riverine and floodplain ecology in the development of floodplain risk management plans*".	Any future activity to be implemented through the Masterplans will be considered from a floodplain risk management perspective. Impacts of works or activities will be assessed against predicted impacts on flood behaviour. The policy sets out the process leading to the preparation of Floodplain Risk Management Plans, for the waterways and associated floodplains.

Table 2.1 Legislative and Policy Framework Review (cont'd)

Legislation or Policy Title	Description Summary	Effects on Maintenance and Rehabilitation Activities in Waterway Corridors
Rivers and Estuaries Policy	A Policy which has as its objectives the management of the State's Rivers and Estuaries in ways which: • "*slow, halt or reverse the overall degradation in their systems"*; • *"ensure the long term sustainability of their essential biophysical functions"*; and • "*maintain the beneficial use of these resources*."	One of the principles of this Policy is: "*Environmentally degraded areas should be rehabilitated and their biophysical functions restored*". This principle will guide the planned activities to be implemented through the Toongabbie Creek Masterplans.
NSW Biodiversity Strategy	A strategy launched by the NSW Government in 1999. The strategy commits all government agencies to biodiversity conservation across all landscapes of the State. Goals of the strategy include, among others: "Ÿ Protecting native species and ecosystems"; "Ÿ Managing natural resources better"; and "Ÿ Involving landowners and communities in biodiversity conservation".	This strategy ensures that State Government authorities involved throughout the preparation and implementation of Masterplans will focus broadly on biodiversity conservation.
NSW Weirs Policy	The aim of this policy is to reduce and remediate the environmental impact of weirs. Main components of the policy require: Ÿ the limiting of approvals for new and expanded weirs; Ÿ the review of all existing weirs in NSW; and Ÿ the consideration of the need for fishways at each structure.	Elements of this policy will ensure the consideration of fish migration where in-stream structures *(eg. a rock riffle)* are proposed for implementation in the Masterplans.

Table 2.1 Legislative and Policy Framework Review (cont'd)

Legislation or Policy Title	Description Summary	Effects on Maintenance and Rehabilitation Activities in Waterway Corridors
NSW Fisheries – Policy and Guidelines for Aquatic Habitat Management and Fish Conservation	These Policies and Guidelines support one of the principal functions of NSW Fisheries, that is, the protection and management of fish resources, marine vegetation and aquatic habitat. General policies include, among others: "*Fish and their aquatic habitats are important natural resources, and impacts on these resources must be assessed, in all development and planning procedures, using a precautionary approach"; and,* *"Terrestrial areas adjoining freshwater, estuarine and coastal habitats should be carefully managed in order to minimise landuse impacts on these aquatic habitats. As a precautionary approach, foreshore buffer zones at least 50 metres wide should be established and maintained, with their natural features and vegetation prescribed.* .....".	Elements of these policies and guidelines will provide direction as to the protection of aquatic habitat during the preparation and implementation of the waterway Masterplans.
State Environmental Planning Policy *(SEPP)* 19 – Bushland in Urban Areas	SEPP 19 offers protection to natural bushland on areas zoned or reserved for public open space purposes	As much of the Council's waterway corridors are zoned 6(a) – Public Open Space, where any works or activities to be implemented through the Masterplans impacts on areas of urban bushland, the provisions of SEPP 19 will apply. Those provisions relate to the extent that the Council must consider the conservation of any bushland proposed to be disturbed.
LOCAL GOVERNMENT		
Parramatta Local Environmental Plan *(LEP)* 2001	Parramatta LEP 2001 describes the planning controls which apply to landuse zones throughout the Parramatta local government area. Most of the land within the Toongabbie Creek waterway corridor is zoned either: • 6(a) – Public Open Space;	The planning provisions which apply to most of the Council's waterway corridors, include as objectives: • to "*enhance, restore and protect the natural environment*"; and • to "*protect environmentally sensitive remnant habitats and*

Table 2.1 Legislative and Policy Framework Review (cont'd)

Legislation or Policy Title	Description Summary	Effects on Maintenance and Rehabilitation Activities in Waterway Corridors
Parramatta Local Environmental Plan *(LEP)* 2001 *(cont'd)*	• 6(b) – Private Open Space; • 7 – Environmental Protection *(Bushland)*; 9(d) – Environmental Protection *(Proposed)*.	*communities.*" Any action or work required through implementation of the Masterplans will be prepared in accordance with these objectives. The planning provisions require that actions or works will require development consent or assessment under Part 5 of the EPA Act.
Parramatta Development Control Plan *(DCP)* 2001	Parramatta DCP 2001 provides "*detailed guidelines and environmental standards that must be considered when carrying out new development*."	Future actions or works proposed to be implemented through the Masterplans will be assessed against the appropriate performance standards set down in Parramatta DCP 2001.
Parramatta City Centre Plan 2001	The City Centre Plan complements and reinforces the aims and objectives of State Regional Environmental Plan No. 28 *(Parramatta) (SREP 28)* 1999 by establishing guidelines and controls for the built form of Parramatta City Centre. The Plan facilitates the establishment of Parramatta City Centre as an attractive, safe and vibrant city.	Future actions or works proposed to be implemented through the Masterplans which affect the City Centre area will be assessed against the appropriate performance standards set down in Parramatta City Centre Plan 2001.
Parramatta City Council Tree Preservation Order	The purpose of Council's Tree Preservation Order is to: "*establish procedures for the proper management of trees in order to minimise the unnecessary loss of significant tree resources*".	Any activity or work required through implementation of the Masterplans, where trees or bushland may be impacted, will require consent under Council's Tree Preservation Order.
Stormwater Management Plans *(various catchments)*	During 1997, the NSW Environment Protection Authority *(EPA)* issued Notices to Councils in NSW requiring the preparation of Stormwater Management Plans *(SMPs)* for catchments under each Council's management. In metropolitan Sydney, most of the SMPs were completed and submitted to the EPA during 1999 and 2000.	Development of a "*Vision*" for each of Council's waterway corridors will be assisted by the range of catchment values developed during preparation of SMPs. It is expected that waterway Masterplans will be consistent with the aims and objectives of each relevant SMP.

Table 2.1 Legislative and Policy Framework Review (cont'd)

Legislation or Policy Title	Description Summary	Effects on Maintenance and Rehabilitation Activities in Waterway Corridors
Stormwater Management Plans *(various catchments) (cont'd)*	Each plan described existing catchment conditions, and established catchment values through a process of consultation. Management options and implementation strategies were developed to achieve aims and objectives set out in the SMPs.	
Upper Parramatta River Catchment Trust: Green Corridors Vegetation Management Strategy	The Green Corridor Vegetation Management Strategy identifies a network of green corridors in the Upper Parramatta River catchment, which are to be protected and managed for biodiversity conservation. The strategy also provides an overview of the catchment's indigenous vegetation and habitat and identifies opportunities for achieving their conservation and enhancement.	Having regard to the rehabilitation of riparian vegetation along waterway corridors and the conservation of biodiversity, actions and implementation strategies proposed in waterway Masterplans should be consistent with those identified in the Green Corridors Vegetation Management Strategy.

2.2 Review of Best Practice in Waterway Corridor Rehabilitation

It is intended that the Waterways Maintenance and Rehabilitation Masterplans are prepared having regard to current *"best practice"* in urban waterway rehabilitation.

The term *"best practice"* in this context can be described as a combination of applied research and the implementation of successfully prioritised and trialled stream management actions.

A review and assessment of a range of relevant local and international technical literature reveals a number of similar and recurrent methodologies relating to river and stream rehabilitation projects. These recurrent methodologies, which consistently have regard to both applied research or a trialled action, are the best representation of *"best practice"* as it is understood by river and stream managers in a broad range of professional disciplines.

As a result, the review of *"best practice"* presented in **Table 2.2**, focuses on these recurrent methodologies, and how they might be applied through individual waterway management actions.

Table 2.2 Waterways Maintenance And Rehabilitation Masterplan Best Practice Review

BEST PRACTICE METHODOLOGY DESCRIPTION	POSSIBLE APPLICATION
• Undertake an early assessment of stream condition & impacts of management practices	• An understanding of stream processes, behaviour and management practices is required prior to establishing, prioritising and implementing rehabilitation actions. This task is being undertaken during the preparation of Masterplans.
• Establish a "*protocol*" for river and stream rehabilitation	• Different stream reaches are often subject to different types of processes, threats or encroachments. Similarly, different reaches may be in various stages of rehabilitation *(or remediation)* or may be able to be ranked according to existing condition or natural value. As a result, different reaches may require different types of management strategies and actions.
• Rehabilitate using a natural channel design and re-establish riparian buffer strips	• Over time, urban streams respond to a change in catchment conditions and hydrologic response by attempting to modify channel dimensions, and become subject to bed and bank erosion. The re-establishment of a naturally functioning system, albeit modified by catchment response will assist in the maintenance of a healthy riverine environment. The re-establishment of riparian buffer strips, where necessary along waterways, will maintain and enhance the vegetation corridor and habitat links. Riparian buffers perform such functions as *(after Hader, 1994)*: o providing shade to the watercourse and restricting sunlight for aggressive *(weed)* growth; o providing a sediment filtering mechanism; o providing protection against upper stream bank erosion; o providing varied habitat.
• Rehabilitate utilising vegetative techniques	• Where practical and when space is not a critical design factor, mid and upper banks should be stabilised and protected from erosion by utilising dense endemic, deep rooted plantings. This technique is in contrast to the process of constructing hard, engineered structures for erosion protection. Hard structural measures should be limited to stream bed and bank interfaces, as bed erosion control measures, and where valuable infrastructure is at risk. Bank stabilisation and erosion protection will enhance downstream water quality and aquatic habitats.

Table 2.2 Waterways Maintenance And Rehabilitation Masterplan Best Practice Review (cont'd)

BEST PRACTICE METHODOLOGY DESCRIPTION	POSSIBLE APPLICATION
• Where possible rehabilitate through a re-introduction of pool, riffle and chain-of-ponds systems	• A naturally functioning stream system is made up of a combination of pool, riffle and chain-of-ponds systems. Riffles *(located between meanders in the stream alignment)* may be made up of rock, hard bed material or simply gravel bars. A varied pool and riffle system may provide the following stream functions: o varied aquatic habitats; o bed stabilisation; and o improvements in water quality through oxygenation.
• Rehabilitate having regard to the modified condition of the urbanised catchment	• As described above, modifications to catchments contributing to each waterway have occurred through urbanisation. This has affected the natural processes which occur including stream flows and sedimentary processes *(sediment nature, delivery rate and transportation)*. Actions to be implemented through the Masterplans should acknowledge that streams seek to achieve their own dynamic equilibrium, and seek further to adjust, repair and sustain themselves according to their modified environments, responding to the forces *(natural or otherwise)* acting on it.
• Stream rehabilitation projects should be undertaken by multidisciplinary teams, with common, complementary objectives	• It is now widely recognised that stream rehabilitation projects require an integrated approach to complementing the hydrological, fluvial, geomorphological, ecological and recreational aspects. It is no longer acceptable to see such projects simply as an engineering exercise in erosion control. The Masterplans are to be prepared with a consultative, multidisciplinary team based approach common to this important methodology.

The "*best practice*" methodologies are best planned and implemented from within an holistic conceptual framework for stream rehabilitation. One such conceptual framework is that presented by Kapitzke *(1999)*, which is shown in **Figure 2.1**.

This conceptual framework has been developed to recognise human uses of a waterway *(particularly those in an urban environment)*, and the pressures brought on the stream as a result of those uses. Stream management problems *(eg. bank erosion, etc.)* result from conflict between human use, pressures on the stream and natural stream processes. Overall, it is recognised that the stream processes provide the link between the human activities, stream pressures, problems and any rehabilitation actions. As a result, the preparation of the Waterway Maintenance and Rehabilitation Masterplans will involve a review of historical and contemporary stream processes and responses which may influence future implementation and priorities.

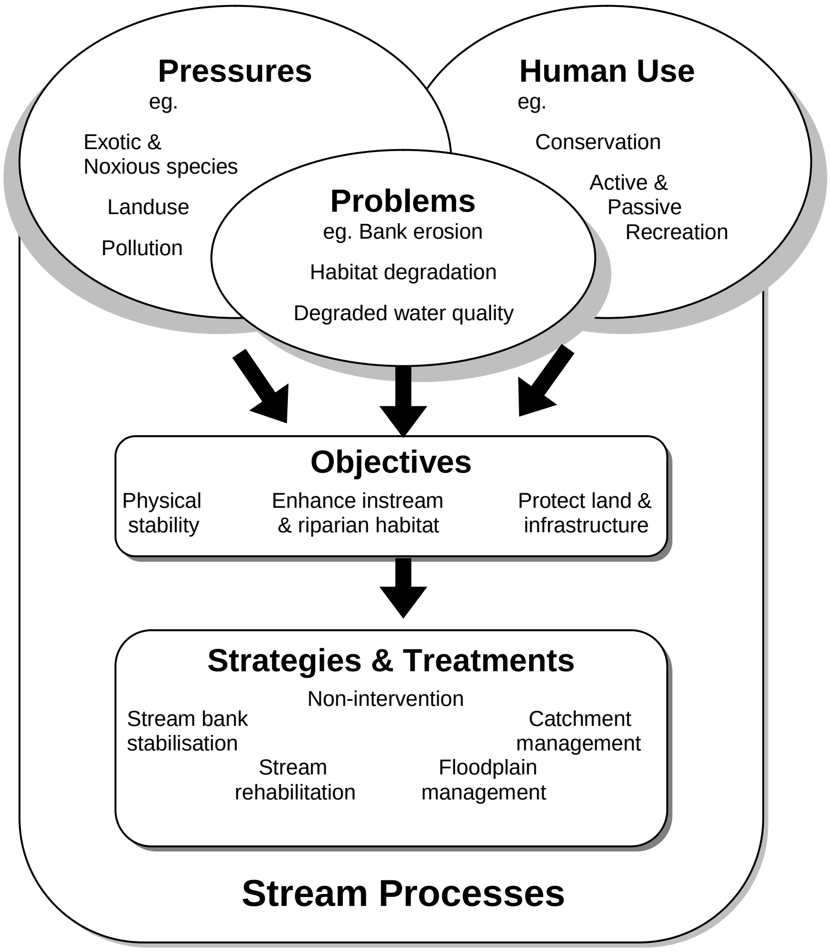


Figure 2.1 Conceptual Framework for Stream Rehabilitation

After Kapitzke *(1999)*

It is also noted by Kapitzke *(1999)* that an accompanying planning and design procedure is also important for stream rehabilitation. The stream rehabilitation planning and design approach, presented in **Table 2.3** is grouped into 5 phases leading from concept, through feasibility and implementation to monitoring and performance review.

Table 2.3 Waterway Maintenance and Rehabilitation Masterplan – Planning and Design Procedure

Phases	Steps	Description
Concept	*Step 1*	Identify and describe the problems or issue
	Step 2	Identify relevant utilities and pressures
	Step 3	Examine stream processes and determine causes
	Step 4	Define remediation objectives and constraints
	Step 5	Identify remediation options and develop concept designs
Feasibility	*Step 6*	Feasibility design and evaluation
	Step 7	Decide on remediation program
Implementation	*Step 8*	Detailed design and implementation
Monitoring & maintenance	*Step 9*	Monitor and maintain
Review	*Step 10*	Review project

After Kapitzke *(1999)*

The preparation of Council's Waterway Maintenance and Rehabilitation Masterplans will typically involve the completion of Steps 1-5 *(inclusive)* shown in **Table 2.3**.

2.3 Guiding Principles for Implementing the Waterway Corridor Vision

The implementation of a *Vision* for each waterway corridor is likely to be an ongoing process, of both rehabilitation and maintenance tasks, over a duration of many years into the future. In this time, different pressures will affect the waterway, different people will be involved in its management, and different funding opportunities or constraints will apply.

In all of this, however, a consistent approach to the waterway management and the implementation of the *Vision* should be applied.

To ensure such a consistent approach, the following set of Guiding Principles for stream rehabilitation presented in **Table 2.4** should be applied.

These Guiding Principles *(after Kapitzke, 1999)* when supported by the Best Practice in Maintenance and Rehabilitation Methodologies, referred to earlier in this Masterplan will provide assistance for all waterway managers in the development a set of prioritised actions, and achievable outcomes in support of the waterway *Vision*

Table 2.4 Guiding Principles for Waterway Maintenance and Rehabilitation

GUIDING PRINCIPLE	COMMENTARY
• Sustainability	• Provide for long term ecological functions, benefits and uses of streams
• Multiple objectives	• Adopt multiple objectives recognising natural stream function and human use
• Catchment context	• Plan maintenance and rehabilitation within reach and catchment contexts, recognising different influences and process that occur
• Multi-disciplinary approach	• Integrate hydrological, geomorphological, ecological, access and recreational considerations in any planning and design stages
• Stakeholder consultation	• Involve stakeholders in identifying problems, setting objectives and determining appropriate and rehabilitation activities

Note: After Kapitzke, 1999

The Best Practice Methodologies, which support the Guiding Principles, are shown again in **Table 2.5**.

Table 2.5 Best Practice Methodology Description

• Undertake an early assessment of stream condition & impacts of management practices
• Establish a “*protocol*” for river and stream rehabilitation
• Rehabilitate using a natural channel design and re-establish riparian buffer strips
• Where possible rehabilitate through a re-introduction of pool & riffle systems
• Rehabilitate having regard to the modified conditio of the urbanised catchment
• Stream rehabilitation projects should be undertaken by multidisciplinary teams, with common, complementary objectives.

3 WATERWAYS MASTERPLANS

3.1 Upper Toongabbie Creek

The Upper Toongabbie Creek study area commences at the McCoy Park Flood Retarding Basin outlet works and continues downstream to the confluence with Quarry Branch Creek, and is shown in the Masterplan Key Map. Superimposed over the 1997 aerial photographs, the Key Map illustrates the location of separate mapping sheets for the study area.

3.1.1 A Vision for the Waterway Corridor

"A sustainable, biologically diverse, stable, naturally functioning waterway corridor providing:

- *an accessible environment*
- *a healthy environment*
- *a recreational environment*
- *a safe environment*
- *a valuable environment; and*
- *a well managed environment*

for all of its users now, and well into the future."

3.1.2 Preparation of the Masterplan

The Maintenance and Rehabilitation Masterplan was prepared following the principles of 'Best Practice in Waterway Corridor Rehabilitation' as described in **Section 2.2**.

In the preparation of the Masterplan an assessment of the pre-European condition of Toongabbie Creek including vegetation structure and stream dynamics was undertaken. This included a review of impacts over time as a result of urbanisation and a history of reconstruction and restoration activities.

A mapping exercise was prepared detailing the present condition of the waterway corridor and specific features such as infrastructure, vegetation, fauna, flow regime and water quality within Toongabbie Creek. A further detailed mapping exercise was then prepared for the Upper Toogabbie Creek corridor producing 10 separate maps of the existing condition and issues.

An opportunities and constraints analysis was prepared to determine the possible future improvements that were feasible. This explored the issues of:

- Quality of remnant vegetation
- Diverse and naturally functioning stream
- Bank stability
- Flood behaviour
- Access and recreation

Due to the significant flooding within the Toongabbie Creek catchment a technical assessment of the hydraulic behaviour within Upper Toongabbie Creek was undertaken to assess the current status and implications of any recommended waterways management activities on flooding.

Based on this history and current status, specific actions were prepared which responded to the desired Vision for Toongabbie Creek that was determined through a consultation and focus group process. The proposed actions were assessed and prioritised based on the following criteria:

- Community benefit
- Risk management
- Environmental benefit
- Effectiveness
- Cost.

For details on this process refer to **Volume 2**.

The result of this process is the development of a detailed Masterplan for Upper Toogabbie Creek that is based on 'best practice' and balances the environmental and social issues to achieve 'a sustainable, biologically diverse, stable, naturally functioning waterway corridor' that we can pass on to future generations.

3.1.3 Activity Table

A ranked schedule of activities proposed for implementation in the Upper Toongabbie Creek Waterway Maintenance and Rehabilitation Masterplan is found in **Table 3.1**. Monitoring activities and other recommended activities, shown in the Masterplan maps, are listed in **Table 3.2** and **Table 3.3** respectively.

For additional details, refer to **Section 2** of **Volume 2**.

Table 3.1 Masterplan Activity Table

Principal Masterplan Activity	Location	Priority Rank
Rehabilitation Activity – Type A[(1)]	• Maps 1 & 2; River Ch 7130-7520	1
	• Map 3; River Ch 7570-7680	2
Provision of riparian groundcover and understorey plantings on denuded embankment	• Map 6; River Ch 8930-8960; right bank	3
Rehabilitation Activity – Type D[(1)]	• Map 9; River Ch 10230-10440	4
Rehabilitation Activity – Type C[(1)]	• Maps 2 & 3; River Ch 7210-7625	5
	• Map 1; Right bank generally	6
Creation of rock riffle integrated with bank protection works.	• Map 3; River Ch 7975; in-channel	7
Construction of erosion protection to stormwater outlets *(upper levels)*.	• Map 9; River Ch 10510;Edison Pde, opposite Reilleys Rd	8
	• Map 9; River Ch 10385; Edison Pde, west of Kelvin Grove	9
	• Map 9; River Ch 10255; Edison Pde, opposite Stephenson St	10
Rehabilitation Activity – Type A	• Maps 9 & 10; River Ch 10350-10500	11
Construction of erosion protection to stormwater outlets *(upper levels)*.	• Map 5; River Ch 8495; Goliath Ave, opposite pathway east of Reuben St	12
Construction of erosion protection to stormwater outlets *(upper levels)*.	• Map 4; River Ch 8400; Goliath Ave, opposite Reuben St	13
	• Map 4; River Ch 8300; Goliath Ave, midway between Gideon St and Reuben St	14
	• Map 4; River Ch 8210; Goliath Ave, east of Gideon St	15
Retention of large woody debris	• Map 4; River Ch 8330; in-channel	16
Construction of rock bank protection works	• Map 5; River Ch 8638-8712; left bank	17
Construction of erosion protection to low level stormwater outlets	• Map 5; Ch 8620; Goliath Ave, opposite Esther St	18
	• Map 6; Ch 9100; Third Settlement Reserve, opposite Volta St	19
Civil works to rehabilitate scoured stormwater tail-out channel.	• Map 1; River Ch 7090; left bank	20
Rehabilitation Activity – Type E[(1)]	• Maps 8 & 9; Generally within wooded area on right bank	21
Rehabilitation Activity – Type B[(1)]	• Maps 5 & 6; River Ch 8400-8900	22
	• Maps 6 & 7; River Ch 8950-9255	23
	• Map 7; River Ch 9400-9600 *(left bank)*	24
	• Maps 7 & 8; River Ch 9450—9770 *(right bank)*	25
	• Map 8; River Ch 9850-10020 *(left bank)*	26

Table 3.1 Masterplan Activity Table (cont'd)

Principal Masterplan Activity	Location	Priority Rank
Rehabilitation Activity – Type A	• Maps 4 & 5; Left bank generally to River Ch 8510	27
	• Map 6; River Ch 8925-9135	28
Removal of sediment berm which forms a remnant low-flow diversion channel	• Maps 1 & 2; River Ch 7180-7350; in-channel	29
Rehabilitation Activity – Type E	• Map 4; River Ch 8100-8400	30
	• Map 10; Generally along right bank	31
Rehabilitation Activity – Type D	• Maps 9 & 10; Generally along left bank	32
	• Map 3; River Ch 7585-7685 *(right bank)*	33
	• Map 3; Generally in wooded area on left bank	34
Rehabilitation Activity – Type D	• Map 4; Generally within wooded area on left bank	35
	• Map 5; River Ch 8510-8635	36
	• Maps 6 & 7; River Ch 9135-9400	37
	• Maps 7 & 8; River Ch 9600-9850	38
	• Map 8; River Ch 10020-10150	39
Provision of gravel based causeway for pedestrian/cycle path	• Map 2; River Ch 7415; in-channel	40

Note (1):

- Rehabilitation Activity Type A:
  - provide bank-top shade planting throughout;
  - undertake intensive maintenance *(weed management)* and intensive planting *(understorey & groundcover)*.
- Rehabilitation Activity Type B:
  - provide "*islands*" of intensive maintenance *(weed management*) and intensive *planting (understorey & groundcover*);
  - elsewhere maintain generally through slashing/mowing.
- Rehabilitation Activity Type C:
  - provide supplementary canopy plantings;
  - undertake light maintenance *(weed management) and associated light plantings (understorey & groundcover).*
- Rehabilitation Activity Type D:
  - Undertake intensive maintenance (weed management) and associated light *planting (understorey & groundcover).*
- Rehabilitation Activity Type E:
  - Provide supplementary canopy plantings;
  - Undertake light maintenance (weed management) and associated light planting *(understorey & groundcover).*

Table 3.2 Monitoring Activities

Masterplan Activity	Location
Visual inspection of reno-mattress at outlet protection works *Periodic inspection*: every three (3) months *Episodic inspection*: after each bank full flood event *Activity trigger*: disengaging of wire panels, loss of infill rock.	Map 1 Ch 7415
Monitor mid and lower bank erosion scarps due to proximity to major trunk sewer infrastructure *Periodic inspection*: every three (3) months *Episodic inspection*: after each bank full flood event *Activity trigger*: bank failure, slumping material and vegetation loss, bank retreat	Map 5 Ch 8510 - 8600
Monitor mid and lower bank erosion scarp at point bar location. Monitor rate of sediment loss to waterway *Periodic inspection*: every three (3) months *Episodic inspection*: after each bank full flood event *Activity trigger*: bank failure, slumping material and vegetation loss, bank retreat	Map 5 Ch 8712
Monitor lower bank erosion scarp due to proximity to service infrastructure Investigate provision of rock bank protection to protect infrastructure failure *Periodic inspection*: every three (3) months *Episodic inspection*: after each bank full flood event *Activity trigger*: bank failure, slumping material and vegetation loss, bank retreat	Map 6 Ch 8820 - Ch 8860
Monitor lower erosion scarps due to proximity to service infrastructure. Investigate provision of rock bank protection to reduce infrastructure failure *Periodic inspection*: every three (3) months *Episodic inspection*: after each bank full flood event *Activity trigger*: bank failure, slumping material and vegetation loss, bank retreat	Map 6 Ch 9095 – Ch 9125
Monitor lower bank erosion scarps Investigate provision of rock bank protection to protect infrastructure failure *Periodic inspection*: every three (3) months *Episodic inspection*: after each bank full flood event *Activity trigger*: bank failure, slumping material and vegetation loss, bank retreat	Map 7 Ch 9350 to Ch 9460

Table 3.3 Other Recommended Activities

Masterplan Activity	Location
Investigate landscape interpretation for historic creek meander alignment. Consider provision of interpretive signage for educational/recreational purposes	Map 2 Ch 7270 – Ch 7400
Selective Willow Removal	Map 2 Ch 7565
Possible location of viewing platforms to allow visitors to experience the remnant river corridor	Map 4, Map 7, Map 8, Map 10
Investigate provision of viewing areas and interpretive signage for heritage/historical experiences	Map 5
Consider reduction of debris trapping and erosive flow behaviour at elevated sewer aquaduct Investigate design/construction modification for removal if in-stream central supporting pier Investigate provision of rock bank protection to protect infrastructure failure Periodic inspection: every three (3) months Episodic inspection: after each bank full flood event Activity trigger: structural damage; trapped debris; concave bank retreat upstream and downstream or structural terminals	Map 8 Ch 9825
Investigate opportunity for linking pedestrian/cycle path between banks by utilising bed rock riffles and an off-road causeway	Map 8

3.1.4 MASTERPLAN MAPPING

PARRAMATTA CITY COUNCIL
UPPER PARRAMATTA RIVER CATCHMENT TRUST

TOONGABBIE CREEK WATERWAYS MAINTENANCE AND REHABILITATION MASTERPLAN

VOLUME 2

Issue No. 2
AUGUST 2002

PARRAMATTA CITY COUNCIL
UPPER PARRAMATTA RIVER CATCHMENT TRUST

Toongabbie Creek
Waterways Maintenance and Rehabilitation Masterplan

VOLUME 2

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AUGUST 2002

Document Amendment and Approval Record

Issue	Description of Amendment	Prepared by [date]	Verified by [date]	Approved by [date]
1	Draft	AG (11.12.01)	MT (19.12.01)	MT (19.12.01)
2	Final	AG (6.8.02)	MT (6.8.02)	

Note: This document is preliminary unless it is approved by a principal of Patterson Britton & Partners.

Document Reference: rp4082ag_ec020806final(vol 2)
Time and Date Printed: 11:33 AM 24 August, 2005

Table of Contents

Page No.

List of Tables

1 CATCHMENT REVIEWS

1.1 Assessment of Toongabbie Creek Waterway Corridor

The overall study area for the waterway corridor assessment is shown in **Figure 1.1**, upon which the present day road and urban development is superimposed over the existing topographical detail.

The assessment of the waterway corridors is based on aerial photography interpretation and the recollections of early, local residents. The assessment also draws from the published history of Toongabbie.

A suite of historical aerial photograph mosaics have been prepared for the overall study area. The photographs were collected for the following years.

- 1951
- 1961
- 1970
- 1978
- 1986
- 1991
- 1997

While settlement in Toongabbie commenced much earlier than the earliest photograph *(1951)*, the photographs allow analysis of the impact of the process of urbanisation on the waterway corridor, through the period of the most intense development and infrastructure construction across the catchment.

The photographs also allow the evaluation of the major changes to stream channel alignment, channel cross-section and form, and the associated impacts on riparian vegetation.

In order to interpret and graphically represent a likely original channel form and riparian corridor, five representative cross-section locations have been selected.

The locations of the representative cross-sections are also shown in **Figure 1.1**, and each was chosen to represent a sample of urban encroachment into typical geomorphic land forms including floodplains, steeply incised channels, and broad moderately incised channels.

For each of the representative cross-sections, three distinct periods of waterway corridor impact, development and encroachment are depicted. Changes in vegetation structure over time are also depicted.

The three periods depicted relate simply to pre-clearing *(ie. pre-European settlement)*, rural landuse *(cleared for rural purposes but prior to major urban encroachment)* and urbanisation.

1.1.1 Pre-European Settlement

The settlement of the Toongabbie Creek floodplain and waterway corridor commenced in 1791, in order to provide agricultural supplies to the infant colony.

The floodplain and surrounding lands were extensively cleared with some evidence suggesting that *"1,000 acres" (approximately 405 ha)* had been cleared by convict labour and crops such as corn, maize, oats, barley, wheat and other vegetables planted.

From the 1800s through to the 1940s further clearing occurred, and the agricultural landuses focussed on orchards, vineyards, poultry and dairying.

Typically the clearing was extended to the waterway corridors, reducing riparian vegetation to *"thinned"* stands of remnant forests and understorey shrubs. Some forest stands in the steeper mid and lower banks of the waterway corridors, particularly along Toongabbie Creek and Quarry Branch Creek, were retained. It is likely that these steeper banks were not suitable for cropping or grazing purposes.

Original Stream Form

Prior to European settlement, and up to the period when urbanisation of the district commenced in earnest *(late 1940s, post war)* Toongabbie Creek and its main tributaries were unspoilt, sinuous watercourses which meandered through the landscape.

These sinuous meanders can be seen in the historical photographs between 1951 and 1970. The original paths of the waterway corridors and conceptualised flood behaviour in the study area are shown superimposed over the 1951 photograph (**Figure 1.2**).

The watercourses shown include:

- Toongabbie Creek
- Greystanes Creek
- Pendle Hill Creek
- Quarry Branch Creek
- Coopers Creek
- Finlaysons Creek

Of particular note are the paths of Toongabbie Creek upstream of Old Windsor Road *(Johnstons Bridge)*, Greystanes Creek and Pendle Hill Creek upstream of their confluences with Toongabbie Creek, and the tortuous meanders of Coopers Creek and Finlaysons Creek.

Toongabbie Creek downstream of Old Windsor Road and Quarry Branch Creek have followed a relatively similar course since the period of settlement. Although overgrown and surrounded by urban development, the Toongabbie Creek anabranch between Coopers Creek and Briens Road still remains.

Prior to settlement and through the early process of development, Toongabbie Creek upstream of Old Windsor Road together with its tributaries flowed across a rich alluvial floodplain. As early as the 1920s, floodwaters were witnessed almost reaching Fitzwilliam Road, spreading across paddocks known locally as *"The Flats".*

This area, where the subdivisions creating Tucks Road, Channel Street and Rausch Street among others now stand, was the confluence of the Toongabbie Creek, Greystanes Creek and Pendle Hill Creek floodplains.

In this area, stream channels would have had a typical *"v-shape"* formed by the floodplain topography. Bed erosion and the formation of deeper pools would have been controlled through bedrock protrusions. Pools deep enough for swimming were located through these reaches, particularly opposite the end of Mimosa Avenue and across *"The Flats"* in Pendle Hill Creek.

Sand and gravely point bars would be expected to have been deposited through these reaches, due to the expected lower velocities on the inside of bends. While some bank erosion would have occurred due to the natural fluvial processes, erosion resistant rock matrices in the banks may have restricted bank retreat.

Downstream of Old Windsor Road, the Toongabbie Creek channel was deeply incised into steep, high banks. Bedrock controlled pool and riffle sequences occurred, as they remain evident in the present day. Despite the sinuosity of the stream to the confluence with Quarry Branch Creek the energy gradient appears steep enough to generate flood flow velocities able to transport sands and gravels.

Quarry Branch Creek was a deeply incised channel in high, steep banks, and remains so in the present day. It is likely that the geomorphic regime which occurred in this stream allowed the transportation of gravels and cobbles, due to its high energy. A large, deep gravel plume delivered from Quarry Branch Creek extends into the Toongabbie Creek waterway, indicating the dominance of the Quarry Branch Creek energy regime.

Downstream of its confluence with Quarry Branch Creek, Toongabbie Creek meanders to a sharp bend adjacent to its confluence with Coopers Creek. Again deeply incised, bedrock controls formed natural pool and riffle systems.

Coopers Creek and Finlaysons Creek appear to have been moderately incised into broad floodplains, with incisions into Toongabbie Creek protected by major bedrock protrusions, particularly Finlaysons Creek.

Downstream of these confluences, Toongabbie Creek again flowed through a broad alluvial floodplain to the confluence with the Upper Parramatta River. Pool and riffle sequences again were bedrock controlled, with protrusions evident in the present day around the Redbank Road Bridge.

Representations of the likely channel form at the typical cross-section locations are shown with the likely vegetation structure, described below.

Original Vegetation Structure

Graphical representations of the original vegetation structure are shown for the typical cross-section locations superimposed over the 1951 aerial photograph on **Figure 1.3**.

It is likely that the character of the waterway corridor prior to European settlement was that of a healthy, diverse and heavily wooded riparian zone.

The size of *"large"* gums, the density of casuarinas *(she-oaks)* and wattles nearer the banks of the waterway have been vividly recalled by residents of the 1920s. They described a dense understorey of maindenhair ferns and blackthorn overhanging the water and recalled a diverse range of heavy timber including river red gums, grey gums, stringy barks and the *"occasional"* iron bark.

The waterway corridors have been previously categorised based on the geological and ecological landscape in which they occur. They were the Cumberland Plain Corridors, and the Sandstone/Shale Transition Zone Corridor *(UPRCT, 1999)*.

The creeks of the study area were categorised as follows:

(i) Cumberland Plain Corridors:
- Greystanes Creek
- Coopers Creek
- Pendle Hill Creek
- Finlaysons Creek

(ii) Sandstone/Shale Transition Zone Corridors
- Toongabbie Creek
- Quarry Branch Creek

The substantial vegetation communities which would have existed prior to European settlement have been identified from the thinned, re mnant stands of the present day.

These include:

- Cumberland Plain Woodland
- Blue Gum River Flat Forest
- Shale/Sandstone Transition Forests
- River-flat Forest

The structures of these vegetation communities prior to European settlement are estimated to have been in the following ranges.

- Canopy *(low and high)* - 10 to 25 metres tall
25% to 40% coverage
- Understorey/Shrub - 3 to 4 metres tall
12% to 16% coverage
- Groundstorey - 0.5 to 1 metre tall
50% to 60% coverage

These vegetation structures and density ranges are represented graphically for each of the typical cross-section locations in **Figure 1.3**.

Additional Information

The diverse range of vegetation communities is likely to have supported abundant fauna and bird life. Residents of the area in the 1920s recall kingfishers, magpies, peewees, kookaburras and swallows.

Ground and tree dwelling animals are also likely to have been prevalent. The vegetation communities would have provided a diverse habitat together with a level of safety from predators and hunters.

Water quality in Toongabbie Creek and its tributaries is likely to have been approaching pristine prior to European settlement. Runoff from natural catchment surfaces would have transported minimal loads of sediments to the waterways. It is likely that natural bank erosion would have provided much of the sediment transported through the system during periods of mid-bank to bankfull flows.

Conceptual flood behaviour and likely fluvial responses are shown in **Figure 1.2**.

The quality of the stream flows, the likely health and distribution of aquatic flora, the pool and riffle systems and occasional samples of large woody debris would have created an aquatic habitat capable of supporting a diverse range of aquatic species.

Large eels were regularly seen and caught during the 1920s and yabbies were readily caught. Native freshwater fish such as Australian Bass and Freshwater Mullet are likely to have been prevalent, and estuarine species would have migrated upstream to spawn. Other species such as the long-necked tortoise and the platypus are also likely to have been common to the waterway corridors.

Impacts Since Settlement

As described above, the floodplains and riparian corridors of Toongabbie Creek and its tributaries were extensively cleared, which commenced in the late 18th century. Extensive clearing continued for the purposes of agriculture and grazing through the 1800s.

The clearing of the flatter, floodplain lands provided attractive, easy building land which allowed the accelerated urbanisation of the area, which commenced post-war.

The impacts of the process of vegetation clearing and the encroachment of urbanisation is shown in **Figure 1.4**, which has as its background the 1961 aerial photography.

The thinned remnant vegetation corridors are evident, following the main stream channels. Vegetation clearing, on the flatter accessible alluvial floodplains has been undertaken to the edge of the upper banks of the waterway corridors. Canopy and understorey vegetation has been retained on the steeper mid-level and upper banks on Toongabbie Creek downstream of the Old Windsor Road bridge, and in Quarry Branch Creek down to the confluence with Toongabbie Creek.

Graphical representations for each of the typical cross-section locations are shown in **Figure 1.5**. The significant reduction in riparian vegetation and forested areas since settlement and due to the commencement of urbanisation is shown.

Impacts of the vegetation reduction include habitat loss and a likely associated reduction in native fauna. The reduction in the understorey and groundcovers which bound the soils and resisted erosion would facilitate increased sedimentation of the waterways through erosion, reducing stream water quality through increased turbidity. Vegetation loss also reduces the resistance to stream flows, increasing flow velocities and thus increasing the likelihood of stream bed and bank erosion, and possible associated bank retreat.

Descriptions of Impact During Urbanisation

Impacts due to urbanisation through the period 1951-1970 are evident in the 1970 photograph, and are further described in **Figure 1.6**.

During this period, modifications to some of the waterway corridors were undertaken, with the middle reaches of both Coopers Creek and Finlaysons Creek now conveyed in concrete lined channels, and Pendle Hill Creek *"straightened"* downstream of Barrangaroo Road.

The Pendle Hill Creek channel downstream of Fitzwilliam Road has become increasingly incised *(evident in the photograph)* due to the increase in urban runoff following the development of the catchment.

A brief chronological history of reconstruction and restoration activities, together with appropriate references to the suite of aerial photography is shown in **Table 1.1** below. The impacts of the major construction activities are shown in the photographs.

Table 1.1 Brief History of Reconstruction and Restoration Activities

Period	Figure No	Nature of Works	Location	Source of Action Implementation	Benefits to Waterway Corridor	Environmental Consequences of Action
1970-1978	1.7	Clearing and straightening of Toongabbie Creek; filling of original watercourse	Opposite Tucks Road	Facilitating development	Improving flood conveyance	Loss of riparian vegetation; loss of aquatic habitat; modification to natural sedimentary *processes (erosion and deposition)*; increased potential for scour; loss of floodplain storage.
1970-1978	1.7	Modifications to Greystanes and Pendle Hill Creeks; concrete channels constructed; filling of original watercourses	Downstream of Fitzwilliam Road	Facilitating development	Improving flood conveyance	As above
1970-1978	1.8	Modifications to Finlaysons Creek; channel extended; meanders cutoff.	Downstream of concrete channel; downstream of Darcy Road	Unknown	Improving flood conveyance	As above
1982-1984		Clearing banks of weeds and vegetation	Not specified	Commonwealth Special Employment Scheme *($50,000)*	Improvements to flood conveyance; removal of blockages *(assumed)*	Reduction of weed infestation; rehabilitation of riparian understorey and groundcover.
1983-1984	1.8	Construction of McCoy Park Flood Retarding basin	McCoy Park, between Local Government Area boundary and confluence of Greystanes/Pendle Hill Creeks and Toongabbie Creeks	Flood investigations by Council's consultants	Mitigation of flood volumes and flow velocities; reduction of flood levels; associated reduction in flood hazards and risk to local residents.	Loss of riparian vegetation and habitat; modification to natural sedimentary processes *(erosion & deposition)*; possible reduction in sustained flood flow velocities – associated reduction in scour potential; potential benefits in water quality improvements.

Table 1.1 Brief History of Reconstruction and Restoration Activities (cont'd)

Period	Figure No	Nature of Works	Location	Source of Action Implementation	Benefits to Waterway Corridor	Environmental Consequences of Action
1988-1989	1.9	Stream clearing and widening; selective clearing operations construction of 30 metre wide channel between McCoy Park Basin and Old Windsor Road (Johnstons Bridge)	Toongabbie Creek downstream of McCoy Park Basin to adjacent to Lister Street, Winston Hills	Flood investigations by Council's Consultants	Improvements to flood conveyance; removal of blockages; reduction in flood levels; associated reduction in flood hazards and risk to local residents.	Loss of riparian vegetation and habitat; modification to natural sedimentary processes *(erosion & deposition)*; short term reduction in water quality through increase in turbidity.
1989-1990	1.9	Construction of gabion wall bank protection measures and flood mitigation	Several Toongabbie Creek locations between Oaks Road bridge and Quarry Branch Creek confluence	Bank protection works identified by Council	Streamlining of flows – reduction of bank and toe erosion induced by flow turbulence. Bank protection reduction in erosion and associated bank retreat water quality benefits due to reduced sedimentation of waterway.	Loss of riparian vegetation and habitat; induced erosion at unprotected terminals of structure.
1991-present	1.10	Construction of Pendle Hill Creek floodway channel	Between Burrabogee Road downstream to Barrangaroo Road	Flood mitigation options identified by UPRCT and Council	Improvements to flood conveyance; reduction in flood levels. Long-term benefits after completion due to regeneration of riparian vegetation corridor.	Loss of riparian vegetation and habitat.
1994-present		Program of bush regeneration/rehabilitation in Quarry Branch Creek corridor	Quarry Branch Creek downstream of Moxhams Road bridge	Required ongoing program identified by Council	Reduction in weed infestation rehabilitation and regeneration of riparian vegetation; re-creation of biodiverse native habitat; water quality benefits due to reduced sedimentation of waterway.	Short term loss of introduced habitat.

Table 1.1 Brief History of Reconstruction and Restoration Activities (cont'd)

Period	Figure No	Nature of Works	Location	Source of Action Implementation	Benefits to Waterway Corridor	Environmental Consequences of Action
1997-1998		Selective removal of willows from banks of Toongabbie Creek.	Toongabbie Creek corridor between McCoy Park Basin and confluence with Quarry Branch Creek.	Required removal as identified by Council.	Reduction of bank erosion and resulting water quality benefits due to reduced sedimentation of waterway. Regeneration of riparian understorey and associated habitat.	Short term loss of introduced habitat; short term water quality impacts due to loss of shade trees over watercourse.
1999-present	-	Program of reduction of Balloon and Modiera Vine from riparian vegetation corridors.	Toongabbie Creek downstream of McCoy Park Basin and confluence with Quarry Branch Creek.	Green Corridors Management Strategy *(UPRCT, 1999)* and program as identified by Council.	Reduction of threat to old growth canopy; regeneration of riparian understorey and associated habitat.	Short term loss of introduced habitat.
1999	1.10	Construction of Pendle Hill Creek floodway channel	Downstream of Barrangaroo Road bridge	Flood mitigation options identified by UPRCT and Council	Improvements to flood conveyance; reduction in flood levels. Bank protection; reduction in erosion and associated bank retreat; water quality benefits due to reduced sedimentation of waterway.	Loss of riparian vegetation and habitat.

Table 1.1 Brief History of Reconstruction and Restoration Activities (cont'd)

Period	Figure No	Nature of Works	Location	Source of Action Implementation	Benefits to Waterway Corridor	Environmental Consequences of Action
1999	1.10	Construction of Greystanes Creek Channel Improvements/Rehabilitation project.	Greystanes Creek downstream of the Railway bridge to Station Road	Bank protection works, flood mitigation options and rehabilitation options identified by UPRCT and Council	Improvements to flood conveyance; reduction in flood levels. Bank protection; reduction in erosion and associated bank retreat; water quality benefits due to reduced sedimentation of waterway. Varietal in-channel habitat improvements due to introduced pool and riffle systems. Long term regeneration of riparian understorey and associated habitat.	Short term loss of riparian vegetation and habitat.

1.1.2 Description of Waterway Corridor in Present Day

Stream Form

Toongabbie Creek and its tributaries have been subjected to substantial modification in stream form through the period of European settlement, but particularly during the period of intense urbanisation since 1970.

Only Quarry Branch Creek of the major tributaries remains similar in structure to the stream form it would have exhibited prior to European settlement, although erosion rates in the lower banks and bed are likely to have accelerated due to changes in runoff patterns and flow velocities.

Upper Tributaries

Pendle Hill Creek is almost entirely conveyed in a formed floodway channel from Burrabogee Road through to its confluence with Greystanes Creek downstream of Fitzwilliam Road. Upstream of Burrabogee Road the channel is severely constrained by industrial buildings.

The predominant stream form is a trapezoidal shaped grassed and landscaped channel with a concrete low flow invert. Some bed and bank erosion occurs at the abrupt terminals of the constructed sections. A remnant meander with some of the original riparian vegetation remains, approximately 300 metres upstream of Barangaroo Road.

A short sectio of the stream downstream of Barangaroo Road is formed in part as a wide, flat, rock lined channel.

Between Barangaroo Road and Fitzwilliam Road the channel is constrained in width between residential properties. Downstream of Fitzwilliam Road, the stream is conveyed in a concrete channel. Wide, grassed berms extend to the corridor limits.

The original waterway corridor which meandered across the land to the north of Fitzwilliam Road has now been filled, the land subdivided and now supports urban landuses.

A newly rehabilitated section of Greystanes Creek conveys flows between the Main Western Railway and Station Road. The stream form is represented as a rock lined *(in part)* and vegetated channel. Rock riffles are placed to provide varietal habitat and some associated water quality benefits through flow aeration. Bank protection works are provided to protect infrastructure and to restrict bank retreat into the adjoining Bowling Club land. When established, the rehabilitated vegetation corridor will provide some habitat for wildlife.

Downstream of Station Road, Greystanes Creek is conveyed in a concrete channel with wide, grassed berms to the edge of the corridor limits. Little vegetation is offered along the grassed berms. The concrete channel extends to the stream confluence with Toongabbie Creek.

Photographic examples of the stream forms described are provided in **Figure 1.10**, which is superimposed over 1997 aerial photography.

Toongabbie Creek

Since the mid 1970's, the Toongabbie Creek waterway corridor has been subjected to substantial modifications. Those modifications are briefly described in **Table 1.1**, and include the straightening of the waterway corridor, widening of the flow channel, and the clearing of the waterway corridor of riparian vegetation which encroached into the main flow channel between the McCoy Park flood retarding basin and the Old Windsor Road bridge. These works were undertaken to facilitate the residential development of the land to the north of Fitzwilliam Road, once known as *"The Flats"*, and to provide an element of flood protection to those properties.

A broad expanse of linear open space has been developed on the southern *(right, looking downstream)* bank, known as Sue Savage Reserve. During 1999, a high level floodway was constructed through part of the reserve, which was supplemented with the planting of local indigenous understorey and shrubs, to assist in the rehabilitation of the riparian corridor.

Areas of sandstone bedrock are now exposed in the lower and mid-level banks of the watercourse, and some bedrock protrusions remain instream creating limited pool and riffle zones.

The constructed reach is also affected by zones of in-channel sedimentary deposition, of predominantly sands and gravels. Low flow channels have incised into these in-channel bars. The sediments are likely to be mobilised during high-energy flood flows through the stream, although some scour protection is offered through dense alligator weed outcropping. Once the scour threshold is reached, however, the sediments together with the alligator weed, which is listed as noxious, would be mobilised and transported downstream through the system.

Large rock spalls are placed to offer bank protection to the bridge abutments at the Old Windsor Road bridge.

Downstream of Old Windsor Road, the stream returns to its original form and remains deeply incised into steep, high banks. Some infrastructure encroachments provide modifications to the flow dynamics, for example the Sydney Water encased watermain, which acts as a weir upstream of Oakes Road, impounding water some distance upstream.

Further examples of sedimentary deposition zones occur downstream of Oakes Road, through to the confluence with Quarry Branch Creek. Sand and gravel point bar formations have developed in several locations, including downstream of Oakes Road, and opposite the Quarry Branch Creek incision into Toongabbie Creek. A cobble and gravel plume has formed at this confluence and has prograded into the Toongabbie Creek low flow channel.

Downstream of Quarry Branch Creek, Toongabbie Creek follows its original meanders to its confluences with Coopers Creek and Finlaysons Creek.

The stream remains deeply incised, with bedrock controlled pool and riffle systems.

Downstream of the Hammers Road bridge, the waterway is constrained by development *(urban residential, industrial and educational)* to a narrow corridor of thinned vegetative understorey and groundcover. The bedrock controlled pool and riffle sequences at Redbank Road are pronounced and provide varietal habitat and amenity through the downstream reaches of the study area.

Between the Briens Road bridge and the downstream confluence with the Upper Parramatta River, bank rehabilitation projects are underway to reduce weed infestation and re-establish a stable, biodiverse riparian corridor.

Again, some photographic examples of the features described are provided in **Figure 1.10**.

Lower Tributaries

Adjacent to Hart Drive, Coopers Creek is conveyed in a concrete channel, closely constrained by urban residential development. Downstream of Hart Drive, the waterway follows its original meanders to its confluence with Toongabbie Creek. Bank erosion and bank retreat is occurring in the reach between Chetwyn Street and Hopkins Street, which is likely to have become more pronounced due to the modifications in catchment runoff due to urbanisation, and the associated change in stream flow dynamics.

Finalysons Creek is conveyed in a concrete lined channel downstream of Darcy Road. For approximately 180 metres upstream of its confluence with Toongabbie Creek, the stream has been established as an earthen channel, with bed and bank rock protrusions resisting erosion and bank retreat. A concrete encased sewer main acts as a weir towards the downstream limits, and impounds flows upstream. Bedrock protrusions prevent scour to bed levels at the incised confluence with Toongabbie Creek.

Representations of the stream forms of the present day, together with representations of the associated vegetation structure are again shown for the selected typical cross-sections on **Figure 1.11**, which is superimposed over the 1997 photograph.

Infrastructure Impacts

Contemporary Infrastructure

The original and modified stream form of waterway corridors of the study area have also been impacted by the construction of contemporary infrastructure. The location of substantial structures is shown in **Figure 1.12**.

A number of major bridges, bridge abutments and culvert crossings constructed since the 1950s would induce a variation to the original, unconstrained stream flow dynamics. Those variations would include an impact on flood levels and stream flow velocities, although most of the bridges have now been reconstructed to increase waterway area and minimise any associated afflux *(or backwater)*.

The McCoy Park flood retarding basin, and the concrete low flow and flood flow outlet works, have been constructed to modify flood behaviour in the downstream reaches, and offer some protection to property constructed in the floodplain.

Levees have also been constructed to modify flood behaviour, particularly through Sue Savage Reserve and Reynolds Park adjacent to Chanel Street. A high gabion wall provides some flood protection to property in Peter Parade, downstream of the Oakes Road bridge.

Water supply and sewerage infrastructure has been constructed across the waterway corridor in a number of locations, which due to the nature of construction either directly impedes or modifies flow behaviour.

Concrete encased water supply or sewerage trunk mains act as weirs and impound flows in a number of locations. The most significant of these structures is located upstream of the Oakes Road bridge and maintains the water surface level upstream as far as the Old Windsor Road bridge. Other substantial structures are located across the tributary incised into the western *(right, looking downstream)* bank of Toongabbie Creek immediately upstream of the Oakes Road bridge, together with across Finlaysons Creek, immediately upstream of its confluence with Toongabbie Creek.

In other locations, elevated sewer aqueducts have been constructed. The most substantial of these are located within the Toongabbie Creek corridor adjacent to Third Settlement Reserve, downstream of the Oakes Road bridge, and also immediately downstream of the Hammers Road bridge.

Historical Infrastructure

There are a number of examples of remnant historical infrastructure located within the study area waterway corridor. The locations are shown in **Figure 1.12**.

The most important site, and of substantial significance in the history of the colony is the former river flat settlement located on the southern *(right, looking downstream)* bank of Toongabbie Creek, between the Old Windsor Road and Oakes Road bridges. The site was once the site of the colony's "*Third Settlement*", first established in 1791. The site is now occupied in part by industrial development *(Baxters Pharmaceuticals)*, and further in part by an open space corridor.

Immediately downstream of the concrete encased water supply pipeline *(described above)*, the stone remains of a weir are evident. Such a structure would have impounded stream flows in Toongabbie Creek providing a water supply for residents of the colony's Third Settlement.

Of additional interest, is the evidence of steps leading to the location of the remnant stone weir. These steps are carved into the natural bedrock protrusions on the western *(right, looking downstream)* bank of Toongabbie Creek, and would have provided access to the impounded water supply.

Further upstream, located on the eastern *(left, looking downstream)*, are an additional set of stone and masonry steps. Referred to locally as the "*Convict Steps*", the steps are considered to have either been connected with the historical settlement of the adjoining land, or perhaps to have been associated with 19th century "*Chinese*" gardens.

The stone remains of what appears as a causeway is located just downstream of the Moxhams Road bridge in the Quarry Branch Creek corridor. The stone causeway appears to have been preserved in good condition.

A concrete tramway pier is located in Toongabbie Creek 200 metres upstream of the Redbank Road bridge. The pier is a remnant of the tramway which existed in Sydney's west and north-west in the early 1900s.

Vegetation Structure

The vegetation through the waterway corridor has been reduced to a series of stands connected by narrow corridors of individual trees along the mid and lower banks. The thinned stands demonstrate a reduced species and aged diversity in canopy, understorey and groundcover.

The remnant stands of significant vegetation however, are all listed as endangered communities. This includes the remnant Cumberland Plain Woodland, River-flat Forest and Shale/Sandstone Transition Forests. These species make up an ecologically diverse waterway corridor with several endangered ecological communities and rare species of high conservation significance *(UPRCT, 1999)*.

The extents of the remnant endangered ecological communities have previously been mapped at a broad scale by the UPRCT. This mapping has been superimposed over the 1997 aerial photograph at **Figure 1.11**. Within these endangered communities, weeds have become firmly established in the mid bank and upper bank regions, but provide some resistance to bank erosion.

Some areas of distinctive, large trees in a woodland setting remain, particularly in the Toongabbie Creek corridor downstream of the Oakes Road bridge through Third Settlement Reserve. The woodland corridor extends beyond the confluence with Quarry Branch Creek, downstream to the Hammers Road bridge.

The growth and regeneration of indigenous vegetation at understorey and groundcover level appear to have been restricted by the density of the weed communities. These communities do offer some habitat to native wildlife, and provide resistance to erosio in mid and lower bank levels.

As described earlier, bush rehabilitation projects are occurring within the Quarry Branch Creek corridor and the Toongabbie Creek corridor downstream of Briens Road. These projects are reducing the impact of weed infestation, and are effectively re-establishing stable, biodiverse riparian corridors.

Much of the Toongabbie Creek corridor is contained within areas of open space managed by Council. Large areas of these linear corridors support mown grassed areas as the principal vegetation cover, particularly on the accessible, flatter, upper slopes.

The modifications to stream form and vegetation structure over time at each of the typical cross-sections shown in the Figures are exhibited for comparative purposes in **Figure 1.13-1.17** respectively. These graphical representations demonstrate the substantial impacts post European Settlement, clearing for agricultural and grazing purposes and the process of urbanisation have had on the natural, original elements of the waterway corridors.

Additional Information

Aquatic Flora and Fauna

The modifications to the vegetation structure in the lower banks of the waterway corridors now limits the aquatic flora principally to freshwater macrophytes and floating algae *(Stormwater Management Plan (SMP), 1999)*.

Native fish species have now been replaced by the introduced European Carp, which have thrived in all sections of the waterway corridors, together with mosquitofish. Large eels are still prevalent, and sightings of long necked tortoises have been reported.

Flow Regime and Water Quality

Monthly average flow data and predicted peak storm flows are reported in SMP, 1999.

Monthly average flows in Toongabbie Creek, measured at the Briens Road bridge range between approximately 0.35 m^3/s to 1.47 m^3/s. The monthly average flow data indicates that the period September through to January is on average drier than the remainder of the year. There is no observable distinct wetter period. February is reported to have the highest monthly average flow.

The 50th percentile *(50% of samples exceeded the value)* daily average flow is reported as approximately 0.1 m^3/s at the same location. The 10th percentile daily average flow is approximately 1 m^3/s. Extremely low flow velocities would be induced by these sustained daily average flow rates, which are not considered likely to cause erosion or re-suspend gravels deposited in the in-channel bars, as described earlier.

Hydrologic and hydraulic modelling undertaken by UPRCT predicts peak flow rates for a range of design flood events throughout the study area.

It is widely considered that bankfull flows in NSW streams are approximated by a 2 year Average Recurrence Interval *(ARI)* design flood. At the Briens Road bridge the 2 year ARI design flood peak flow is reported as 307 m^3/s. Typically, some bank and bed erosion could be expected during bankfull flows. Suspended and bed sediment transport would occur.

The 100 year ARI design flood peak flow is reported as 516 m^3/s. Interrogation of the UPRCT hydraulic model results indicates that at the Briens Road bridge, this peak flow rate is associated with *(cross-section averaged)* flow velocities in the range of 1.8 m/s – 2.0 m/s approximately. At this flow velocity significant examples of bank erosion within the waterway corridors would occur. Suspended sediment and bed load transport would occur in significant volumes.

Channel modifications in the form of flood mitigation works have varied flood behaviour through the study area. Council has adopted the 100 year ARI design flood event for the purposes of development assessment and the setting of a Flood Planning Level. For this event, peak flows are contained within the upper banks of the waterway corridors over much of the study area, particularly where the corridor remains deeply incised into steep banks.

Typically, overbank flooding occurs for the 100 year ARI design flood event, adjacent to the confluence of Toongabbie, Greystanes and Pendle Hill Creeks, adjacent to the Oakes Road bridge, and adjacent to the confluence of Toongabbie, Coopers and Finalysons Creeks in the North Wentworthville area. Conceptual flood behaviour as it is currently expected to occur is shown in **Figure 1.10**.

A number of water quality studies have been undertaken within the study area, and are reported in the SMP, 1999. Monthly water quality monitoring has been undertaken since 1990, as directed by UPRCT. The sampling station within the overall study area is located at the Redbank Road bridge crossing Toongabbie Creek.

Compared to the suggested water quality criteria for the protection of aquatic ecosystems, which are those criteria *(standards)* thought to have existed prior to European settlement, no compliance with water quality objectives was achieved during the reporting period 1990-1997. Additional biological monitoring of the environmental health of Toongabbie Creek was undertaken during 1997. As a result of that study, the ecosystem health of the Toongabbie Creek subcatchment was rated as "*poor*", as a rich diversity of macroinvertebrates was not supported.

A large number of Sydney Water sewage overflows are located within, or upstream of the study area. Sewer system modelling by Sydney Water estimates that the sewage overflow adjacent to Hood Street, and discharging to Toongabbie Creek downstream of Hammers Road, delivers approximately 536 ML/year of raw sewage to the waterway during wet weather.

Due to the nature of the landuses in the catchment draining through the overall study areas *(eg. residential, commercial, industrial)* a wide range of diffuse pollutants also contribute to the water quality of the waterways. Of particular note is the volume of litter observed to be trapped upstream of flow barriers *(eg. concrete water supply or sewerage infrastructure acting as weirs)*, and trapping devices specifically placed instream to collect litter before it is transported downstream. Such devices are now placed within Pendle Hill Creek at Burrabogee Road and within Toongabbie Creek upstream of the Oakes Road bridge.

Water quality in the waterway corridors has also been threatened by a number of reported "*dumping*" occurrences. The most recent of these occurrences, the discharge of a toxic material into the waterway, resulted in the killing of approximately 400-500 fish *(particularly European Carp)* and eels.

1.1.3 Detailed Mapping for Upper Toongabbie Creek

The Upper Toongabbie Creek study area commences at the upstream limits *(the McCoy Park Flood Retarding Basin outlet works)* and continues downstream to the confluence with Quarry Branch Creek and is shown in **Figure 1.18**.

Superimposed over the 1997 aerial photography, **Figure 1.18** also acts as a key to illustrate the location of separate mapping sheets for the study area.

Maps 1-10, **Figures 1.19 to 1.28** respectively, comprise consolidated existing information held digitally by Council and UPRCT and original field observations and investigations.

The vegetation extents shown in **Figures 1.19 to 1.28** respectively have been interpreted and mapped from high resolution aerial photography held by UPRCT, supplemented through ground investigations.

Principal Features Of Waterway Corridor

The current landuses throughout the study area are shown in **Figure 1.29**, which has been compiled from Council's Local Environmental Plan 2001 *(LEP 2001)*. The waterway corridor is encompassed by land predominately zoned Open Space 6(a) or Environment Protection (7).

Map 1

The upstream limits of the study area are dominated by the earthen embankment and concrete outlet structure for the McCoy Park Flood Retarding Basin. The downstream limits of bed protection works, incorporating rock filled reno-mattresses, extends to encompass the sewer main which crosses the waterway.

The tail out drain for a stormwater outlet discharging from Tucks Road *(North)* has eroded substantially into the dispersive clays in the left *(looking downstream)* bank. A narrow central low flow channel has formed through banks of dense wetland grasses *(phragmites)* colonising deposited sediments.

Map 2

The overbank floodplain areas of both the left and right *(looking downstream)* banks are generally grassed, passive open space, with linear plantings of mid-storey and understorey trees and shrubs.

The low flow channel has been impacted by the deposition of coarse sands and gravels, forming in-channel bars. The width of the channel between the lower banks, and the observed moderate bed gradients induces lower in-channel velocities through this reach, resulting in the coarser, heavier sands and gravels falling out of suspension. The in-channel bars support dense colonies of alligator weed *(listed as noxious)*, juncus and pepperweed.

A low level gravel access track has been constructed across the channel as a causeway, and three *(3)* stormwater outlets discharge into the creek system from the southern *(right, looking downstream)* banks. Each of the outlets are fitted with floodgates to prevent floodwater intrusion and the subsequent backing up of flows into the residential area to the south.

A sewer trunk main is located within Sue Savage Reserve, in the upper levels of the floodplain in the right overbank areas.

Map 3

Up the upstream end of this element of the study area, the low flow channel has meandered to the lower left bank, and an in-channel bar of coarse sands and gravels has formed and prograded from the right bank towards the mid-channel region. Exposed clays and firm muds are evident in the lower left bank. The muds may be a relict from filling operations for the Old Windsor Road embankment, which is contiguous with the lower left bank for part of its length.

The dominating features of this element of the study area are the exposed sedimentary sandstone layers in the lower to mid right bank. A sewer maintenance chamber stands exposed in the rock region.

An instream cobble deposition zone is evident, although this may have been a result of overburden spilling to the waterway during embankment filling operations. Small boulders and cobbles have formed attractive rock riffles in-stream. Bed rock outcropping is evident in the left bank adjacent to the lower rock riffle.

A brick and masonry flood levee has been constructed to offer flood protection to property in Channel Street. Relief drainage outlets are located in the upper, steeper right bank, with reno mattress erosion protection. Some of the mattress panels are damaged.

The remnant Cumberland Plain woodland located high in the left bank appears to be in a deteriorated condition, affected by a major infestation of balloon vine.

Map 4

The waterway corridor in this element remains in its original, deeply incised channel form.

The Old Windsor Road bridge, known as Johnstons Bridge, has been constructed over the waterway. Large boulders have been placed to armour the lower banks of the stream to offer protection to the adjacent bridge piers. The bed of the stream in the vicinity of the bridge is cobbled, and the remains of a damaged concrete encasement structure is also exposed.

Downstream of the bridge, weathered bedrock outcropping is evident in the lower left bank. Some interspersed clays are also evident. Flows in this region are impounded behind the concrete encased water main *(downstream)* and flow velocities in average daily conditions are observed to be low *(approximately 0.2 m/s)*.

Remnant Cumberland Plain woodland and River Flat forest exist in Palestine Park in the upper left bank. The lower left bank is heavily infested with weeds.

The upper right bank has been substantially cleared to the adjoining property boundary, with a mown grassed open space interspersed with mature trees. A dense understorey lines the upper edge of the lower right bank.

Map 5

The waterway corridor continues as a deeply incised channel in this region. Steep bedrock outcropping is evident in the lower left bank with coarse sands and gravels depositing against the right bank.

A number of bank failures have occurred in the lower right bank, with bank slumping leaving steep exposed erosion scarps. Typically, this form of bank failure occurs as a result of rapid drawdown as a flood recedes, or through undercutting of the toe, leading to higher bank slumps. The prograding point bar formation on the right bank, at the sharp bend in the waterway is also experiencing toe undercutting and resultant failure, which is likely to be caused by high velocity flood flows.

The steep left bank adjacent to the sharp bend in the waterway, which is adjacent to the Goliath Avenue boundary is also experiencing toe undercutting and resultant failure. Subsequent lower bank recession may adversely affect the Goliath Avenue infrastructure.

Immediately downstream of the sharp bend in the waterway, a series of steps have been formed by excavation of bedrock, and through the laying of stone steps above the bedrock outcrop. The steps are considered to be of heritage significance.

Map 6

This element of the study area is impacted by a number of examples of contemporary and heritage infrastructure. At the upstream limit of this element, a concrete encased water supply pipeline impounds flows for some distance upstream. A floating boom, for the entrapment of gross pollutants during low flows has been located immediately upstream.

Some lower bank erosion has occurred just upstream of the concrete encased structure in the right bank, caused by apparent toe failure and subsequent slumping.

Immediately downstream of the concrete encased structure the remains of a rock impoundment weir have been described by heritage consultants for the Council. Not immediately evident to the casual observer, the location of the weir is supported by the location of steps, carved into the bedrock outcrops which are exposed in the lower right bank. The steps would have provided a safe access to the water impounded by the rock weir.

Bedrock outcropping is exposed in the lower left bank and through the bed.

Immediately upstream of the Oakes Road bridge, a small tributary flows into Toongabbie Creek from a channel incised into the right bank. Flow in the tributary is impounded behind a concrete encased sewer main.

A rock filled reno mattress protects the stream bed through and immediately downstream of the Oakes Road bridge. A near vertical high gabion wall has been constructed to protect the outside *(right)* bank through a sharp bend, immediately downstream of the bridge. A point bar of cobbles, gravels and coarse sands has developed on the inside *(left)* bank of the bend.

The edge of a grassed open space at the top of the gabion wall has been denuded, apparently through spraying for weed control. Regeneration and planting of riparian vegetation along the upper right bank is showing strong growth while a heavy weed infestation has colonised the lower and mid-level left bank.

An elevated sewer aqueduct traverses the creek, and is supported mid channel with a brick and concrete pier. Debris has collected behind the pier, and would create a modified flow pattern immediately downstream potentially creating flow eddies which may cause toe and mid-bank erosion.

Map 7

An element of the study area dominated by sharp bends, bedrock outcropping in the bed and left bank at the upstream end create a significant in-channel riffle. A series of near vertical erosion scarps have formed through horizons of clays in the left bank. Towards the downstream end of the element a rock matrix protects the toe of the left bank from additional failure.

A high, near vertical gabion wall has been constructed to protect the right bank from retreat, protect the sewer trunk main which follows the right bank, and to act as the foundation for a flood levee which offers flood protection to properties in Peter Parade and adjacent land.

A sharp meander occurs opposite property in Faulkner Street, and coarse sands have deposited in forming a point bar. A grassed open space, remnant woodland and some indigenous plantings occupy the mid and upper right bank. The outside *(left)* bank of the meander is protected from typical toe failure by bedrock outcropping.

Map 8

Bedrock outcropping in both banks and exposed bedrock forming riffles, and natural grade control structures dominate the upper sections of this element of the study area.

Deeply incised through a high energy section of the stream, a broad pool has formed in the outside *(right)* bank downstream from one of the riffles. The bank has retreated over time until exposed bedrock resists further movement.

An elevated sewer aqueduct traverses the waterway corridor between the riffle locations.

A series of earthen flood levees have been constructed adjacent to the left bank, offering protection to properties fronting Edison Parade. High level relief drainage outlets allows drainage to occur from behind the levees. At the easterly extent of this element a high near vertical gabion wall protects the outside *(left)* bank in a severe meander from retreat, protecting the Edison Parade road infrastructure and supports the eastern extent of the adjacent flood.

A drainage outlet has been constructed *(2001)*, incised into the lower right bank, from the recent development of the Grand United land *(known colloquially as Constitution Hill)*.

A mix of eucalypts, lantana and other weeds dominates the thinned remnant woodland community.

Map 9

This element of the study area is encapsulated in a steep sided deeply incised corridor. The waterway corridor passes through a remnant woodland community, with a dense understorey of weeds.

Residential development adjacent to the right bank has resulted in a thinned canopy cover. A bush regeneration program *(1999 – 2001)* in the mid and upper left bank has resulted in the removal of a dense understorey of madiera vine, balloon vine and woody weeds. Selective plantings have been undertaken to restore the riparian corridor.

In-channel bars have formed of coarse sands and gravels, which have been colonised in dense alligator weed.

A stone lined stormwater outlet has been constructed *(2001)* from the upper to the lower right bank to service the recently constructed residential development. The works are limited to the top of the lower bank. Uncontrolled flows cross the informal walking trail and discharge to the creek through thick grasses which colonise the lower bank.

Map 10

This element of the study area continues downstream through a deeply incised corridor.

Two sharp bends dominate the element, with point bar formations prograding into the channel with coarse sand deposits. The informal walking trail, which follows a narrow bench at the top of the lower right bank, passes under overhanging bedrock protrusions, and traverses the remains of a disused quarry. The sheer working face of the quarry is evident.

The left bank, in part, is protected by bedrock outcropping, which is interspersed with exposed clay horizons. The corridor vegetation is dominated by eucalypts offering a continuous canopy, with understorey weeds and open grassed areas within the Bundilla Scout Camp.

A plume of gravels and coarse sands has prograded into the mid-channel region from Quarry Branch Creek. Thick alligator weed has colonised the plume.

1.1.4 Waterway Opportunities and Constraints

With a view to supporting the "*Vision*" for the waterway corridor developed earlier in this Masterplan, **Table 1.2** describes the principal opportunities and constraints considered likely to affect future implementation of the Masterplan for the focussed study area.

Table 1.2 Waterway Constraints & Opportunities

Issue	Constraint	Opportunities	"*Vision*" Element Supported
• Quality of remnant vegetation	• Introduced species planted in small "groves" becoming visually significant and part of "the river experience". • Management of small remnant vegetation pockets difficult.	• Recreate and extend the riparian understorey and canopy. • Restore a complexity in vegetation, providing enhanced varietal habitat. • Re-establish a vegetative corridor of appropriate density and complexity for full length of study area – a corridor "link". • Understorey management through bush regeneration programs.	• Sustainability. • Biological diversity. • Stability. • Naturally functioning waterway.
• A diverse and naturally functioning stream	• Works may influence flow behaviour and flooding. • Location of services infrastructure including sewer trunk mains, water supply mains, storm drainage outlets. • Transportation of bed sediments may establish new colonies of noxious weeds throughout waterway – significant environmental and statutory controls would apply to any works. • Apparent oversupply of sediments from outside of study area. • Reintroduction of meander *(see opportunities)* may influence sediment transport regime due to apparent oversupply of sediments.	• Possible provision of pool and riffle systems to provide varietal habitat, water quality enhancement and improved amenity. These works to be located where flow behaviour would not impact on flood risk. • Possible removal of part or all of the in-channel sediments, improving flow behaviour and restricting transportation downstream. Possibly result in improved water quality. • Allow woody debris to remain to add varietal habitat, particularly where minor bank erosion does not threaten infrastructure or influence safety issues. • Introduce wetland plantings along waterway fringes, particularly in low energy reaches where flows are impounded behind artificial structures or bed controls *(natural riffles)*. • Investigate possibility to re-introduce stream meander adjacent to Sue Savage Reserve. Improvements to riparian corridor, provision of varietal habitat, enhancements to recreational amenity.	• Sustainability. • Biological diversity. • Naturally functioning waterway.

Table 1.2 Waterway Constraints & Opportunities (cont'd)

Issue	Constraint	Opportunities	"*Vision*" Element Supported
• Bank stability	• Infrastructure services possibly induce bank erosion in some locations *(eg. adjacent to and downstream of elevated sewer aqueducts)*. • Stormwater drainage outlets induce bank erosion through uncontrolled discharge points. • Existing structural measures for bank stability may induce prograding erosion at unprotected structure terminals. • Steep banks with weed vegetation coverage supporting road infrastructure experiencing toe failure require immediate attention. • Continued spraying of areas unable to be mown *(eg. at top of gabion wall, downstream of Oakes Road)*, creating denuded soil zone.	• Strengthen vegetative understorey corridor through utilising vegetative techniques in bank stability works *(eg. between Old Windsor Road and Oakes Road bridges)*. • Establish generic outlet protection works for stormwater drainage. Incorporate water quality management facilities where feasible. • Provide high priority ranking for bank stability works required to protect infrastructure *(eg. adjacent to the eastern end of Goliath Avenue)*. • Provide high priority ranking for restoration of understorey corridor in denuded soil zones. • Provide high priority ranking for bank stability works required to protect public safety.	• Sustainability. • Stability. • Naturally functioning waterway.
• Flood behaviour	• Location of infrastructure services restricts further channel modification works. • Elevated sewer aqueduct structures restrict flows, particularly when debris builds up behind in-channel pier. • Heavy weed infestation in overbank areas may affect flow behaviour. • Accumulation of sediments in-channel may affect flow behaviour. Removal subject to significant environmental and statutory controls.	• Possible streamlining of flows by structural modifications to elevated sewer aqueducts. • Promote weed removal and restoration of riparian corridor to enhance flow conditions. • Possible removal of part or all of the in-channel sediments, improving flow behaviour. • Possible combination of erosion protection and flow streamlining works, where feasible, reducing energy losses in sharp bends – positively modifying flood behaviour.	• Sustainability. • Stability. • Naturally functioning waterway.

Table 1.2 Waterway Constraints & Opportunities (cont'd)

Issue	Constraint	Opportunities	"*Vision*" Element Supported
• Access and recreation	• Possible impact on understorey and canopy continuity if formal pedestrian/cycle access provided. • Continued need for mowing of open space areas, impacting on riparian corridor edge and damaging native grasses. • Public safety potentially at risk if attracted to recreation areas with dense understorey. • Potential for damage to important Heritage items if location known and access improved.	• Create interesting pedestrian and shared cycle link for full length of restored riparian corridor, linking Upper Toongabbie to Parramatta – provide link to existing pathways. • Provide educative and interpretive signage to identify importance of rehabilitation and maintenance activities. • Create recreational opportunities adjacent to stream features of interest *(eg. rock riffles and deep pools)*. • Identification and protection for important heritage items. • Create *"no mow"* areas of native grasses in linked corridors adjacent to informal open space areas to provide and enhance varietal habitat.	• Sustainability. • Biological diversity

1.1.5 Review of Hydraulic Behaviour

Hydraulic Modelling by UPRCT

The UPRCT has developed a detailed, sophisticated hydraulic computer based model of the Upper Parramatta River floodplain, which includes all of the river's major tributaries. Upper Toongabbie Creek, together with minor tributaries, is represented in the hydraulic model.

In order to satisfactorily account for floodplain storages and the timing of incident flows within each river reach and from inflow tributaries, the fully hydrodynamic *(time-varying)* hydraulic model MIKE-11, produced by the Danish Hydraulics Institute *(DHI)* has been utilised by UPRCT to represent flood behaviour.

The model routes inflow hydrographs from the hydrologic *(rainfall-runoff)* model RAFTS through a series of cross-sections and structures, and through a series of computations allows the determination of flow *(flood)* depths and flow velocities. MIKE-11 is a one-dimensional model, which means that flow paths and directions are fixed by the user, and assumes that flows are perpendicular to each cross-section represented in the model.

The UPRCT have determined flood levels and flow velocities in the Upper Parramatta River floodplain for a range of predicted flood events. These model results are frequently updated and presented to Councils for adoption and use in floodplain risk management, emergency response and development assessment.

Results of the hydraulic modelling are also utilised in the conceptual and detailed designs of erosion control measures and stream rehabilitation projects.

Representation of Upper Toongabbie Creek in Hydraulic Model

The Upper Toongabbie Creek study area is represented in the hydraulic model by a series of cross-sections which have either been directly surveyed or have been produced through interpretation of orthophoto *(aerial photography)* mapping.

The location of a selection of the cross-sections in the model scheme is shown in **Figure 1.30**. Plots of the cross-sections at each of the nominated locations are provided in the **Appendices**.

Overview of Surface Roughness

One of the principal characteristics affecting the behaviour of in-channel and overbank flows is the roughness of the surfaces over which flows occur. This surface roughness, represented as a roughness or resistance coefficient, impacts significantly on flow velocities and associated flow depths.

For example, extremely smooth surfaces such as concrete *(with a resistance coefficient with a numerical value of, say, 0.013)*, do not resist flows at or near the surface and accordingly, for a given energy gradient *(or bedslope)*, flows may be quite fast. For the same energy gradient, however, flows against a very rough surface, such as dense understorey vegetation or a dense copse of trees *(with a resistance coefficient with a numerical value of say, 0.12)*, are resisted and accordingly flow velocities would be much lower. These theoretical impacts on flow velocity due to surface roughness have the practical effect of impacting flow depths, and hence flood levels. The selection of an appropriate resistance coefficient *(or a series of coefficients)* across each cross-section is important in ensuring the ground surface is correctly represented in the hydraulic models.

Additionally, an iterative process of optimisation of resistance coefficients is a technique utilised in the calibration of hydraulic models. Calibration is the method of replicating observed behaviour of a real flood event, so that predicted results from "design" flood events are more widely accepted.

Graphical Representation of Surface Roughness

Five cross-sections from those selected from the UPRCT model data have been chosen from various stream reaches to provide a graphical depiction of the resistance coefficients adopted.

The cross-sections, identified by river chainage *(which is a reference to distance along the creek, commencing at an arbitrary starting point at the upstream end)* are listed in **Table 1.3**.

Table 1.3 Selected Cross-Sections

Cross-Section (River Chainage)	Description in Reach Location
CH 7211	Example of broad floodplain, with little vegetative coverage, between McCoy Park and Old Windsor Road.
CH 7550	Example of broad floodplain, with heavier vegetative coverage on the left bank, between McCoy Park and Old Windsor Road.
CH 8424	Example of incised channel, with some mown grass open space and medium understorey and canopy communities, between Old Windsor Road and Oakes Road.
CH 9650	Example of incised channel with structural protection measures with some grass open space and medium understorey and canopy communities located approximately mid way between Oakes Road and Quarry Branch Creek.
CH 10941	Example of incised channel with dense understorey and canopy communities, located just upstream of the Quarry Branch Creek confluence.

Cross-sections for each of the nominated river chainages are shown in the Figures describing the resistance coefficients utilised in the hydraulic model across each section. Predicted flood levels for 1 year Average Recurrence Interval *(ARI)*, 2 year ARI and 100 year ARI design floods are also shown.

Each formal cross-section plot is accompanied by a graphical representation of vegetative characteristics across the section. This is to allow a comparative analysis of the resistance coefficients used and a depiction of the vegetative densities and surface types that each coefficient has been adopted to represent.

It is also noted that the adopted resistance coefficients are wholly consistent with those described in the relevant literature *(Chow, 1959 & Rutherfurd et al, 2000)*.

Hydraulic Behaviour in Upper Toongabbie Creek

A summary of hydraulic behaviour in Upper Toongabbie Creek is shown in **Table 1.4**, which incorporates information compiled directly from the UPRCT hydraulic model result files.

Table 1.4 Upper Toongabbie Creek Hydraulic Behaviour

River Chainage	1 Year ARI		2 Year ARI	100 Year ARI	
	Flood Level (m AHD)	Flow Velocity (m/s)	Flood Level (m AHD)	Flood Level (m AHD)	Flow Velocity (m/s)
7009	23.1	1.1	23.9	25.5	1.9
7131	23	0.8	23.9	25.6	1.8
7211	22.9	1.4	23.8	25.6	1.5
7371	22.7	1.1	23.7	25.6	1.3
7550	22.4	0.5	23.5	25.4	1.6
7775	22.2	0.9	23.3	25.3	1.6
8194	21.7	1.0	22.8	24.7	1.8
8424	21.3	1.1	22.4	24.3	2.3
8638	20.9	0.9	21.9	23.9	2.6
8712	20.9	1.4	22.0	23.9	1.5
8832	20.6	1.1	21.8	23.7	1.9
8953	20.3	2.3	21.4	23.6	1.6
9049	20.0	1.8	21.2	23.4	1.9
9255	19.7	1.5	20.9	23.2	1.7
9650	18.9	1.2	20.2	22.6	1.8
10070	18.1	0.9	19.6	22.2	1.2
10318	17.6	1.0	19.1	21.7	1.5
10721	16.6	1.1	17.8	20.1	2.3
10941	16.0	0.8	17.2	19.5	1.8

Flow velocities for the 1 year ARI design flood have been estimated through application of the Manning Formula, with hydraulic radius, compound resistance coefficient *(Manning's "n")* and energy gradient either directly extracted or extrapolated from the hydraulic model data.

The 1 year ARI details have been provided as flows from this event approximate "*bankfull*" conditions, as seen from the flood levels superimposed over the cross-sections, provided in the **Appendices**.

Bankfull conditions are widely considered those which approach major channel-forming activity *(erosion and depositional events affecting the long-term form of stream bed and banks)* which occurs during regular *(1-2 year)* flooding events. Bankfull flows are typically used as design conditions for in-stream rehabilitation works *(Rutherfurd et al, March 2000).*

Estimated "*bankfull*" flow velocities *(ie. flow velocities for the 1 year ARI design flood)* appear relatively constant in the range 0.5 m/s – 1.4 m/s, with an average flow velocity within that range of 1 m/s. Excluded from this range are flow velocities between 1.5 m/s – 2.3 m/s, occurring across the cross-sections at river chainages 8953-9255 respectively.

These sections are located downstream of the Oakes Road bridge, and the estimated higher flow velocities are consistent with the characteristics of a hydraulic jet downstream of a flow constriction *(such as a bridge)*.

Corresponding high flow velocities at the same locations for a 100 year ARI design flood do not occur, which is consistent with the effects of the bridge being negated by outflanking and drowning of the structure at the rarer, higher flood events.

Predicted flow velocities for the 100 year ARI design flood range consistently between 1.2 m/s – 1.9 m/s. Higher velocities outside this range are predicted to occur across cross-sections at river chainages 8424-8638. These sections are located downstream of the Old Windsor Road bridge, in a deeply incised narrow channel with a broad alluvial floodplain across the right bank. This region does display some erosion characteristics, with slumping of the lower banks induced by toe failure. Bankfull velocities do not appear higher than average through this region however, and the observed examples of bank failure may have been caused by the effects of rapid drawdown after flooding.

Discussion on Sedimentary Processes

A number of in-channel sedimentary deposition zones are described in the detailed study area mapping. The main locations of these zones are between the McCoy Park Flood Retarding Basin and Old Windsor Road, a reach which has been substantially modified through straightening and clearing, and the relatively straight, narrow reach adjacent to the site of recent residential development between river chainages 10232-10721 *(approximately)*.

A large volume of coarse sands and gravels have been deposited within these zones, and the in-channel bars have been predominately colonised by dense alligator weed.

The modification of the reach upstream of Old Windsor Road bridge has led to the straightening and shortening of the reach, which in turn has led to an increase in channel bed gradient.

Such an increase in gradient usually elevates sediment transport capacity so that it is greater than the available natural sediment supply rate at the upstream end of the straightened reach. This difference in sediment load is usually balanced through the erosion of the channel bed and banks, leading to destabilisation of the straightened reach.

As described, however, the reach has experienced an accumulation of sediments, with no observable erosion patterns. This indicates that over recent time, it is likely that there has been a substantial oversupply of sediments at the upstream end of the reach, which has been transported by flood flows until settling through each receding flood.

Similarly, the in-channel sedimentary processes described in the downstream reaches of the study area have been dominated by an over supply, with sediments in transport settling through the lower energy flood recession.

Continued aggradation of the in-channel deposition zones may adversely impact flood behaviour *(through channel in-filling)* and an important matter for consideration during the implementation of this Masterplan will be the development of an understanding of the provenance *(source)* of the accumulating sediments.

Flow behaviour has also been examined to determine whether the accumulated coarse sands and gravels may be set back into motion and transported further downstream. Approximations of the bed shear stress *(the force per unit area exerted by flowing water on the stream bed or sediment surface)* which occurs adjacent to the location of sediment deposition, and the bed shear stress required to set various materials in motion are shown in **Table 1.5**.

Table 1.5 Bed Shear Comparisons

River Chainage	Bed Shear Stress at Bankfull Flow (N/m^2)	Bed Shear Stress at 100yr ARI Flood (N/m^2)	Bed Shear Stress Required to set in Motion:		
			Top 10mm of sand (<1mm) (N/m^2)	Top 20mm of coarse sand (2-5mm) (N/m^2)	Top 60mm of medium grain gravel (5-20mm) (N/m^2)
7550	14	15	36	84	378
7775	30.6	38			
8953	47	34			
10318	53	47			

A comparative review of these results indicates that it is likely that the sands, and coarser grained sands stored within most of the in-channel deposition zones are likely to be re-mobilised by bankfull and major flood flow conditions. Some resistance to the re-mobilisation will be offered by the vegetative cover provided by the weeds, grasses and shrubs which have colonised the sediments.

Implications of Hydraulic Behaviour on Future Waterway Management

The UPRCT hydraulic model for the Upper Toongabbie Creek study area represents the waterway corridor and broader floodplain in a series of cross-sections, with associated surface resistance coefficients, as it currently exists *(2002)*.

As noted earlier, and as demonstrated by a graphical representation, the adopted surface resistance coefficients are consistent with "*real-world*" characteristics described in the relevant literature.

It would appear however, that the data in the cross-sections is unlikely to be sensitive to minor modifications in the characteristics of the surface of the waterway corridor. It is also unlikely that the data is sufficiently detailed to have been sensitive to minor losses in the main low flow channel by the sedimentary deposition, described earlier.

Such implications, however, suggest that future maintenance and rehabilitation should be formulated such that no substantial modifications in "*actual*" surface resistance occurs throughout the implementation of the Masterplan. This would be achieved through a co-ordinated scope of works which provides compensatory elements of weed management where any intense riparian plantings are proposed. Vegetation structure and densities should be replicated by any management activities. Any long term strategy to reduce or remove the accumulated sedimentary deposits would increase effective waterway area in the main stream channel and provide a positive benefit in flow behaviour from a floodplain risk management perspective. Such benefits will include a reduction in flow velocity and an associated lowering in local flood levels.

2 DEVELOPMENT OF MASTERPLANS

2.1 Detailed Maintenance and Rehabilitation Activities for Upper Toongabbie Creek

The Upper Toongabbie Creek study area extends between the McCoy Park Flood Retarding Basin outlet, and the confluence between Toongabbie Creek and Quarry Branch Creek. The extent of the study area is shown in **Figure 2.1**, which is superimposed over the 1997 aerial photography.

Figure 2.1 also acts as the key map to illustrate the location of each of the separate mapping sheets, used to describe the maintenance and rehabilitation activities in the Masterplan.

2.1.1 A Vision for Upper Toongabbie Creek

"A sustainable, biologically diverse, stable, naturally functioning waterway corridor providing:

- *an accessible environment*
- *a healthy environment*
- *a recreational environment*
- *a safe environment*
- *a valuable environment; and*
- *a well managed environment*

for all of its users now, and well into the future."

Consultation Framework

Stakeholder group, Focus group and Councillor workshops were held to assist in the development of a "*Vision*" for the waterway corridor.

Each of the groups was asked to identify a range of issues and values they attributed to the importance of the waterway corridors. Having done this, and recognised the wide range of matters which became important to individual member of each group, and those matters which became important collectively, a description *(a word or phrase)* of the "*Vision*" for the waterway corridor was sought.

The values, issues and description of each groups "*Vision*" are summarised below.

Stakeholder Group

This group was made up of invited attendees with an interest, or stakeholding, in the management and future of the waterway corridor. Attendees included Council staff from a range of professional disciplines, staff of UPRCT and the NSW Department of Land and Water Conservation. Representatives of local businesses and service authorities also attended the workshop, which was held on September 11, 2001.

Table 2.1 summarises the Group's responses.

Table 2.1 Stakeholder Group Responses

VALUES/ISSUES	VISION
• Unique • Natural • Sustainable • Stormwater Drain • Continuity West • Neglect • Accessibility • Respite • Escape Habitat • Educational • Varietal • Services corridor • Safety • Clean water • Community spirit & ownership • Recreational • Historical • Cultural • Amenity • Potential tourism values • Generational differences in waterway users • Clarity in responsibility	• Environmentally sustainable/healthy • Healthy, productive system • Holistically managed system • A green corridor • Healthy usable corridor • Inclusive community asset • Well resourced asset

Focus Group

This group was made up of people, with a clear interest in the future of the waterway corridor and either responded to advertisements regarding the workshop, or who had provided an input to the Council's associated "*Tales of Toongabbie Creek*" project. The workshop was held on September 13, 2001.

Table 2.2 summarises the Group's responses.

Table 2.2 Focus Group Responses

VALUES/ISSUES	VISION
• Weed • Buffer zones • Floodplain management • Educational resource • Valuable resource • Wildlife corridor • Heritage link • Expensive • Community education	• Weed management • Bush regeneration • Recreational areas • Different management techniques for different areas • Historical, valuable asset • Ecotourism potential Managing existing areas with value • Manage stormwater runoff • Rehabilitation leading to preservation

Councillor Workshop

As part of a broader workshop, Parramatta City Councillors were asked to provide input to their values and vision for the Toongabbie Creek waterway.

The Councillor workshop was held on September 19, 2001 and **Table 2.3** summarises the Councillors' responses.

Table 2.3 Councillor Group Responses

VALUES/ISSUES	VISION
• Pollutants • Rubbish in creek • Stormwater inflows • Weeds • Sediments • Clear banks for safety • Nutrient runoff • Protection of biodiversity • Safety • Risk	• Cleanliness • Accessible • Natural state • Well managed waterway system • Control of flooding • Safety • Presentation • Beauty

Vision Development

Recognising that the waterway corridor is no longer able to be restored to its previous, pre-settlement condition, a number of recurrent themes occur in each of the group's responses, referred to above.

The value of the waterway corridor for biological diversity and habitat is recognised. So too are the themes of the corridors as a community asset, for accessibility and recreation. Safety incorporating stability, flooding issues and visibility are also strongly recurring, as are management issues.

With these issues at the forefront, and with the best practice methodologies, as reviewed earlier in this Masterplan document combined, the following *Vision* for the future rehabilitation and maintenance of the waterway corridors has been developed.

"A sustainable, biologically diverse, stable, naturally functioning waterway corridor providing:

- *an accessible environment*
- *a healthy environment*
- *a recreational environment*
- *a safe environment*
- *a valuable environment; and*
- *a well managed environment*

for all of its users now, and well into the future."

2.1.2 Elements of Masterplan Activities

A range of maintenance and rehabilitation activities are described in Masterplan Maps 1-10 *(inclusive)*.

Formulated to address the "*Vision*" developed for the waterway corridor, together with the range of "*Waterway Constraints & Opportunities*" identified earlier in this Masterplan, the activities are a balanced combination of hard and soft civil works together with a range of intensive vegetative measures. Due to likely funding constraints and the priority ranking of competing Council projects and services, the activities are understood to have a longer term focus. Some important vegetative measures are recommended to build on established initiatives, while some civil works are recommended to avoid potential infrastructure failure.

Some monitoring of bank erosion zones, particularly adjacent to infrastructure services, is recommended.

The timing of some less formal maintenance activities has been broken into defined Periodic and Episodic elements. Activity triggers are briefly described so that inspection and monitoring regimes are as efficient as possible.

The principal maintenance and rehabilitation components of the Masterplan are described in the following report sections. To accompany the activities described in the Masterplan maps, brief descriptions of weeding techniques, and a representative planting schedule are found in the **Appendices**.

Map 1

The upstream limits of the study area are dominated by the McCoy Park Flood Retarding Basin outlet works. Regular inspection of the reno mattress bed protection works immediately downstream of the basin outlet is recommended. The bed protection works also provide some protection against failure for the sewerage infrastructure which crosses the waterway corridor at river chainage 7085 *(approx)*[(1)].

Civil works to rehabilitate the scoured stormwater drainage tail-out channel *(river chainage 7090)* are proposed. These works will allow facilitation of a safe pedestrian/cycleway link, proposed for the *northern (left; looking downstream)* bank by Council.

Continuity of riparian corridor planting is recommended for the southern *(right; looking downstream)* bank. The corridor planting is to strengthen and link to the existing vegetated lower and mid-bank.

Left bank-top planting is recommended to strengthen and link to the existing corridor extending varietal habitat. Further, the low bank shade planting, proposed for the interface with the top of the sediment zone has an additional long term weed management purpose.

For more details, see the Explanatory Notes commencing on page 2-11.

Map 2

The sediment deposition zone extends through this reach adjacent to the left bank generally between river chainages 7180 – 7520 *(inclusive).* Bank-top shade planting is recommended to strengthen and link existing corridor plantings, and also as a weed management technique

"*Island*" style maintenance and plantings are proposed for the right bank area, together with a strengthening of the canopy corridor. Substantial weed management is recommended within the high quality remnant forest located on land on the upper left bank.

The historical stream alignment meanders into the mid-right bank between river chainages 7270 - 7400 *(approximately).* Identification of the historical meander alignment through landscape interpretation is recommended for educative and heritage purposes. For more details, see the Explanatory Notes commencing on page 2-11.

It is recommended to lower and remove the sediment berm which remains in-stream from past construction practices. Located between river

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(1) *"River chainage"* is the distance along the waterway, commencing at an arbitrary starting point at the upstream end.

chainages 7180-7350, the berm forms a remnant low-flow diversion channel. In-stream plantings are recommended to stabilise the surface after removal, which will add to low flow and bankfull waterway area.

The informal stream crossing at river chainage 7415, used for recreational purposes and by maintenance mowing staff to access the open, grassed areas adjacent to the left bank is proposed to be stabilised through construction of a graded rock causeway. The causeway is set along the alignment of the pedestrian/cycle path proposed by Council.

Set at the existing bed level, and extending to mid-bank levels, the causeway will assist in resisting further bank erosion and is considered unlikely to modify existing flow behaviour.

Map 3

Located immediately upstream of the Old Windsor Road bridge *(Johnstons Bridge)* this element of the Upper Toongabbie Creek study area comprises the transition between the channlised reach and the remnant stream form.

Bank top shade planting is proposed as a management strategy for the sediment deposition zone adjacent to the left bank between river chainages 7570 – 7690 *(inclusive).* Willow removal is also recommended at the downstream limits of the bank-top shade planting.

Intensive weed management is recommended for the dense "*Wandering Jew*" infestation adjacent to the lower and mid right bank at river chainage 7585 – 7685 *(inclusive).* Intensive weed management is also recommended within the high quality remnant forest located in the upper left bank.

"*Island*" style maintenance and planting together with a strengthening of the canopy corridor is recommended generally within, and extending beyond, the existing remnant forest occupying the mid and upper right bank.

A graded rock riffle structure is proposed at the downstream end of the stream transition, and downstream of two existing natural riffle zones. The rock structure is intended to be integrated with lower right bank protection works, to resist further bank retreat towards the trunk sewerage infrastructure located adjacent to the lower right bank. For more details, see the Explanatory Notes commencing on page 2-11.

Some minor maintenance/repair works are recommended for the reno-mattress stormwater drainage outlet protection located in the upper right bank at river chainage 7945 *(approximately).* These works however are to be considered in the context of a safe interaction with the proposed pedestrian/cycle path.

Map 4

This element of the study area remains an incised channel, with corridors of remnant and introduced vegetation affecting both banks.

Palestine Park, occupying the left bank, has a number of stormwater outlets high in the upper banks, discharging directly across the ground surface of the park. Stormwater outlet protection works are proposed to prevent further erosion and to act as a "*level spreader*" for storm flows.

Intense weed management is proposed for the remnant bushland areas, while banktop planting is recommended to improve aquatic habitat through temperature reductions in the impounded *(ie. acting as a pool)* stream flows.

The sediment deposition zone, located at river chainage 8170 *(approx)* and noted in the Data Compilation mapping, is immediately downstream of a stream nick point *(narrowing)*. It is considered that high energy flows, induced by the change in flow energy across the narrowing will, over time, remobilise these sediments. With an associated reduction in catchment supply it is expected that this sediment zone will dissipate without additional management action.

Supplementary canopy plantings to improve continuity is proposed generally for the right bank areas.

Varietal habitat is proposed by retention of fallen trees as "*large woody debris*". Monitoring of possible erosive impacts is recommended due to the proximity of the trunk sewerage infrastructure.

Map 5

This element of the study area is dominated by the deeply incised channel, flows in which are impounded behind the concrete encased water main located at river chainage 8832 *(approximately)*. Sections of the lower left bank are stable due to the location of bed rock outcropping.

Bank-top shade planting is proposed for the lower left bank, above the areas of rock outcropping to provide improved aquatic habitat. Intensive weed management is recommended mid way through the study area element, generally upstream of the stormwater outlet located in the lower left bank.

Stormwater outlet protection works are recommended for those discharge points in the high, upper, and lower left bank. Separate concept designs are suggested for the different outlet types *(eg. upper bank and low bank outlet types).*

Substantial bank protection works are proposed for the lower left bank between river chainages 8638-8712. For more details, see the Explanatory Notes commencing on page 2-11.

Islands of intensive weed maintenance and associated planting is proposed for the existing vegetated corridor in the right bank. Monitoring of prograding erosion scarps in the lower right bank is recommended due to the proximity of the trunk sewerage infrastructure. Stable bank protection works may be required to reduce any risk of infrastructure failure due to bank retreat .

Increased access to the stream bank from the pedestrian/cycle path proposed by Council offers opportunities for educative interpretation for the stone and masonry "*Convict*" steps considered to have historical/heritage significance possibly in the context of the colonial Third Settlement.

Map 6

Upstream of the Oakes Road bridge this study area element is dominated by the presence of a concrete encased watermain, which impounds flows upstream while acting effectively as a weir. The structure is also likely to have caused lower bank erosion patterns, particularly upstream in the right bank. Monitoring of these erosion scarps are recommended due to the proximity of major trunk sewerage and water supply infrastructure.

Damaged remains of a stone weir and possible access steps, carved into rock in the lower right bank have been identified. The weir remnants and access steps may have significant heritage value in the context of the colonial Third Settlement, which is known to have been located across the broad alluvial floodplain in the right bank. Increased access to the stream bank made available by the pedestrian/cycle path proposed by Council potentially offers opportunities for educative interpretation and archaeological research.

Intensive "*island*" maintenance and associated plantings is recommended to strengthen the existing remnant vegetation corridor following the right bank.

Bedrock outcropping protects the lower left bank from failure downstream of the concrete encased watermain. The residual clay layers overlying the rock matrices are experiencing some erosion, although it is considered unlikely to create infrastructure failure risk.

Monitoring of bank retreat is suggested, primarily to assess risk to pedestrian visitors to the streambank.

Third Settlement Reserve is located adjacent to the left bank downstream of the Oakes Road bridge.

Bank-top shade planting and intensive weed maintenance is recommended for the left bank between the bridge and the sewer aqueduct which is elevated above minor stream flows. Intensive weed management and associated plantings is recommended for the generally wooded left bank area downstream of the sewer aqueduct.

Placed rock erosion protection is recommended for the stormwater outlet which discharges high in the steep lower bank.

Strewn cobbles and small boulders are evident in the stream bed between the Oakes Road bridge and the elevated sewer aqueduct, which is consistent with a higher energy flow regime through this short stream reach.

The sewer aqueduct is supported at the banks on concrete piers, and is supported centrally with another, in-channel, concrete pier. An investigation into possible modification of the aqueduct structure is recommended. For more details, see the Explanatory Notes commencing on page 2-11.

The open space located downstream of the Oakes Road bridge which follows the right bank contains regeneration and planting areas experiencing relatively strong growth. It is recommended that islands of intensive maintenance be undertaken, together with associated plantings, through this area.

Continuous weed spraying has reduced the steeper batter at the top of the gabion wall, which offers resistance to failure downstream of the bridge, to a narrow corridor of wholly denuded soil. It is recommended that the batter be eased and rehabilitated with dense undercover plantings.

Map 7

The waterway corridor is dominated by sharp bends in this study element. A pedestrian/cycle path exists at the top of a high gabion wall which offers protection to the right bank. The wall acts as a flood levee, and offers protection against failure for the sewer trunk main which follows the right bank alignment. The proposed pedestrian/cycle path proposed by Council should link to the limits of the existing isolated path, offering access continuity.

The erosion rates of the steep scarps in the lower left bank are recommended for monitoring. Bank retreat in this location does not threaten infrastructure, although a pedestrian/cycle path has been constructed some distance from the top of the lower bank. Likely to be dominated by high flow velocities, continued soil loss will contribute to a reduction in water quality through sedimentation. Although a natural process *(modified through catchment change)*, bank protection works may be required.

Intensive weed management with associated rehabilitation planting is recommended for the wooded area within Third Settlement Reserve, while downstream of the Scout Hall buildings high in the upper left bank, the recommended management activity is to undertake "*islands*" of intensive maintenance, with associated intensive plantings to strengthen the connectivity of the existing vegetation groves.

The area of partially wooded open space occupying the formed point bar on the right bank at river chainage 9650 offers possible recreational opportunities utilising improved access from the pedestrian/cycle path proposed by Council.

Supplementary canopy plantings and light maintenance is proposed in this area to strengthen canopy continuity, species diversity and varietal habitat.

Map 8

Dominated by a series of sharp bends, this element of the study area is also characterised by two bedrock riffle structures located upstream and downstream of an additional elevated sewer aqueduct. Encouragement to experience river vistas can be offered by providing access to the stream bank from the pedestrian/cycle path proposed by Council.

Access to the riffle downstream of the aqueduct, at river chainage 9895 *(approximately)* might be encouraged to provide a link to the open space and residential areas adjacent to the upper left bank. Such a low level access would be limited by flood depth, and Council's Duty of Care is a major consideration.

The area generally following the right bank of this element of the study area is heavily wooded and substantially infested with weed species.

Supplementary canopy plantings, together with intensive "*island*" style weed maintenance is proposed. These activities will strengthen the canopy continuity, and rehabilitate the banks in riparian groundcover and understorey.

The left bank experiences a substantial weed infestation *(particularly lantana)* between river chainages 9600 – 9850 *(inclusive)*. Intensive weed maintenance and associated planting is recommended. A similar maintenance activity is recommended for further downstream, on the steeper banks.

The broader open space area in the upper left bank is mainly grassed, with a narrow vegetated corridor at the top of the lower bank. "*Islands*" of maintenance and associated planting is recommended to improve riparian groundcover and understorey continuity and habitat.

A stormwater outlet from the nearby urban development discharges from the lower right bank at river chainage 10220 *(approximately)*. Bank protection measures above the outlet have failed during recent flood events. In order to prevent additional bank erosion and subsequent soil loss, it is suggested that an alternative bank protection method be investigated. The use of a terraced timber crib-wall *(for example)* offers bank stability, and mid-bank vegetation continuity.

Map 9

This study area element is dominated by a remnant vegetative corridor, with a thinned canopy and weed infestation in the right bank, and a recently rehabilitated area in the upper left bank.

Stormwater outlets discharge higher in the upper left bank, with heavily eroded, weed infested tail out channels. Outlet protection works are proposed to prevent further erosion and act as a "*level spreader*" for storm flows.

Intensive weed maintenance is recommended in the mid and upper left bank, to continue the valuable work previously undertaken. Bank top shade planting is recommended for the lower bank, sediment zone interface. The in-channel sediment deposition zone is infested with alligator weed in this location, which is located within a deep, incised channel and is subjected to high flow velocities for rarer flood events *(eg. a 100 year ARI flood)*. As described in the Explanatory Notes on page 2-11, the proposed bank top planting will assist in reducing the density of the alligator weed infestation. This in turn is expected to reduce the resistance to mobilisation of the sediments in the in-channel bars.

"*Islands*" of intense weeding, associated riparian plantings and supplementary canopy plantings are recommended rehabilitation and maintenance activities for the right bank area in this study area element.

Map 10

The most downstream study area element is dominated by two sharp bends, and the confluence with Quarry Branch Creek. Valuable remnant forest provides some canopy continuity.

Bank top shade planting together with associated weed management is recommended for the left bank to river chainage 10500, in order to manage the sediment deposition zone *(as described in the Explanatory Notes below)* which is colonised with Alligator Weed.

Intensive weed management and associated planting is recommended generally for the riparian corridor along the left bank to the confluence with Quarry Branch Creek. The Bundilla Scout Camp occupies this land.

"*Islands*" of intensive maintenance and associated planting is recommended generally for the riparian corridor following the right bank area which is closely adjoined by new and existing residential development. Supplementary canopy planting is recommended to strengthen canopy continuity and provide varietal habitat.

The open nature of the floor of the disused quarry offers recreational opportunities *(the area is currently used informally by "off-road" cyclists).* Access to the top of the lower bank, at the apex of the stream bend adjacent to the quarry site, will encourage pedestrian/cycle path users to enjoy the riverine corridor vistas which occur both upstream and downstream at this location.

Explanatory Notes

Map 1 An instream sediment deposition zone has developed over time, since construction of the channelised reach, due to an oversupply of catchment sediments available at the upstream end of the waterway corridor. Much of the in-channel sediment bars have prograded into the channel from the lower left bank alignment, and have been densely colonised with Alligator Weed (see **Plate 1**).

Plate 1 Example of Sediment Deposition Zone

Declared a W1 noxious weed under the Noxious Weeds Act 1993, Alligator Weed is required to be "*fully and continuously suppressed and destroyed*".

Mechanical removal of the in-channel sediments *(in the case of Toongabbie Creek through the use of either land based or in-channel excavator)* is problematic and is likely to contribute to further downstream spread *(NSW Agriculture).*

The sediment deposition zone has reduced channel waterway area and hence has modified flow behaviour in this element of Toongabbie Creek. It is likely, however, that the infilling has had little effect on predicted flood levels at the rarer flooding events, when substantial overbank flows occur.

It is, however, considered appropriate to initiate a management strategy for reducing the in-channel sediment bars, while reducing the density and prevalence of a W1 declared noxious weed. It is considered that the density of the Alligator Weed contributes to the stability of the in-channel bars.

The proposed management strategy comprises the planting of dense, bank –top shade vegetation. Alligator Weed is a summer growing perennial herb, which thrives in sunlight. The introduction of shade trees to the interface between the low bank and the top of the sediment zone is expected to restrict plant growth, and contribute to a break-down of plant density. In turn, the reduction of plant density will diminish the plant's role in stabilising the sediments and resisting remobilisation of the sediments during flood events.

Over time it is expected that the sediment zones will be reduced in size through mobilisation and re-suspension during more frequent flood events. The sediments will be transported through the river reach until reduced stream power allows settlement.

This process is expected to improve flow conditions, and reduce Alligator Weed infestation while introducing valuable, varietal riparian habitat. A graphical representation of the existing and future waterway conditions in relation to the sediment deposition zone is shown in **Figure 2.2**.

Map 2 The possibility of restoring the historical meander which occurred at river chainages 7270 – 7400 *(approximately)* was considered. The site of the historical meander is shown in **Plate 2**.

Plate 2 Site of Historical Meander in Photo Mid-Ground

It is acknowledged that the restoration of the meander in its original form was unlikely to be possible due to the changes in catchment characteristics *(and hence stream flow behaviour)* over time and the more recent *(over the last 30 years or so)* lowering of the floodplain in the vicinity of the meander location.

The meander originally consisted of a deeply incised channel, and it is likely that bedrock provided protection against erosion for the bed and banks. Some local deposition of sediments would likely have occurred, with the source of those sediments being a combination of catchment soils together with natural riverine bed and bank erosion occurrences upstream. The incised channel would have provided enough energy to transport the sediments in a natural process to downstream reaches.

It is widely considered that watercourses in the Cumberland Plain experienced bankfull flows generally in the order of a flood event with a recurrence between 4-7 years *(ARR, 1987)*. It is estimated that peak flow rates of a representative 5 year ARI design flood were in the order of 230 m^3/s *(approximately)* prior to modification of catchment characteristics *(ie. prior to European Settlement).*

It is now estimated that bankfull flows in the modified stream channel are represented by a 1 year ARI design floods, peak flows from which are estimated to be approximately 243 m^3/s *(extracted from the Trust's hydraulic models).*

With the lowering of the floodplain, and hence restricting the available depth of a contemporary meander restoration, it is clear that historical bankfull flows would not be achievable.

A design concept consisting of a broad based channel, benched side slopes and relatively flat *(1:4)* batters was developed, with a view to conveying up to 25% of a 1 year ARI design flood peak *(ie. a 3 month ARI design flood with a peak of approximately 60 m^3/s).* Batters from the right bank *(looking downstream)* were constrained due to the proximity of the trunk sewerage infrastructure.

In order to divert flows from the main channel into the restored meander, a diversion weir would be required to be formed across the bed of main channel. Such a weir would affect normal flow behaviour in the channel. It was also considered that such a weir would act to direct suspended sediments to the meander entrance subsequently reducing the effectiveness of the meander through deposition.

Further, at the bends in the meander, it was considered that an aggressive point bar formation would occur, directing flows into the right bank adjacent to the trunk sewerage infrastructure, possibly inducing a failure risk. A costly hard structural edge may therefore have been required.

At the point of re-entry, that is, where flows in the restored meander and main channel combine, it is considered that a sediment plume may prograde outward across the main channel. This possible in-channel sediment deposition is considered likely to impact on main channel flow behaviour, and is also likely to create a sediment supply susceptible to further alligator weed infestation.

Accordingly, due to matters described above, it was considered inappropriate to implement the meander restoration as a waterway corridor management activity. It is recommended however, to represent the alignment of the historical stream meander through landscape interpretation.

Map 3 The graded rock riffle is to be located upstream of the Old Windsor Road bridge, a significant hydraulic control on flow behaviour in this stream element. The structure, with rocks embedded into a secondary rock layer recessed into the bed, would be designed to resist failure induced by hydraulic loadings up to bankfull *(1 year ARI)* flows. The structure would be substantially drowned at rarer floods *(say the 100 year ARI flood event)* and is considered unlikely to modify flow behaviour so as to substantially impact predicted flood levels.

The structure is proposed to be integrated with bank protection works on the right bank. The bank is experiencing erosion, induced by local flow characteristics and associated toe failure. The erosion zone may impact the trunk sewerage infrastructure located within the bank if the top of the bank continues to retreat in the landward direction. The proposed pedestrian/cycle path is also likely to be located close to the bank top due to local topography, and would be at less risk of failure with a stable supporting embankment.

The riffle structure itself, designed to be formed in a "*vee*" shape to centralise low flows immediately upstream of the bank protection constructed for the Old Windsor Road bridge works, is also located immediately upstream of the limits of influence of the flows impounded behind the concrete encased water main located downstream at river chainage 8832 *(approximately).* The structure is expected to provide positive benefits in water quality through aeration, provide additional varietal aquatic habitat and is considered unlikely to restrict fish migration.

The concept will provide recreational opportunities through offering an enhanced river experience in proximity to the planned pedestrian/cycle access path. The stream form immediately upstream of the proposed riffle site is shown in **Plate 3**.

Plate 3 Stream Form adjacent to Riffle Site. A Natural Riffle occurs in the photo centre ground.

Map 5 The lower bank is experiencing erosion consistent with toe failure. Concave slumping is evident, and it is considered that structural management is required in order to protect road and allied infrastructure (see **Plate 4**). The proposed structure, recommended as a placed rock *(sandstone, preferably)* wall, founded on a gabion *(rock filled rectangular cage)* toe. The gabion row is proposed to be placed below anticipated bed scour depth.

Plate 4 Concave Bank Slumping at Site of Proposed Bank Protection Works

It is suggested that the detailed design for bank protection works incorporate resistance to failure for rarer flood events *(say, up to a 100 year ARI flood)*, although it is suggested that the overall wall height be limited to the predicted flood level for a more frequent flood event *(in this case, a 5 year ARI flood, or RL 22.5 m AHD).* It is proposed that lower flow velocities in the upper bank be resisted by dense riparian understorey and groundcover planting providing vegetative and varietal habitat continuity and maintaining vegetative corridor views.

Map 6

As described, the sewer aqueduct is supported at the banks on concrete piers, and is supported centrally with another, in-channel, concrete pier (see **Plate 5**). The central support may contribute to circular flow patterns which may in turn induce bank erosion. Although not located where flood levels are critical to adjacent property flood liability, the pier may cause channel blockages through trapped debris, modifying flow behaviour.

Plate 5 Site of Sewer Aqueduct

Accordingly as a management response it is recommended that the possibility of central pier removal be investigated. Involving close liaison with Sydney Water, the infrastructure owner, removal might be facilitated through an unsupported pipe, designed to withstand hydraulic and debris impact loadings. Alternatively the use of an "*inverted siphon*" might be considered, although the presence of rock in the banks and stream bed may be cost prohibitive.

2.1.3 Waterway Corridor Responses to Principal Masterplan Activities

The principal maintenance and rehabilitation activities proposed for implementation in the Masterplan have been selected to address aspects of the "*Vision*" for the waterway corridor. The defining elements of the "*Vision*", are:

- sustainability;
- biological diversity;
- stability; and
- the natural function of a waterway corridor.

These defining elements contribute a number of valuable processes to the stream itself.

The processes, a combination of fluvial, geomorphic and ecologic are considered to be positively impacted by the activities described above, and represented in the accompanying Maps 1-10 *(inclusive).* Descriptions of the Waterway Corridor responses to Masterplan activities are found in **Table 2.4** below.

Fluvial / Hydraulic Waterway Response to Management Activity – A Commentary

As described earlier in this Masterplan, one of the principal characteristics affecting the behaviour of in-channel and overbank flows is the "*roughness*" of surfaces over which flows occur. This roughness may impact significantly on flow velocities and associated flow depths, and is represented in the Trust's hydraulic model as a resistance coefficient.

Typically the maintenance and rehabilitation activities in the Masterplan are focussed on limited structural works, but principally on vegetative management.

Resistance coefficients for representative cross-sections in the Study Area are graphically represented earlier in this Masterplan.

The principal element of the Masterplan activities, particularly relating to vegetative management, is that vegetative densities, and hence a corresponding flow resistance, are not substantially altered from those which exist in the waterway corridor in its current form. This approach focuses on achieving a negligible impact on flow behaviour and associated predicted flood levels.

This is proposed to be achieved through the implementation of a balanced program of vegetative works. For example, in areas where additional riparian vegetative structure is recommended, an associated program of intensive weed management is also recommended.

In this way, throughout the length of the Study Area, where resistance coefficients may be locally affected by additional, denser '*islands*' of planting, an offsetting reduction in weed infestation will also take place. These actions will contribute to satisfying part of Council's floodplain management obligations along the Study Area waterway corridor.

Typical examples of how cross-sections may be modified through the proposed vegetative measures, in three representative locations, are shown graphically in **Figures 2.3 – 2.5** respectively, shown on the following pages.

Additionally, a graphical representation of the anticipated long term reduction in the sediment deposition zones, described above, is depicted in **Figure 2.2** earlier in this report. The resultant increase in low flow waterway channel area and associated modification in lower bank vegetative structure is expected to have a positive impact on flow behaviour, particularly for the more frequent flood events, up to and including bankfull flows.

The location and features of the graphical representations of modified waterway corridor sections are described in **Table 2.5**. Estimates for waterway corridor resistance coefficients pre- and post-implementation of the recommended Masterplan activities are presented. The proposed post implementation resistance coefficients are generally presented in a range, having regard to values presented in **Table 2.5**.

Table 2.4 Waterway Corridor Responses to Principal Masterplan Activities

PRINCIPAL MASTERPLAN ACTIVITY	LOCATION	WATERWAY "*VISION*" ELEMENT ADDRESSED	GEOMORPHIC RESPONSE TO ACTIVITY	FLUVIAL/HYDRAULIC RESPONSE TO ACTIVITY	ECOLOGIC RESPONSE TO ACTIVITY
• Rehabilitation Activity – Type A o Provide bank-top shade planting throughout. o Undertake intensive maintenance (weed management) and intensive planting (understorey & groundcover).	• Maps 1, 2, 3, 4, 5, 6, 9 & 10	• Sustainability. • Biological diversity. • Stability. • Naturally functioning waterway.	• Improved stability of lower bank. • Mobilisation of sediment deposition zones. • Associated reduction in sediment deposition, as a result of plant entrapment, due to reduction of weed infestation.	• Gradual increase in low flow channel, waterway area, through reduction in sediment deposition zones. • Modification in flow behaviour through reduction in flow resistance due to intensive weed maintenance, balanced through groundcover and understorey plantings. • Long term positive benefit in flood behaviour.	• Short term, episodic reduction in water quality due to suspended sediments during transportation in waterway. • Reduction in alligator weed infestation through introduction of shade and species competition. • Improved varietal habitat through rehabilitation of riparian corridor. • Improved species diversity. • Positive benefits to aquatic ecology through introduction of shade and associated impacts on temperature.
• Rehabilitation Activity – Type B o Provide "*islands*" of intensive maintenance (weed management) and intensive planting (understorey & groundcover). o Elsewhere maintain generally through slashing/mowing.	• Maps 5, 6, 7 & 8	• Sustainability. • Biological diversity. • Naturally functioning waterway.	• Resistance to mid and upper bank erosion. • Reduction of local sediment supply to stream system. • Reduction in sediment deposition on higher banks as a result of reduced density in weed infestation.	• Localised modification in flow behaviour; impacts of increase in riparian planting density balanced through associated reduction in weed infestation. • Negligible anticipated change in cross-section averaged flow velocities and associated flood behaviour.	• Improved varietal habitat through rehabilitation of riparian corridor. • Improved species diversity. • Understorey and groundcover continuity – offering native plant competition to introduced weed species. • Short term introduced habitat loss, due to weed management. Impacts managed through small work-front maintenance techniques.
• Rehabilitation Activity – Type C o Provide supplementary canopy plantings. o Undertake light maintenance (weed management) and associated light plantings (understorey & groundcover).	• Maps 1, 2 & 3.	• Sustainability. • Biological diversity. • Stability. • Naturally functioning waterway.	• Resistance to mid and upper bank erosion in longer term.	• Localised modification in flow behaviour; impacts of increase in planting density balanced by associated reduction in weed infestation. • Negligible anticipated change in cross-section averaged flow velocities and associated flood behaviour.	• Strengthening of canopy species continuity. • Improved varietal habitat through rehabilitation of riparian corridor. • Improved species diversity.

Table 2.4 Waterway Corridor Responses to Principal Masterplan Activities (cont'd)

PRINCIPAL MASTERPLAN ACTIVITY	LOCATION	WATERWAY "*VISION*" ELEMENT ADDRESSED	GEOMORPHIC RESPONSE TO ACTIVITY	FLUVIAL/HYDRAULIC RESPONSE TO ACTIVITY	ECOLOGIC RESPONSE TO ACTIVITY
• Rehabilitation Activity – Type D o Undertake intensive maintenance (weed management) and associated light planting (understorey & groundcover).	• Maps 3, 4, 5, 6, 7, 8, 9 & 10.	• Sustainability. • Biological diversity. • Stability.	• Depending on location, resistance to bank erosion in longer term. • Reduction of sediment supply to stream system. • Reduction in plant entrapment sediment depositions in higher banks as a result of reduction in density of weed infestation. Sediments entrained in flow, transported further in waterway systems.	• Improved mid and upper overbank flow behaviour due to reduction in weed infestation, with associated reduction in flow resistance. • Impacts balanced through increase in riparian groundcover and understorey planting densities.	• Improved varietal habitat through rehabilitation of riparian corridor. • Improved species diversity. • Reduction in balloon vine and lantana infestation. • Reduction in wandering jew infestation as a result of weed management and species competition.
• Rehabilitation Activity – Type E o Provide supplementary canopy plantings. o Undertake light maintenance (weed management) and associated light plantings (understorey & groundcover).	• Maps 4, 8, 9 & 10.	• Sustainability. • Biological diversity. • Stability. • Naturally functioning waterway.	• Depending on location, resistance to bank erosion in longer term. • Reduction in sediment supply to stream system as a result of stable, well protected banks.	• Localised modification in flow behaviour; impacts of increase in riparian planting densities balanced through associated reduction in weed infestation. • Negligible anticipated change in cross-section averaged flow velocities and associated flood behaviour.	• Strengthening of canopy species continuity. • Improved varietal habitat through rehabilitation of riparian corridor. • Improved species diversity.
• Civil works to rehabilitate scoured stormwater tail-out channel.	• River Ch 7090; left bank (**Map 1**).	• Sustainability. • Stability.	• Reduction in bank erosion; reduction in sedimentation of waterway. • Resistance to bank retreat.	• Dissipation of energy at stormwater inflow. • Negligible impact on stream flow behaviour. • No impact on flood behaviour.	• Reduced sediment load to waterway; improved water quality. • Positive benefits to aquatic floral, fish and benthic communities. • Improved varietal habitat through landscape rehabilitation.
• Maintenance & rehabilitation activity – removal of sediment berm which forms a remnant low flow diversion channel.	• River Ch 7180-7350 (**Maps 1 & 2**)	• Sustainability. • Naturally functioning waterway.	• Resistance to bed erosion in longer term.	• Localised modification in low flow and bankfull stream behaviour. • Reduction in flow velocities for frequent events due to increase in waterway area. • Improved flood behaviour for frequent *(up to bankfull)* flood events; negligible fluvial impacts for rarer flood events *(eg. greater than bankfull)*.	• Improved aquatic habitat through strengthening of in-stream and fringing vegetative structure. • Improved varietal habitat through rehabilitation of riparian corridor. • Improved riparian and fringing species diversity.
• Maintenance activity provision of gravel based causeway for pedestrian/cycle path.	• River Ch 7415; in-channel (**Map 2**).	• Sustainability. • Naturally functioning waterway.	• Resistance to bed and bank erosion. • Reduction of potential sediment source from stream system.	• Negligible fluvial impact.	• Negligible ecological impact.

Table 2.4 Waterway Corridor Responses to Principal Masterplan Activities (cont'd)

PRINCIPAL MASTERPLAN ACTIVITY	LOCATION	WATERWAY "*VISION*" ELEMENT ADDRESSED	GEOMORPHIC RESPONSE TO ACTIVITY	FLUVIAL/HYDRAULIC RESPONSE TO ACTIVITY	ECOLOGIC RESPONSE TO ACTIVITY
• Rehabilitation activity; creation of rock riffle integrated with bank protection works	• River Ch 7975; in-channel (**Map 3**).	• Sustainability. • Stability. • Naturally functioning waterway.	• Resistance to prograding bed and bank erosion, reducing infrastructure failure risk. • Reduction of sediment supply to stream system. • Imitating natural flow regime in limited reach. • Structure shape proposed to centralise low flows, reducing bank failure risk adjacent to bridge protection works.	• Localised modification in flow behaviour; reduction in flow velocities for low *(daily average)* flows through local increase in bed resistance. • Resultant centralised low flow improves flow behaviour through bridge pier protection works. • Structure drowned out by influence in hydraulic control by bridge; no anticipated variation in flood level or risk to property.	• Improved aquatic ecology through water quality enhancement. • Enhanced varietal aquatic habitat. • Structure allows fish migration; no anticipated influence on fish breeding areas.
• Maintenance activity; construction of erosion protection to stormwater outlets.	• Various river chainages; upper left bank (**Maps 4, 5 & 9**)	• Sustainability. • Stability.	• Reduction in sediment supply to stream system. • Resistance to upper bank erosion through maintaining a more stable surface downstream of outlets.	• No anticipated modification in flow behaviour.	• Improved aquatic ecology through water quality enhancement brought about by reduction in suspended sediments.
• Rehabilitation activity; retention of large woody debris.	• River Ch 8330; in-channel (**Map 4**)	• Sustainability. • Biological diversity. • Naturally functioning waterway.	• Possible cause of erosion/bank retreat. • Possible cause of in-stream sediment deposition.	• Possible flow modification due to in-channel debris buildup. • Reduction in flow velocities due to increased bed resistance, and associated flood level increases, up to bankfull flow. At this location, the woody debris would be drowned out at rarer flood events, and would be unlikely to contribute to an increase in flood risk to property.	• Improved aquatic habitat through introduction of elements typical of "pool" environments *(eg vegetation, shade, leaf litter & logs).* • Improved aquatic habitat directly through increased occurrence of "*snags*" in waterway corridor. • Improved faunal recruitment and dispersal – rough/diverse channel cross-sections offer shelter to fish moving upstream in high-flow events.
• Maintenance activity; construction of erosion protection to low level stormwater outlets.	• Various river chainages lower left bank (**Maps 5 & 6**)	• Sustainability. • Stability.	• Reduction in sediment supply to stream systems. • Reduction in toe failure and bed erosion; minimisation of local bed lowering through reduction of plunge - pool effect. • Reduction in outflanking and lower bank erosion during mid-bank flows.	• No anticipated modification in flow behaviour.	• Improved aquatic ecology through water quality enhancement brought about by reduction in suspended sediments. • Net increase in aquatic habitat diversity as smothering from sediment loads is reduced.

Table 2.4 Waterway Corridor Responses to Principal Masterplan Activities (cont'd)

PRINCIPAL MASTERPLAN ACTIVITY	LOCATION	WATERWAY "*VISION*" ELEMENT ADDRESSED	GEOMORPHIC RESPONSE TO ACTIVITY	FLUVIAL/HYDRAULIC RESPONSE TO ACTIVITY	ECOLOGIC RESPONSE TO ACTIVITY
• Maintenance activity; construction of rock bank protection works.	• River Ch 8638-8712; left bank. (**Map 5**)	• Sustainability. • Stability.	• Minimising potential for toe failure and subsequent bank slumping and retreat – reduction in potential for sediment loss to stream system. • Less resistance to flow; potential to induce additional bed scour downstream of structure terminal – banks protected through bedrock and rock matrices in bank through downstream bend.	• Lower flow resistance in bank may induce higher velocity flows at bank full levels. • Cross-section averaged flow velocities at rarer floods *(ie. higher than bankfull)* balanced through proposed dense riparian understorey and groundcover plantings in upper bank.	• Loss of weed infestation in bank reduces habitat for surface dwellers and birds. • Habitat rehabilitated through dense riparian plantings in upper bank. • Improved species diversity.
• Rehabilitation activity; provision of riparian groundcover and understorey plantings on denuded embankment.	• River Ch 8930-8960; right bank (**Map 6**).	• Sustainability. • Biological diversity. • Stability.	• Resistance to upper bank erosion. • Reduction in sediment supply to stream system. • Minimising risk of gabion wall outflanking and possible subsequent failure.	• Negligible impact on local flow behaviour through increased upper bank resistance.	• Improved varietal habitat, through rehabilitation of riparian corridor. • Improved species diversity. • Understorey and groundcover continuity.
• Maintenance activity; possible provision of densely planted terraced timber crib retaining wall.	• River Ch 10220; right bank (**Map 8**).	• Sustainability. • Biological diversity. • Stability.	• Resistance to mid and lower bank erosion. • Minimising potential for mid-bank failure and bank retreat.	• Short term lower flow resistance may induce higher velocity flows at bankfull levels.	• Improved varietal habitat through rehabilitation of riparian corridor. • Improved species diversity. • Understorey and groundcover vegetative continuity.

Table 2.5 Selected Cross-Sections

Cross Section (approximate River Chainage)	Location	Description in Reach Location	Proposed Modification in Vegetative Structure	Compound Resistance Coefficient Estimate		
				Left Bank Existing *(Proposed)*[(1)]	In-Channel Existing *(Proposed)*	Right Bank Existing *(Proposed)*
CH 7211 (Fig 2.3)	Between McCoy Park Basin & Old Windsor Road	Example of broad floodplain with little vegetative coverage	Left Bank: Reduction of weed infestation; bank-top shade planting	0.045 *(0.035-0.06)*		
			In-channel: Reduction of alligator weed infestation; reduction in sediment deposition zone *(see detail in* Figure 2.2)		0.035 *(0.03-0.035)*	
			Right Bank: Strengthening in lower bank understorey; provision of upper bank '*islands*' of planting			0.04 *(0.035-0.06)*
CH 8424 (Fig 2.4)	Between Old Windsor Road and Oakes Road	Example of incised channel, with some mown grass, open space and medium understorey and canopy communities	Left Bank: Restoration of canopy communities; strengthening of understorey; reduction in weed infestation	0.075 *(0.035-0.06)*		
			In-channel: Reduction in low bank, fringing weed infestation		0.035 *(0.035)*	
			Right Bank: Strengthening of low and mid bank understorey/groundcovers			0.055 *(0.035-0.06)*

Table 2.5 Selected Cross-Sections (cont'd)

Cross Section (approximate River Chainage)	Location	Description in Reach Location	Proposed Modification in Vegetative Structure	Compound Resistance Coefficient Estimate		
CH 9049 (Fig 2.5)	Downstream of Oakes Road	Example of deeply incised, steep sided channel, with dense weed infestations covering the banks; lower quality understorey and canopy in Third Settlement Reserve *(left bank)* with high quality '*islands*' of rehabilitated understorey and canopy in the upper right bank area.	Left Bank: Reduction in lower bank weed infestation; provision of bank-top shade planting.	0.035 *(0.035-0.06)*		
			In-channel: Reduction in fringing weed infestation.		0.035 *(0.035)*	
			Right Bank: Reduction in lower bank weed infestation; strengthening of existing canopy continuity			0.04 *(0.035-0.06)*

Note (1) after Chow *(1959)* & Rutherfurd et al *(2000)*

2.1.4 Costings and Priority for Principal Masterplan Activities

Cost Estimation Methodology

One-off capital costs for "*engineered*" maintenance and rehabilitation activities have been estimated.

For each activity, conceptual designs have been prepared and construction methods and preliminary quantities assessed. Appropriate costings have been made through reference to the relevant literature *(eg. Rawlinsons 2002)* and by reference to tendered prices for recent similar project work.

Costs for vegetative maintenance and rehabilitation activities have been estimated from daily cost rates and associated consumables attributed to recent similar project work, as shown in the footnotes to **Table 2.8**.

Principal activities are categorised against current vegetative structure and recommended activity type *(Types A-E inclusive, as described in* **Table 2.4** *above).* Field work durations are then attributed to each category/activity type, as shown in **Table 2.6**.

Table 2.6 Vegetative Maintenance and Rehabilitation Activity Durations for Cost Estimation

Category	Current Vegetation Structure	Activity Period	Recurrence (times per year)
Major	- poor structure - substantially altered bushland	4 weeks *(min)*	2 x
Intermediate	- sound structure - substantially altered bushland experiencing rehabilitation	2 weeks *(min)*	2 x
Follow-up maintenance	- sound structure - species diversity and corridor continuity - rehabilitated bushland	1 week *(min)*	1 x

Priority Evaluation Methodology

The priority evaluation for each of the principal Masterplan activities reflects the priority description in the database for management activities proposed for Council's Waterways.

The need *(desirability)* for each principal activity and the possibility *(likelihood)* of each principal activity have been assessed utilising a value judgement against the criteria described in **Table 2.7**.

Table 2.7 Value Judgement Criteria

Criteria	Value Judgement	Description
COMMUNITY BENEFIT	High	• Significant participation in project by community, engaging in all aspects of project • Significant improvements to access to waterway corridor for whole community
	Medium	• Moderate participation in project by community, through a process of general consultation • Moderate improvements to access to waterway corridor
	Low	• Involvement in partnerships with special interest stakeholders only, limited general consultation • Little improvement in access to waterway corridor
RISK MANAGEMENT	High	Remove or reduce a significant risk
	Medium	Remove or reduce a moderate risk
	Low	Reduce a moderate risk
ENVIRONMENTAL BENEFIT	High	• Significant species and/or habitat improvement or rehabilitation • Significant contribution to erosion and sedimentary processes
	Medium	• Moderate species and/or habitat improvement or rehabilitation • Moderate contribution to erosion and sedimentary processes
	Low	• Little species and/or habitat improvement or rehabilitation • Little contribution to erosion and sedimentary processes
EFFECTIVENESS • Number of Waterway "*Vision*" Elements Addressed	High	4
	Medium	2-3
	Low	0-1
COST	High	< $20,000
	Medium	Between $20,000 & $50,000
	Low	> $50,000

The priority rankings for activity proposed for implementation in the Masterplan are shown in **Table 2.8**. The rankings have been undertaken to assist Council and its possible stakeholder partners to assess timing and importance for an implementation program.

In preparing the priority rankings, the following issues have been taken into account.

- An objective assessment of the Value Judgement Criteria (**Table 2.7**);
- The importance of consolidating, and improving on, existing maintenance and rehabilitation programs and activities;
- Maximising early benefits to stream form and vegetative structure;
- Improved access to the waterway corridor for recreational and educative purposes; and
- Infrastructure protection *(asset management)*, floodplain risk management and streambank stability.

2.2 Costings and Priority Evaluation

Based on the criteria described above, cost estimates and priority evaluation for principal Masterplan activities are presented in **Table 2.8**.

Table 2.8 Costings and Priority Evaluation

Principal Masterplan Activity	Location	Vegetative Activity Category	Capital Cost Estimate *(One-off or annual)*	Annual Maintenance Estimate *(periodic only)*	Criteria					Priority Rank
					Community Benefit	Risk Management	Environmental Benefit	Effectiveness	Cost	
Rehabilitation Activity – Type A	• Maps 1 & 2 River Ch 7130-7520	Major	$50,000[(1)]	$6,250[(2)]	High	Low	High	High	Medium	1
	• Map 3 River Ch 7570-7680	Major	$50,000	$6,250	High	Low	High	High	Medium	2
	• Maps 4 & 5 Left bank generally to River Ch 8510	Intermediate	$25,000[(3)]	$6,250	Medium	Low	Medium	High	Medium	27
	• Map 6 River Ch 8925-9135	Intermediate	$25,000	$6,250	Medium	Low	Medium	High	Medium	28
	• Maps 9 & 10 River Ch 10350-10500	Major	$50,000	$6,250	Medium	Low	High	High	Medium	11
Rehabilitation Activity – Type B	• Maps 5 & 6 River Ch 8400-8900	Intermediate	$25,000	$6,250	High	Low	High	Medium	Medium	22
	• Maps 6 & 7 River Ch 8950-9255	Intermediate	$25,000	$6,250	High	Low	High	Medium	Medium	23
	• Map 7 River Ch 9400-9600 *(left bank)*	Intermediate	$25,000	$6,250	Medium	Low	High	Medium	Medium	24
	• Maps 7 & 8 River Ch 9450—9770 *(right bank)*	Intermediate	$25,000	$6,250	High	Low	High	Medium	Medium	25
	• Map 8 River Ch 9850-10020 *(left bank)*	Intermediate	$25,000	$6,250	Medium	Low	High	Medium	Medium	26
Rehabilitation Activity – Type C	• Map 1 *(Right bank generally)*	Intermediate	$25,000	$6,250	Medium	Low	High	High	Medium	6
	• Maps 2 & 3 River Ch 7210-7625	Intermediate	$25,000	$6,250	Medium	Low	High	High	Medium	5
Rehabilitation Activity – Type D	• Map 3 River Ch 7585-7685 *(right bank)*	Intermediate	$25,000	$6,250	High	Low	Medium	Medium	Medium	33
	• Map 3 *(Generally in wooded area on left bank)*	Major	$50,000	$6,250	High	Low	Medium	Medium	Medium	34
	• Map 4 *(Generally within wooded area on left bank)*	Intermediate	$25,000	$6,250	Medium	Low	Medium	Medium	Medium	35
	• Map 5 River Ch 8510-8635	Major	$50,000	$6,250	Medium	Low	Medium	Medium	Medium	36

Table 2.8 Costings and Priority Evaluation (cont'd)

Principal Masterplan Activity	Location	Vegetative Activity Category	Capital Cost Estimate *(One-off or annual)*	Annual Maintenance Estimate *(periodic only)*	Criteria					Priority Rank
	• Maps 6 & 7 River Ch 9135-9400	Major	$50,000	$6,250	Medium	Low	Medium	Medium	Medium	37
	• Maps 7 & 8 River Ch 9600-9850	Major	$50,000	$6,250	Medium	Low	Medium	Medium	Medium	38
	• Map 8 River Ch 10020-10150	Major	$50,000	$6,250	Medium	Low	Medium	Medium	Medium	39
	• Map 9 River Ch 10230-10440	Follow-up		$12,500(4)	High	Low	High	Medium	High	4
	• Maps 9 & 10 *(Generally along left bank)*	Intermediate	$25,000	$6,250	Medium	Low	Medium	Medium	Medium	32
Rehabilitation Activity – Type E	• Map 4 River Ch 8100-8400	Intermediate	$25,000	$6,250	High	Low	Medium	Medium	Medium	30
	• Maps 8 & 9 *(Generally within wooded area on right bank)*	Major	$50,000	$6,250	Medium	Low	Medium	Medium	Medium	21
	• Map 10 *(Generally along right bank)*	Intermediate	$25,000	$6,250	Medium	Low	High	Medium	Medium	31
Civil works to rehabilitate scoured stormwater tail-out channel.	• Map 1; River Ch 7090; left bank	N/A	$93,500(5)	$1,200(6)	Medium	High	Medium	Medium	Low	20
Provision of gravel based causeway for pedestrian/cycle path	• Map 2; River Ch 7415; in-channel	N/A	$40,500	$1,200	Low	Low	Medium	Medium	Medium	40
Removal of sediment berm which forms a remnant low-flow diversion channel	• Maps 1 & 2 River Ch 7180-7350; in-channel	N/A	$126,000	$1,200	Low	Low	Medium	Medium	Low	29
Creation of rock riffle integrated with bank protection works.	• Map 3; River Ch 7975; in-channel	N/A	$57,500	$1,200	Medium	High	High	Medium	Low	7
Construction of erosion protection to stormwater outlets *(upper levels)*.	• Map 4; River Ch 8210; Goliath Ave, east of Gideon St	N/A	$9,500	$600	Medium	Low	High	Medium	High	15
	• Map 4; River Ch 8300; Goliath Ave, midway between Gideon St and Reuben St	N/A	$9,500	$600	Medium	Low	High	Medium	High	14
	• Map 4; River Ch 8400; Goliath Ave, opposite Reuben St	N/A	$9,500	$600	Medium	Low	High	Medium	High	13

Table 2.8 Costings and Priority Evaluation (cont'd)

Principal Masterplan Activity	Location	Vegetative Activity Category	Capital Cost Estimate *(One-off or annual)*	Annual Maintenance Estimate *(periodic only)*	Criteria					Priority Rank
Construction of erosion protection to stormwater outlets *(upper levels).*	• Map 5; River Ch 8495; Goliath Ave, opposite pathway east of Reuben St	N/A	$9,500	$600	Medium	Low	High	Medium	High	12
	• Map 9; River Ch 10255; Edison Pde, opposite Stephenson St	N/A	$9,500	$600	Medium	Low	High	Medium	High	10
	• Map 9; River Ch 10385; Edison Pde, west of Kelvin Grove	N/A	$9,500	$600	Medium	Low	High	Medium	High	9
	• Map 9; River Ch 10510;Edison Pde, opposite Reilleys Rd	N/A	$9,500	$600	Medium	Low	High	Medium	High	8
Retention of large woody debris	• Map 4; River Ch 8330; in-channel	N/A	Nil	$1,200	Low	Low	Medium	Medium	High	16
Construction of erosion protection to low level stormwater outlets	• Map 5; Ch 8620; Goliath Ave, opposite Esther St	N/A	$36,500	$600	Medium	Low	High	Medium	Medium	18
	• Map 6; Ch 9100; Third Settlement Reserve, opposite Volta St	N/A	$36,500	$600	Medium	Low	High	Medium	Medium	19
Construction of rock bank protection works	• Map 5; River Ch 8638-8712; left bank	N/A	$256,500	$2,400(7)	Medium	High	Medium	Medium	Low	17
Provision of riparian groundcover and understorey plantings on denuded embankment	• Map 6; River Ch 8930-8960; right bank	N/A	$17,500	$600	High	Low	High	Medium	High	3

(1) Based on Greening Australia team – well trained & equipped (5 people, 7 hours per day, $25/hr, 20% on-costs, add $200 consumables). 20 days @ $ 1,250/day; 2 x per year.
(2) 5 days@ $1,250/day; annually
(3) 10 days @ $1,250/day; 2 x per year.
(4) 5 days @ $1,250/day; 2 x per year.
(5) Civil cost estimates include a 20% contingency
(6) 1 day, 2 labourers @ $140/day (each). Add 100% consumables; say $600; 2 x per year.
(7) 2 days, 2 labourers @ $140/day (each). Add 100% consumables; say $1,200; 2 x per year.

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4 ACKNOWLEDGEMENTS

There have been many people and organisations that have been consulted during the development of the Waterways Maintenance and Rehabilitation Masterplans for Parramatta's waterways. The following key people and organisations were involved in the production and review of the specific Masterplans.

4.1 Toongabbie Creek Maintenance and Rehabilitation Masterplan

The Toongabbie Creek Maintenance and Rehabilitation Masterplan was part funded by the Upper Parramatta River Catchment Trust.

Consultant: Report compiled and developed by Patterson Britton & Partners in collaboration with EDAW (Aust).

Patterson Britton & Partners Pty Ltd

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Waterways Maintenance and Rehabilitation Masterplan

APPENDIX A

Parramatta City Council
August 2002
V2.0

Waterways Maintenance and Rehabilitation Masterplan

APPENDIX B

Parramatta City Council
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Appendix B

B.1 ACCOMPANYING NOTES

B.1.1. Weed Removal Techniques

These techniques are to be used in small areas utilising the "*Bradley"* method.

Work to be in small intense areas, from least infected to most. Access to site to be gained from a mown park, existing walking track or existing areas subject to maintenance/rehabilitation.

B.1.2 Herbs and Small Woody Weeds

Wandering Jew:

- Primary weeding; physical removal by hand or roll or rake. Any stem parts left in the soil will regrow.
- Secondary *(Maintenance)* weeding; physical removal of plants growing from fragments of stem.

Small Woody Weeds:

- Primary weeding; remove roots by pulling horizontally in the direction of tap root *(carefully dispose of material)*.

B.1.3 Larger Woody Weeds

Lantana:

- Primary weeding; larger plants should be cut as close to the ground as possible and painted ASAP. Roots may be left in place. Whole plants may be left in piles to breakdown.
- Secondary *(Maintenance)* weeding; return periodically to remove new seedlings.

B.1.4 Vines

Balloon Vine and Madiera Vine:

- Primary weeding; scrape stem to reach layer below the bark/outer layer, or cut the stem as close to the ground as possible. Paint ASAP. Roots may be left in place. Vines can be left hanging in trees and will eventually break down naturally.
- Secondary *(Maintenance)* weeding; return periodically to remove new seedlings.

B.1.5 Islands and Supplementary Planting

"*Islands*" of maintenance and supplementary planting should be in the order of 15 m^2 - 30 m^2 *(2 – 3 m radius)* and 10 to 50 metres apart in the first instance. Subsequent planting can be in the form of new islands or enlarging existing islands.

In dense weed areas islands should be enlarged to concentrate maintenance efforts.

Species selection should reflect the structure of remnant forest distribution through the Study Area.

Access is generally to be gained from mown/slashed areas and walking tracks. Work should be restricted to small areas, allocating the maintenance of new and existing riparian plantings as a high priority.

B.1.6 Bank-Top Plantings

Typically the bank-top planting should be 1-5 metres wide in any year, and not more than 2 metres wide in dense weed areas.

For example, plantings could straddle the boundary of currently slashed/mown areas *(1 metre in the weeds at banktop and further down the batter, with 1-2 metres upslope)*.

This could be maintained and widened, primarily towards the low-flow channel, each year.

B.2 PLANTING SPECIES LIST

Stratum and Scientific Name	Common Name	Comments
Canopy		Plant on or near bank top
Eucalyptus amplifolia	Cabbage gum	
Eucalyptus tereticornis	forest red gum	
angophora floribunda	rough barked apple	
corymbia citridora	spotted gum	was C. maculata
eucalyptus moluccana	gum topped box	
eucalyptus punctata	greygum	
Understorey		Plan from banktop towards low flow channel
acacia parramattensis parramattensis	a wattle	
casuarina glauca	swamp oak	
melaleuca linariifolia	flaxleaf paperbark	
melaleuca decora	a paperbark/tea tree	
angophora subvrelutina	broad leaved apple	
callistemon salignus	willow bottlebrush	
backhousia myrtifolia	grey myrtle	
rapanea howittiana		
notelaea longifolia	a native olive	
bursaria spinosa	blackthorn	
leptospermum polygalifolium	wild may	
atriplex spp.	saltbush	

B.2 PLANTING SPECIES LIST (cont'd)

Stratum and Scientific Name	Common Name	Comments
Groundcover		Plant at the base of canopy and understorey
oplismenus aemula	a grass	
microlaena stipuloides stipuloides	a grass	
entolasia marginata	a grass	
entolasia stricta	barbed wire grass	
echinopogon ovatus	a grass	
solanum prinophyllum	a herb	
pratia purpurascens	lobelia/white root	
commelina cyanea	a herb	
lamandra multiflora multilora	manyheaded matrush	
lomandra liongifolia	spiny headed matrush	
dianela revoluta	blue flat lily	
doodia caudata	Small rasp fern	
glycine microphylla	a glycine	
Instream Vegetation		
Open water		To be used in re-naturalisation of channel and wetlands
nymphoides geminata	a water lily	
ludwigia peploides montevidensis	water primrose	
ottelia ovalifolia		
alisma plantago aquatica	an aquatic herb	
triglochin procerum	water ribbons	
myriophyllum spp.		
azolla filiculoides rubra	a floating fern	
potomogeton tricarinatus	floating pondweed	
High flow edge to 500 mm deep		
phragmites australis	common reed	To be used in re-naturalisation of channel and wetlands or when banktop/shading
typha orientalis	cumbungee	
cyperus sanguinolentus	rice sedges	
juncus spp.	rushes	
paspalum distichum	water couch	
panicum obseptum	white water panic	
persicaria spp.		
phylidrum lanuginosum	forgsmouth	
pratia purpuracens	lobelia/white root	
centella asiatica	pennywort	
eleocharis cylyndrostachys	a spkerush	
haloragis heterophylly	rough raspweed	
centipeda minima	spreading sneezeweed	