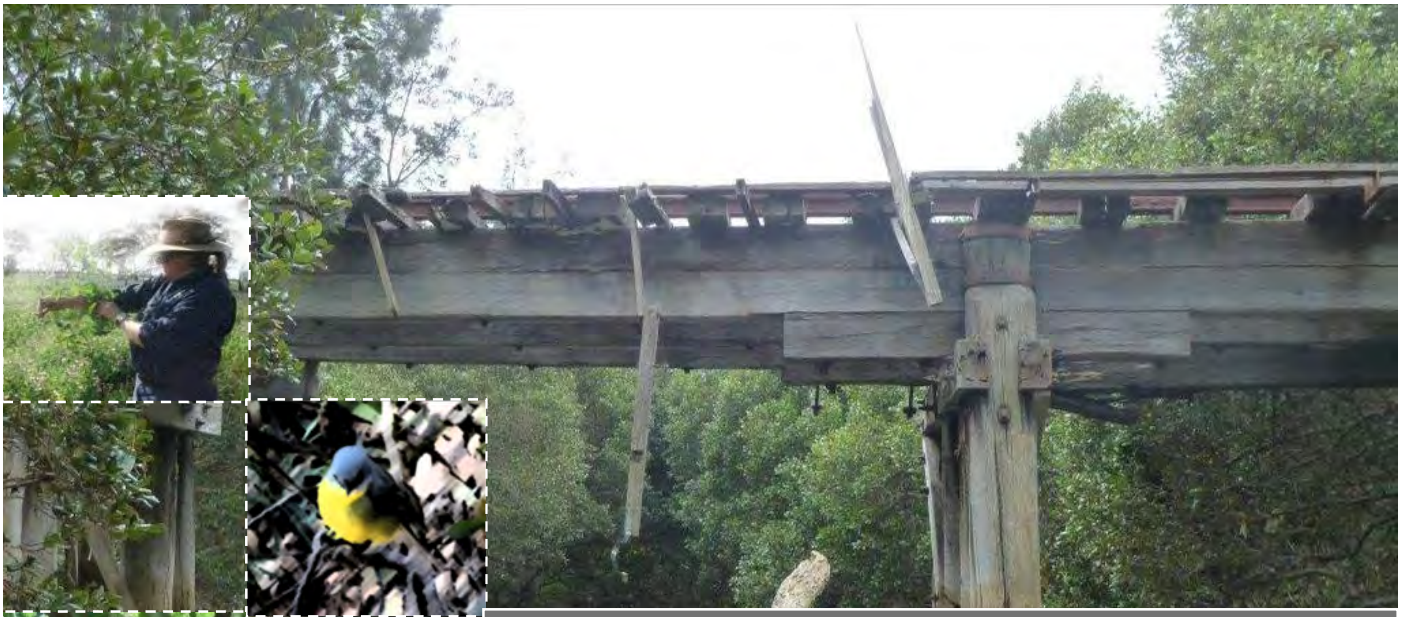
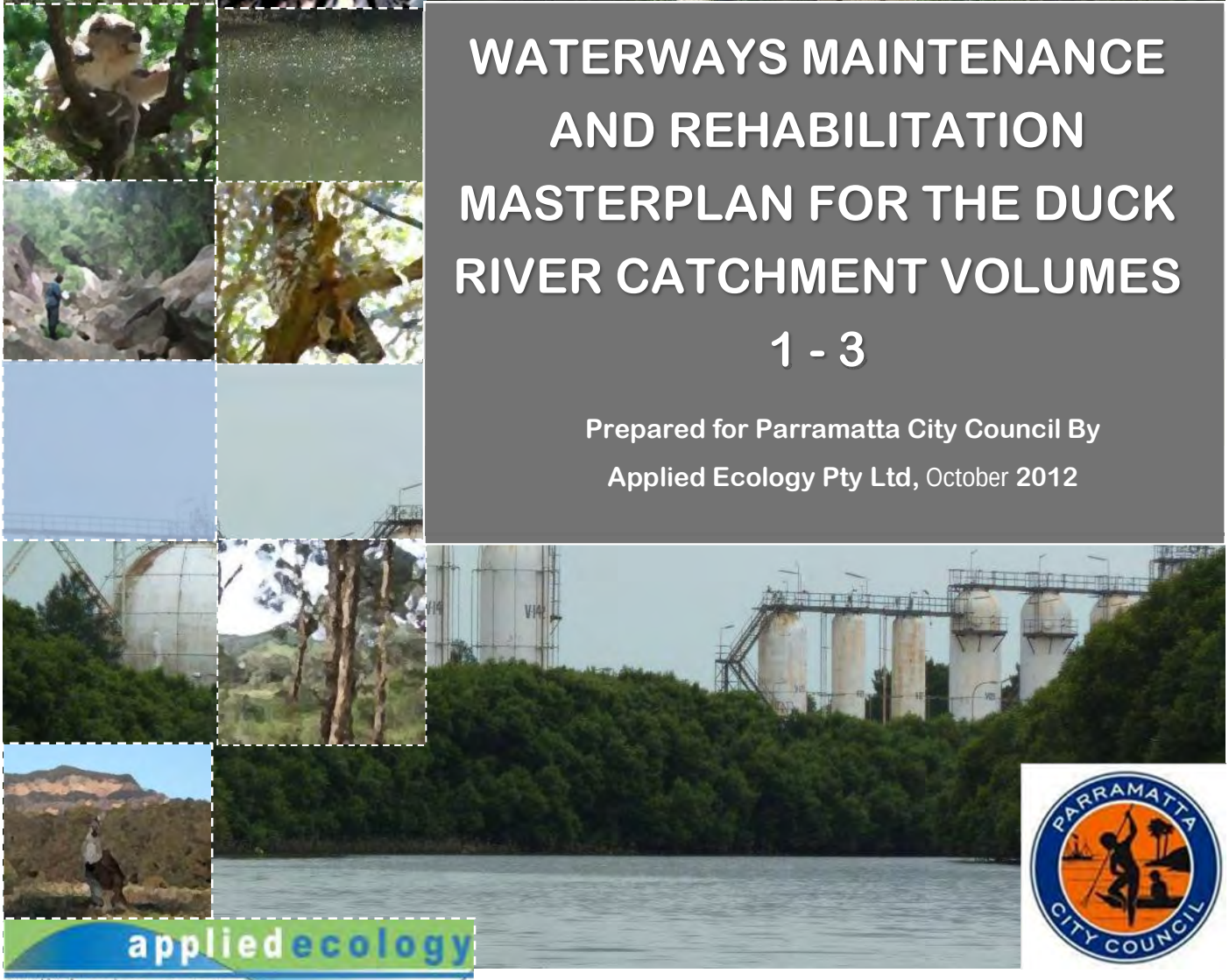


WATERWAYS MAINTENANCE AND REHABILITATION MASTERPLAN FOR THE DUCK RIVER CATCHMENT VOLUMES 1 - 3

Prepared for Parramatta City Council By

Applied Ecology Pty Ltd, October **2012**



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PARRAMATTA CITY COUNCIL

THE MASTERPLAN FOR THE DUCK RIVER CATCHMENT

The Masterplan for the Duck River Catchment was prepared in 2012 for Parramatta City Council, and was prepared in conjunction with the Upper Duck River Wetlands and Riparian Corridor Plan of Management, a joint initiative by Parramatta and Auburn Councils.

The Masterplan applies to all of the streams in the Duck River Catchment that fall within the boundaries of Parramatta LGA, including Duck River, Duck Creek, Little Duck Creek, A'Becketts Creek, Smalls Creek, and several unnamed tributaries.

The Masterplan is organised in three volumes:

- Volume One provides a review of existing knowledge, including the legislative framework, previous plans, findings of flora and fauna surveys, and indigenous and non-indigenous cultural heritage assessments.
- Volume Two provides a set of detailed maps that show the nature, location and extent of the catchment's topography, land tenure, stream processes and channel attributes, stormwater pipe networks and treatment devices, vegetation communities and restoration activities, indigenous and non-indigenous cultural heritage, and contaminated lands and associated issues. These maps were also provided to council as GIS layers.
- Volume Three comprises the actual plan, and provides plan objectives, reach apportionment for streams, rehabilitation works and activities, expected waterways corridor responses to works, detailed works plans for each of 28 reaches, with indicative initial and ongoing costs, recommendations for riparian buffers and development setbacks, and timeframe for review of the Masterplan. The appendices include detailed lists of native flora species for revegetation in each of the Endangered Ecological Communities present, description of works activities and guidelines for best practice techniques for these works.

To assist with navigation of the Masterplan, an overview of the contents of each volume is provided below.

VOLUME ONE: PRELIMINARY STUDY OF DUCK RIVER CATCHMENT

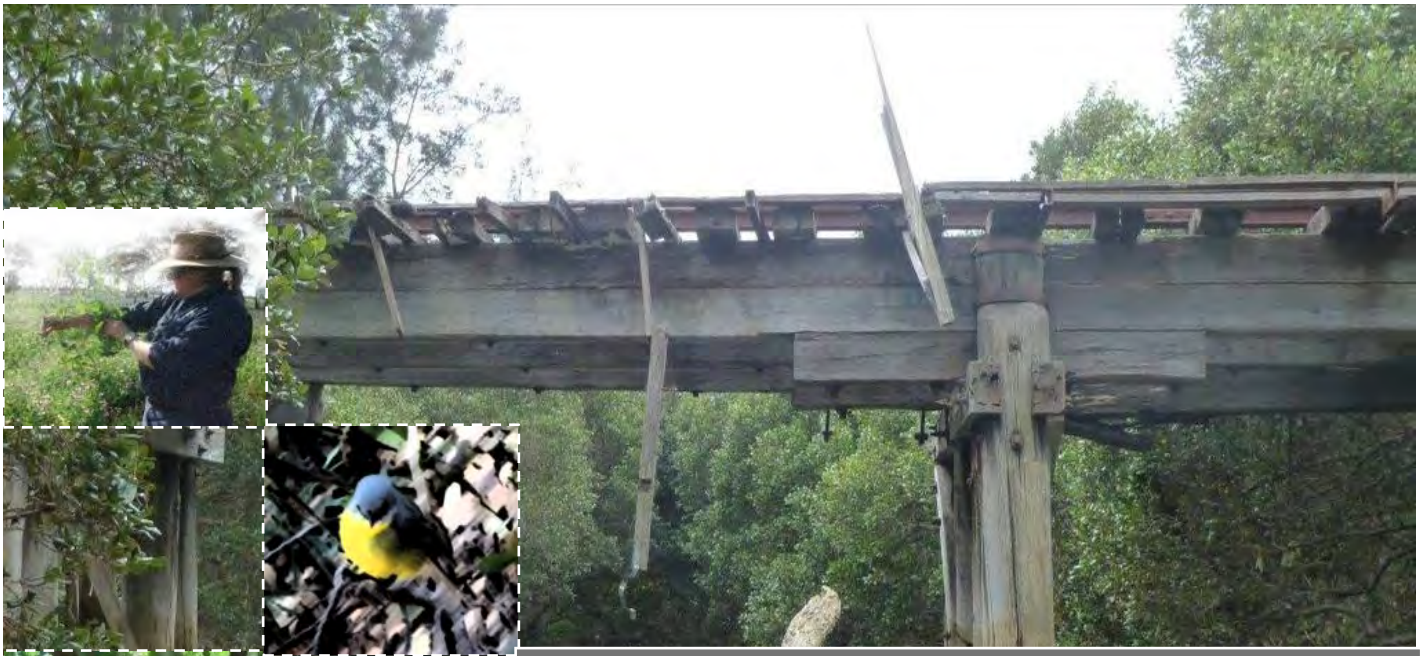
CONTENTS

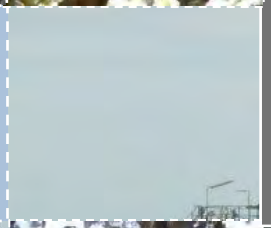
VOLUME TWO: DETAILED MAPPING OF THE DUCK RIVER CATCHMENT

CONTENTS

VOLUME THREE: A MASTERPLAN FOR DUCK RIVER CATCHMENT

CONTENTS





PRELIMINARY ASSESSMENT OF THE DUCK RIVER CATCHMENT

Prepared for Parramatta City Council

By Applied Ecology Pty Ltd

19/10/2012

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DOCUMENT VERIFICATION

Project Title	**DUCK RIVER CATCHMENT WATERWAYS MAINTENANCE AND REHABILITATION MASTER PLAN**
Document Title	**PRELIMINARY ASSESSMENT OF THE DUCK RIVER CATCHMENT WATERWAYS**
Client	**Parramatta City Council**
Client contact	**Pino Todarello**

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ACKNOWLEDGMENTS

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Pino Todarello Parramatta City Council
Anthony Collins Parramatta City Council

1 Contents

1.1 List of Tables

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2 PURPOSE OF A MASTERPLAN

Parramatta City Council requires Maintenance and Rehabilitation Masterplans for waterways within its jurisdiction. The Masterplan will identify:

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

Actions that are recommended in the Masterplan include estimated budgets, areas of responsibility, priority and type of action. Types of action may include:

- Capital works
- Education
- Research
- Strategic Management
- Maintenance

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

2.1 THE NEED FOR THE DUCK RIVER WATERWAYS MASTER PLAN

In order to develop a consistent and agreed maintenance and regeneration program for the Duck River Catchment, a 'Waterways Maintenance and Rehabilitation Master Plan' is required. The Master Plan will be the primary guiding document in the management of the Duck River catchment and will provide a framework and foundation for the necessary collaboration between the relevant state and local government authorities for the associated maintenance and rehabilitation planning and works.

The Master Plan considers the whole of the Duck River catchment in the development of actions and recommendations. These actions and recommendations are primarily for Community Lands within Parramatta LGA that border Duck River and its tributaries. In some cases, specific recommendations may be made with respect to other lands.

This report provides a review of all relevant issues associated with the Duck River Catchment, and seeks to inform the development of the Waterways Maintenance and Rehabilitation Master Plan for the Duck River Catchment.

2.2 CATCHMENT OVERVIEW

The Duck River catchment covers an area of 4056 hectares. Duck River passes through three local government areas, with the upstream section in Bankstown LGA. The river then forms the boundary between Parramatta and Auburn LGAs until it discharges to Parramatta River at Silverwater. Duck River is tidal from its mouth at Parramatta River to the Clyde Weir near the Main Western Railway Line at Granville, and freshwater above the weir. It has several major tributaries, including Duck

Creek, Little Duck Creek, and A'Becketts Creek. Landuse in the Parramatta LGA section of the catchment is predominantly residential, with major areas of industrial and commercial development, and a smaller proportion of open space, which includes sportsgrounds, parks, areas of General Community Use, areas of Cultural Significance and natural areas.

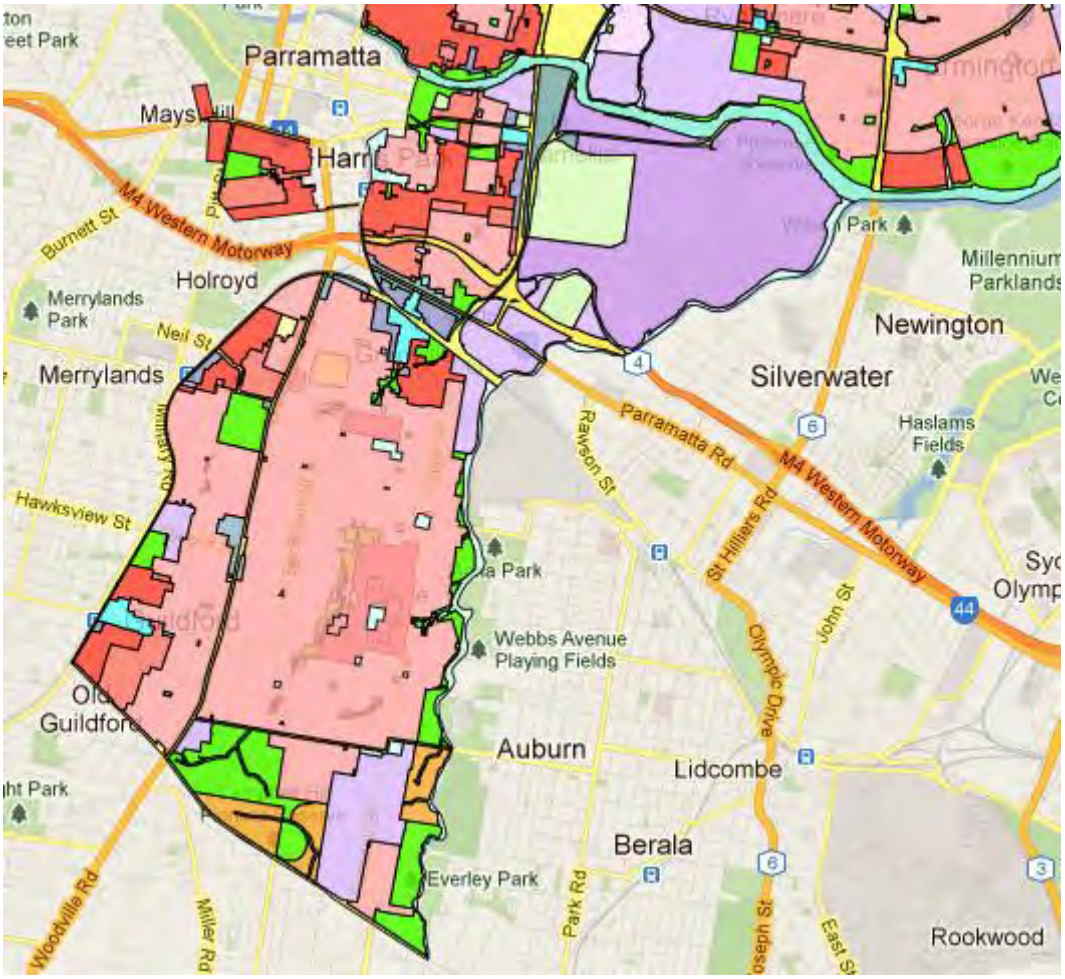

Figure 1. Land tenure in the Duck River catchment section of Parramatta LGA

The Duck Creek subcatchment is approximately 790 hectares and is mainly in Parramatta LGA, with a small upstream section in Holroyd LGA. The main channel of Duck Creek is largely a concrete or brick lined open channel. Little Duck Creek is a major tributary of Duck Creek, and has large sections of concrete lined channel. West of the railway line another stretch of concrete lined channel known as Guildford Rd Branch drains land in Holroyd LGA before being piped to Duck Creek.

A'Becketts Creek subcatchment is approximately 690 hectares, with about half in Parramatta LGA and half in Holroyd LGA. It joins Duck Creek about 1km above the confluence with Duck River. The lower reaches of A'Becketts Creek are tidally affected, and much of the channel has been concrete lined.

2.3 WHAT IS COMMUNITY LAND?

The Local Government Act 1993, herein referred to as the Act, requires Council to take and maintain an inventory of all land owned by Council. This land was then to be classified as either:

- Community Land, or
- Operational Land

The 1999 Regulation (as amended in 2005) has provided Council's with guidelines to ensure all community land is appropriately categorised and managed in accordance with identified management objectives, described in the Act as core objectives.

Community land must now be categorised as one, or more, of the following:

a) Sportsground
b) Park
c) General Community Use
d) Area of Cultural Significance
e) Natural Area

Natural Areas must be further sub-categorised as:

1. Foreshore
2. Bushland
3. Wetland
4. Escarpment
5. Watercourse

2.4 LEGISLATIVE AND POLICY FRAMEWORK

A summary of the relevant state and federal legislation and their applications to management and restoration of wetland ecosystems is provided in Appendix One (Table A1). Any actions that are undertaken that are likely to cause a significant impact on a matter of National Environmental Significance (including threatened species and ecological communities and migratory species) will require a referral to the Federal Minister for consideration.

Under the terms of the NSW TSC Act, Local Government must assess the impacts of any proposed development or activity which might adversely impact on an Endangered Ecological Community, threatened species or populations, including restoration works associated with streambanks and bushland rehabilitation. Where impacts are likely to occur, it must also identify strategies to minimise such impacts. Where a conflict arises, the development proposal must be referred to the NSW Office of Environment & Heritage (OEH) for resolution.

For many communities and species listed under the TSC Act, Threatened Species Recovery Plans have been prepared, while others are addressed more generally in the Priorities Action Statement (PAS). The PAS identifies 36 broad strategies to help threatened plants and animals recover, and establishes relative priorities to implement these strategies. Each of these strategies has more specific priority actions within them, which cover things like:

- surveys to clarify the distribution of a species
- weed and pest management programs
- guidelines for threatened species issues in development assessments
- research into factors influencing the survival of threatened species
- community education programs to raise awareness of a species or threat in a particular area

The PAS also establishes performance indicators to report achievements in implementing recovery and threat abatement strategies and their effectiveness and sets out clear timetables for recovery and threat abatement planning and achievement. A variety of strategies outlined in the PAS can be used to manage a threatening process. One of these strategies is the preparation of a detailed threat abatement plan (TAP) which presents a strategic framework for a targeted threat abatement program. Threat abatement plans have been finalised for a number of key threatening processes, including the following recorded in the Upper Duck River Wetlands:

- Predation by *Gambusia holbrooki* (Plague Minnow)
- Predation by the Red Fox (*Vulpes vulpes*)
- Infestation by Lantana, managed through the national Plan to Protect Environmental Assets from Lantana

2.5 REVIEW OF LITERATURE: EXISTING PLANS

Numerous plans of management have been prepared for the Duck River Catchment in the last 15 years. These cover a range of aspects, from stormwater and flood mitigation to biodiversity management, and have been developed by the three City Councils that manage the main channel of Duck River.

2.5.1 Duck River Management Plan (EDAW, 1996)

The Duck River Management Plan was prepared for the freshwater reach of Duck River. The aim of this plan was to provide a strategy for the restoration of Duck River as a functioning, diverse river system maximising habitat, recreation and aesthetic opportunities. The plan described issues associated with the river, providing a management philosophy for the river and presenting strategies for implementation of the plan's recommendations.

The Duck River MP states a vision for Duck River's management as "to continually work towards improving the ecological values of the Duck River corridor while enhancing the recreational and educational opportunities and ensuring that landuses within the catchment are developed and managed in line with the principles of Ecologically Sustainable Development." The recommendations covered areas including:

- Vegetation (conservation, restoration and ongoing management)
- Wildlife (control of feral animal, wetlands construction and habitat enhancement)
- Water resources (water quality, WQ control measures, sewer overflows, flooding, flow retardation techniques, stormwater detention techniques, runoff quantity and quality, stream erosion and sedimentation, and irrigation)

Sixteen years later, this MP needs to be reviewed and updated, forming the basis for the current project.

2.5.2 Lower Duck River Foreshores Improvement Plan (EDAW/DUAP, 1998)

The Lower Duck River Foreshores Improvement Plan formed part of the Parramatta River Foreshores Improvement Program, a state government funded initiative. It focused on the lower Duck River, below Clyde Weir to the confluence with Parramatta River, as well as Duck Creek and A'Becketts Creek below the M4 Freeway, and included lands in Parramatta and Auburn LGAs. Following an

extensive consultation process, they developed the following vision statement for the lower Duck River:

"There are five elements of the river that provide the inherent means for its improvement and new appreciation. These are the foundation of a new vision for the river, one that can be realised in the short term but will ensure its value and sustainability for the century ahead. The Duck River Foreshores Improvement Program will:

- Build on the rich Aboriginal and European history of the river system
- Rejuvenate the river through careful stewardship as a dynamic and healthy natural system
- Make the river a place for quiet personal recreation in a varied and interesting setting, encouraging exploration and creating opportunities for relaxation and privacy
- Develop and manage the river as a focus for community life, special events, festivals and tourism
- Establish the river as an expression of the identity of the cities of Sydney and Parramatta, reviving its role as an attractive and useable corridor linking pubic open spaces between the cities"

In many respects, this vision is valid today, and could underpin the current Masterplan.

2.5.3 Duck River Stormwater Management Plan (SKM, 1999)

The Duck River Stormwater Management Plan was prepared for Parramatta, Auburn, Bankstown and Holroyd City Councils in July, 1999. The primary goal of this plan is to: "facilitate the coordinated management of stormwater within the Duck River catchment, to improve the health and quality of the catchment waterways". It makes the following general statements about the catchment condition in 1999:

- Significant erosion and sedimentation in the freshwater reach of Duck River
- A large proportion of the open channel waterways have been replaced with concrete lined channels, including Duck Creek, Little Duck Creek, and A'Becketts Creek
- Poor water quality in Duck River, with microbiological and nutrient levels exceeding the recommended levels for primary contact recreational activities such as swimming and boating. In the freshwater reaches, algal blooms are frequent. During wet weather pollutant concentrations are significantly increased. No water quality data was available for any of the tributary creeks
- Sewer overflows in Duck River contribute significantly to pollutant loads into the river, especially during large storm events
- From sediment sampling the main pollutants tend to be catchment-wide, and are introduced in stormwater runoff from roads, roofs and open space areas
- Mangroves, saltmarshes and mudflats are common in the estuarine reaches, and provide important bird habitat for migratory waders. Little documented information existed on the aquatic habitat within the catchment

Many of these issues are still relevant for the catchment today.

2.5.4 Auburn Council Plan of Management for Duck River Foreshore (2001)

The Plan of Management for Duck River Foreshore was prepared for Auburn Council in 2000/1. It applies primarily to community land along Duck River in Auburn LGA, thus it covers land that is predominantly council's open space areas, but includes Crown Land under the care and control of Council, and some land that is privately owned or owned by other public authorities. This range of land tenure as the subject of the plan is similar to that recommended for the current project on behalf of Parramatta Council.

Management objectives are directed towards conservation of biodiversity and maintenance of ecosystem functions within the Duck River environment. A series of management actions thus aimed to protect the aesthetic, heritage, recreational, educational and scientific values of the Duck River and Foreshore environment. Key activities are directed towards restoration of degraded bushland, reduce high edge effects and poor connectivity, and comply with relevant threatened species recovery plans. Management of water quality, community access and recreational use are also identified as important outcomes in the plan.

2.5.5 Lower Duck River Riparian Management Plan (EP, 2002)

The Lower Duck River Riparian Management Plan was commissioned by the Duck River Steering Committee and completed in November, 2002. It identifies key issues for the catchment to include a lengthy history of degrading processes including weed invasion, clearing, nutrient runoff from adjoining sites, and altered fire regimes. They identify the need to coordinate management among a range of local councils and other organisations.

Management recommendations were directed by the community and environmental values identified during the study. The required outcomes, based on these values, were used to develop strategies and actions that addressed the issues identified, providing the basis to build the resulting RMP. The RMP addressed issues associated with private land, public access, community and social needs, and the natural environment. A range of strategies was proposed to manage these potentially conflicting requirements, so that each identified issue was managed through a series of identified actions. The outcomes included development of a masterplan and a plan of management.

Current requirements for development setbacks were reviewed and recommendation made to improve the management outcomes by modifications to Auburn Council's LEP. The expressed aims were to implement development setbacks that provide stable foreshore banks, riparian vegetation conservation zones (including threatened species and communities), and "regionally significant public foreshore access between the river and wetland edge and riverfront industrial developments". This was further defined as a shared pedestrian/cycle path through open space areas with a range of passive recreation uses. Another key environmental issue addressed was management of mangroves through protection of existing mangrove communities and management of colonisation to retain a range of other vegetation communities and recreational opportunities.

This plan provided a comprehensive series of strategies and management actions that addressed all the identified issues. These covered both banks of the Lower Duck River, encompassing Auburn City Council and Parramatta City Council, and provided an excellent basis for ongoing management.

2.5.6 Duck Creek Sub-catchment Management Plan (Cardno Willing, 2003)

The objectives of the Plan were to:

- Manage stormwater assets in a strategic manner
- Implement a catchment focussed unified approach for stormwater management involving both quality and quantity
- Systematically identify and address stormwater problems
- Ensure ecologically sustainable in social, development principles are achieved
- Maintain and enhance the quality of the waterways and adjoining open space and creek corridors

Typical stormwater issues of concern included the following:

- Flooding of buildings and properties along main watercourses and elsewhere in catchments
- Water quality issues related to the quality of sewer overflows, contaminants in stormwater runoff, siltation and pollution of watercourses and harbours
- Destruction of flora and fauna
- Balancing on-going residential and business development with environmental concerns.

In all cases, recommended measures were based on consideration of economic and ecological factors as well as community aspirations.

2.5.7 Duck River Biodiversity Corridor Masterplan Report for Bankstown LGA (Mather & Associates, 2003)

The implementation of the Duck River Biodiversity Corridor has been identified as one of the key outcomes of Bankstown City Council's (BCC) recently adopted Biodiversity Strategy. The Duck River Biodiversity Corridor is significant in a regional sense, both in terms of its biodiversity values and the recreational opportunities it presents. The purpose of this study is to provide Bankstown City Council with a Masterplan to serve as the basis for planting and habitat creation as well as the enhancement of recreational opportunity in the nominated reserves and neighbourhoods within and adjacent to the Duck River Biodiversity Corridor. The Masterplan provides a management framework and an action list which is to be undertaken in a staged process, to achieve Council's objectives for the Duck River Biodiversity Corridor.

Bankstown City Council's primary objectives are:

- To enhance the biodiversity values of the Duck River Biodiversity Corridor through planting and habitat creation within the reserves.
- To enhance and promote recreational opportunities through the management of the reserves as a discrete corridor.

The Duck River riparian corridor in Parramatta and Auburn LGAs connects with key reserves covered in this plan at the southern, or upstream, end of the catchment. For the Duck River riparian corridor to function effectively as a connectivity corridor, rather than a biodiversity sink, management planning also needs to consider the biological health and capacity of these reserves.

2.5.8 PCC Biodiversity Plan (PCC, 2003)

Parramatta Council's Biodiversity Plan was prepared by council staff in 2003, and comprises two volumes. The first volume provides background information for the plan, an overview of the status of biodiversity in Parramatta LGA, a vision, goals and outcomes, and a set of management actions to achieve these aims. The vision for biodiversity management in Parramatta was stated as "Parramatta is a City that values, protects and conserves its locally occurring native plants, animals and other living things, the environment they live in and the way they interact, so that biodiversity is sustained and enhanced." To realise the Vision, the following key outcomes were identified, and management actions were tailored to meet these:

1. Biodiversity is recognised as a core business of Council.
2. Biodiversity principles are reflected across a range of public and private land uses.
3. Biodiversity principles are applied across Council units.
4. Biodiversity values are optimised while providing for adequate recreational, access, safety and cultural heritage opportunities.
5. Planning instruments are effective in protecting biodiversity.
6. The Parramatta LGA has a system of sustainable, natural corridors as well as ecological communities.
7. Populations of native plant and animal species are sustainable.
8. Council is a recognised leader in biodiversity management.
9. The local community is empowered and involved in biodiversity management and values natural areas and things.
10. Council has in place an effective system to manage, monitor and update biodiversity information.

Volume two of the Biodiversity Plan includes a review of the status of biodiversity in Parramatta LGA, including: ecological communities, native flora and conservation status of rare plants, and native fauna and the conservation status of threatened and other significant species. Considerable community input is summarized in this report, including community values and issues associated with biodiversity management, and the outcomes of several workshops.

This plan is currently being rewritten, with a new draft plan to be completed in the near future.

2.5.9 PCC Open Space Plan (PCC, 2003)

Parramatta Council's Open Space Plan is underpinned by the following vision statement: "From the smallest park to the river foreshore, the City of Parramatta's open space network, will offer its residents, workers and visitors an appealing, accessible and sustainable resource; one that conserves and reflects the landscape's significant natural qualities, offers recreational opportunities for all and builds on the City's rich heritage." Open space establishes a sense of place for the community and is an important contributor to the character of the area.

The principal purpose of the Open Space Plan is to provide a framework to guide the planning, development and management of Parramatta's open space system in the short and long term in line with Council's Strategic Outcomes. This includes ensuring that open space quality is maintained, the availability fits projected population demographics, complies with all the required legislation, and conforms with changing community values and cultural diversity. More importantly it recognises the

need to provide adequate resources to ensure best practice planning and management of open space. The provision of ongoing maintenance is vital to the long term success of any natural area restoration program.

The Open Space Plan discusses the importance of Parramatta's natural heritage and biodiversity and the opportunities for improvement. Issues identified include the lack of awareness in sections of the community of the significance and value of this natural heritage. Public safety and pressure from the urban environment were also highlighted as major issues for natural areas. The Open Space Plan links its recommended management actions with the Parramatta Biodiversity Plan 2003 (currently under review), Parramatta Planting Strategy 2002 and the Parramatta Street Tree Masterplan 2011.

2.5.10 PCC Sport and Recreation Plan (Stratcorp, 2005)

The main purpose of the Plan was to develop a set of guiding principles and strategies that will provide the basis and direction to Council and other stakeholders for the future development of sport and recreation resources within the Parramatta Local Government Area (LGA). Recently, recreation participation has also been linked to the prevention and treatment of other physical and mental illnesses, and as a useful intervention strategy in reducing anti-social behaviour. Further, parks and nature have enormous untapped health potential as they provide an opportunity for people to re-establish and maintain their health in a holistic manner. Most sports reserves have at least one sport being played on them each season, which is maximising the usage and multipurpose nature of the grounds. Sporting facilities for a range of sporting activities are located along the Duck River open space corridor.

Key issues identified for open space management included improved personal security in open space areas is a key issue for residents (e.g. lighting, appropriate planting schedules, location and lighting of car parks). Residents value highly their access to well maintained and well located parks. Emerging importance noted for accommodating the needs of dog owners in relation to the provision of off leash zones that are accessible and strategically located. Sustainable turf management and maintenance practices will become increasingly more important for Council and clubs. Many of these issues have direct impacts for management of the Duck River riparian buffer.

2.5.11 PCC Natural Areas Plan of Management (PCC, 2006)

The Natural Areas Plan of Management complied with changes to the Local Government Act 1993, and established directions for planning, resource management and maintenance of community land, with the community actively involved in decisions affecting management and use. The Plan relates to all community land within the Parramatta City Council LGA categorised as Natural Area (Bushland and Watercourse), with the exception of those that have their own individual Plan of Management. It addresses Natural Areas in their current condition and established clear directions for future management and conservation of this important public resource.

Aspects of community values for Natural Areas include

- Ecological and environmental values, including functional diversity and species richness, capacity to improve water quality, lower air temperatures and improve air quality, especially through removal of carbon dioxide during photosynthesis.

- Educational and scientific values, including opportunities for education and research in areas such as environmental awareness, monitoring processes, bush skills, species lifecycles and ecosystem functions.
- Health values, including increased physical activity and relaxation, leading to improved overall health and wellbeing. Regular participation in these activities allows individuals to improve their overall health and wellbeing through development of mental alertness, stress management, coordination, balance and other functions
- Heritage and cultural values, particularly Aboriginal culture through significant places such as carving trees, shell middens, rock art and campsites. Parramatta LGA was one of the earliest European settlements, and historic structures are often preserved partially intact in natural areas.
- Recreational values, including the health and wellbeing benefits of recreation activities such as walking, fishing, photography, painting, birdwatching and picnicking. Linking Natural Areas greatly increases their recreational value to the community.
- Social values. The outdoors has long been part of the Australian culture, with open space areas highly valued as social venues. These areas are becoming increasingly important to the community, particularly in the city, where increasing urbanisation is leading to the replacement of the traditional 'backyard' with community open space.

All of these core community values for open space and natural areas need to be considered in the preparation of management plans for Duck River catchment.

2.5.12 Wetland Management Plan for the Clyde Wetlands at Shell Clyde Refinery at Rosehill, NSW (UBM Consultants, 2007)

The Wetland Management Plan for Clyde Wetlands applies only to the freshwater wetlands, and does not apply to saltmarsh, mangroves or intertidal/transitional wetland areas. The Plan addressed the rehabilitation and management of the adjoining terrestrial plant communities. The native vegetation within the Refinery comprises three different plant communities:

1. A small Freshwater Wetland;
2. A fringing Low Woodland; and
3. Stands of Swamp Oak Floodplain Forest.

The Wetland, Low Woodland and Swamp Oak Floodplain Forest are located in the north-eastern section of the Refinery.

The plan aims to "clarify the goals and objectives of management" and describes a series of proposed actions and their general sequence, thus providing guidance for bushland restoration and ongoing management strategies. Other works recommended included track construction, fencing, signage, soil remediation and drainage works. The WMP identifies the significant natural areas occurring within the Refinery, and establishes the means of more effectively managing the environmental values of the land. As such, it applies to a very specific part of the catchment which is currently undergoing major changes in management as a result of the decommissioning of the Shell Refinery at Clyde. Shell will retain storage facilities on the site, but will no longer operate the refinery. Implications for the wetland are unclear, and as the plan is now 5 years old, a review is recommended in the near future.

2.5.13 Duck River Remediation Plan for Clyde Marshalling Yards, Auburn, on behalf of Railcorp (PB, 2009)

Douglas Partners Pty Ltd (DP) has been commissioned by the Transport Construction Authority (TCA) to develop this Remediation Action Plan (RAP) for the remediation of contaminated soils at the site of the proposed Auburn Stabling Project (the ASP site). The results of the DP July 2010 contamination assessment have shown that the fill at the site is contaminated with asbestos, medium to heavy fraction petroleum hydrocarbons (TPH C10-C36) and polycyclic aromatic hydrocarbons (PAHs). The TPH C10-C36 and PAHs in the fill were noted to have low leachable concentrations and were found to be associated with the ash, slag, charcoal and cinder that are present sporadically in the fill material. Importantly, the results of the assessment also showed that the contaminated fill had not impacted the groundwater at the site.

In view of the nature of the contaminants and the heterogeneity of the fill, the preferred remedial strategy is the, 'Encapsulation of the Contaminated Soil by Constructing a Properly Designed Physical Barrier System'. The strategy involves the installation of an engineered physical barrier system to limit the exposure of site users and/or off-site receptors to contaminants. The remedial strategy seeks to minimise potential exposure pathways (routes) to the underlying contaminants. Given the anticipated low leachability of the contaminants, the cap does not need to be impermeable. Subject to proper implementation of the RAP it is considered that the site can be rendered suitable for the proposed commercial/industrial land-use.

2.5.14 Parramatta River Estuary Processes Study (AECOM, 2010)

Parramatta City Council, on behalf of the Parramatta River Estuary Committee, commissioned AECOM to deliver the estuary process study. The study is an important stage in the development of an estuary management plan for the river, as guided by State Government processes established for Coastal Management in NSW.

Specific issues investigated, for which management options were presented, included the following:

- Historical land-use changes by way of analysis of aerial photography taken in 1943 and present day: Parramatta and Auburn LGAs contain the greatest areas of contemporary industrial land-use. Historically, Auburn LGA also exhibited large areas of industrial land use, and contains large areas of reclaimed land. Therefore, estuarine areas more likely to be adversely affected by industrial areas and leachate from land reclamation are located in Parramatta and Auburn LGAs (e.g. Parramatta River, Duck River, and Homebush Bay).
- Stormwater management, with a focus on existing stormwater control devices, and catchments where such are required: Duck River subcatchment (4531 ha in total) was identified as being in need of additional gross pollutant management.
- Condition assessment of seawalls and prioritisation of where replacement or repairs of seawalls would provide opportunities for habitat creation: no impacts identified for management as part of this Masterplan.
- Natural shoreline erosion, which included conceptual options for managing erosion of mangroves upstream of Silverwater Bridge due to large vessel impacts: some impacts were identified in lower Duck River.
- Condition assessment of foreshore facilities and prioritisation of where facilities require repairs or replacement: tidal reaches of Duck River are largely unavailable for public access.

- Estuarine vegetation, including seagrass, mangroves, saltmarsh and riparian vegetation communities up to the 40m mean high water mark.

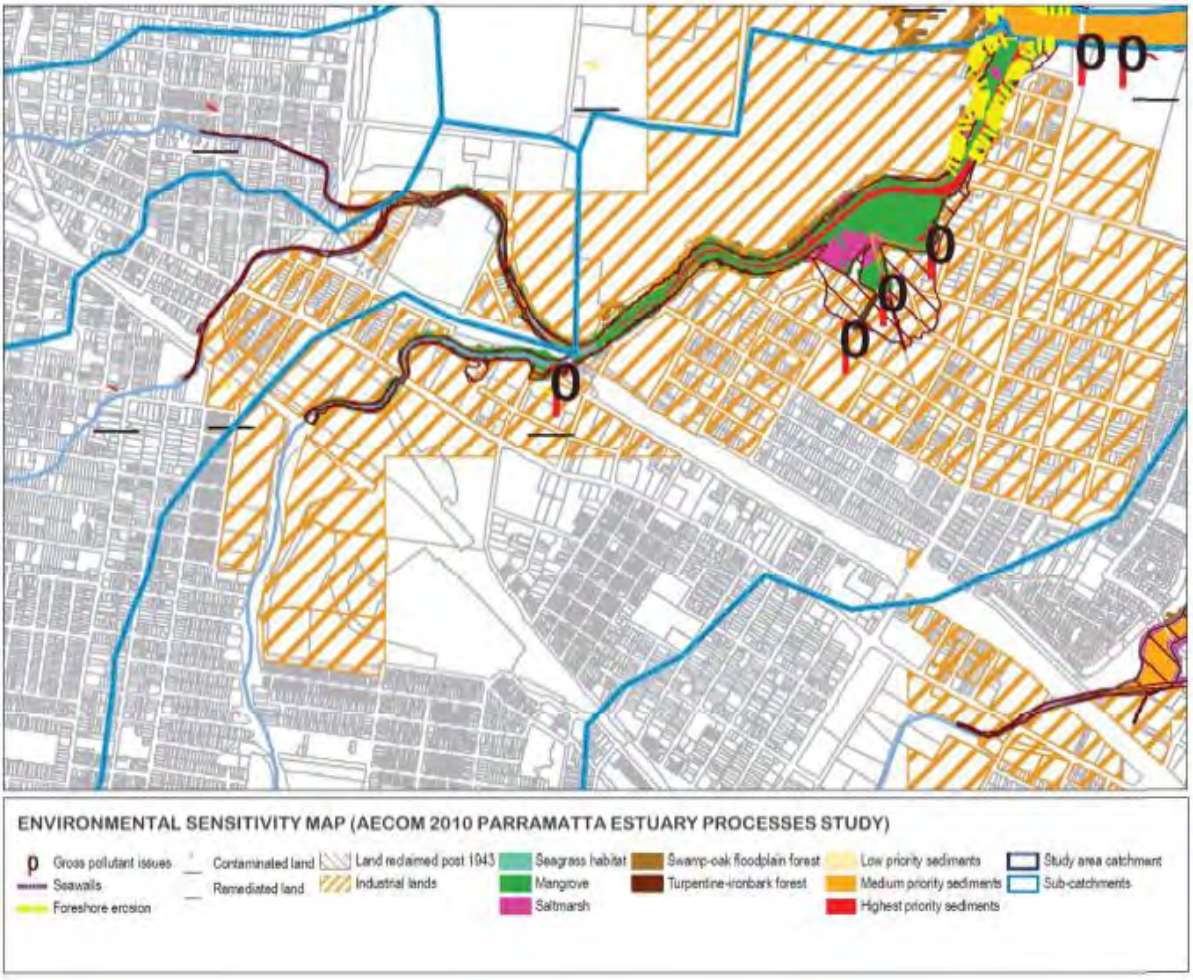

Figure 2. Environmental Sensitivity mapping for Duck River catchment (adapted from Parramatta Estuary Processes Study, AECOM 2010)

The main issues affecting riparian vegetation within the study area are:

- Infestations of introduced tree and shrub species, vines, and encroachment of grass species from adjacent open space areas;
- Access impacts (use of informal walking trails and trampling); and
- Sea level rise, which will also significantly limit the present extent of estuarine riparian vegetation where intertidal vegetation is able to migrate and tidal influences alter soil salinity and inundation frequencies.

An outcome of the study is an environmental sensitivity map of the study area (Figure 2), which identifies values, threats, and areas in which management should be prioritised.

2.5.15 Duck River Floodplain Risk Management Study and Plan (Molino Stewart/WMA, 2011)

The Duck River Floodplain Risk Management Study and Plan applies to the Duck River catchment in Parramatta, Auburn and Bankstown LGAs. This includes Duck Creek, Little Duck Creek and A'Becketts Creek, located in Parramatta LGA. The project included a Flood Study, Floodplain Risk Management Study, Floodplain Risk Management Plan, Plan Implementation, and Review of Plan.

The Floodplain Risk Management Study reviewed flood behaviour and impacts, heritage and environmental issues, emergency management, and community ideas and opinions. Floodplain risk management options were assessed, including response modification measures (local flood plans, predictions and warnings, education and recovery planning), flood modification measures (flood mitigation dams, retardation basins, bypass floodways, levees, channel modification and flood gates), property modification measures (legislative planning, property modification works, flood planning, and hazard categorisation). A number of options were shortlisted based on suitability, and included biodiversity enhancement.

The Floodplain Risk Management Plan detailed management measures based on the assessment of shortlisted options in the Study. For Parramatta Council this included

a) Flood modification, including the use of Woodville Golf Course as a retardation basin, with relevant environmental impact assessments
b) Property modification, including a voluntary buyback scheme, and voluntary house raising scheme, amending open space plans to buy and incorporate high probability flood liable properties into open space areas, and update/amendment of planning instruments to advise local residents accordingly
c) Environmental measures, including maintenance of designated open space areas to improve the passage of flood waters, ongoing management of riparian vegetation, and expansion of riparian corridors through revegetation.

Many of these recommendations are consistent with normal riparian management strategies, and the rest need to be considered in the design of riparian management actions.

3 REVIEW OF STUDY AREA: CATCHMENT CHARACTERISTICS AND CONDITIONS

3.1 ECOLOGY

3.1.1 Geology and soils

3.1.1.1 Soil Landscapes

The Duck River study area lies predominantly on Wianamatta Shales that have been cut in some areas to reveal the underlying Narrabeen Group sandstones. The soil groups in the study area have been described as follows:

Blacktown Soils: This is the predominant soil type within the catchment. These soils occur away from the waterways and join the Birrong Soils at the lower slopes.

Birrong Soils: Typical of floodplains of watercourses such as Duck River. Soils are predominant adjacent to all major water courses in the catchment.

Glenorie Soils: There is little of this soil type in the study area. Small areas of this soil group are present along the lower section of A'Becketts Creek, in the Parramatta LGA.

Disturbed Areas: The landform along the waterways has been altered through progressive infill for land reclamation. These areas of infill are referred to as disturbed soil areas and typically comprise variable, unidentified fill materials. Significant disturbed areas exist adjacent to Duck River, particularly towards the downstream end of the catchment, and around Parramatta River.

Characteristics of each soil landscape are described in Table 1 (DLWC 1:100 000 Soil Landscape Map, 1989).

Table 1. Soil landscape characteristics for soils mapped in the Duck River catchment

SOIL LANDSCAPE	SOIL DEPTH	EROSION HAZARD		URBAN CAPABILITY
		CONCENTRATED FLOWS	NON-CONCENTRATED FLOWS	
Blacktown	<100cm	Moderate to High	Low to Very High (generally Moderate)	High
Birrong	>250cm		Low to Moderate	Not capable without drainage works
Glenorie	<100cm	High	Moderate to Very High	Low to Moderate
Disturbed	40-60cm	Low to High	Low to Extreme	Capable with restrictive conditions

3.1.1.2 Acid Sulphate Soils

Acid Sulphate Soils (ASS) means naturally occurring sediments and soils containing iron sulphides (principally pyrite) or their precursors or oxidation products, whose exposure to oxygen leads to the generation of sulphuric acid, for example by drainage or excavation. ASS potential within the study area is shown in Figure 3.

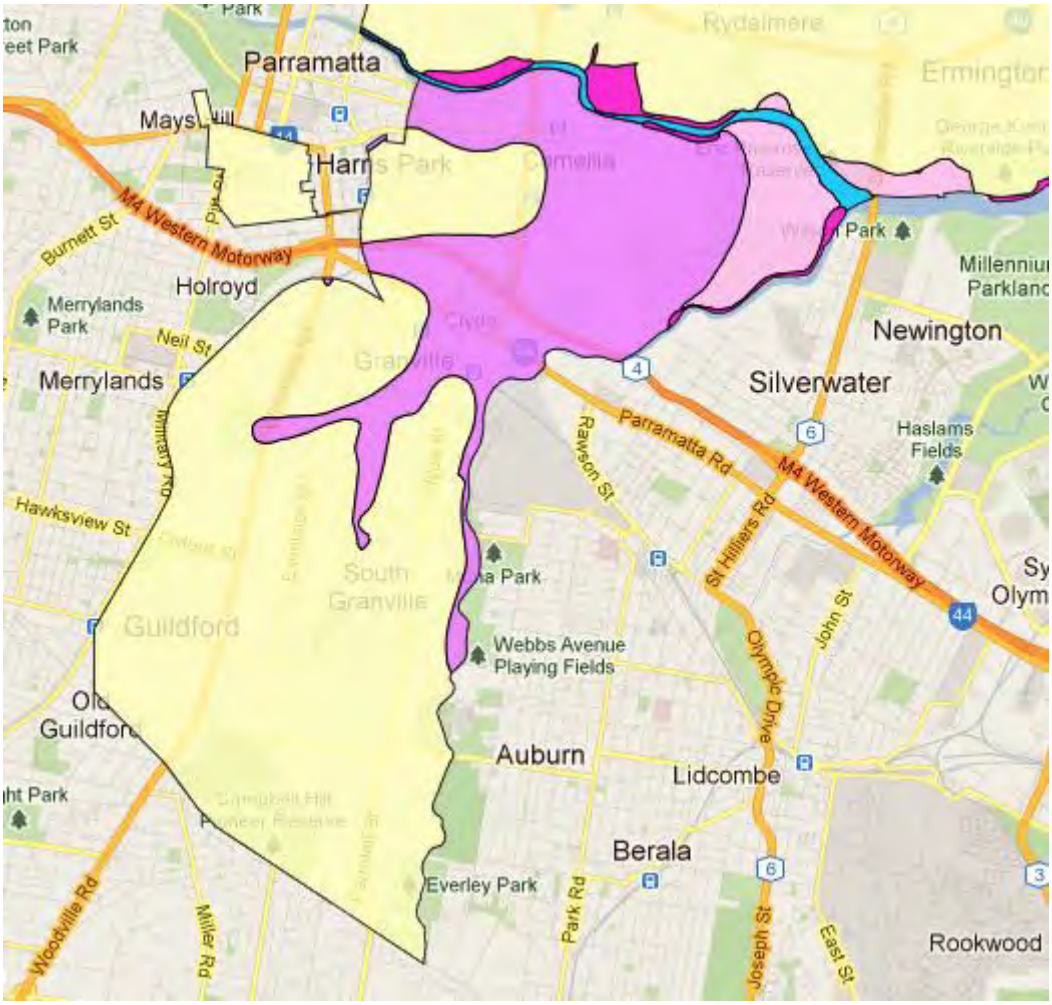

Figure 3. Acid Sulphate Soils probability mapping for Duck River catchment (PCC, 2012)

There is a low probability of ASS 1 to 3m below ground surface adjacent to all waterways, predominantly towards the downstream section of each waterway. There is a high probability of ASS at or near the surface and at depths greater than 3m in the estuarine region of Duck River.

3.1.2 Flora, fauna and vegetation communities

A number of recent surveys have been conducted in the Duck River corridor. These include fauna surveys conducted by Applied Ecology P/L at a number of reserves during 2011/12, and flora lists compiled during bush regeneration works conducted by Bushit P/L during 2010/11. These lists are indicative of catchment condition, rather than exhaustive, and include few areas downstream from Clyde Weir. The section of Duck River below the weir is tidal, and would reasonably be expected to support a quite different suite of animals and plants.

3.1.2.1 Fauna

In recent surveys Applied Ecology P/L staff recorded 58 species of birds in the Duck River catchment riparian corridors and associated reserves (Appendix Two, Table A2), focussing on the area upstream of Clyde Weir. This included 9 species of introduced birds, and 3 threatened species. Distribution across the catchment was not consistent, with more birds recorded along the main Duck River corridor (28 species south of Ray Marshall Reserve, and 43 between Clyde Weir and Ray Marshall Reserve), and at Campbell Hill-Waddangalli Reserves (31 species). Avian diversity was considerably lower in all of the tributaries surveyed.

In addition, 5 species of frog were recorded, 7 lizards and one snake species, 7 bats (including 3 threatened species), 4 introduced mammals, 2 fish, a turtle and one significant invertebrate, the endangered Cumberland Plain Land Snail (Figure 3; Appendix Three, Table A3). Once again, areas of higher diversity were concentrated in the larger bushland reserves, and considerably lower in all of the tributaries surveyed.

3.1.2.2 Threatened Fauna

Six species of threatened fauna have been recorded from the Duck River riparian corridor. These include:

Green and Golden Bell Frog (*Litoria aurea*)

A relatively large, stout frog, ranging in size from approximately 45 mm to approximately 100 mm snout to vent length. Diagnostic features are a gold or creamish white stripe running along the side, extending from the upper eyelids almost to the groin, with a narrow dark brown stripe beneath it, from nostril to eye. It also has blue or bluish-green colour on the inside of the thighs.The colour of the body varies. Usually a vivid pea-green, splotched with an almost metallic brassy brown or gold. The backs of some individuals may be almost entirely green; in others golden-brown markings may dominate.

Inhabits marshes, dams and stream-sides, particularly those containing bullrushes (*Typha* spp.) or spikerushes (*Eleocharis* spp.). Optimum habitat includes water-bodies that are unshaded, free of predatory fish such as Plague Minnow (*Gambusia holbrooki*), have a grassy area nearby and diurnal sheltering sites available. Some sites, particularly in the Greater Sydney region occur in highly disturbed areas. Several records from around Camelia, one from Duck Creek in Granville, and several records from A'Becketts Creek upper reaches in Holroyd LGA.

Main threats for this species include destruction of wetlands; alteration of drainage patterns and stormwater runoff; a fungal pathogen known as Frog Chytrid Fungus; predation by feral animals such as foxes; herbicides and other weed-control measures; road mortality, where populations are already small due to other threats; predation by exotic fish such as Plague Minnow; and loss of suitable breeding habitat through alteration by infilling and destruction of wetlands.

Little Eagle (*Hieraetus morphnoides*)

The Little Eagle is a medium-sized bird of prey that occurs in two colour forms: either pale brown with an obscure underwing pattern, or dark brown on the upperparts and pale underneath, with a rusty head and a distinctive underwing patter of rufous leading edge, pale 'M' marking and black-

barred wingtips. Both forms have a black-streaked head with a slight crest, a pale shoulder band on the upperwings, a rather short and square-tipped barred tail, and feathered legs.

Occupies open eucalypt forest, woodland or open woodland. Sheoak or acacia woodlands and riparian woodlands of interior NSW are also used. One record from Duck River Bushland Reserve in 2007. Main threats for this species include clearing and degradation of foraging and breeding habitat; urban expansion; rural-residential subdivision and associated land uses (e.g. horse and goat grazing); and secondary poisoning from rabbit baiting.

Spotted-tailed Quoll (*Dasyurus maculates*)

The Spotted-tailed Quoll is about the size of a domestic cat, from which it differs most obviously in its shorter legs and pointed face. The average weight of an adult male is about 3500 grams and an adult female about 2000 grams. It has rich-rust to dark-brown fur above, with irregular white spots on the back and tail, and a pale belly. The spotted tail distinguishes it from all other Australian mammals, including other quoll species. However, the spots may be indistinct on juvenile animals.

Mostly nocturnal, although will hunt during the day; spends most of the time on the ground, although also an excellent climber and may raid possum and glider dens and prey on roosting birds. Recorded across a range of habitat types, including rainforest, open forest, woodland, coastal heath and inland riparian forest, from the sub-alpine zone to the coastline. Individual animals use hollow-bearing trees, fallen logs, small caves, rock crevices, boulder fields and rocky-cliff faces as den sites.

Main threats for this species include loss, fragmentation and degradation of habitat; accidental poisoning during wild dog and fox control programs; deliberate poisoning, shooting and trapping may also be an issue; competition with introduced predators such as cats and foxes. One record from the vicinity of Mona St in 1993.

Grey-headed Flying Fox (*Pteropus poliocephalus*)

The Grey-headed Flying-fox is the largest Australian bat, with a head and body length of 23 - 29 cm. It has dark grey fur on the body, lighter grey fur on the head and a russet collar encircling the neck. The wing membranes are black and the wingspan can be up to 1 m. It can be distinguished from other flying-foxes by the leg fur, which extends to the ankle.

Occur in subtropical and temperate rainforests, tall sclerophyll forests and woodlands, heaths and swamps as well as urban gardens and cultivated fruit crops. Roosting camps are generally located within 20 km of a regular food source and are commonly found in gullies, close to water, in vegetation with a dense canopy. Individual camps may have tens of thousands of animals and are used for mating, birth and the rearing of young. A camp is located on Duck River immediately upstream from Clyde Weir.

Main threats for this species include loss of foraging habitat; disturbance of roosting sites; unregulated shooting; and electrocution on powerlines. A number of records from Clyde Weir, Granville to the confluence with Parramatta River.

Eastern Bentwing Bat (*Miniopterus schreibersii oceanensis*)

The Eastern Bent-wing Bat has chocolate to reddish-brown fur on its back and slightly lighter coloured fur on its belly. It has a short snout and a high 'domed' head with short round ears. The wing membranes attach to the ankle, not to the base of the toe. The last bone of the third finger is much longer than the other finger-bones giving the "bent wing" appearance.

Caves are the primary roosting habitat, but also use derelict mines, storm-water tunnels, buildings and other man-made structures. Form discrete populations centred on a maternity cave that is used annually in spring and summer for the birth and rearing of young. Breeding or roosting colonies can number from 100 to 150,000 individuals. Hunt in forested areas, catching moths and other flying insects above the tree tops.

Main threats for this species include damage to or disturbance of roosting caves, particularly during winter or breeding; loss of foraging habitat; application of pesticides in or adjacent to foraging areas; and predation by feral cats and foxes. One record from Duck River Bushland Reserve, and one from nearby at Campbell Hill Pioneer Reserve.

Cumberland Plain Land Snail (*Meridolum corneovirens*)

Superficially similar to the familiar exotic Garden Snail. It differs most obviously in its 25 - 30 mm diameter shell. While this shell may be almost any shade of brown, it is always uniform in colour, while that of Helix consists of dark patches on a pale background. The Cumberland Land Snail also has a more flattened shell that is very thin and fragile, compared with the thick shell of the Garden Snail.

Figure 4. Cumberland Plain Land Snails at Duck River Bushland Reserve, a threatened species

Primarily inhabits Cumberland Plain Woodland (an endangered ecological community). This community is a grassy, open woodland with occasional dense patches of shrubs. Lives under litter of bark, leaves and logs, or shelters in loose soil around grass clumps. Occasionally shelters under rubbish. Can dig several centimetres into soil to escape drought. Is a fungus specialist. Unlike the Garden Snail, does not eat green plants.

Main threats for this species include clearing and degradation of Cumberland Plain Woodland remnants. There is generally a poor understanding of other threats to this species. One record from Duck River Bushland Reserve.

3.1.2.3 Flora

As part of their works report, Bushit P/L compiled a list of all native species recorded on work sites along Duck River between November, 2010 and October, 2011, providing an up to date snapshot of floristic diversity in the riparian corridor. Bushland restoration sites covered by this report comprised:

- Site 1 – Parramatta Road (both sides)
- Site 2 – Duck River Reserve (Clyde Station to Mona Street)
- Site 3 – Horlyck Reserve (Mona St to Mons St)
- Site 4 – Duck River Reserve (Mons St to Chiswick St)
- Site 5 – Clyde St Reserve (Bennett St)
- Site 6 – Ray Marshall Reserve (Chiswick St to Wellington Rd)
- Site 7 – Everley Park and Norford Park

They recorded 259 native plant species, including one threatened species (Appendix 3). Ironically this list doesn't include the Duck River Bushland Reserve, where the most intact bushland is conserved.

Native flora species was recorded in a single survey for Duck River Bushland Reserve during recent flora and fauna surveys conducted by Applied Ecology P/L. This survey recorded 100 species of native flora in the reserve (Appendix 3), a number of which were not reported elsewhere by Bushit in 2011.

Key outcomes for this project were to ground-truth the extent of vegetation community mapping compiled by SMCMA, and species were ranked against the indicative species lists provided for each vegetation community in the reserve. Based on this, minor adjustments were made to the distribution boundaries for Cumberland Ironbark Forest (CIF) and Cumberland River Flat Forest (CRFF). Species present and distribution among vegetation communities is shown in Table 2. Species were recorded as diagnostic, listed or additional when present. Diagnostic species are those that are important for defining the community, while listed species are often encountered but not considered to separate this community from others. Additional species are those that were not reported as being commonly found for that community, and frequently include species from adjoining communities in transitional areas.

Table 2. Summary of flora species recorded in Duck River Bushland Reserve and their relationship with mapped vegetation communities (for a full list of species see Appendix Four, Table A4).

SPECIES NAME	CIF	CRFF
Species listed for community	**69**	**36**
Species diagnostic for community	**28**	**12**
Additional species	**16**	**21**
Total species recorded in community	**85**	**57**
Total species recorded in reserve	**100**	

3.1.2.4 Threatened Flora

Three species of threatened flora have been recorded along the Duck River riparian corridor. These include:

Acacia pubescens

A spreading shrub, 1 - 5 m high with brilliant yellow flowers, bipinnate leaves (divided twice pinnately) and conspicuously hairy branchlets. Occurs on alluviums, shales and at the intergrade between shales and sandstones. The soils are characteristically gravely soils, often with ironstone. Occurs in open woodland and forest, in a variety of plant communities, including Cooks River/ Castlereagh Ironbark Forest, Shale/ Gravel Transition Forest and Cumberland Plain Woodland. Main threats for this species include habitat loss; habitat degradation (through weed invasion, mechanical damage, rubbish dumping, illegal track creation, and inappropriate fire regimes); disease; and hybridisation. Recorded from a number of locations in Duck River Bushland Reserve.

Tetratheca glandulosa

Small, spreading shrub which grows 20 - 50cm in height. Stems often become entwined among other small shrubs, sedges and grasses. Leaves are opposite 5 - 10 mm long and 1 mm wide with recurved (rolled under) margins. Leaf margins have small stiff hairs that give them a “toothed” appearance. The flower stalk and sepals (leaf-like structure at base of flower) are covered with dark-red gland-tipped hairs, which distinguishes *T. glandulosa* from other *Tetratheca* species. Associated with shale-sandstone transition habitat where shale-cappings occur over sandstone Topographically, the plant occupies ridgetops, upper-slopes and to a lesser extent mid-slope sandstone benches. Vegetation structure varies from heaths and scrub to woodlands/open woodlands, and open forest. Vegetation communities correspond broadly to Benson & Howell’s Sydney Sandstone Ridgetop Woodland. Common woodland tree species include: C*orymbia gummifera, C. eximia, Eucalyptus haemastoma, E. punctata, E. racemosa*, and/or *E. sparsifolia*, with an understorey dominated by species from the families Proteaceae, Fabaceae, and Epacridaceae. Main threats for this species are habitat loss through vegetation clearing and habitat degradation; fire control activities, particularly frequent prescribed burning and mechanical fuel reduction and the construction/maintenance of fire access

tracks; and habitat fragmentation of small, isolated populations. A single record from the vicinity of Horlyck Park in 1887.

Wilsonia backhousei

Narrow-leafed Wilsonia is a perennial, sprawling, matted shrub less than 15 cm tall. The narrow, pointed, dark green, stalkless leaves are succulent and less than 20 mm long. The single white flowers are also stalkless. This is a species of the margins of salt marshes and lakes. Main threats to this species are trampling, weed competition, rubbish dumping, poor water quality in runoff, and habitat loss through development. Recorded from tidal mudflats around Camelia industrial area.

3.1.2.5 Vegetation communities

Vegetation communities along Duck River have been mapped recently by SMCMA as part of the draft Native Vegetation of the Sydney Metropolitan Catchment Management Authority Area (2010). Most of the communities identified have been listed as Endangered Ecological Communities (Figure 5 and 6), and are described in the following section. Additional vegetation has been described as Urban Exotic/Natives and Weeds & Exotics. Both of these communities are dominated by introduced species. The first is a highly degraded form of native vegetation that retains limited representation of the original species, often with only canopy species remaining, but may include areas where revegetation has commenced but is still challenged by weed invasion. In the second community local native species may be completely absent, and this community is much harder to rehabilitate.

Figure 5. Coastal Freshwater Reedlands EEC with a backdrop of Cumberland Riverflat Forest EEC in reach DUCK RIVER 5B

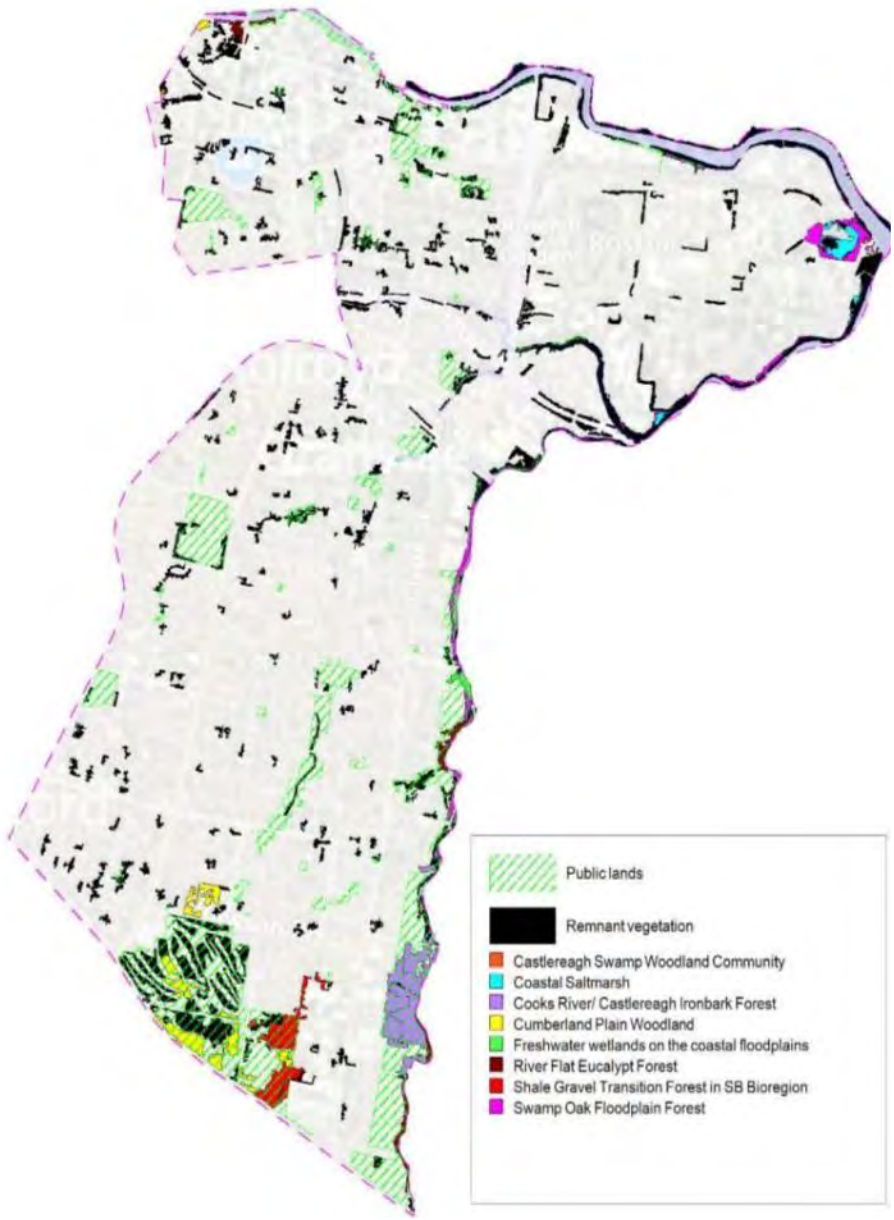

Figure 6. Vegetation communities along the Duck River catchment riparian corridor (SMCMA, 2010)

3.1.2.6 Endangered Ecological Communities

Five Endangered Ecological Communities (EECs) have been recorded from the Duck River catchment. These include:

Coastal Saltmarsh EEC

Coastal Saltmarsh occurs in the intertidal zone on the shores of estuaries and lagoons that are permanently or intermittently open to the sea. It is frequently found as a zone on the landward side of mangrove stands. Characteristic plants include *Baumea juncea, Juncus krausii, Sarcocornia quinqueflora, Sporobolus virginicus, Triglochin striata, Isolepis nodosa, Samolus repens, Selliera radicans, Suaeda australis* and *Zoysia macrantha*. Occasionally mangroves are scattered through the saltmarsh. Tall reeds may also occur, as well as salt pans.

This community occurs in the intertidal zone along the NSW coast. Species composition varies with elevation and latitude, with Saltmarsh in southern NSW being generally more species-rich than further north. Along Duck River these species include threatened species *Wilsonia backhousei* (vulnerable). Main threats for this community include:

- In-filling for development, including roads, residential, industrial, recreational, waste disposal and agricultural purposes.
- Modification of tidal flows as a consequence of artificial structures being erected.
- Alteration of salinity and increasing nutrient levels resulting from the discharge of stormwater into saltmarshes.
- Weed invasion, particularly by Juncus acutus.
- Physical damage from human disturbance, domestic and feral animals.
- Dumping of rubbish and pollution from oil or chemical spills from shipping or road accidents; catchment runoff of nutrients and agricultural chemicals.
- Invasion by mangroves.
- Inappropriate fire regimes.

Cumberland Swamp Oak Riparian Forest (Swamp Oak Floodplain Forest EEC)

This community is found on the coastal floodplains of NSW. It has a dense to sparse tree layer in which *Casuarina glauca* (swamp oak) is the dominant species. Other trees including Acmena smithii (lilly pilly), Glochidion spp. (cheese trees) and Melaleuca spp. (paperbarks) may be present as subordinate species, and are found most frequently in stands of the community northwards from Gosford. The understorey is characterised by frequent occurrences of vines, *Parsonsia straminea, Geitonoplesium cymosum* and *Stephania japonica* var. *discolor*, a sparse cover of shrubs, and a continuous groundcover of forbs, sedges, grasses and leaf litter.

The composition of the ground stratum varies depending on levels of salinity in the groundwater. Under less saline conditions prominent ground layer plants include forbs such *Centella asiatica, Commelina cyanea, Persicaria decipiens* and *Viola banksii*; graminoids such as *Carex appressa*, *Gahnia clarkei, Lomandra longifolia, Oplismenus imbecillis*; and the fern *Hypolepis muelleri*. On the fringes of coastal estuaries, where soils are more saline, the ground layer may include *Baumea juncea, Juncus kraussii, Phragmites australis, Selliera radicans* and other saltmarsh species.

Main threats for this community include:

- Clearing for urban and rural development, and the subsequent impacts from fragmentation
- Flood mitigation and drainage works
- Grazing and trampling by stock and feral animals (eg. pigs)
- Activation of acid sulfate soils
- Landfilling and earthworks associated with urban and industrial development
- Pollution from urban and agricultural runoff
- Rubbish dumping
- Climate change
- Localised areas, particularly those within urbanised regions, may also be exposed to frequent burning which reduces the diversity of woody plant species.

Cumberland Riverflat Forest (Riverflat Eucalypt Forest EEC)

As the name suggests, this EEC is found on the river flats of the coastal floodplains. It has a tall open tree layer of eucalypts, which may exceed 40 m in height, but can be considerably shorter in regrowth stands or under conditions of lower site quality. While the composition of the tree stratum varies considerably, the most widespread and abundant dominant trees include *Eucalyptus tereticornis* (forest red gum), *E. amplifolia* (cabbage gum), *Angophora floribunda* (rough-barked apple) and *A. subvelutina* (broad-leaved apple).

A layer of small trees may be present, including *Melaleuca decora, M. styphelioides* (prickly-leaved teatree), *Backhousia myrtifolia* (grey myrtle), *Melia azaderach* (white cedar), *Casuarina cunninghamiana* (river oak) and *C. glauca* (swamp oak). Scattered shrubs include *Bursaria spinosa* , *Solanum prinophyllum, Rubus parvifolius, Breynia oblongifolia, Ozothamnus diosmifolius, Hymenanthera dentata, Acacia floribunda* and *Phyllanthus gunnii*.

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

Main threats for this community include:

- Further clearing for urban and rural development, and the subsequent impacts from fragmentation
- Flood mitigation and drainage works
- Landfilling and earthworks associated with urban and industrial development
- Grazing and trampling by stock and feral animals (particularly pigs)
- Changes in water quality, particularly increased nutrients and sedimentation
- Weed invasion
- Climate change
- Activation of acid sulfate soils
- Removal of dead wood
- Rubbish dumping
- Frequent burning which reduces the diversity of woody plant species

Coastal Freshwater Reedland (Freshwater Wetlands on the Coastal Floodplain EEC)

Associated with coastal areas subject to periodic flooding and in which standing fresh water persists for at least part of the year in most years. Typically occurs on silts, muds or humic loams in low-lying parts of floodplains, alluvial flats, depressions, drainage lines, backswamps, lagoons and lakes but may also occur in backbarrier landforms where floodplains adjoin coastal sandplains. Generally occur below 20 m elevation on level areas. They are dominated by herbaceous plants and have very few woody species. The structure and composition of the community varies both spatially and temporally depending on the water regime: Those that lack standing water most of the time are usually dominated by dense grassland or sedgeland vegetation, often forming a turf less than 0.5 metre tall and dominated by amphibious plants including *Paspalum distichum* (water couch), *Leersia*

hexandra (swamp rice-grass), *Pseudoraphis spinescens* (mud grass) and *Carex appressa* (tussock sedge). Where they are subject to regular inundation and drying the vegetation may include large emergent sedges over 1 metre tall, such as *Baumea articulata, Eleocharis equisetina* and *Lepironia articulata*, as well as emergent or floating herbs such as *Hydrocharis dubia* (frogbit), *Philydrum lanuginosum* (frogsmouth), *Ludwigia peploides* subsp. *montevidensis* (water primrose), *Marsilea mutica* (nardoo) and *Myriophyllum* spp. (milfoils). As standing water becomes deeper or more permanent, amphibious and emergent plants become less abundant, while floating and submerged aquatic herbs become more abundant.

Main threats for this community include:

- Land clearing, continuing fragmentation and degradation
- Flood mitigation and drainage works
- Filling associated with urban and industrial development
- Pollution and eutrophication from urban and agricultural runoff
- Weed invasion
- Overgrazing, trampling by livestock
- Soil disturbance by pigs
- Activation of acid sulfate soils
- Dumping of landfill, rubbish and garden refuse
- Native fauna is threatened by predation, particularly by mosquito fish and cane toads
- Anthropogenic climate change

Cooks River/Castlereagh Ironbark Forest EEC

Ranges from open forest to low woodland, with a canopy dominated by Broad-leaved Ironbark *Eucalyptus fibrosa* and Paperbark *Melaleuca decora*. The canopy may also include other eucalypts such as Woolybutt *E. longifolia*. The dense shrubby understorey consists of *Melaleuca nodosa* and Peach Heath *Lissanthe strigosa*, with a range of 'pea' flower shrubs, such as *Dillwynia tenuifolia*, *Pultenaea villosa* and *Daviesia ulicifolia* (can be locally abundant). The sparse ground layer contains a range of grasses and herbs.

Has a very restricted natural distribution and mainly occurs on clay soils derived from the deposits of ancient river systems (alluvium), or on shale soils of the Wianamatta Shales. Can intergrade into Shale-Gravel Transition Forest (where the alluvium is shallow), Castlereagh Swamp Woodland (in moist depressions) and Castlereagh Scribbly Gum Woodland (on more sandy soils). Most species in the community are able to regenerate from lignotubers and buds beneath the bark as well as seeds stored in the soil.

The main threats for the community include:

- Further clearing for urban/rural residential development or clay/shale extraction, and the subsequent impacts from fragmentation.
- Urban run-off, which leads to increased nutrients and sedimentation.
- Weed invasion.
- Inappropriate fire regimes, which have altered the appropriate floristic and structural diversity.

3.2 CATCHMENT RUNOFF AND WATER QUALITY

3.2.1 Hydrology

The Duck River catchment receives approximately 950mm of rainfall per year (1950 to present) and evaporation of approximately 1490mm/year (SILO, 2010). Rainfall can vary significantly from year to year, but generally ranges between 600 and 1300mm/yr (Figure 7).

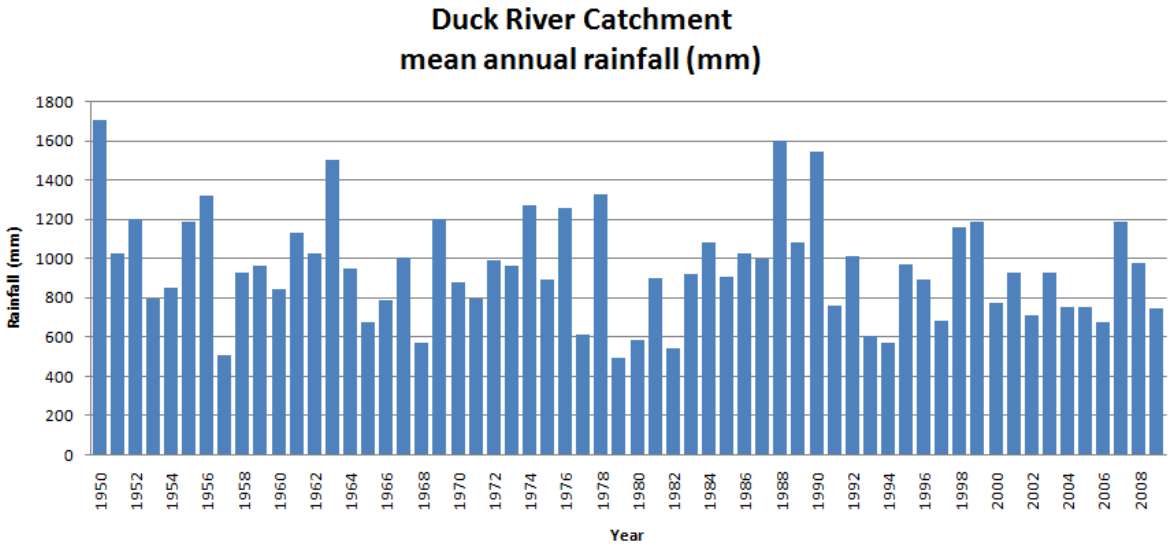

Figure 7. Duck River Catchment Annual Rainfall (SILO 2010)

3.2.2 Catchment Runoff

Catchment runoff does not appear to be systematically monitored on the Duck River. However, a surface water monitoring station at Mackay Road, South Granville (ID 213209) is reported in the Australian Natural Resources Atlas (ANRA 2009) indicating that at some time, water flows may have been recorded at this site. This site is located approximately mid way between the upper and lower bounds of this study. In the absence of stream flow records, a recent catchment modeling study has been reviewed to provide insight to the Duck River hydrology.

The Duck River catchment hydrology has recently been modeled (SMCMA Draft in progress) and draft hydrology results for the Duck River before the confluence with Duck Creek have been made available for this review. This modeling covers only a relatively short period between 2003 and 2008 and cannot be interpreted as being indicative of the entire range of conditions in the Duck River. Nevertheless, this modeling provides insight to the responsiveness of the catchment to rainfall and volume of runoff generated from rainfall in this highly urbanised catchment. The draft modeled daily flow hydrograph and associated rainfall for the Duck River is presented in Figure 8. The model results indicate a runoff coefficient of approximately 30%, which, when applied to average catchment rainfall equates to approximately 285mm of runoff per year.

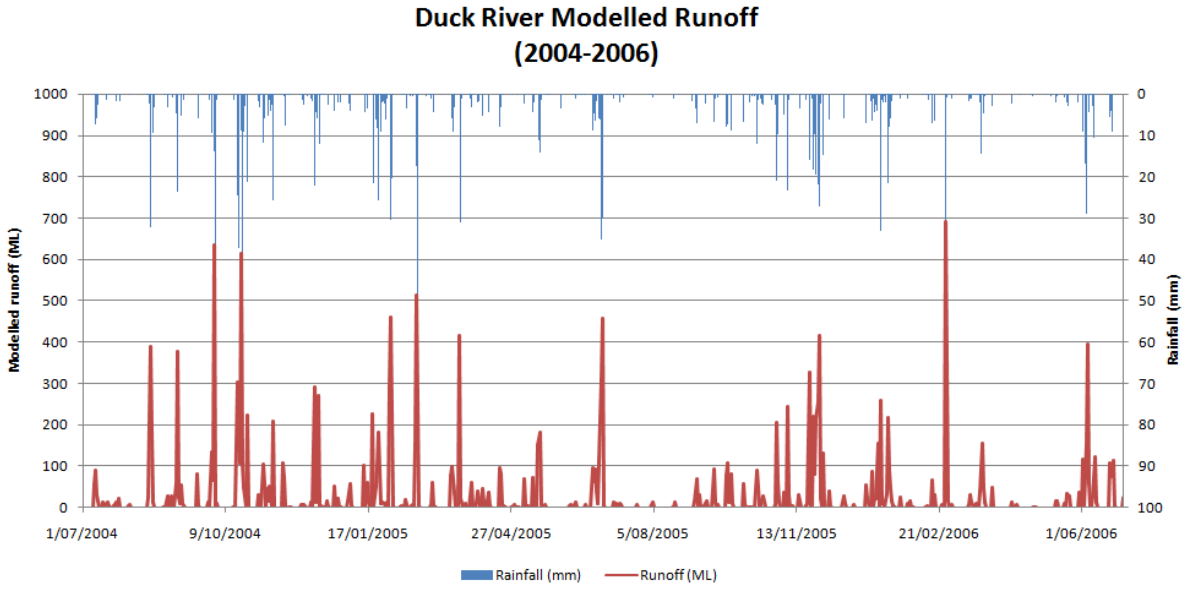

Figure 8. Daily Rainfall and Modeled Flows in the Duck River, 2004-2006. (Data provided by SMCMA 2012)

The runoff response to rainfall in the Duck River Catchment is generally swift with sharp rises in flows typical of urbanised catchments with significant portions of directly connected impervious areas. Figure 9 shows a typical runoff hydrograph (modeled data, 30 minute time step) showing the sharp increase in flows and relatively short hydrograph recession with little or no baseflow. The modeled flow duration curve (Figure 10) shows that for approximately 50% of the time, flows in the Duck River are less than 0.02ML/d.

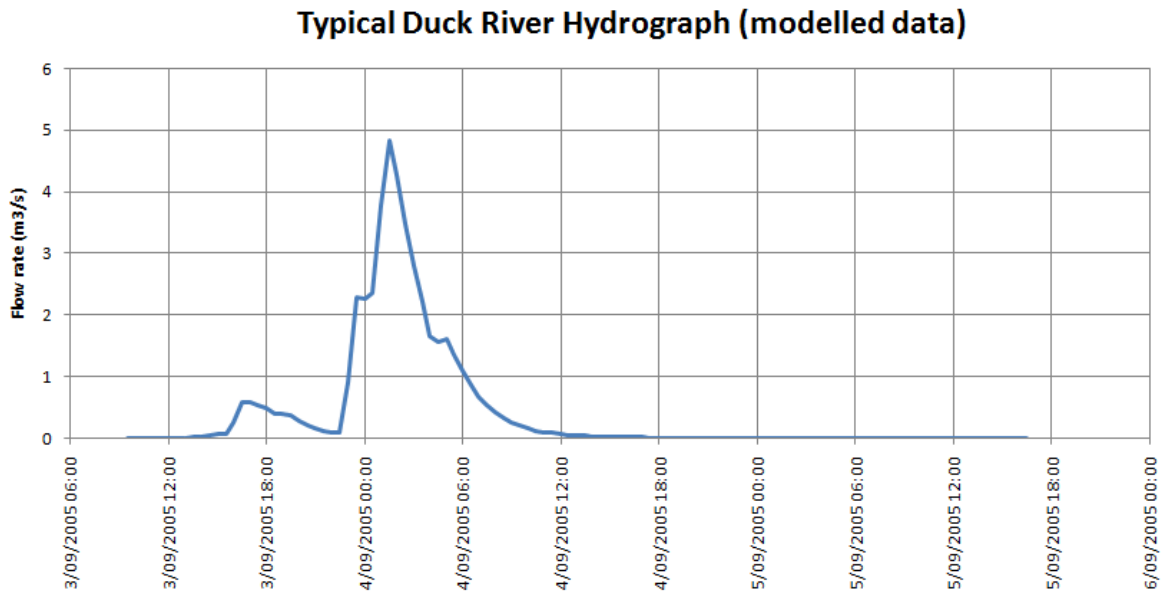

Figure 9. Typical Modeled Hydrograph for the Duck River, (Data provided by SMCMA 2012)

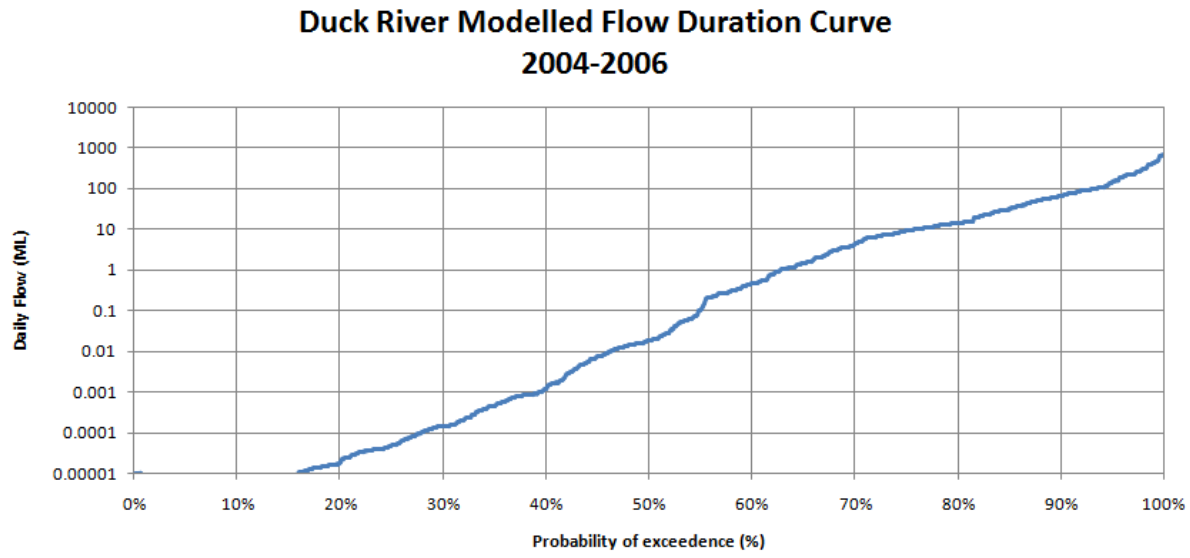

Figure 10. Flow Duration Curve in the Duck River, 2004-2006. (data provided by SMCMA 2012)

3.2.3 Water quality

Water Quality on one site in the Duck River has been systematically sampled and analysed for a wide range of water quality constituents between 1995 and 2007 and the results have been presented in Laxton et al (2008). The Duck River site is located at Parramatta Road, just outside the study area and is tidally influenced in dry weather. A nearby site on Duck Creek which is not tidally influenced has also been included in this review as this site is probably more indicative of freshwater conditions in the Duck River.

Figure 11 summarises nutrient water quality at Duck River related monitoring sites with red figures indicating non-compliance against water quality guidelines (protection of aquatic ecosystems). 50th percentile values are exceeded for all nutrient species during 2007 and Laxton et al (2008) reports that this is the case for any of the previous years sampled. Furthermore, Laxton et al (2008) reports that in the upper Duck Creek, nutrient concentrations increased substantially in 2005/2006 due to a suspected sewage leak.

Freshwater - Upper Duck Creek (2007)

Nutrient	50 percentile	90 percentile
Ammonia	0.109 mg-N/L	0.178 mg-N/L
Oxidised nitrogen	0.471 mg-N/L	0.718 mg-N/L
Total nitrogen	1.685 mg-N/L	3.246 mg-N/L
Orthophosphate	0.0436 mg-P/L	0.1798 mg-P/L
Total phosphorus	0.1355 mg-P/L	0.3389 mg-P/L

Saltwater - Parramatta River and Duck River (2007) Surface water

Nutrient	50 percentile	90 percentile
Ammonia	0.110 mg-N/L	0.330 mg-N/L
Oxidised nitrogen	0.179 mg-N/L	0.378 mg-N/L
Total nitrogen	0.987 mg-N/L	1.771 mg-N/L
Orthophosphate	0.0446 mg-P/L	0.0926 mg-P/L
Total phosphorus	0.1612 mg-P/L	0.3378 mg-P/L

Figure 11. Water Quality in Duck Creek -2007. (Laxton et al 2008)

High nutrient concentrations in the Duck River correspond with high chlorophyll-a concentrations indicating an over-productive system that has resulted in fish kills in the estuarine section of the Duck River in the past (Laxton et al 2008).

The water quality monitoring program and data reported by Laxton et al (2008) is generally representative if baseflow conditions, rather than event based conditions, therefore estimating catchment pollutant loads in the Duck River catchment is not possible without the use of a model. The SMCMA Upper Parramatta River Source Catchments Model (SMCMA 2012) has been used to estimate pollutant loading rates in the Duck River catchment.

In Spring 2009 and Autumn 2010, biological surveys were undertaken at 20 representative sites in the Parramatta LGA, including two sites on Duck River (Cardno Ecology Lab, 2010). The primary objective of these surveys was to determine the biological health of each waterway as indicated by water quality, the condition of aquatic habitats and their associated fauna and flora. The secondary objective was to determine whether the biological health of each waterway was related to the level of effective imperviousness (the proportion of the catchment that consists of impervious surfaces connected directly to streams by stormwater pipes).

Of the two sites, one (DR2BG2) was located just upstream from the stepping stones weir, and the other (DRXX01) near Seventh St, upstream of Clyde Weir. DRXX01 was found to be very depauperate for macroinvertebrates in edge habitats. DR2BG2 had a very high percentage of exotic macrophytes (>50%). Duck River had the highest percentage effective imperviousness of the four Parramatta catchments investigated. The diversity of diatoms and fish tended to increase as % effective imperviousness increased.

The study found that there was no obvious relationship between the condition of the aquatic habitat and that of the biological assemblages, nor was there much link between the different biological components. The lack of consistency reflects the differential responses of the biological indicators to the environmental disturbances associated with urbanisation (Cardno Ecology Lab, 2010).

3.3 STREAM AND CHANNEL MORPHOLOGY,

3.3.1 Changes in the Catchment Since European Settlement

The Duck River catchment and river have undergone significant changes since European settlement including:

- Extensive urbanisation and industrialisation resulting in catchment hardening;
- Land clearing;
- Channelisation and lining of sections of the Duck River and side creeks resulting in hydraulically efficient drainage system;
- Construction of barrages and weirs along the Duck River including the Clyde Weir and Mackay Road causeway; and
- Introduction of additional pollutant sources such as agriculture, and now urbanisation and sewage infrastructure.

The landscape and river prior to European settlement has been captured in maps, journals and paintings and a selection of these historic sources relating to the estuarine environment have been

collated and reviewed by McLoughlin (2000). These sources and descriptions are reproduced in Figure 12.

Table 1. Description of the Foreshore Vegetation of the Parramatta River, 1788–1933.

	Observation	Location	Year	Observer and Source
1	*...about 4 mile higher than where the ships lay, the country was open and improved the farther we went up & in most places not any underwood, grass very long.*	Upper harbour	1788	Lt. William Bradley, Bradley 1969, p. 75
2	*...along the bank the grass was tolerably rich and succulent, and in height nearly up to the middle, interspersed with a plant much resembling the indigo.*	Above Duck River	1788	Surgeon John White, White 1962, p. 127
3	*The banks of it were now pleasant, the trees immensely large, and at a considerable distance from each other; and the land around us flat and rather low, but well covered in the kind of grass just mentioned.*	Above Clay Cliff Creek	1788	Surgeon John White, White 1962, p. 128
4	*About two miles below this settlement, the harbour becomes quite narrow, being not more than ten or twelve yards across, and the banks are about six feet high: here the country has the appearance of a park. In rowing up this branch, we saw a flock of about thirty kangaroos or paderong, but they were only visible during their leaps, as the long grass hid them from our view...*	3–4 km down-stream from Parramatta	1790	Lt. Phillip Gidley King, King 1968, p. 402

Figure 12. Collation of landscape description of the Upper Parramatta River, extracted from McLoughlin (2000)

Aerial photographs provide a more objective means of gauging catchment change and a selection of photographs from 2008 and 1943 showing the same river stretches are shown in Figures 13-16. The photographs show that by 1943, much of the Duck River catchment either had already undergone urbanisation or was in the process of doing so. Large sections of the upper catchment remained rural with some stands of trees still present.

Figure 13. 2008 and 1943 Aerial Photography:. Source: LPI NSW, Spatial Information Exchange

Figure 14. 2008 and 1943 Aerial Photography:. Source: LPI NSW, Spatial Information Exchange

Figure 15. 2008 and 1943 Aerial Photography:. Source: LPI NSW, Spatial Information Exchange

Figure 16. 2008 and 1943 Aerial Photography:. Source: LPI NSW, Spatial Information Exchange

3.3.2 Stream and Channel Morphology

The changes in the catchment since European Settlement are likely to have resulted in:

- Larger runoff volumes, higher peak flow rates and higher frequency of surface runoff;
- Decreased low flow volumes;
- Increased channel erosion and incision and sedimentation in dead zones/pools;
- Higher nutrient loads and more sunlight; and
- Lower water tables delivering subsurface flows and baseflows to the stream.

These impacts are typical of urban developments in Eastern Australia. These changes typically would have begun following land settlement and are not necessarily very recent changes. Closer aerial photograph inspection of selected Duck River sections indicate extensive riverbank erosion in 1943 that has since undergone partial revegetation (Figure 17a and 17b). The aerial photographs of 1943 show a number of similar areas of apparent riverbank erosion indicating that substantial changes to catchment hydrology and bank stability had occurred prior to this time.

Figure 17(a) Upper Duck River Wellington Road 1943; (b) 2008:. Source: LPI NSW, Spatial Information Exchange

Pre and post urbanisation conceptual models of catchment responses to rainfall and channel morphology are provided in Figures 18 and 19 (extracted from Walsh et al 2004). Pre and post development of the highly urbanised Duck River catchment are likely to exhibit many of the features shown in these conceptual models.

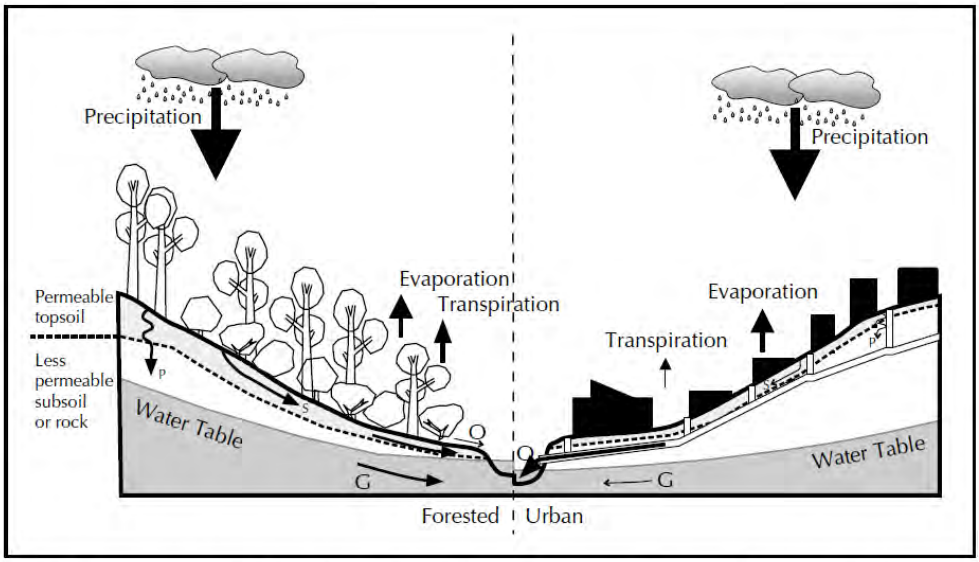

Figure 2. The water cycle in a forested catchment and in an urbanized catchment with a conventional stormwater drainage system (not considering imports of water supply or export of wastewater). The size of arrows indicates qualitative differences in the relative size of annual water volumes through each pathway in a typical south-eastern Australian coastal catchment. Water that falls on the catchment and is not evaporated or transpired may reach the stream by three possible paths: overland flow (O: almost all of which is transmitted to the stream by stormwater pipes in the urban catchment), subsurface flow through permeable topsoil (S), or percolation (P) into groundwater flow (G). (Partly adapted from Dunne & Leopold, 1978.)

Figure 18. Water cycle changes for pre and post catchment urbanisation

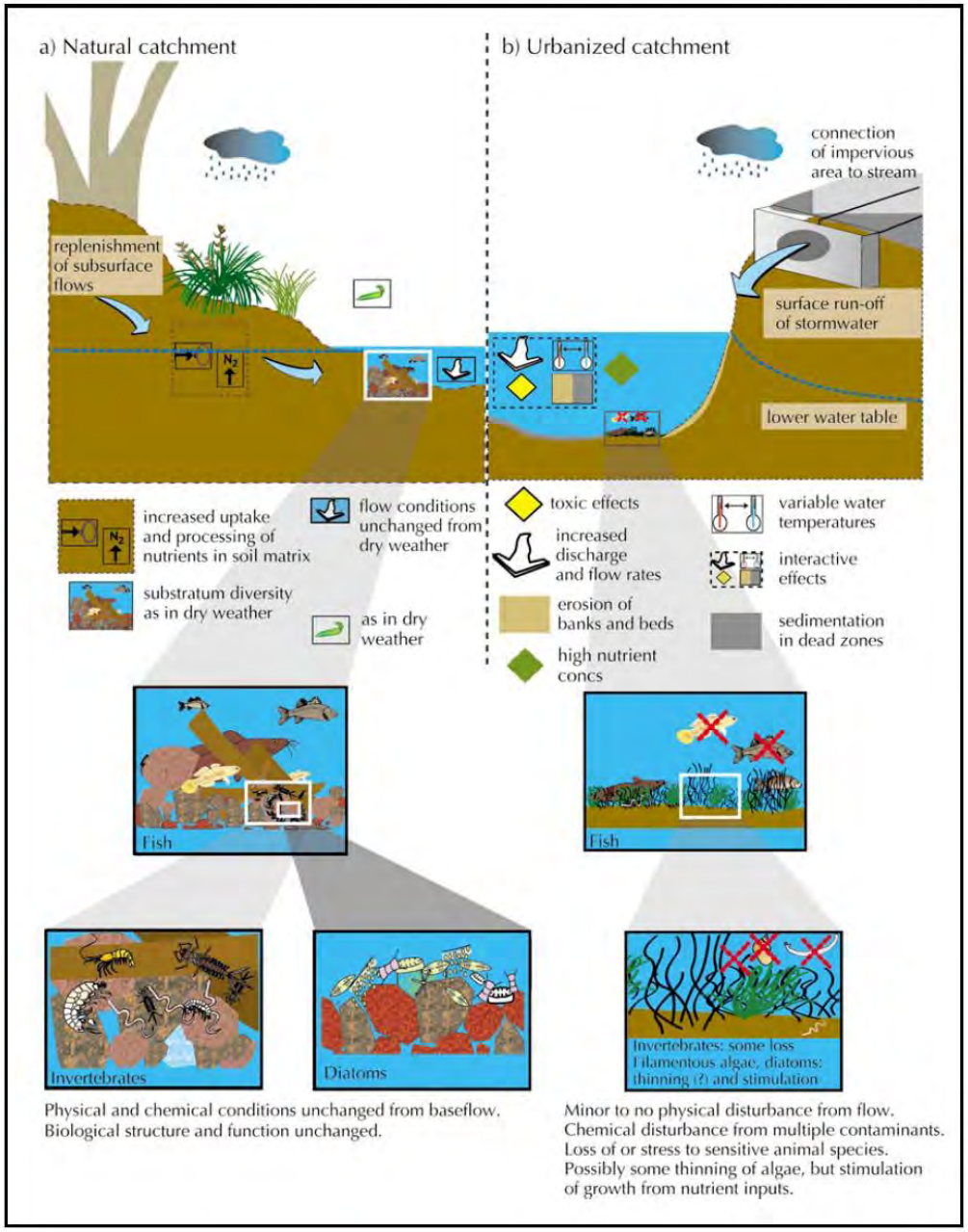

Figure 19. Conceptual processes in natural and urbanised streams following moderate rainfall events (Walsh et al 2004).

3.3.3 Sydney Water's Concrete Channel Assets

Both the Duck Creek, including Little Duck Creek, and A'Becketts Creek concrete lined channel systems (Figure 20 and 21) were initially constructed by the Department of Public Works in the 1930s and then transferred to Sydney Water in 1948 (Figure 22). Sydney Water's role today is to maintain the assets as they were constructed. This means that they repair the assets as required, clean the system of any obstructions, including the build-up of sediments in some spots and repair and maintain any Sydney Water fences along those channels.

Sydney Water works with local council through their floodplain coordination committees. These committees determine whether any works are required and Sydney Water then negotiates with Councils to facilitate outcomes. While some concrete lined channels in the Cooks River catchment

have been broken out and replaced with “naturalized” channels, there are no plans for this type of action in the Duck River catchment.

Figure 20. Larger channels in the lower catchment include reach A’BECKETTS 1, with an open space corridor

Figure 21. In many cases there is little room between the channel and surrounding development (UNNAMED 8 GUILDFORD RD)

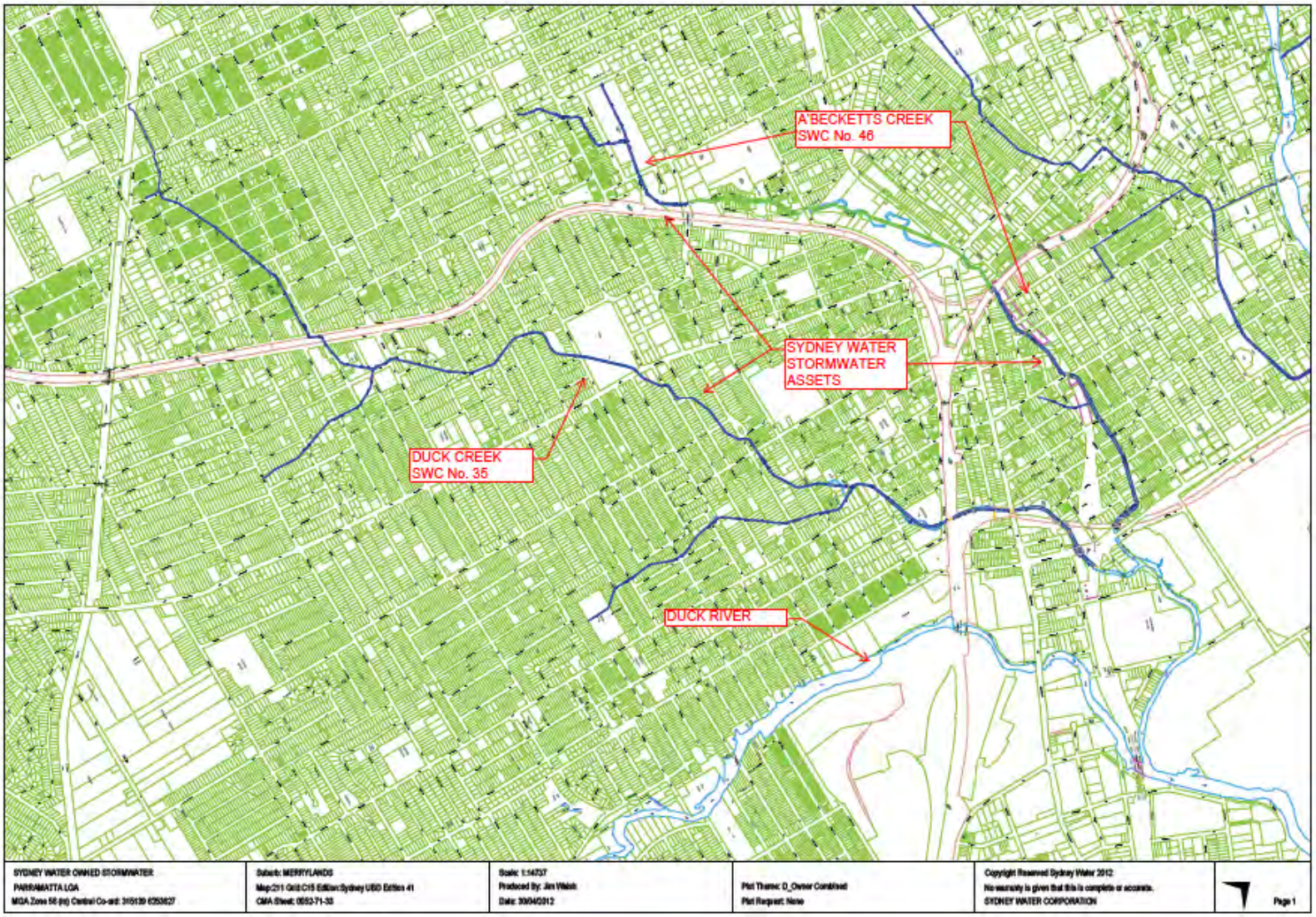

Figure 22. Sydney Water's stormwater asset network in Duck River catchment (Sydney Water, 2012)

3.3.4 Duck River Rehabilitation, Maintenance and Restoration Activities

The management and maintenance of the Duck River corridor is primarily guided by principles outlined in the Parramatta City Council Natural Areas Plan of Management (2006). This document only contains general actions to be undertaken or encouraged across all open space areas in the LGA and does not contain specific management actions for the Duck River corridor. Nevertheless, this plan can be used as a guide for the present study to confirm the identified areas of importance for rehabilitation and maintenance.

In recent years considerable effort has been directed towards improving the health of aquatic ecosystems in Duck River. Two major Environmental Trust Grants have supported this:

(i) **TBL in the Duck River Catchment – a model for Industrial Sustainability (2007-2011) $1.3M** – joint with Auburn Council, Parramatta the lead Council. The grant focussed on working with businesses in the Camellia and Silverwater Industrial areas (lower Duck River) to improve their environmental sustainability across energy, water, travel, waste and biodiversity. The grant also included a capital improvement component associated with cycle way upgrades, riparian weed removal, installation of stormwater pollutant traps and interpretive signage regarding natural and built heritage.

(ii) **Sustainable Water Management in the Duck River Catchment (2009-2012) $1.8M** – joint with Auburn, Bankstown and Parramatta Councils, Auburn the lead Council. The objective was to improve the management of water supply (and seek alternative supply options) to open space and recreational assets across the three Council areas within the catchment. Works within Parramatta Council include: River water extraction licence, storage tanks, treatment technology and new irrigation system for Horlyck Reserve Granville; amplification of existing dam capacity at Woodville Golf Course; supply of recycled effluent to Granville Park; and studies on future works at Granville Pool and Ray Marshall Reserve.

Table 3. Stormwater improvement devices installed in the Duck River catchment in 2009-2012

LOCATION	DESCRIPTION OF WORKS
GPTS INSTALLED	
Clyde St, South Granville (opp Dellwood St, in park)	Channel net and sediment basin
Dixmude St, South Granville (in park)	Channel net
Mackay Rd (corner Dixmude St) South Granville	Nettech, sediment basin and channel armouring (10m)
Mons St, South Granville (end of park)	Channel net, sediment basin and channel armouring (12m)
Wellington Rd, South Granville (creek crossing)	Nettech, sediment basin and channel armouring/ planting (25m)
Shirley St, Rosehill (end of private road)	Ecosol – underground sump
Shirley St, Rosehill (start of private road)	2 x Nettechs

Additional works to improve the health and water quality in the catchment include installation of a range of gross pollutant traps at key points in the catchment (Table 3). A number of on-ground projects and programs aimed at maintaining, restoring and enhancing the health of vegetation around Duck River have been identified through this review (Table 4).

Table 4. Bush regeneration activities in the Duck River catchment from 2007/8 to 2011/2.

LOCATION	YEAR	DESCRIPTION OF WORKS
CONTRACT REGENERATORS		
Prince St capping	2011/12	Planting 400 tubes, maintain plantings on capped asbestos contamination site, spray and mulch
Parramatta Rd	2007/08	Planting 500 tubes, control vines and woody weeds
	2008/09	Planting 500 tubes, control vines and woody weeds
	2009/10	Planting 400 tubes, control vines and woody weeds
	2010/11	Planting 440 tubes, direct seed, maintain plantings and mulch, control vines and woody weeds
	2011/12	Planting 295 tubes, install silt fencing, control vines, mulch, spot spray and direct seed
Duck River Reserve: rear Australia Post	2007/08	Planting 500 tubes, reduce vines and woody weeds
	2008/09	Planting 200 tubes, control vines and woody weeds
	2009/10	Planting 200 tubes, secondary weeding
	2010/11	Manage habitat for snakes and security, control vines and woody weeds
	2011/12	Planting 200 tubes, maintain drainage line, reduce woody weeds
Duck River Reserve: Bangor St to Neilson St	2007/08	Planting 500 tubes, secondary weeding and control vines
	2008/09	Planting 1600 tubes, secondary weeding and control vines
	2009/10	Planting 1760 tubes, secondary weeding, and mulching, install log barrier and fencing
	2010/11	Planting 280 tubes, spot spray, direct seed
	2011/12	Planting 580 tubes, secondary weeding, target woody weeds, spot spray and maintain plantings
Duck River Reserve: Heath St	2007/08	Planting 280 tubes, target woody weeds
	2008/09	Planting 280 tubes, secondary weeding
	2009/10	Planting 280 tubes
	2010/11	Planting 80 tubes, maintain plantings, followup woody weeds
	2011/12	Planting 420 tubes, control woody weeds
Horlyck Reserve: Mona St	2007/08	Planting 200 tubes, target woody weeds and vines
	2008/09	Planting 200 tubes, target weeding for vines and woody weeds
	2009/10	Planting 200 tubes, target vines and woody weeds,

LOCATION	YEAR	DESCRIPTION OF WORKS
		reduce large woody weed infestation
	2010/11	Planting 80 tubes, target woody weeds, spot spray groundcover weeds
	2011/12	Planting 100 tubes, spot spray and maintain plantings
Horlyck Reserve: Riverside remnants	2007/08	Secondary weeding
	2008/09	Secondary weeding
	2009/10	Target weeding for vines and woody weeds
	2010/11	Planting 20 tubes, target vines and woody weeds
	2011/12	Planting 20 tubes, target weeding
Duck River Reserve: Mons St to Chiswick Rd	2007/08	Planting 1770 tubes, maintain plantings
	2008/09	Planting 1100 tubes, restaking boundary logs after flooding, secondary weed control
	2009/10	Planting 1180 tubes, secondary weed control for vines and grasses
	2010/11	Planting 390 tubes, spot spray, control Morning Glory and reduce woody weeds
	2011/12	Planting 280 tubes, maintain plantings
Clyde St Reserve	2007/08	Planting 200 tubes
	2008/09	Planting 400 tubes
	2009/10	Planting 400 tubes, maintain plantings
	2010/11	Planting 80 tubes, maintain plantings
	2011/12	Planting 220 tubes, maintain plantings
Ray Marshall Reserve	2007/08	Planting 1000 tubes, mulch edges
	2008/09	Planting 700 tubes
	2009/10	Planting 700 tubes
	2010/11	Planting 300 tubes, spot spray and direct seed
	2011/12	Planting 340 tubes, maintain plantings
Everley Park and Norford Park	2007/08	Planting 200 tubes, secondary weeding
	2008/09	Planting 1000 tubes, spot spray around plantings
	2009/10	Planting 1000 tubes, spot spray around plantings
	2010/11	Planting 80 tubes, maintain plantings, spot spray
	2011/12	Planting 280 tubes, maintain plantings, spot spray
Campbell Hill Pioneer Reserve	2007/08	Planting 1120 tubes, target noxious and woody weeds, maintain core bushland areas
	2008/09	Planting 1020 tubes, control vines, blackberry and woody weeds, maintain core bushland areas
	2009/10	Planting 1520 tubes, spot spray around plantings, control vines, woody weeds and blackberry
Waddangalli Woodland	2007/08	Planting 60 tubes, control Blackberry and woody weeds, maintain core bushland areas
	2008/09	Planting 1000 tubes, reduce woody weeds

LOCATION	YEAR	DESCRIPTION OF WORKS
	2009/10	Planting 1000 tubes, maintain core bushland areas, reduce blackberry and woody weeds
Duck River Bushland Reserve	2007/08	Planting 1100 tubes, maintain plantings, target weeding, control exotic grasses
	2008/09	Planting 4000 tubes, control vines and woody weeds along creekline, spot spray and maintain plantings
	2009/10	Planting 1200 tubes, spot spray and maintain plantings, maintain core bushland areas
VOLUNTEER GROUPS		
MDRRC, Duck River Reserve between Seventh Ave and Mona St	monthly, ongoing	Aim: to widen the riparian corridor Maintenance of plantings, spot spray, mulch and plant, maintenance weed control
Friends of Duck River Bushcare	monthly, ongoing	Aim: to encourage native regeneration through edge weeding Maintenance of core bushland edges, some planting

- Duck River Icon Project (SMCMA 2006-2008). Rehabilitation of riverbanks and an island adjacent to Webb Avenue playing fields and Mackay Road, South Granville. A green corridor linking existing remnant vegetation including Castlereagh Ironbark Forest was established
- Mighty Duck River Restoration Collective (MDRRC). Protection of endangered remnants and wetland along the Duck River. NSW Government 2002 Restoration and Rehabilitation - community grants
- Mighty Duck River Restoration Collective (MDRRC) Stage 2. Protection of endangered remnants and wetland along the Duck River. NSW Government 2003 Restoration and Rehabilitation - community grants

Revegetation and Expansion management options in the Duck River catchment listed by Molino Stewart (2011) include:

- The northern bank of Duck River at the confluence with Duck Creek, adjacent to a factory on Shirley Street
- Duck River Reserve (additional revegetation west of existing vegetation toward pathway)
- Ray Marshall Reserve (small area suitable for revegetation at the end of Chiswick Road)
- Norford Park (triangle area at the southern end suitable for revegetation)

4 REVIEW OF LITERATURE AND SITE SURVEYS: CULTURAL HERITAGE

4.1 INDIGENOUS HERITAGE

The Duck River appears to have been the boundary between two major groups of indigenous people prior to European occupation of New South Wales.

The Auburn area was located on the border between the Darug inland group and the Eora/Dharawal coastal group of Aboriginal people. The Wangal and Wategoro, sub-groups or clans, are the groups most often recognised as the original inhabitants of the Auburn / Homebush Bay region. Bennelong, one of the most famous Aborigines of the time, was a member of Wangal, as was his wife, Barangaroo. Pemulwuy, who organised tribes to resist the white settlement of the Sydney region from 1790 to 1802 was also a member of the Wangal. The agreed boundary between Burramattagal country and their neighbours, the Wategora clan, seems to have been the Duck River (McClymont, 2008). The Auburn area was once used by Aboriginal people as a market place for the exchange of goods, a site for ritual battles and a 'Law Place' for ceremonies.

Further to the west, the original inhabitants of the area that is now Parramatta belonged to the Darug (Dharug, Daruk) language group. The clan that occupied the area was known as the Burramattagal. The Bidjigal occupied the areas to the north and west. The Burramattagal relied on the mixed food sources available from the river and the surrounding woods (Kass, 2008). The southern riverbank and the mostly freshwater stream now known as Clay Cliff Creek were vital sources of their food and living resources. In their seasonal rotation of campsites around their territory, the clan would have found that the reasonably abundant fish, shellfish, bird life, reptiles and marsupials large and small contributed greatly to their daily quest for food (McClymont, 2008).

A number of searches were conducted to identify whether there were Aboriginal heritage items, places or other relevant information for the Upper Duck River area. These included searches of the National Native Title Tribunal (Table 5) with the following results.

Table 5. National Native Title Tribunal search results

TRIBUNAL DATABASE SEARCHED	SEARCH RESULT
Schedule of Applications	no relevant entries
Register of Native Title Claims	no relevant entries
National Native Title Register	no relevant entries
Register of Indigenous Land Use Agreements	no relevant entries
Notified Indigenous Land Use Agreements	no relevant entries

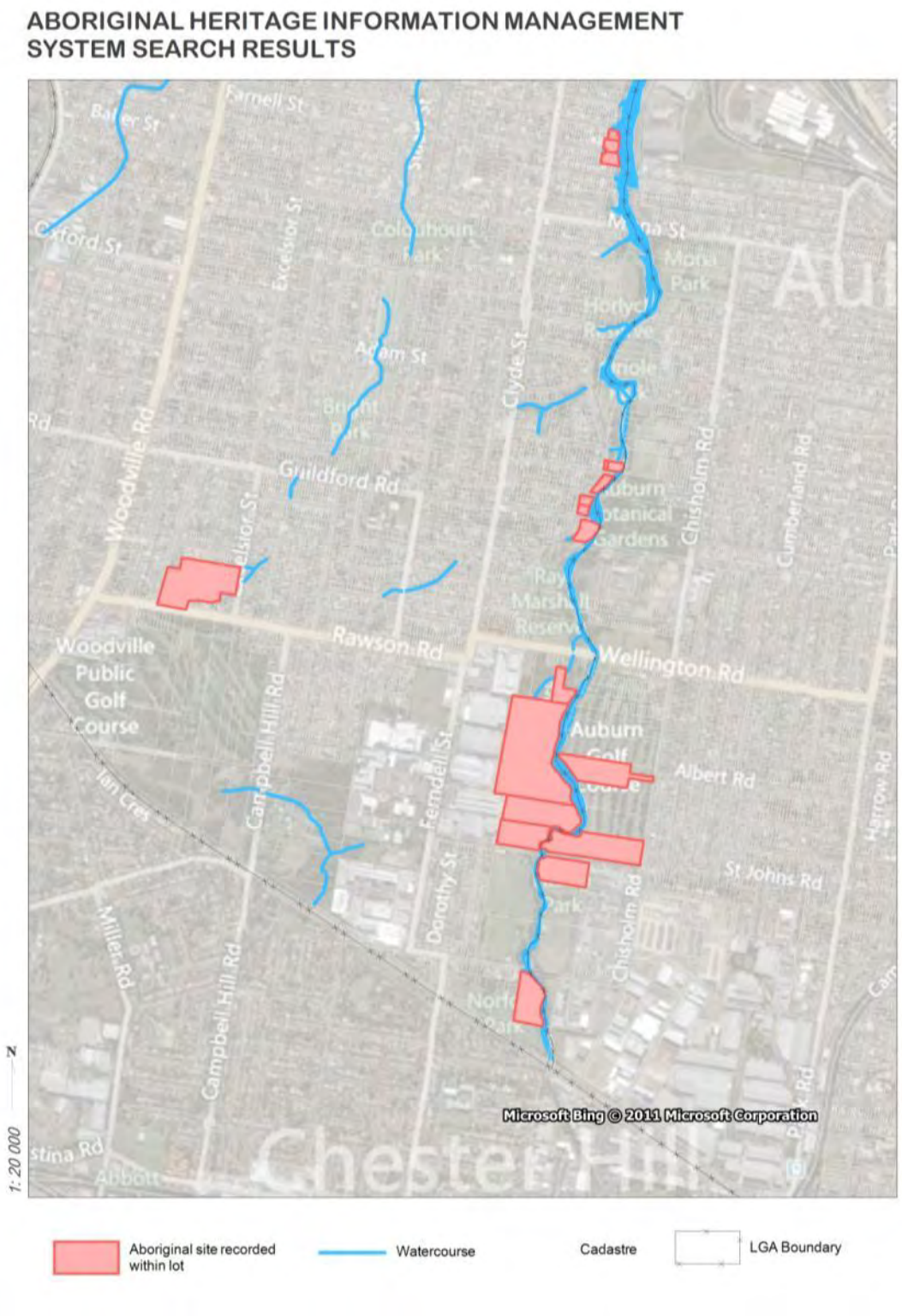

Figure 23. Indicative locations of indigenous heritage items along Upper Duck River

Further searches were conducted with the Aboriginal Heritage Information Management Service (AHIMS database; Appendix 5, Table A5). Basic searches for heritage items on properties by individual lot numbers revealed that there are numerous indigenous heritage items located at various points along the Upper Duck River (Figure 23). Mary Dallas Consulting (2002) identified a number of these heritage item locations, but also reported that all of the Upper Duck River Wetlands

and Riparian Corridor was classified as high sensitivity for indigenous heritage potential. Before any works can be conducted in these areas a full search of the AHIMS database should be conducted, and if heritage items are located then Aboriginal Heritage Impact Permit must be obtained under Part 6 of the National Parks and Wildlife Act 1974.

4.2 NON-INDIGENOUS HERITAGE (MUSECAPE, 2012)

On 5 February 1788, soon after the landing of Captain Arthur Phillip at Sydney Cove, Captain John Hunter and Lieutenant William Bradley sailed up what is now known as the Parramatta River, as far as Homebush Bay. Captain Hunter was the first white person to set foot within what is now the Auburn LGA.

Ten days later, Governor Phillip, along with a well-armed party in three boats, reached Homebush Bay. They ventured about 3 kilometres inland. The following day a party of explorers traced the river in a westerly direction, coming to the place where the Duck River enters the Parramatta River. They explored the tributary as far as the depth of water permitted. The party entered the mouth of Duck River while exploring the Parramatta River. Seeing a group of wild ducks taking flight from a reed bed, and thinking it might be a breeding ground for ducks, Governor Phillip named the waterway Duck River. The ducks were most likely specimens of *Porphyrio porphyrio* (Eastern Swamp Hen), but the name Duck River stuck.

Granville remained relatively untouched by European colonisation for many years. Early governors did make land grants to soldiers, officials and a handful of families who had established themselves as the elite of Parramatta. The Wentworths (D'Arcy Wentworth and his son William Charles) held land on the Duck River. The largest landowner in the district was the merchant Garnham Blaxcell, who snapped up some small grants given to members of the New South Wales Corps, and then received a massive consolidated grant of 1,125 acres (455 hectares) in 1806. This area is now bounded by Clyde Street and Parramatta, Woodville and Rawson roads. The forest was a resort for timber-getters, charcoal burners and men who trapped the prevalent native dogs; the original name for Woodville Road was Dog Trap Road.

The soil in what is now Auburn LGA proved too poor for agriculture, but early industries included timber-getting, and brick-making, which began with the establishment of the Duck River Brickworks by Charles Linney. In the 1850s, the construction of the Sydney-Parramatta railway brought large-scale deforestation and much of the useable timber was cut out by 1860. The railway line, opened with much ceremony in 1855, actually terminated on Dog Trap Road at a station called Parramatta Junction. In 1860 the railway was extended into Parramatta proper. The opening of the railway made suburban development possible, and the township of Auburn emerged from subdivisions by John Yelverton Mills near the railway station.

During the 1860s, subdivision of the old Jamieson estate began. Although James Bergan established a tweed mill close to the railway, many of the first buyers were orchardists and farmers. There was room also for middle-class villas, occupied by men who were responsible for renaming, not just the disreputable Dog Trap Road, but the whole area. In the 1880s it became Granville, in honour of the then British Foreign Minister, Lord Granville. Five years later, the Municipality of Granville was declared: it encompassed all or part of the modern suburbs of Camellia, Rosehill, Harris Park,

Granville, Clyde, and South Granville. The municipality – which took in Guildford in 1906 – lasted until 1949 when it was subsumed in the enlarged City of Parramatta.

Granville municipality grew quickly in the 1880s and 1890s, as industrialists were attracted by its road, rail and water access: the municipality also gained gas street lighting and a connection to the metropolitan water supply in this period. Hudson Brothers, manufacturers of railway rolling stock, chose a site on the Duck River at Granville to establish works, which opened in 1883 and covered 14 acres (5.6 hectares). Other new enterprises in Granville included James Brunton's six-storey flour mill and William Ritchie's factory producing agricultural machinery. The workers in these large factories – along with those in smaller tanneries and brickworks – boosted the area's population and stimulated the subdivision of existing farm lots.

During the 1920s, developments in building and the growth of motor transport brought more manufacturers to the Municipality of Granville. Private developers and the War Services Homes Commission tried to meet the resulting demand for housing: between 1921 and 1933 the number of 'occupied dwellings' in Granville municipality rose by 54 per cent. By 1933, however, the Depression was devastating the area. Male unemployment was over 20 per cent and the Granville Council struggled to provide relief works.

After World War II, state planning policies – which designated Parramatta as a growth centre – and federal immigration programs impacted on Granville, which had been reduced in size and status to become one of many suburbs of the City of Parramatta. At first, industrial expansion continued, but mainly in South Granville, while the Housing Commission built estates to accommodate an urban population growing as a result of the baby boom and immigration. The area was developed with an unusually high proportion of low income and/or non-English-speaking families.

In the immediate post-war period, growth was boosted by government initiatives. But it was the gazettal of the Strata Title Act of 1961 that had the greatest impact throughout the suburb, permitting the erection of multi-unit housing blocks. By the 1960s and 1970s, the number of Middle Eastern immigrants settling in Auburn had grown, making Auburn one of the main Arabic / Middle Eastern centres in Sydney, vying only with Canterbury. In the 1991 census, 47 per cent of the population of the municipality had been born overseas.

A cultural precinct and associated structures have been recorded around the Duck River catchment (Table 6, Figure 24). Preservation of these is an important part of the conservation process for the wetlands and riparian corridor.

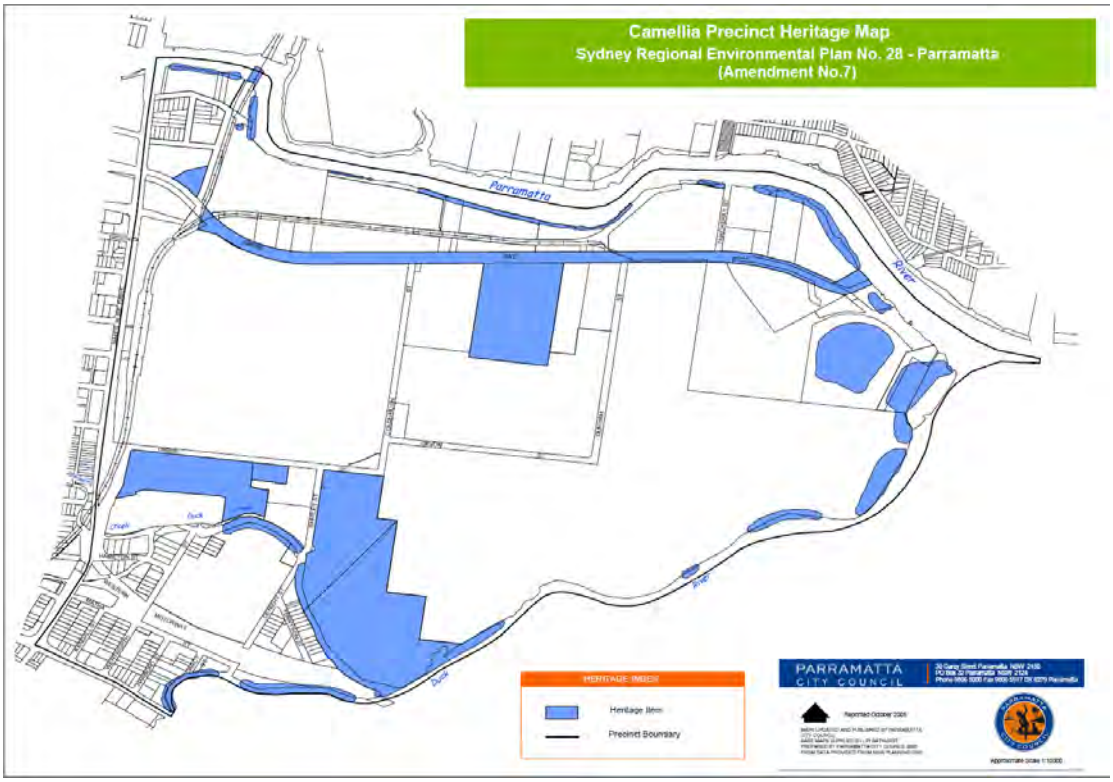

Figure 24. Camellia Precinct Heritage Map from Sydney Regional Environmental Plan No.28 – Parramatta (Amendment No.7), with listed Heritage Items shown in blue. (Source: Parramatta City Council).

A desktop survey of currently listed heritage items within the heritage precinct has revealed a number of items, including historic industrial sites, archaeological sites and landscape areas (Table 6; Musecape, 2012).

Table 6. List of heritage items derived from Schedule 6 (Heritage Items) within the area covered by Sydney REP No 28 Parramatta Amendment No.7, Schedule 3 Amendment of Parramatta Local Environmental Plan 1996 (Heritage and Conservation) and Schedule 5 (Heritage Items) in Parramatta LEP 2011

ITEM NO.	ADDRESS	SUBURB	ITEM	PROPERTY DESCRIPTION	LEVEL OF SIGNIFICANCE
I1	Parramatta River	Camellia	Wetlands		Local
I6	Grand Avenue	Camellia	Tram alignment		Local
I3	1 Grand Avenue	Camellia	Grave of Eliner Magee & child	Lot 1, DP 226202	Local
I2	1A Grand Avenue (north of)	Camellia	Clyde Carlingford Rail Bridge abutments		Local
I01643	1B Grand Avenue	Camellia	Sewage Pumping Station 67	Lot 2 DP 430623	State
I5	39 and 41 Grand Avenue	Camellia	Pumping Station	Lots 1 and 2, DP 615549	Local
SREP	3 Grand Avenue	Camellia	Wunderlich	Lot 4 DP 623497	Regional

ITEM NO.	ADDRESS	SUBURB	ITEM	PROPERTY DESCRIPTION	LEVEL OF SIGNIFICANCE
SREP	Unwin Street	Camellia	RTA Depot	Lot 120 DP 817742	Regional
SREP	2 Unwin Street (4a James Ruse Drive)	Camellia	Capral Aluminium	Lot 1 DP 818736	Regional

Further literature reviews revealed additional heritage items listed elsewhere in the catchment (Table 7; Molino Stewart, 2011). These sites have been extracted from the Australian Heritage Places Inventory, items listed under the NSW Heritage Act, items listed by State Agencies and items/locations listed in the various LEPs.

Table 7. Additional heritage items and their locations (Molino Stewart, 2011 and others)

ITEM NO.	ITEM NAME	ADDRESS	SUBURB
	Crest Theatre	157 Blaxcell Street	Granville
	Cottage (1)	1 Salisbury Road	Guildford
	Uniting Church	104 South Street	Granville
	Cottage (2)	54 Stuart Street	Granville
	Monuments	29 William Street	Granville
	Homes for the unemployed cottage	46 Bertha Street	Merrylands
	Wunderlich	10 Grand Avenue	Rosehill
	RTA Depot	4a James Ruse Drive	Rosehill
	Capral Aluminium	Unwin Street	Rosehill
	Former shop and dwelling	15 Abbott Street	Granville
	Terraces	5 – 23 Arthur Street	Granville
	Cottage (4)	29 Bertha Street	Merrylands
	Colquhuon park and monument t	196 Blaxcell Street	Granville
	Electrical substation	417 Blaxcell Street	Granville
	Electrical substation	2 Bright Street	Granville
	Cottage (5)	10 Bury Street	Guildford
	East St residences	21-23 East Street	Parramatta
	Granville pool	1a Enid Avenue	Granville
	Scout Hall	1A Glen Street	Granville
	Electrical substation	133 Guildford Road	Guildford
	Cottage (7)	2 Lisgar Street	Granville
	Sandstone bridge	The Avenue	Granville

Location of European heritage items and conservation precincts around the Duck River catchment is shown in the following map (Figure 25).

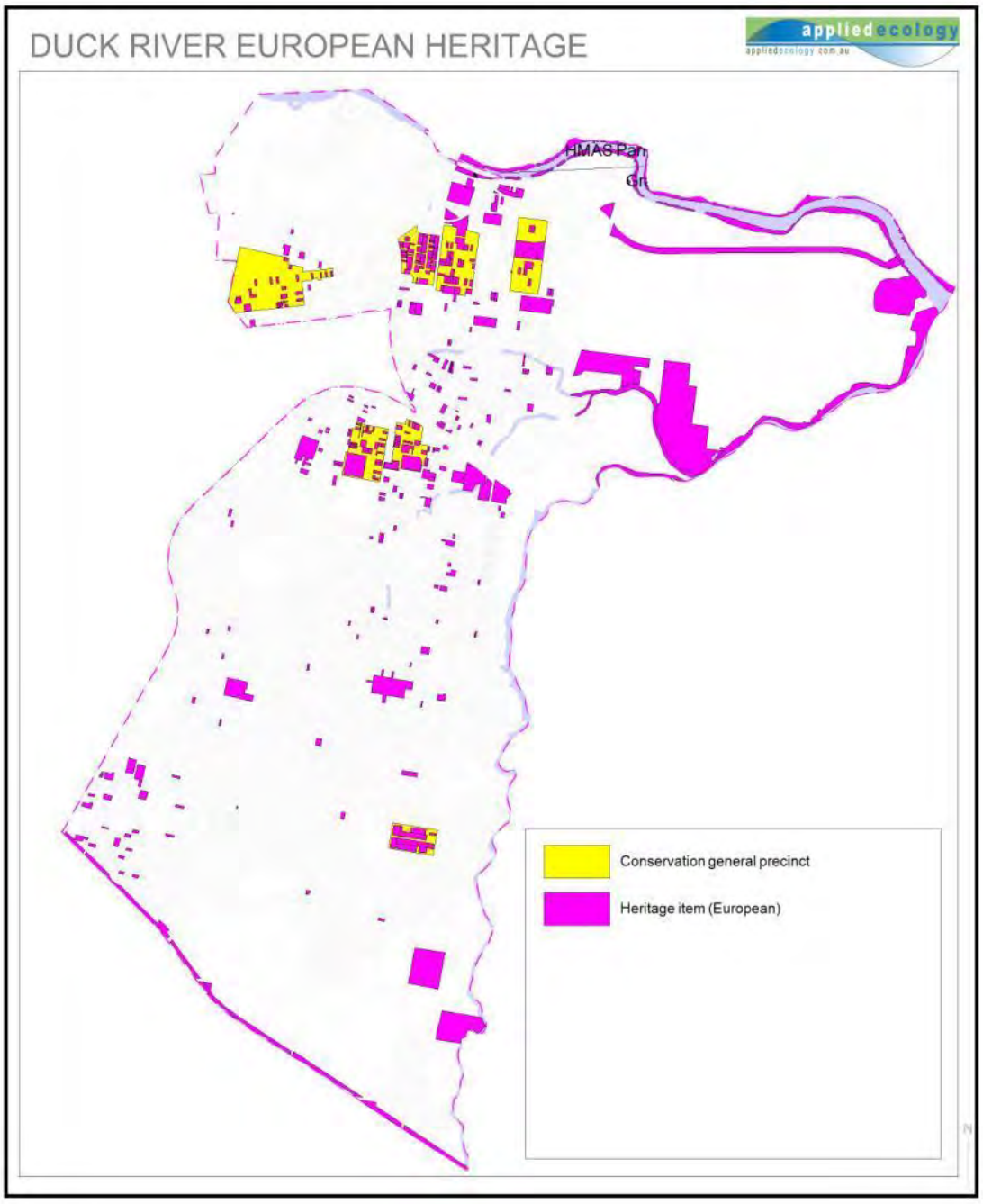

Figure 25. European heritage items and conservation precincts around the Duck River catchment

Analysis of documentary and physical evidence relating to the Study Areas has revealed a number of potential heritage items, archaeological sites and areas worthy of further investigation (Musecape, 2012).

1. Sandstone block crossing and stone “bridge” over piped outflow point for stormwater, both near Mackay Road, South Granville (Figure 26).
2. Low sandstone block retaining wall and possible road formation located next to the wetlands off Randolph Street, South Granville.

3. Remaining piles and other possible archaeological evidence from former Mona Street bridge (Figure 27).
4. Low weir across Duck River just upstream of the Main Western Railway Line bridge over the river.
5. Old abutments of Main Western Railway Line bridge over the river, just east of Clyde Railway station.
6. Brick arched former railway bridge over Duck River immediately downstream of existing Main Western Railway Line bridge.
7. Remains of timber former railway bridge over Duck River just upstream of Parramatta Road bridge. This bridge appears to have carried a spur line from near Clyde Railway Station to industrial sites on the western side of the river.
8. Possible archaeological evidence of wharf for former Parramatta Tramway on western side of confluence of Duck River and Parramatta River.

Figure 26. Sandstone block crossing and stone "bridge" over stormwater pipe, near Mackay Road, South Granville

Figure 27(a) Remaining piles from former Mona St bridge; (b) Original Mona St bridge in 1915 (Source: Auburn City Council Local Studies collection image 839)

5 REVIEW OF LITERATURE: BUFFER ZONES AND SETBACK

5.1 REVIEW OF SCIENTIFIC KNOWLEDGE

5.1.1 The importance of the riparian zone

A riparian zone is broadly defined as "the area of land that forms the banks of a waterbody and the adjacent land it directly affects, including the vegetation". Riparian systems play an important role in maintaining the ecological and geomorphic health of ecosystems, particularly in urban areas where the last remaining remnant vegetation often exists adjacent to streams within a catchment. Riparian systems also have disproportionately high levels of biodiversity in relation to the surrounding area because of their position at an interface between fluvial and terrestrial environments.

Riparian zones contain biota with various adaptations used to survive in a frequently changing environment with a diverse range of habitats. The value of connected wildlife corridors especially in maintaining biodiversity is widely recognised by scientists and environmental managers. They are considered to be of great importance for the movement of both flora and fauna across environmental gradients as well as helping to maintain high levels of genetic diversity especially in urban areas. Riparian vegetation also contributes large woody debris to the channel which is important for in stream habitat for fish and macroinvertebrates and affecting the flow of water.

Riparian vegetation plays a significant role in influencing the geomorphic condition of a stream by preventing bank erosion, aiding rainfall and runoff infiltration and contributing to soil, bank and channel stability. Riparian zones are sources of nutrients to the stream through leaf litter and organic matter and also nutrient sinks, storing nutrients from upslope, which is particularly significant in nutrient rich urban catchments. Riparian zones act also as a filter and a buffer against pollutants which may be derived from upslope urban or industrial areas. In addition to the ecosystem services they provide, riparian zones provide valuable social value due to their usefulness as aesthetic visual buffers, flood mitigation, property protection and enhanced economic value as well as amenity.

5.1.2 Riparian zones in an urbanised environment

Unfortunately, the highly productive nature of riparian land makes it a prime target for intensive cropping, intensive grazing and intensive irrigation, and this was the early history of land use change in the Duck River catchment. Further modification involved changes relating to industry establishment in areas that were accessible by water transport. Today, the scenic values associated with waterways can make adjacent land a prime target for development. Past patterns of modification along Duck River will drive the direction of more recent changes in land use. Tradeoffs will exist, depending on the relative importance of development and waterway improvement to the community.

In a disturbed catchment, once the nutrient levels in the water of the creek and creekbank soils become too high, the natural vegetation becomes out-competed by weeds. Consequently, relying solely on protection from clearing or erosion is insufficient to protect the integrity of the riparian vegetation. As a consequence of the high ecological and social value of riparian zones, there are often conflicting interests between conservation and development. Although some studies have

examined the relationship between buffer width and biodiversity, there remains a paucity of research in that area particularly with respect to urban environments.

5.1.3 Riparian buffers and zone boundaries

Current literature generally accepts the following assumptions:

- the riparian zone is a definable biophysical unit;
- a riparian buffer is a practical/functional construct, which may be influenced by the width of the riparian zone, but can include considerations of social equity, cost, practicality etc;
- the riparian zone width can vary between streams and along streams; and
- geomorphologic protection generally defines a minimum riparian zone (see Rutherfurd et al, 1999).

The use of nominated riparian buffer distances is common in planning and development regulation (e.g. a 40m protection zone applied in the Rivers and Foreshores Improvement Act 1948). However, the basis for the distances are not always apparent and may have a number of shortcomings, including:

- compromises which reflect social and political realities;
- adherence to a single width, regardless of biophysical context;
- use of arbitrary distances which may bear little relationships to a functional riparian zone; and
- a wide range of distances used in plans and policies, for example a range from 5m to 400m is used in a selection of Australian planning documents.

A more effective approach to defining the riparian zone was to use both structural (channel geomorphology, vegetation type) and functional (geomorphologic, hydrological and water quality processes) relationships. On this basis, different reaches will generally have different riparian zone widths and the best depiction of the zone is a continuously mapped line. The approach adopted the largest of a range of estimates at reach scale, based on using one or more of the methods in Table 8 (adapted from Montgomery Watson Harza (MWH) Australia P/L, 2003).

Table 8. Alternative methods for riparian zone estimation

BASIS FOR WIDTH	METHOD	COMMENTS
Channel depth and erosion rate	5m minimum, plus depth factor, plus establishment allowance[1]	The method is a means of determining widths for revegetation. For stable channels, riparian width may be underestimated (minimum 5m). Very useful for modified creeks.
Flora	Extent of riparian vegetation species or associations	Transitional or ecotonal vegetation tends to blur the boundaries. Clearing or weed growth can invalidate the estimate by masking potential riparian areas. Most useful for natural systems, but reliant on detailed species mapping. Some weed species can also be good indicators of zone, due to their response to moisture and nutrients.

BASIS FOR WIDTH	METHOD	COMMENTS
Flood levels	The zone of influence of relatively frequent flood events (e.g. ARI 1 year flood zone)	Choice of recurrence interval is subjective; inundation zone tends to increase rapidly from headwaters to lowlands. Otherwise, the method is reasonably precise and simple - if flood studies are available[2]. Wong et al (2000) suggested that 1.5 year ARI represents a re-set mechanism for stream communities. 1.5 year ARI may be a reasonable benchmark for riparian zones, although more research is needed to determine whether it is equally valid for pristine or fully developed streams. For small creeks, the entire floodplain may be narrow and smaller floods may not exceed channel capacity. Riparian vegetation may extend well above flood levels due to deep roots of some trees.
Water quality	The minimum distance through which the effects of surface water runoff are likely to be attenuated. The distance is primarily a function of soils, rainfall intensity, groundcover densities, slope and type of pollution.	This recognises that the riparian zone protects waterways from the direct influence of overland flow and the associated dissolved and particulate matter. The corollary is that the riparian zone itself influences water quality, ecology and local geomorphology (e.g. by supplying organic matter to the stream). Table 9 provides some rules of thumb.
Channel form	The shape of the channel can be used to infer a riparian zone for rock platforms (edge of platform) and for steep-sided gorges (edge of gorge at base).	The majority of channels in the LGA do not fall into these categories and channel form is difficult to use as a surrogate for riparian zones.

Notes:

1. Abernethy and Rutherfurd (1999); establishment is erosion rate (m/yr) multiplied by time for natural riparian forest to mature and stabilise banks (yr).
2. Draft Duck River Floodplain Risk Management Study and Plan (Molino Stewart/WMA, 2011).

Table 9.Minimum distances to attenuate impacts of overland flow[A]

SLOPE	GROUNDCOVER DENSITY		
	Low	Medium	High
Steep	50m	40m[B]	30m
Moderate	35m	30m	20m
Gentle	20m[C]	15m[C]	10m[C]

Notes: (see next page)

A. There is no definitive scientific study of water quality processes in the riparian zone in Australia, and the figures are a rough estimate, based on a various publications. The figures do not allow for rainfall intensity and soil type variation across the LGA.
B. A number of US brochures suggest a range of 38-46m for nutrient removal in forests with medium density groundcover on moderate slopes (e.g. Connecticut River Joint Commission, 1998)
C. Based on a study by McKergow et al (1999) and allowing for lower rainfall intensities and overland flow velocities; LWA (2000) recommend a minimum of 20m as being suitable for most situations, but needing to be wider where pollutant loads and slopes are greater.

Determining values associated with fauna movement can also be complex, although such considerations may be useful, especially if a creek's value would increase through the provision of a basic corridor linkage (i.e. ecological connectivity).

The implication of this approach is that the riparian zone may include existing developed areas – such as sporting fields, ovals, fences and even small buildings. In effect, these are part of the functional riparian zone, even though they are unnatural. From a land use management perspective, we suggest that the designation should not affect existing use rights, but that community education and landholder co-operation could be used by Council to actively support and encourage better management (such as joint rehabilitation projects and control of polluted runoff).

5.2 REVIEW OF CURRENT LEGISLATION

5.2.1 Planning Instruments and Controls (Buffer Zones and Setbacks)

Land zoning surrounding the Duck River is provided in the Parramatta Local Environment Plan (2011) and reproduced below. The Duck River itself is generally classified as Natural Waterway (W1). Land zoning surrounding the Duck River primarily consists of (see Figure 28):

- I1, General Industrial. Northern section of the study area;
- RE1, Public recreation;
- R2, Low density residential (limited areas adjacent to the waterway); and
- E2, Environment Conservation.

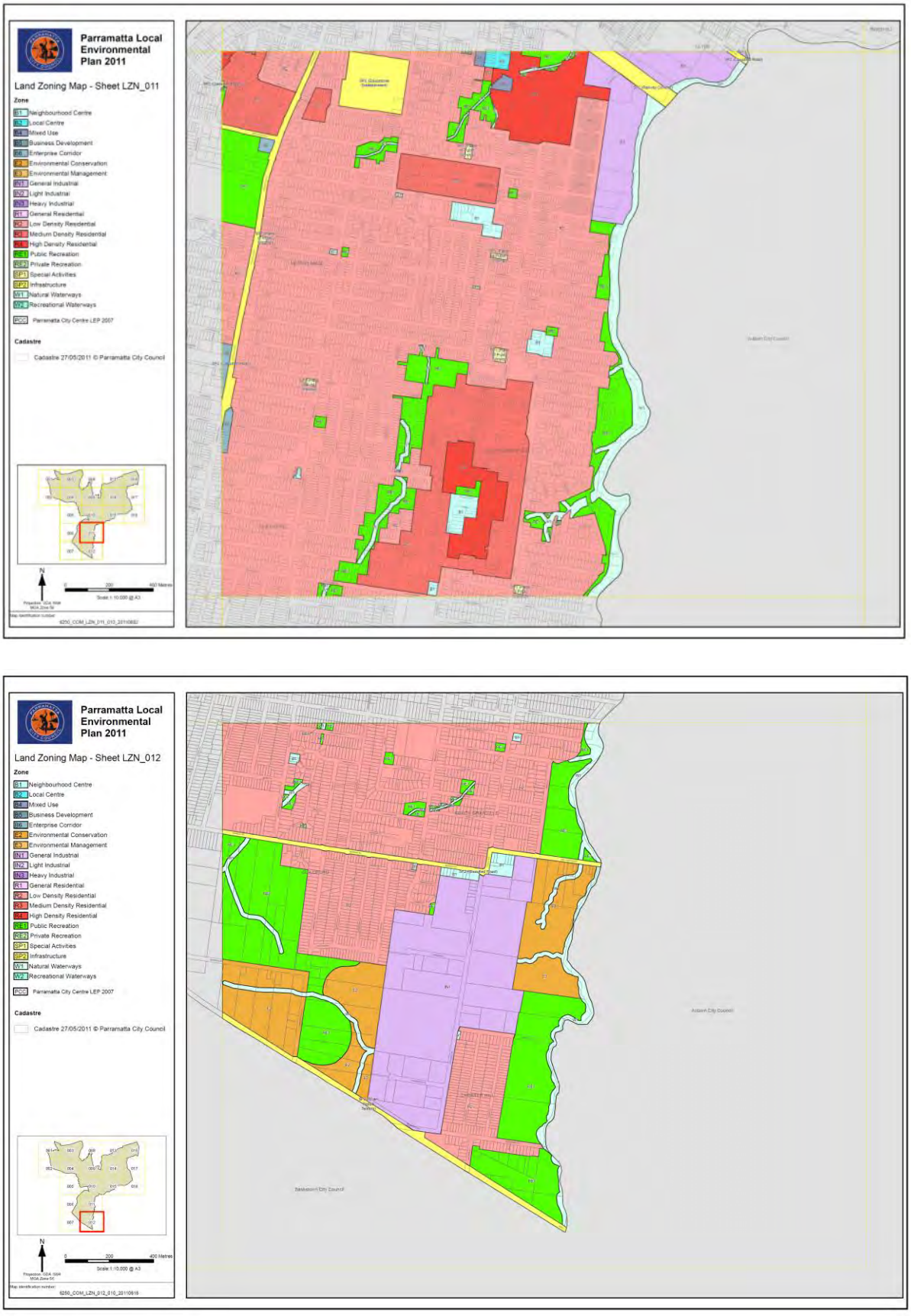

Figure 28. Land Use Zoning along the Duck River. PCC LEP 2011

Design principles regarding development that may apply to these land use zones adjacent to the Duck River in the LEP relating to the protection of waterways are:

- P.1 Development is to make provision for buffer areas for the preservation and maintenance of floodway, riparian corridors and habitat protection. Refer to Clause 6.7 Foreshore Building Line and Clause 6.5 Water Protection in the Parramatta LEP 2011.
- P.2 Development on land subject to Clause 6.5 Water Protection in the Parramatta LEP 2011 or that abuts a waterway is to be landscaped with local indigenous species, to protect bushland and wildlife corridors and soften the interface between the natural landscape and the urban environment. Riparian vegetation also plays an important role in stabilising bed and banks and attenuating flood flows.
- P.3 The piping, enclosing or artificial channelling of natural watercourses and drainage channels is not permitted. Consideration is to be given to re-opening piped or lined drainage systems wherever feasible.
- P.4 Development is to ensure that natural channel design principles are incorporated in any works on or in waterways.
- P.5 Ongoing maintenance costs are to be considered in the design of any waterway protection features.

The specific reference to provision of buffers in design principle P1 (above) refers to Clause 6.7 Foreshore Building Line and Clause 6.5 Water Protection in the Parramatta LEP 2011. The foreshore building line is outside of the study area and generally applies to foreshore downstream of the M4 motorway crossing. There is no specific reference to buffers or setbacks under Clause 6.5, Water Protection that may otherwise suggest a specific buffer distance or setback to riparian land and waterways.

Biodiversity design principles for development of land abutting land zones E2 and W1 in the LEP (2011) also recognise the need for "the requirement for provision of a buffer zone on the abutting land to protect the bushland area" although a specific distance/width is not specified. Molino Stewart (2011) suggests a riparian zone of between 20m and 40m on both sides of the Duck River based on the need for three specific zones:

1. Core riparian zone – land in and adjacent to the channel;
2. Vegetated buffer to protect the integrity of the core riparian zone; and
3. An asset protection zone for protection against bushfire damage.

5.2.2 Flooding

Flooding impacts to property on the Duck River between the Sydney Water pipeline and railway crossing appear to be limited as shown in Figure 29 (Molino Stewart 2011). This study showed that no properties are likely to be impacted in the 1 in 100yr ARI runoff event (or smaller events) and relatively few properties may be impacted in the PMF event. This study indicates that much of the development in the Duck River catchment between the pipeline and railway can be classified as low risk. The Duck River itself and surrounding lands may be considered high to medium risk attracting a wide range of planning controls and building restrictions for new developments, however much of the riparian corridor is already zoned for open space and non-urban land use.

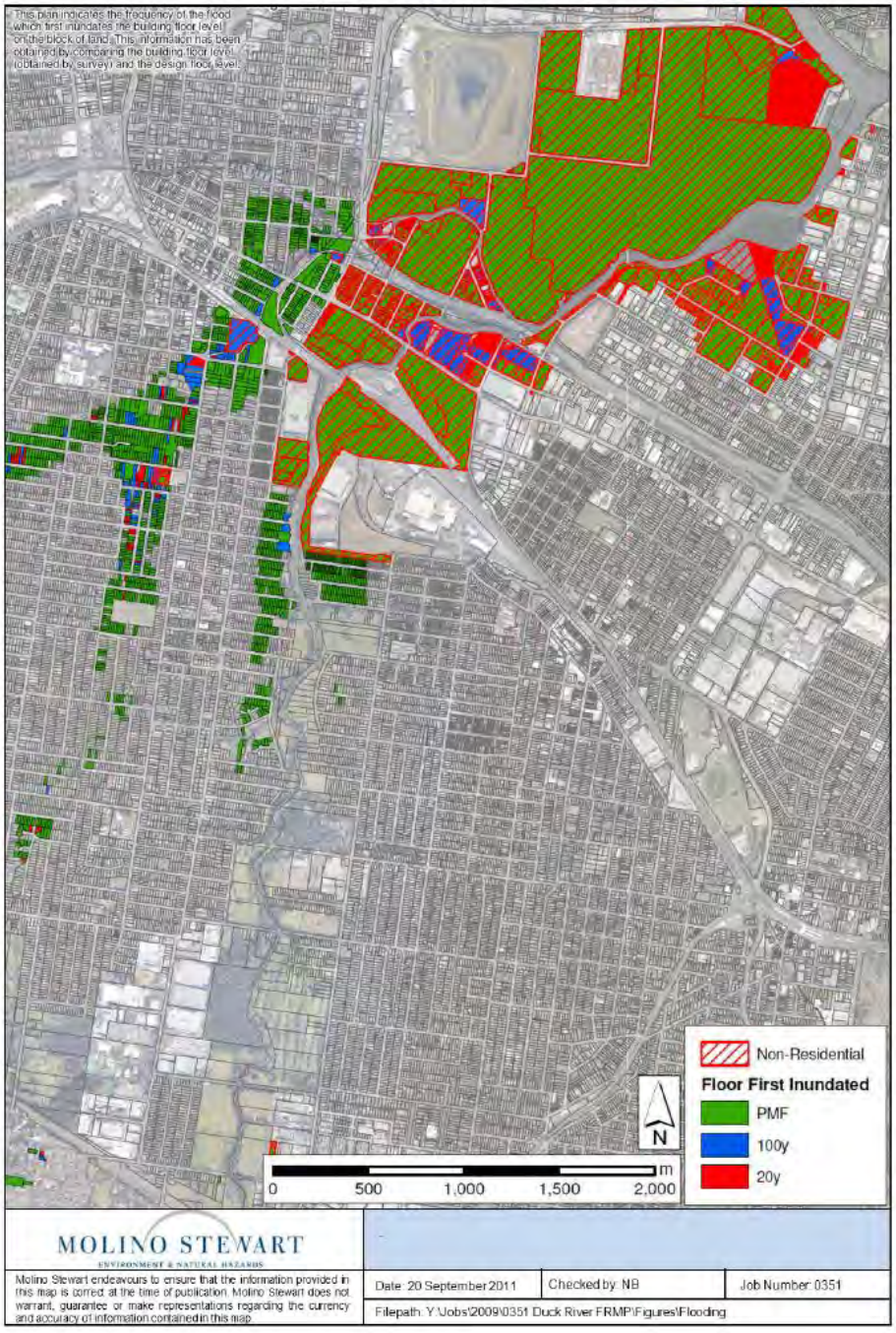

Figure 2: Overfloor flooding localities in Auburn/Parramatta

Figure 29. Overfloor flooding localities in the Duck River Catchment (Extracted from Molino Stewart 2011)

5.2.3 Additional local provisions

Part 6 of LEP 2011 includes several sub-clauses that provide additional protection for lands in the riparian corridor. Part 6.4 Biodiversity protection aims to maintain terrestrial and aquatic biodiversity, including the following:

a) protecting native fauna and flora,
b) protecting the ecological processes necessary for their continued existence,
c) encouraging the recovery of native fauna and flora and their habitats.

This clause applied to the following private lands (Figure 30):

Figure 30. Areas protected under Clause 6.4 Biodiversity protection (LEP 2011)

Part 6.5 Water protection aims to maintain the hydrological functions of riparian land, waterways and aquifers, including protecting the following:

a) water quality,
b) natural water flows,
c) the stability of the bed and banks of waterways,
d) groundwater systems.

And applied to the following private lands (Figure 31):

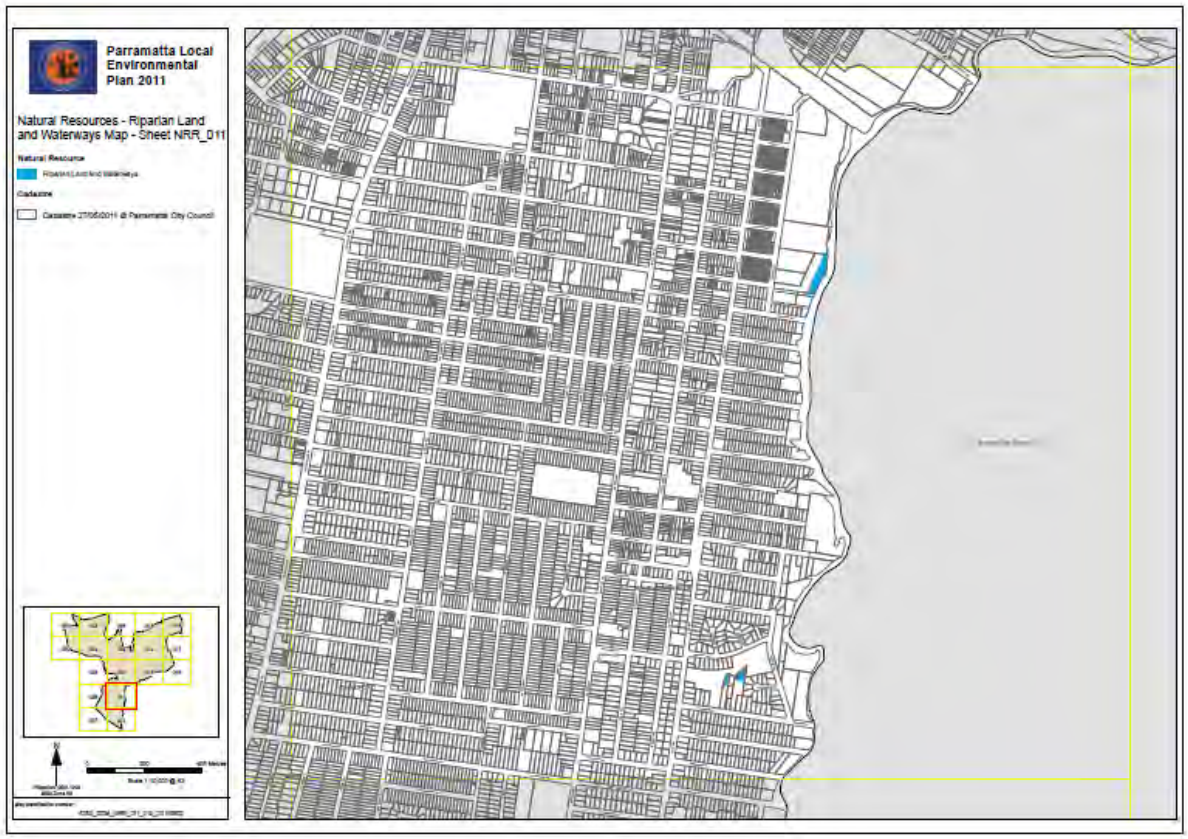

Figure 31. Areas protected under Clause 6.5 Water protection (LEP 2011)

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7 APPENDIX ONE: FEDERAL AND STATE LEGISLATION AND POLICIES

Table A 1. Overview of Legislation and its relevance for maintenance and rehabilitation in Duck River waterways corridor

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 main objects of this Act are: "_ to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance" and "_ 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. If approvals are required, NSW system can be accredited upon application being made to the Commonwealth Department.
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 is: "_ 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 waterways corridors should be undertaken within a framework of ESD.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
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 master plans.
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 master plans.
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 master plans will ensure management within a framework of ESD. Stakeholder and Focus Group meetings were designed to involve the community through the development of specific "Vision" for Duck River catchment.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
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.
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. Approvals may be required under this Act depending on the nature of the proposed works.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
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: • 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".	The Council's management of its waterways, and in particular the preparation of waterways Maintenance and Rehabilitation master plans, is driven through compliance with this Act.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
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. Noxious weeds declared in Parramatta LGA and recorded in Duck River catchment include: • Alligator Weed – Class 3 • Asparagus Fern – Class 4 • Asthma Weed – Class 4 • Balloon Vine – Class 4 • Blackberry – Class 4 • Bridal Creeper – Class 4 • Castor Oil Plant – Class 4 • Lantana – Class 4 • Large-leaved Privet – Class 4 • Madeira Vine – Class 4 • Montpellier Broom – Class 3 • Morning Glory – Class 4 • Sagittaria – Class 5 • Small-leaved Privet – Class 4
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 provides for a range of key pollution control legislation including waters, noise and air. 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.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
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.
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: • 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".	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.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
Water Management Act 2000	This Act replaces the Water Act 1912 and the River and Foreshores Improvement Act 1948 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"; • "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. If a 'controlled activity' is proposed on 'waterfront land', an approval is required under the Water Management Act. (s91) 'Controlled activities' include, inter alia: • the removal of material or vegetation from land by excavation or any other means; • the deposition of material on land by landfill or otherwise; or • any activity that affects the quantity or flow of water in a water source. 'Waterfront land' is defined as the bed of any river or lake, and any land lying between the river or lake and a line drawn parallel to and forty metres inland from either the highest bank or shore (in relation to non-tidal waters) or the mean high water mark (in relation to tidal waters).

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
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 master plans 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.
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 Duck River master plans.
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: "_ Protecting native species and ecosystems"; "_ Managing natural resources better"; and "_ Involving landowners and communities in biodiversity conservation".	This strategy ensures that State Government authorities involved throughout the preparation and implementation of master plans will focus broadly on biodiversity conservation.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
NSW Weirs Policy	The aim of this policy is to reduce and remediate the environmental impact of weirs. Main components of the policy require: _ the limiting of approvals for new and expanded weirs; _ the review of all existing weirs in NSW; and _ the consideration of the need for fishways ateach 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 master plans.
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 master plans.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
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	Where any works or activities to be implemented through the Masterplan 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 PLANS		
Draft Parramatta Local Environmental Plan (LEP) 2008	Draft Parramatta LEP 2008 describes the planning controls which apply to landuse zones throughout the Parramatta local government area. Most of the land within the riparian corridor is zoned: • E2 - Environmental conservation • RE1 – Public recreation	Any action or work required through implementation of the Masterplan will be prepared in accordance with the objectives and requirements of the relevant land use zone.
Draft Parramatta Development Control Plan (DCP) 2008	The Draft DCP 2008 provides controls to support the standards set down in the Draft PLEP 2008. This document will consolidate all of Council's existing DCPs into a single document. The controls will include requirements for such issues as setbacks.	Future actions or works proposed to be implemented through the Masterplans will be assessed against the appropriate performance standards set down in Parramatta's Draft DCP 2008.
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.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
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. 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.	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.
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.

8 APPENDIX TWO: AVIAN SPECIES RECORDED IN THE CATCHMENT

Table A 2. Avian species recorded in Duck River catchment and their location

COMMON NAME	SPECIES NAME	DUCK RIVER NORTH	DUCK RIVER SOUTH	CAMPBELL HILL-WADDANGALLI	UPPER DUCK CREEK	LOWER DUCK CREEK	LITTLE DUCK CREEK
Number of species by locality		43	28	31	12	6	10
Australasian Darter	*Anhinga melanogaster*	y				y	
Australian Magpie	*Gymnorhina tibicen*	y	y	y	y	y	y
Australian Raven	*Corvus coronoides*	y	y	y			
Australian White Ibis	*Threskiornis molucca*	y	y	y	y		y
Australian Wood Duck	*Chenonetta jabata*	y	y	y			
Azure Kingfisher	*Alcedo azurea*	y					
Barn Swallow	*Hirundo rustica*	y		y			
Bell Miner	*Manorina melanophrys*			y			
Black Bird	*Turdus merula*		y				
Black-faced Cuckoo Shrike	*Coracina novaehollandiae*			y			
Brown Thornbill	*Acanthiza pusilla*		y	y			
Bulbul*	*Pycnonotus jocosus*	y	y	y	y		y
Chestnut Teal	*Anas castanea*	y					
Common Starling*	*Sturnus vulgaris*			y			
Australian Coot	*Fulica atra*	y	y				
Crested Pigeon	*Ocyphaps lophotes*	y	y	y	y		y
Diamond Dove	*Geopelia cuneata*	y					
Domestic pigeon*	*Columba livia* f. *domestica*	y	y	y			
Dusky Moorhen	*Gallinula tenebrosa*	y	y				
Eastern Spinebill	*Acanthorhynchus tenuirostris*	y					
Galah	*Eolophus roseicapillus*					y	
Grey Butcherbird	*Cracticus torquatus*			y			
House Sparrow	*Passer domesticus*	y	y	y	y		
Indian (or common) Myna*	*Acridotheres tristis*	y	y	y	y		y
Jacky Winter	*Microeca fascinans*	y					
Koel (Common)	*Eudynamys scolopacea*		y				
Laughing Kookaburra	*Dacelo novaeguineae*	y	y	y			
Lewins Honeyeater	*Meliphaga lewinii*	y				y	
Little wattlebird	*Anthochaera chrysoptera*	y		y			
Magpie-lark (Pee wee)	*Grallina cyanoleuca*	y	y	y	y		y
Mallard	*Anas platyrhynchos*		y				
Masked Lapwing	*Vanellus miles*			y	y		
Noisy Miner	*Manorina melanocephala*	y	y	y	y	y	y
Olive-backed Oriole	*Oriolus sagittatus*	y					
Pacific Black duck	*Anas superciliosa*	y	y	y	y		

Pekin Duck (domestic duck breed)*	*Anas platyrhynchos domestica*	y					
COMMON NAME	SPECIES NAME	DUCK RIVER NORTH	DUCK RIVER SOUTH	CAMPBELL HILL-WADDANGALLI	UPPER DUCK CREEK	LOWER DUCK CREEK	LITTLE DUCK CREEK
Pied Currawong	*Strepera graculina*	y	y	y	y		
Purple Swamp Hen	*Porphyrio porphyrio*	y					
Rainbow Lorikeet	*Trichoglossus haematodus*	y		y			y
Red-browed Finch	*Neochmia temporalis*	y	y	y			
Red-rumped Parrot	*Psephotus haematonotus*		y				
Reed warbler	*Acrocephalus australis*	y					
Restless Flycatcher	*Myiagra inquieta*	y	y	y			y
Rock Dove*	*Columba livia*		y				
Scarlet Robin**	*Petroica boodang*			y			
Silvereye**	*Zosterops lateralis*			y			
Spotted Turle-Dove*	*Streptopelia chinensis*	y	y	y			y
Striated Pardalote	*Pardalotus striatus*	y	y				
Sulphur-crested Cockatoo	*Cacatua galerita*	y			y		
Superb Fairy-wren	*Malurus cyaneus*	y	y	y		y	
Tawny Frogmouth	*Podargus strigoides*	y	y				
Welcome Swallow	*Hirundo neoxena*	y					
White-plumed Honeyeater	*Lichenostomus penicillatus*	y					
Willie Wagtail	*Rhipidura leucophrys*	y		y			
Yellow Thornbill	*Acanthiza nana*	y					
Yellow-faced Honeyeater	*Lichenostomus chrysops*	y		y			
Yellow-tailed Black Cockatoo	*Calyptorhynchus funereus*	y					

9 APPENDIX THREE: OTHER FAUNA SPECIES RECORDED IN DUCK RIVER CATCHMENT

Table A 3. Other species recorded in Duck River catchment and their location

COMMON NAME	SPECIES NAME	DUCK RIVER NORTH	DUCK RIVER SOUTH	CAMPBELL HILL-WADDANGALLI	UPPER DUCK CREEK	LOWER DUCK CREEK	LITTLE DUCK CREEK
FROGS							
Bleating Tree Frog	*Litoria dentata*		y				
Common Froglet	*Crinia signifera*		y				y
Eastern Banjo Frog	*Limnodynastes dumerilii*	y	y	y			y
Peron's Tree Frog	*Litoria peronii*			y			
Green Tree Frog	*Litoria caeralea*	y	y				y
REPTILES							

COMMON NAME	SPECIES NAME	DUCK RIVER NORTH	DUCK RIVER SOUTH	CAMPBELL HILL-WADDANGALLI	UPPER DUCK CREEK	LOWER DUCK CREEK	LITTLE DUCK CREEK
Delicate or Garden Skink	*Lampropholis delicata*		y			y	
Eastern Blue-tongue Lizard	*Tiliqua scincoides scincoides*	y		y			
Eastern Blue-tongue Lizard	*Tiliqua scincoides*	y					
Eastern Water Dragon	*Physignathus lesueurii*	y	y				
Eastern Water Skink	*Eulamprus quoyii*	y	y	y			
Grass Sun-skink	*Lampropholis guichenoti*	y	y			y	
Jacky Lizard	*Amphibolurus muricatus*		y				
Red-bellied Black Snake	*Pseudechis porphyriacus*	y					
MAMMALS							
Grey-headed Flying-fox**	*Pteropus poliocephalus*	y	y				y
Eastern Bent-wing Bat**	*Miniopterus schreibersii oceanensis*		y	y			
Gould's Wattle Bat	*Chalinolobus gouldii*		y	y			
Long-eared Bat	*Nyctophilus* sp			y			
Southern Freetail Bat (short penis)	*Mormopterus* sp. 2		y				
White-striped Free-tailed Bat	*Tadarida australis*			y			
Yellow-bellied Sheathtail Bat**	*Saccolaimus flaviventris*		y				
Domestic Cat*	*Felis catus*	y	y		y	y	y
Domestic Dog*	*Canis lupus*	y	y	y			y
Rabbit*	*Oryctolagus cuniculus*			y			
Red Fox	*Vulpus vulpus*		y	y			
FISH							
Common Carp*	*Cyprinus carpio*	y	y				
Mosquito Fish*	*Gambusia holbrookii*		y	y			
OTHER HERPS							
Long necked turtle	*Chelodina longicollis*	y					
THREATENED INVERTEBRATES							
Cumberland Land Snail	*Meridolum corneovirens*		y				

10 APPENDIX FOUR: NATIVE FLORA SPECIES RECORDED IN DUCK RIVER CATCHMENT

Table A 4. Native flora species recorded in Duck River catchment and their location

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Acacia binervia	Coastal Myall		y
Acacia brownei			y
Acacia decurrens	Sydney Green Wattle	y	y
Acacia falcata		y	y
Acacia longifolia var. longifolia	Sydney Golden Wattle	y	y
Acacia parramattensis	Parramatta Green Wattle	y	y
Acacia pubescens	Downy Wattle	y	y
Acacia stricta	Straight Wattle		y
Acacia ulicifolia	Prickley Moses	y	y
Adiantum aethiopicum	Common Maidenhair Fern	y	y
Agrostis aemula	Blown Grass		y
Agrostis avenacea	Blown Grass		y
Allocasuarina torulosa	Forest Oak		y
Alternathera denticulata	Lesser Joyweed		y
Amyema gaudichaudii			y
Angophora floribunda	Rough Barked Apple	y	y
Aristida ramosa	Three-awn Speargrass	y	y
Aristida vagans	Three-awn Speargrass	y	y
Arthrodium minus	Small Vanilla Lily		y
Arthropoduum milleflorum	Pale Vanilla Lily		y
Asperula conferta	Common Woodruff		y
Asterolasia correifolia			y
Astoloma humifusum			y
Billardiera scandens	Apple Berry	y	y
Boronia polygalifolia	Milkwort Boronia		y
Bossiaea buxifolia			y
Bossiaea prostrata			y
Bothriochloa decipiens			y
Bothrochloa macra			y
Brachiara foliosa			y
Brachychiton populneus	Kurrajong		y
Brachycome angustifolia var. angustifolia			y
Breynia oblongifolia	Coffee Bush	y	y
Brunoniella australis	Blue Trumpet	y	y
Brunoniella pumilio	Dwarf Trumpet		y

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Bursaria spinosa	Blackthorn	y	y
Caesia parviflora	Pale Grass Lily		y
Caesia vittata	Blue Grass lily		y
Callistemon linearifolius	Bottlebrush		y
Callistemon linearis	Narrow-leaved Bottlebrush		y
Callistemon pinifolius	Bottlebrush		y
Callistemon rigidus	Stiff Bottlebrush	y	y
Callistemon salignus	Willow Bottlebrush		y
Calotis cuneifolia	Blue Burr-daisy	y	y
Calotis lappulacea	Wooly-headed Burr-daisy		y
Carex inversa			y
Cassinia aculeata	Dogwood		y
Cassytha glabella	Slender Devil's Twine		y
Cassytha pubescens	Common Devils Twine	y	y
Casuarina glauca	Swamp She-Oak	y	y
Cayratia clematidea		y	
Centella asiatica	Centella	y	y
Centipeda minima	Spreading Sneezeweed		y
Cheilanthes sieberi ssp sieberi	Mulga Fern	y	y
Chorizema parviflorum			y
Clematis aristata	Old Man's Beard		y
Clematis glycinoides var. glycinoides	Forest Clematis, Old Man's Beard	y	y
Commelina cyanea	Scurvy Weed	y	y
Correa reflexa		y	y
Cotula australis			y
Cotula coronopifolia	Water Buttons, Marsh Daisy		y
Crassula sieberana	Austral Stonecrop		y
Cymbopogon refractus	Barbed-wire Grass	y	y
Cynodon dactylon	Common Couch		y
Cyperus gracilis	Slender Sedge	y	
Cyperus mirus	Sedge		y
Cyperus polystachyos	Sedge		y
Austrodanthonia linkii var. fulva	Wallaby Grass	y	y
Austrodanthonia linkii var. linkii	Wallaby Grass		y
Austrodanthonia longifolia	Wallaby Grass		y
Austrodanthonia racemosa	Wallaby Grass	y	y
Austrodanthonia setacea	Wallaby Grass		y
Austrodanthonia tenuior	Wallaby Grass	y	y
Daviesia ulicifolia		y	y

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Dendrophthoe vitellina			y
Desmodium rhytidophyllum			y
Desmodium varians			y
Deyeuxia appressa	Bent Grass		y
Deyeuxia quadriseta	Reed Bent Grass		y
Dianella caerulea	Blue Flax Lily		y
Dianella laevis	Flax Lily		y
Dianella longifolia	Flax Lily	y	
Dianella revoluta	Mauve Flax Lily	y	y
Dichelacne micrantha	Shorthair Plume Grass	y	y
Dichelacne rara	Plume Grass		y
Dichondra repens	Kidney Weed	y	y
Dichopogon strictus	Grass Lily		y
Digitaria parviflora	Small-flower Fingergrass		y
Digitaria ramularis	Fingergrass		y
Dillwynia juniperina	Parrot Pea		y
Dillwynia sieberi		y	
Diuris brevifolia	Double Tail		y
Diuris maculata	Spotted Double Tail		y
Diuris sulphurea	Tiger Orchid		y
Dodonaea triquetra	Hop Bush	y	y
Drosera peltata	Sundew		y
Dysphania littoralis			y
Echinochloa telmatophila			y
Echinopogon caespitosus var. caespitosus	Tufted Hedgehog Grass	y	y
Echinopogon ovatus	Hedgehog Grass	y	y
Einadia hastata	Einadia	y	y
Einadia nutans ssp. nutans	Einadia		y
Einadia polygonoides	Einadia		y
Einadia trigonos	Einadia		y
Entolasia marginata	Right-angle Grass	y	y
Entolasia stricta	Right-angle Grass	y	y
Epilobium billardierianum ssp. billardierianum	Willow Herb		y
Epilobium billardierianum ssp. cinereum	Willow Herb		y
Eragrostis philippica	Love Grass		y
Eragrostis brownii	Browne's Love Grass	y	y
Eragrostis parviflora	Love Grass		y
Eremophila debilis		y	y

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Eriochloa pseudoacrotricha	Early Spring Grass		y
Eucalyptus amplifolia	Cabbage Gum	y	y
Eucalyptus crebra		y	
Eucalyptus fibrosa ssp. fibrosa	Broad-leaved Ironbark	y	y
Eucalyptus globoidea	White Stringybark	y	y
Eucalyptus longifolia	Woolybutt		y
Eucalyptus moluccana	Grey Box	y	y
Eucalyptus moluccana X Eucalyptus fibrosa ssp. fibrosa			y
Eucalyptus punctata ssp. punctata	Grey Gum	y	y
Eucalyptus resinifera	Red Mahogany		y
Eucalyptus tereticornis	Forest Red Gum		y
Euchiton sphaericus		y	
Eustrephus latifolius	Wombat Berry	y	y
Exocarpos cupressiformis	Cherry Ballart	y	y
Exocarpos strictus	Dwarf Currant		y
Gahnia aspera	Saw Sedge	y	y
Gahnia melanocarpa	Saw Sedge		y
Geranium solanderi	Cutleaf Cranesbill		y
Glochidion ferdinandi	Cheese Tree		y
Glossogyne tenuifolia	Cobblers Tack		y
Glycine clandestina	Love Creeper	y	y
Glycine microphylla	Lesser Love Creeper	y	
Glycine tabacina	Love Creeper		y
Gompholobium glabratum	Golden Glory Pea		y
Gonocarpus tetragynus	Poverty Raspwort		y
Goodenia bellidifolia ssp. bellidifolia	Daisy-leaved Goodenia		y
Goodenia hederacea subsp. hederacea	Violet-leaved Goodenia	y	y
Goodenia ovata	Hop Goodenia		y
Goodenia paniculata	Swamp Goodenia		y
Hakea sericea	Bushy Needlebush		y
Hardenbergia violacea	Hardenbergia	y	y
Helichrysum apiculatum	Paper Daisy		y
Helichrysum diosmifolium	Paper Daisy		y
Helichrysum scopioides	Paper Daisy		y
Hibbertia aspera	Guinea Flower		y
Hibbertia diffusa	Guinea Flower		y
Hibbertia pedunculata	Guinea Flower		y
Hovea longifolia var. longifolia			y

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Hydrocotyle peduncularis	Native Pennywort		y
Hypericum gramineum	Native St Johns Wort		y
Hypoxis hygrometrica	Yellow Stars		y
Imperata cylindrica var. major	Blady Grass	y	y
Indigofera australis	Indigofera	y	y
Isotoma fluviatalis ssp. fluviatalis			y
Jacksonia scoparia	Dogwood		y
Juncus bufonius	Juncus		y
Juncus homalocaulis	Juncus		y
Juncus planifolius	Broad-leaf Rush		y
Juncus sarophorus	Juncus		y
Juncus usitatus	Common Rush		y
Kennedia rubicunda	Dusky Coral Pea		y
Kunzea ambigua	Tick Bush		y
Lachnagrostis filiformis		y	
Lagenifera sp.			y
Lagenifera stipatata			y
Lasiopetalum ferrugineum		y	
Lasiopetalum parviflorum	Rusty Petals		y
Laxmannia gracilis		y	
Lepidosperma laterale		y	
Lepidosperma lineare	Sword Sedge		y
Leptospermum attenuatum	Tea Tree		y
Leptospermum flavescens	Tea Tree		y
Leucopogon juniperinus	Bearded Heath	y	y
Leucopogon lanceolatus var. lanceolatus	Lance Beard Heath		y
Linum marginale	Native Flax		y
Lissanthe strigosa	Native Cranberry	y	y
Lomandra filiformis ssp. coriacea	Mat Rush	y	y
Lomandra longifolia	Mat Rush	y	y
Lomandra multiflora ssp. multiflora	Mat Rush	y	y
Macrozamia spiralis	Burrawang	y	y
Maytenus silvestris		y	y
Melaleuca decora	White Feather Honeymyrtle	y	y
Melaleuca erubescens	Pink Honeymyrtle		y
Melaleuca linariifolia	Snow-in-Summer		y
Melaleuca nodosa	Ball Honeymyrtle	y	y
Melaleuca quinquenervia		y	
Melaleuca sieberi		y	

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Melaleuca styphelioides	Prickly-leaved Paperbark	y	y
Mentha saturejoides	Creeping Mint		y
Microlaena stipoides var. stipoides	Weeping Meadow Grass	y	y
Mitrasacme polymorpha	Mitreworts		y
Muellerina eucalyptioides		y	y
Myoporum insulare	Boobialla		y
Notelaea longifolia f. longifolia	Mock Olive	y	y
Notelaea ovata	Mock Olive		y
Olearia microphylla	Bridal Daisy Bush		y
Olearia visciudula	Daisy Bush		y
Homalanthus populifolius	Bleeding Heart Tree	y	y
Omphacomeria acerba			y
Opercularia aspera	Coarse Stinkweed		y
Opercularia diphylla	Stinkweed	y	y
Opercularia varia	Variable Stinkweed		y
Oplismenus imbecillis	Basket Grass		y
Oxalis corniculata			y
Oxalis perennans		y	
Pandorea pandorana ssp. pandorana	Wonga Vine	y	y
Panicum effusum	Hairy Panic		y
Panicum simile	Two-colour Panic		y
Paspalidium aversum			y
Paspalidium criniforme			y
Paspalidium radiatum			y
Paspalum vaginatum	Saltwater Couch		y
Pelargoium inodorum	Wild Geranium		y
Pellaea falcata	Sickle Fern		y
Persicaria lapathifolium	Knotweed		y
Persicaria sp. A, once *Polygonum decipiens*	Knotweed		y
Persoonia linearis	Narrow-leaved Geebung	y	y
Phragmites australis	Giant Reed		y
Phyllanthus gasstroemii	Spurge		y
Pimelea linifolia	Rice Flower	y	y
Pittosporum revolutum	Pittosporum		y
Pittosporum undulatum	Sweet Pittosporum	y	y
Plectranthus parviflorus	Cockspur		y
Poa labillardierei	Snow Grass	y	
Polymeria calycina	Swamp Bindweed	y	y

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Polyscias sambucifolia	Elderberry Panax		y
Pomaderris ferruginea	Rusty Pomaderris		y
Pomaderris lanigera	Wooly Pomaderris		y
Poranthera microphylla			y
Pratia purpurascens	Whiteroot	y	y
Pseuderanthemum variabile	Pastel Flower	y	
Pseudognaphalium luteoalbum	Jersey Cudweed		y
Pterostylis nutans	Parrot's Beak Orchid		y
Pultenaea retusa	Notched Bush Pea		y
Pultenaea villosa	Hairy Bush Pea	y	y
Ranunculus lappaceus	Common Buttercup		y
Rapanea variabilis	Muttonwood		y
Rubus parvifolius	Native Raspberry		y
Rulingia pannosa			y
Rumex brownii	Swamp Dock		y
Sarcopetalum harveyanum	Pearl Vine		y
Scaevola albida	Pale Fan Flower		y
Senecio hispidulum var. hispidulus	Rough Groundsel		y
Senecio hispidulus var. dissectus	Rough Groundsel		y
Senecio linearifolius	Groundsel		y
Senecio quadridentatus	Groundsel		y
Sporobolus creber		y	
Sporobolus elongatus	Couch		y
Stackhousia viminea			y
Austrostipa pubescens	Tall Speargrass		y
Austrostipa rudis ssp. nervosa	Speargrass	y	y
Austrostipa scabra	Speargrass		y
Syncarpia glomulifera	Turpentine		y
Thelymitra pauciflora	Slender Sun Orchid		y
Themeda australis	Kangaroo Grass	y	y
Thysanotus tuberosus	Fringe Lily		y
Tricoryne elatior	Yellow Rush-Lily		y
Tricoryne simplex	Yellow Rush-Lily		y
Triplodiscus pygmaeus			y
Tylophoroa barbata		y	y
Typha domingensis	Bullrush		y
Typha orientalis	Bullrush		y
Vernonia cinerea var. cinerea			y
Veronica calycina	Speedwell		y

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Veronica plebeia	Speedwell		y
Viola betonicifolia	Purple Violet		y
Vittadinia cuneata	Fuzzweed		y
Vittadinia. muelleri	Fuzzweed		y
Wahlenbergia communis	Tufted Bluebell		y
Wahlenbergia gracilis	Native Bluebell		y
Wahlenbergia stricta	Tall Bluebell		y
Xanthorrhoea resinosa ssp. concava	Grass Tree		y
Zieria smithii	Sandfly Zieria	y	y
Zornia dyctiocarpa			y

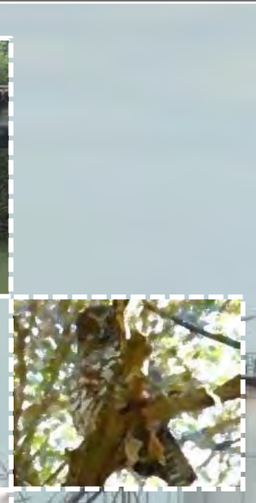
11 APPENDIX FIVE: RESULTS OF AHIMS BASIC SEARCHES

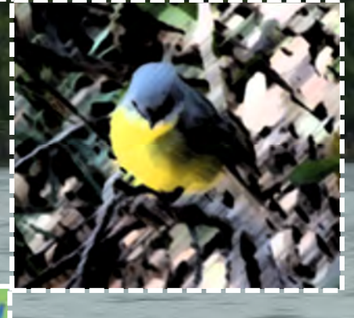
FOR INTERNAL USE ONLY

DETAILED MAPPING OF THE DUCK RIVER CATCHMENT

Prepared for Parramatta City Council

By Applied Ecology Pty Ltd





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DOCUMENT VERIFICATION

Project Title	**DUCK RIVER CATCHMENT WATERWAYS MAINTENANCE AND REHABILITATION MASTER PLAN**
Document Title	**PRELIMINARY ASSESSMENT OF THE DUCK RIVER CATCHMENT WATERWAYS**
Client	**Parramatta City Council**
Client contact	**Pino Todarello**

Revision	Prepared by	Reviewed by	Date
Draft (D)	**MB/AC/JS**	**A. Collins, P. Todarello**	**May 2012**
Final			**Issued 19th October 2012**

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ACKNOWLEDGMENTS

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Anthony Collins Parramatta City Council
Greg Hodges Auburn City Council

Jonathon Chan SMCMA

Vector images (used in cross sections) courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/)

CONTENTS

DETAILED MAPPING OF DUCK RIVER CATCHMENT

METHODOLOGY

The first stage in the detailed mapping process was to divide each stream into reaches. Determination of reaches and sample points was conducted using the following steps:

1. **Division of longitudinal continuity:** Individual reaches were identified as being longitudinally bounded by a confluence or termination of the stream.
2. **Division of different land use:** Changes in land use between bushland, urban areas and sporting fields/parks were used to further sub-divide the reaches. Land surface composition, in particular, area of impervious surfaces can greatly impact the quality and quantity of stormwater and thus affects stream condition.
3. **Division by buffer width:** For bushland and parkland stretches, the reaches were further divided according to width of riparian buffer (distance of vegetated zone before urban development). A substantive riparian buffer is in effect a "biophysical highway;" it provides effective filtration by trapping sediments and nutrients, attenuates flood impacts and provides habitat and wildlife corridors. Presence of headwalls, culverts and other infrastructure were used to further subdivide reaches.

Reach watershed profiles were created and used to build an ecological profile for each identified reach, including:

a) contours;
b) physical features/structures, barriers;
c) stormwater outlets, including piped and open channel drainage within the catchment (location, impact, litter loads, scour etc);
d) comparative land use, with typical cross-sections for each reach;
e) geomorphic features (bank type, pools, erosion points, deposition zones, bed material etc);
f) stream behaviour and processing zones, existing bank structure/works, floodplain limits;
g) vegetation associations, aquatic flora and fauna, level of weed infestation, significant snags, vegetation blockages;
h) other information considered necessary (eg contaminated sites such as landfill sites and asbestos contamination, existing gross pollutant traps and weirs, existing volunteer and contract bush regeneration sites, cadastre maps and aerial photos, service facilities such as sewerage, power, gas and water, and evidence of encroachment/dumping)

This data will underpin the development of the prioritised works plan and maintenance plan, and draws largely on the Australian Streambank Rehabilitation Manual Vols 1 & 2 (Rutherford et al, 1999).

THE CATCHMENT

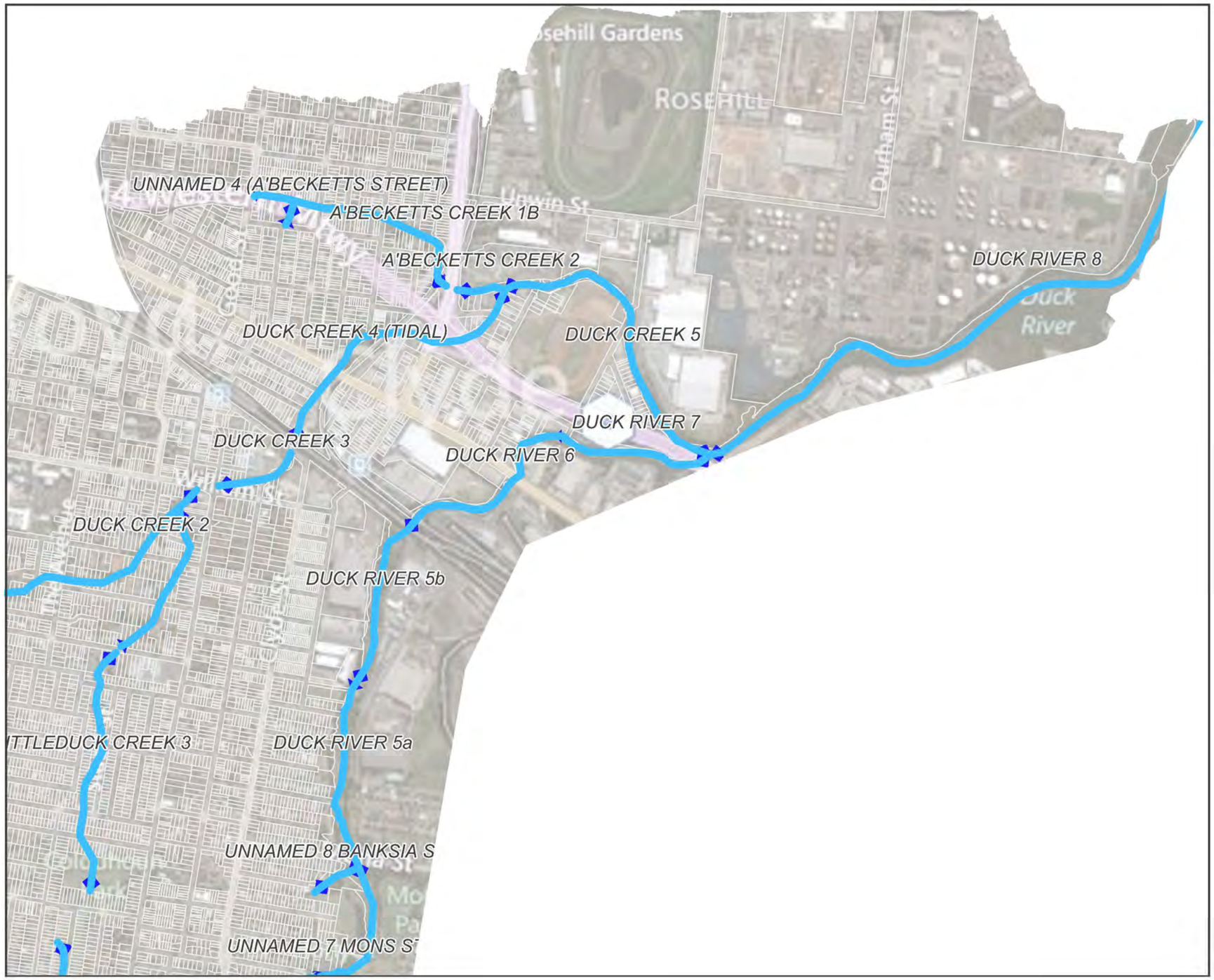
OVERVIEW OF MAPPING

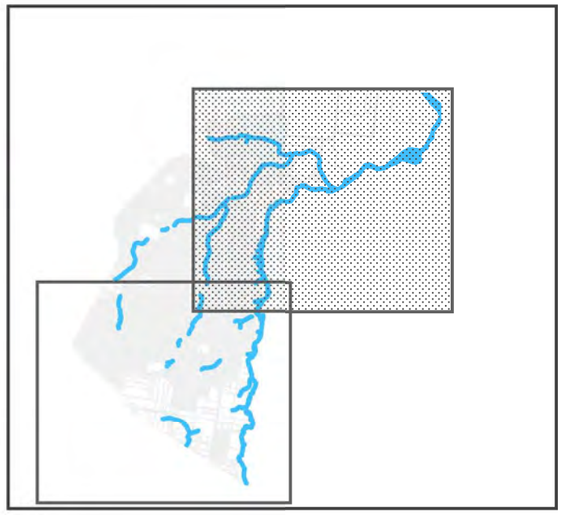
All maps were prepared using MapInfo v11. All products are in .tab format **Projection: MGA56** **Datum: GDA94**

The following maps were prepared from database reviews and field survey data:

	MAP NAME	MAPSHEETS#	DESCRIPTION	DATA SOURCE
1	REACH OVERVIEW DUCK RIVER CATCHEMNT PARRAMATTA LGA	2	Watercourses were divided into reaches. These sheets provide an overview of the location of these reaches within the Duck River catchment	Cadastre-PCC Watercourses-PCC AP-Microsoft terra server Map server
2	ELEVEVATION MODEL (2M CONTOUR) DUCK RIVER CATCHMENT PARRAMATTA LGA	1	Elevation model (2m contours) for Duck River Catchment	Contour_2 - PCC
3	CHANNEL ATTRIBUTES DUCK RIVER CATCHMENT PARRAMATTA LGA	2	Observed erosion/deposition features reach overview	Field observations Cadastre-PCC Watercourses-PCC
4	CHANNEL PROCESSES DUCK RIVER CATCHMENT PARRAMATTA LGA	2	Observed processes reach overview	Field observations Cadastre-PCC Watercourses-PCC
5	CROSS SECTIONS	12	Typical reach cross sections for the key reach types within the catchment	Tidal reaches: SMCMA: DR_XpRafts_SubCats Non-tidal reaches: field work Vector images (used in cross sections) courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/)
6	PIPE NETWORK, GPTS AND WEIRS- DUCK RIVER CATCHMENT PARRAMATTA LGA	3	Pipe network and outlets to watercourses and any stormwater improvement devices noted and any other obstructions noted. This data is potentially incomplete due to the concealed nature of many GPTs (such as CDS units)	Field observations Cadastre-PCC Watercourses-PCC Pipe network-PCC
7	VEGETATION COMMUNITIES DUCK RIVER CATCHMENT PARRAMATTA LGA	3	Vegetation communities are represented by polygons.	Cadastre-PCC Watercourses-PCC Vegetation (Draft) : SMCMA
8	BUSHCARE/CONTRACT WORK SITES DUCK RIVER MAIN CHANNEL PARRAMATTA LGA	3	Bushcare and contract work sites as polygons overlaid on extant vegetation to provide context of current and past works (2008-)	Conversion of hard data provided by PCC Cadastre-PCC Watercourses-PCC Vegetation (Draft) : SMCMA
9	LAND USE DUCK RIVER CATCHEMNT PARRAMATTA LGA	3	Key land use categories for each minor subcatchments adjoining open watercourses are represented graphically as % of subcatchment area	Subcatchments: SMCMA: - DR_XpRafts_SubCats Cadastre-PCC Watercourses-PCC
10	AHIMs SEARCH DUCK RIVER CATCHMENT PARRAMATTA LGA	1	AHIMs database search based on lot or DP numbers as per cadastre layer of lots adjoining watercourses + 50 m buffer	Cadastre-PCC Watercourses-PCC
11	HERITAGE ITEMS (EUROPEAN/GENENERAL) DUCK RIVER CATCHMENT PARRAMATTA LGA	3	Lots based maps where lots contain heritage items of local, state or national significance	Heritage-PCC Cadastre-PCC Watercourses-PCC
12	CONTAMINATED SITES DUCK RIVER CATCHMENT PARRAMATTA LGA	1	Sites from NSW Contaminated Land Register, accessed 10th May, 2012	Cadastre-PCC Watercourses-PCC

REACH OVERVIEW DUCK RIVER CATCHMENT PARRAMATTA LGA





Cadastre

N

0 500

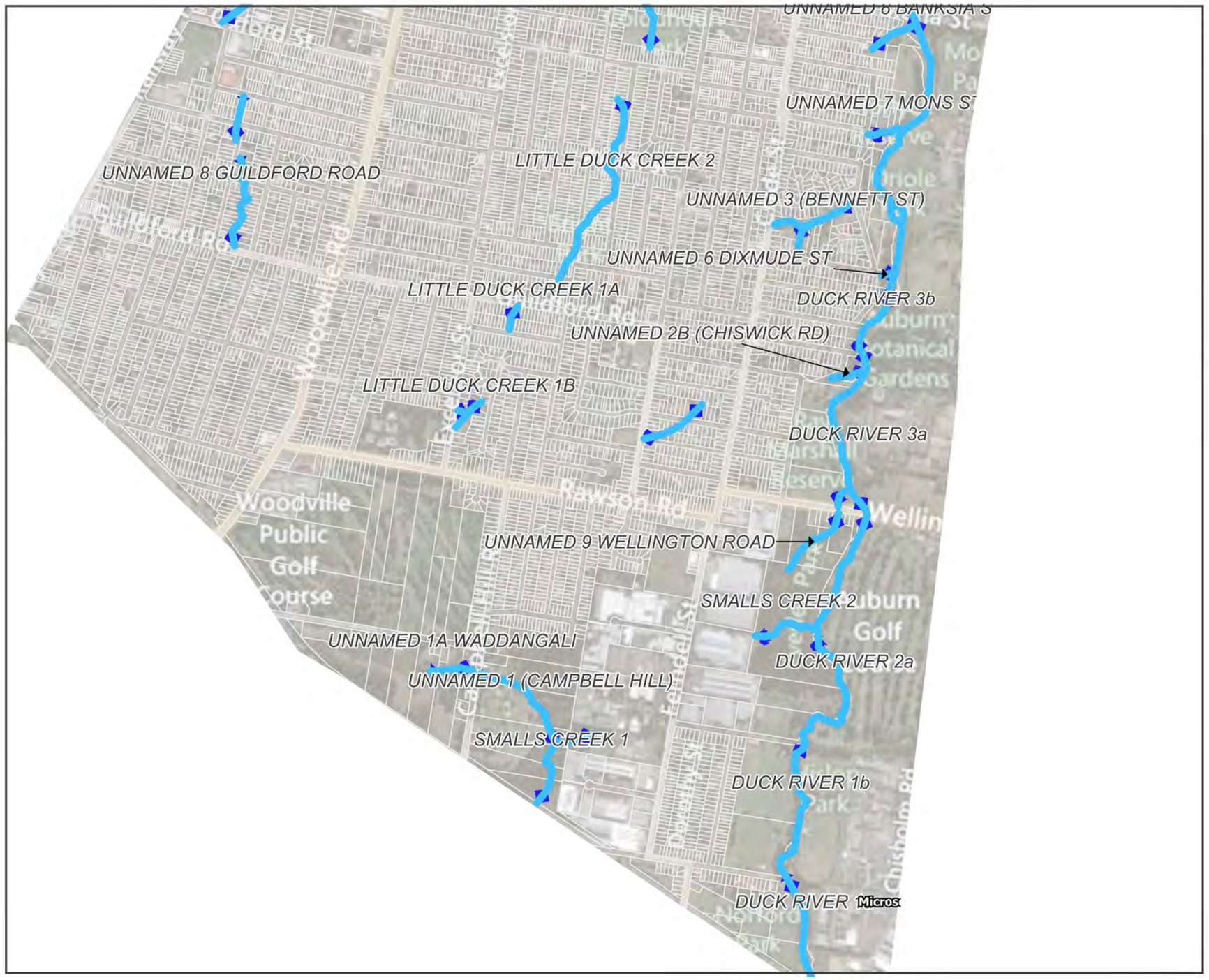
metres

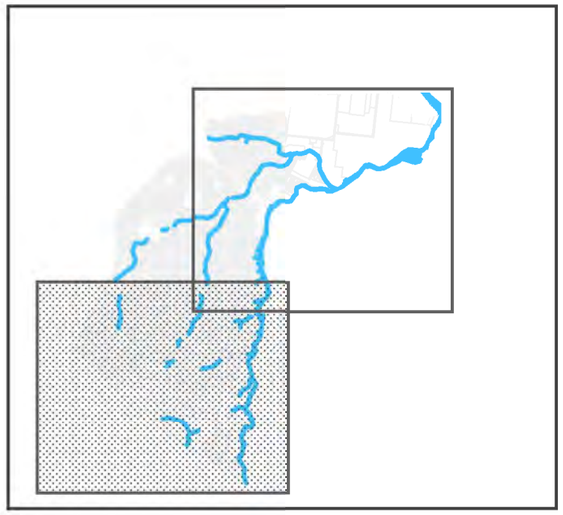
Reach extent

Watercourse

file: overviewMP Map 1
date: 17/05/2012

REACH OVERVIEW DUCK RIVER CATCHMENT PARRAMATTA LGA





Cadastre

N

0 500

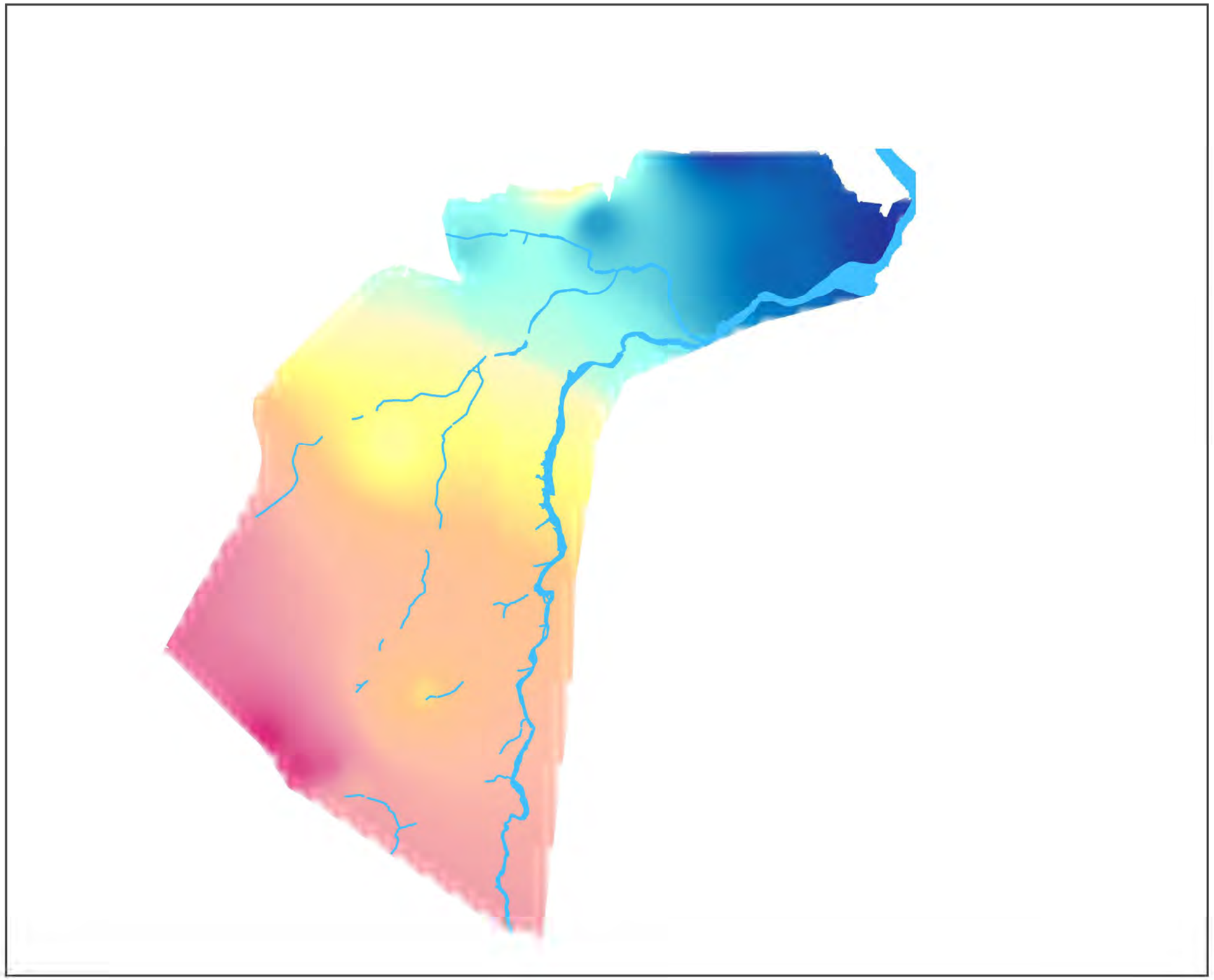
metres

Reach extent

Watercourse

file: processesMP Map 2
date: 17/05/2012

ELEVATION MODEL (2m CONTOUR) DUCK RIVER CATCHMENT PARRAMATTA LGA



Cadastre

Watercourse

N

0 1

kilometres

Elevation m
2m Contour

50
45
35
30
25
20
15
10
5
0

file: CONTOURS
date: 14/05/2012

STREAM PROCESSING

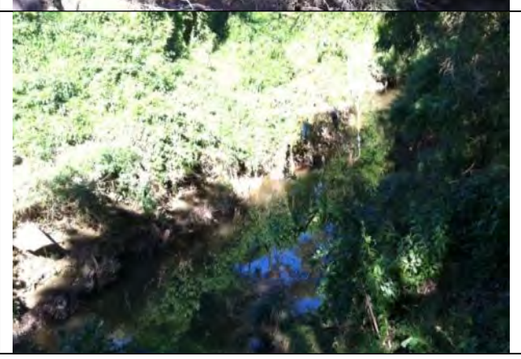
Geomorphic Features and Stream Behaviour

Reaches of the Duck River, Duck Creek, Little Duck creek and Smalls Creek have been assessed and broadly characterised into dominant stream processing character and channel stability. The assessment process was undertaken via visual inspection and key stream character attributes were:

1. Stream bed and bank stability; and
2. Stream processing zones.

Stream bed and bank stability was assessed visually by walking between 50 and 250m channel segments and assigning appropriate ratings. The rating elements and example photographs are provided in Table 1.

Table 1. Channel form and condition – criteria for allocation and examples

CHANNEL CONDITION	EXAMPLE
Concrete Lined Example: Duck Creek 2 (pictured)	
Highly Eroding: Stream is deeply incised, generally earth/rock lined with regular pinch points. Example: Smalls Creek (pictured)	
Moderately Eroding: Stream is incised and contained, regular bank undercutting and evidence of scour Example: Duck River bank erosion in Reach 1 (Pictured)	

CHANNEL CONDITION	EXAMPLE
Stable: Few or no signs of bed and bank erosion, vegetated floodplain Example: Duck River Reach 4 (Pictured)	
Aggregating. Weirs or impoundments assist in trapping the movement of sediment leading to buildup Example: behind the ‘stepping stones’ weir (Pictured)	
Tidal: Stream is under tidal influence Example Lower Duck River reaches 4-6	

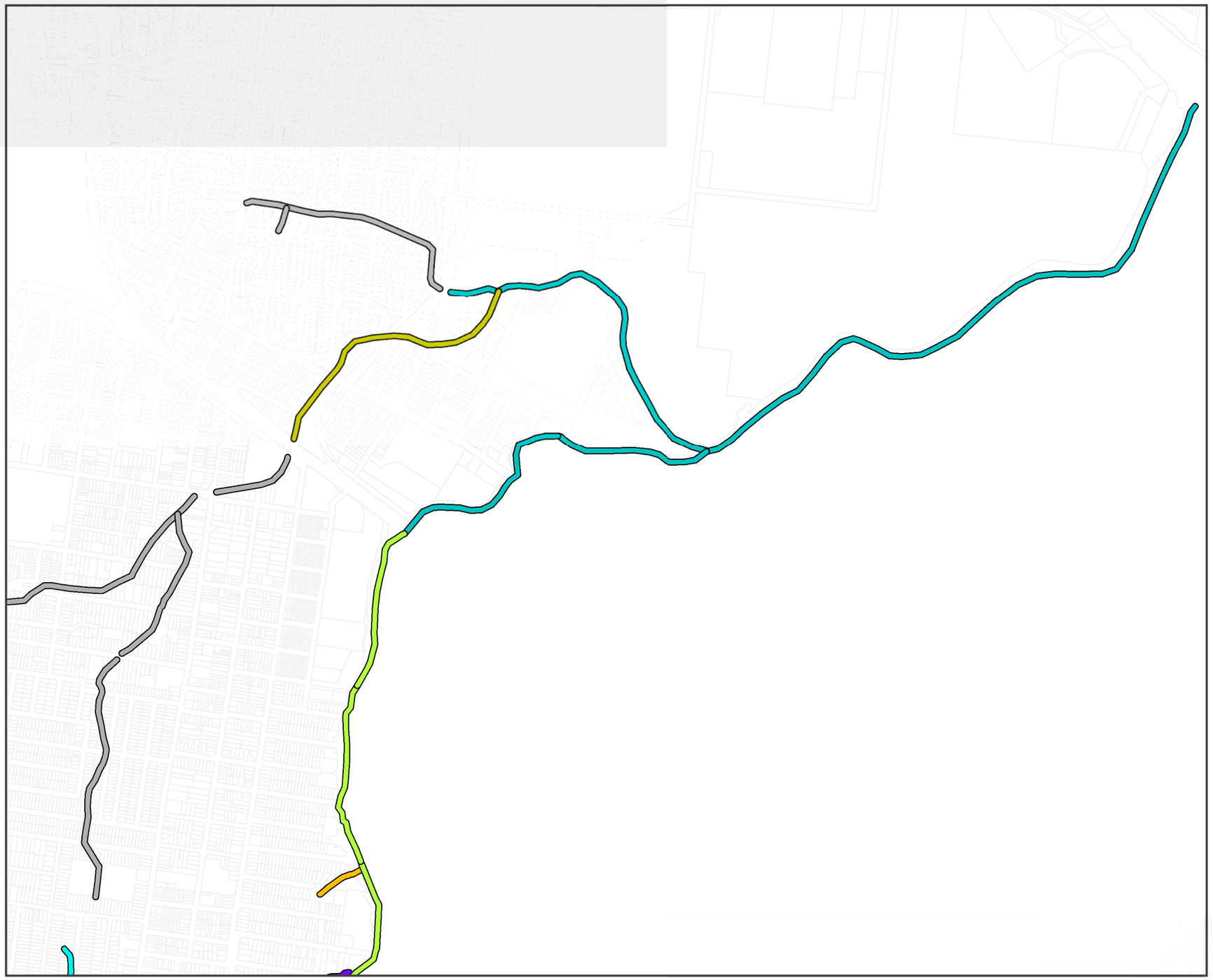
CHANNEL ATTRIBUTES

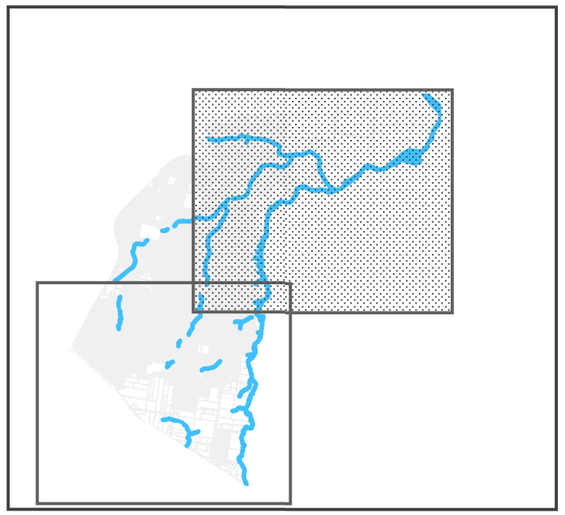
Results of the hydro-geomorphic assessment are provided in Table 4.

Table 2. Results of hydro-geomorphic assessment of reaches in Duck River catchment

REACH NAME	EROSION RATING	PROCESSING CHARACTERISTICS
A'BECKETTS CREEK 1	Concrete lined	Concrete lined
A'BECKETTS CREEK 2	Tidal/mangrove/aggregating	Tidal
DUCK CREEK 1	Concrete lined	Concrete lined
DUCK CREEK 2	Concrete lined	Concrete lined
DUCK CREEK 2a	Concrete lined	Concrete lined
DUCK CREEK 3	Concrete lined	Concrete lined
DUCK CREEK 4	Tidal/concrete	Tidal/concrete
DUCK CREEK 5	Tidal/mangrove/aggregating	Tidal
DUCK RIVER 1A	Moderately eroding	Riffles/pools
DUCK RIVER 1B	Moderately eroding	Riffles/pools
DUCK RIVER 2A	Moderate/high erosion	Riffles/pools
DUCK RIVER 2B	Moderate/high erosion	Riffles/pools
DUCK RIVER 3A	Moderate/high erosion	Riffles/pools
DUCK RIVER 3B	Moderately eroding	pool
DUCK RIVER 4A	Stable/aggregating	pool/impoundment
DUCK RIVER 4B	Stable	pool
DUCK RIVER 5A	Stable	pool/impoundment
DUCK RIVER 5B	Stable	pool/impoundment
DUCK RIVER 6	Tidal/mangrove/aggregating	Tidal
DUCK RIVER 7	Tidal/mangrove/aggregating	Tidal
DUCK RIVER 8	Tidal/mangrove/aggregating	Tidal
LITTLE DUCK CREEK 1A	Stable/ moderately eroding	ephemeral
LITTLE DUCK CREEK 1B	Stable	vegetated/ephemeral
LITTLE DUCK CREEK 2	Stable/ moderately eroding	riffles/glide
LITTLE DUCK CREEK 3	concrete lined	Concrete lined
LITTLE DUCK CREEK 4	Concrete Lined	Concrete lined
SMALLS CREEK 1	Stable/ moderately eroding	riffles/glide
SMALLS CREEK 2	Highly eroding	riffles/pools/pinches
UNNAMED 1A WADDANGALI	Stable	ephemeral
UNNAMED 1B CAMPBELL HILL	Stable	vegetated/ephemeral
UNNAMED 2A RANDOLPH ST	Stable/aggregating	vegetated/ephemeral
UNNAMED 2B CHISWICK RD	Moderate/Highly Eroding	pools/pinches
UNNAMED 3 BENNETT RD	Stable	pools/pinch/vegetated
UNNAMED 4 A'BECKETTS ST	concrete lined	concrete lined
UNNAMED 5 DIXMUDE ST	stable	ephemeral
UNNAMED 6 MONS ST	Stable/Moderately eroding	ephemeral
UNNAMED 7 BANKSIA ST	Stable/aggregating	vegetated
UNNAMED 8 GUILDFORD RD	Concrete lined	Concrete lined
UNNAMED 9 WENTWORTH RD	Stable	ephemeral

CHANNEL ATTRIBUTES DUCK RIVER CATCHMENT PARRAMATTA LGA





N

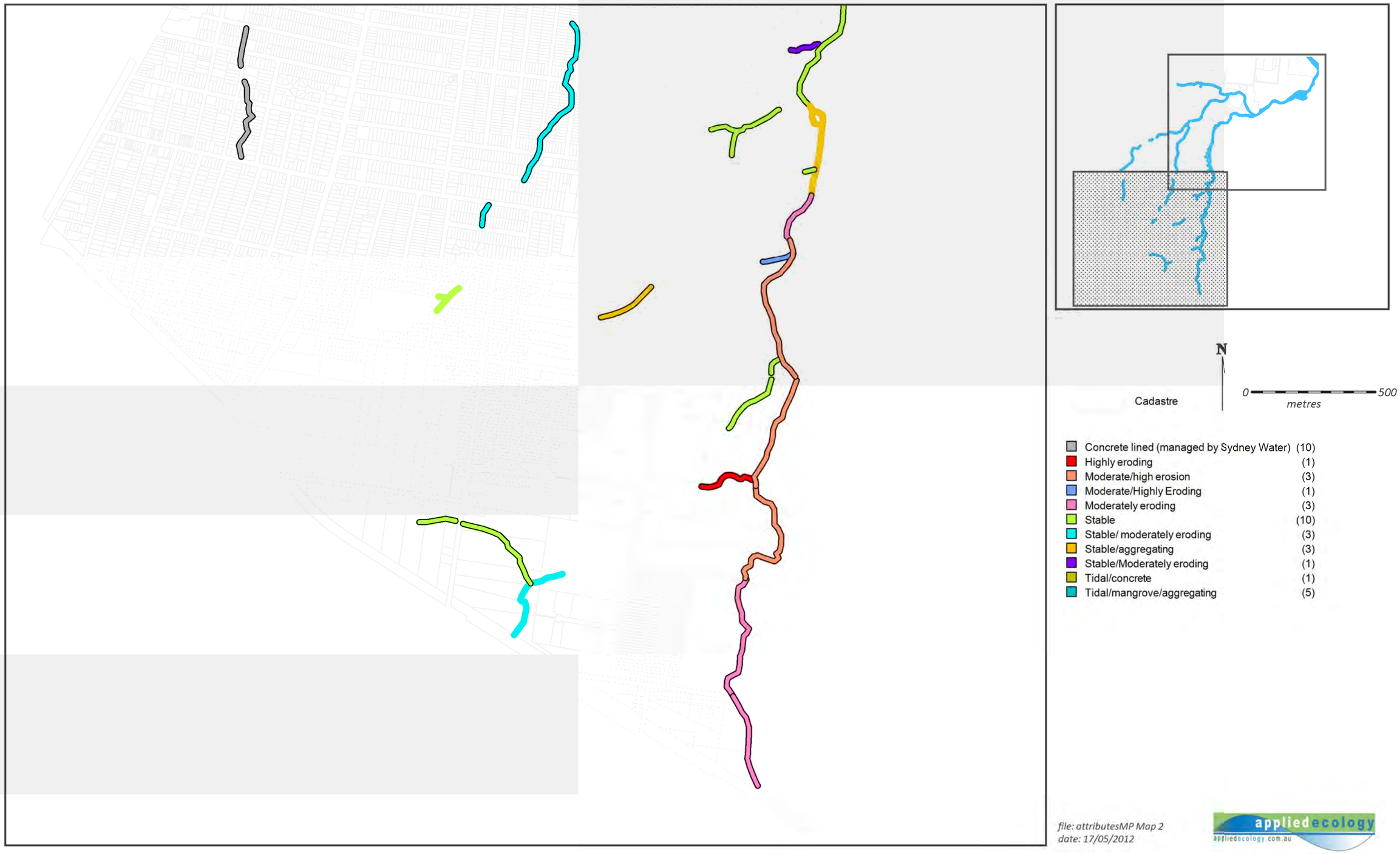
Cadastre

0 500
metres

- Concrete lined (managed by Sydney Water) (10)
- Highly eroding (1)
- Moderate/high erosion (3)
- Moderate/Highly Eroding (1)
- Moderately eroding (3)
- Stable (10)
- Stable/ moderately eroding (3)
- Stable/aggregating (3)
- Stable/Moderately eroding (1)
- Tidal/concrete (1)
- Tidal/mangrove/aggregating (5)

file: attributesMP Map 1
date: 17/05/2012

CHANNEL ATTRIBUTES DUCK RIVER CATCHMENT PARRAMATTA LGA



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date: 17/05/2012

CHANNEL PROCESSES

Results of the hydro-geomorphic assessment are provided in Table 4.

Table 3. Results of hydro-geomorphic assessment of reaches in Duck River catchment

REACH NAME	EROSION RATING	PROCESSING CHARACTERISTICS
A'BECKETTS CREEK 1	Concrete lined	Concrete lined
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DUCK RIVER 2B	Moderate/high erosion	Riffles/pools
DUCK RIVER 3A	Moderate/high erosion	Riffles/pools
DUCK RIVER 3B	Moderately eroding	pool
DUCK RIVER 4A	Stable/aggregating	pool/impoundment
DUCK RIVER 4B	Stable	pool
DUCK RIVER 5A	Stable	pool/impoundment
DUCK RIVER 5B	Stable	pool/impoundment
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DUCK RIVER 7	Tidal/mangrove/aggregating	Tidal
DUCK RIVER 8	Tidal/mangrove/aggregating	Tidal
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LITTLE DUCK CREEK 4	Concrete Lined	Concrete lined
SMALLS CREEK 1	Stable/ moderately eroding	riffles/glide
SMALLS CREEK 2	Highly eroding	riffles/pools/pinches
UNNAMED 1A WADDANGALI	Stable	ephemeral
UNNAMED 1B CAMPBELL HILL	Stable	vegetated/ephemeral
UNNAMED 2A RANDOLPH ST	Stable/aggregating	vegetated/ephemeral
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UNNAMED 6 MONS ST	Stable/Moderately eroding	ephemeral
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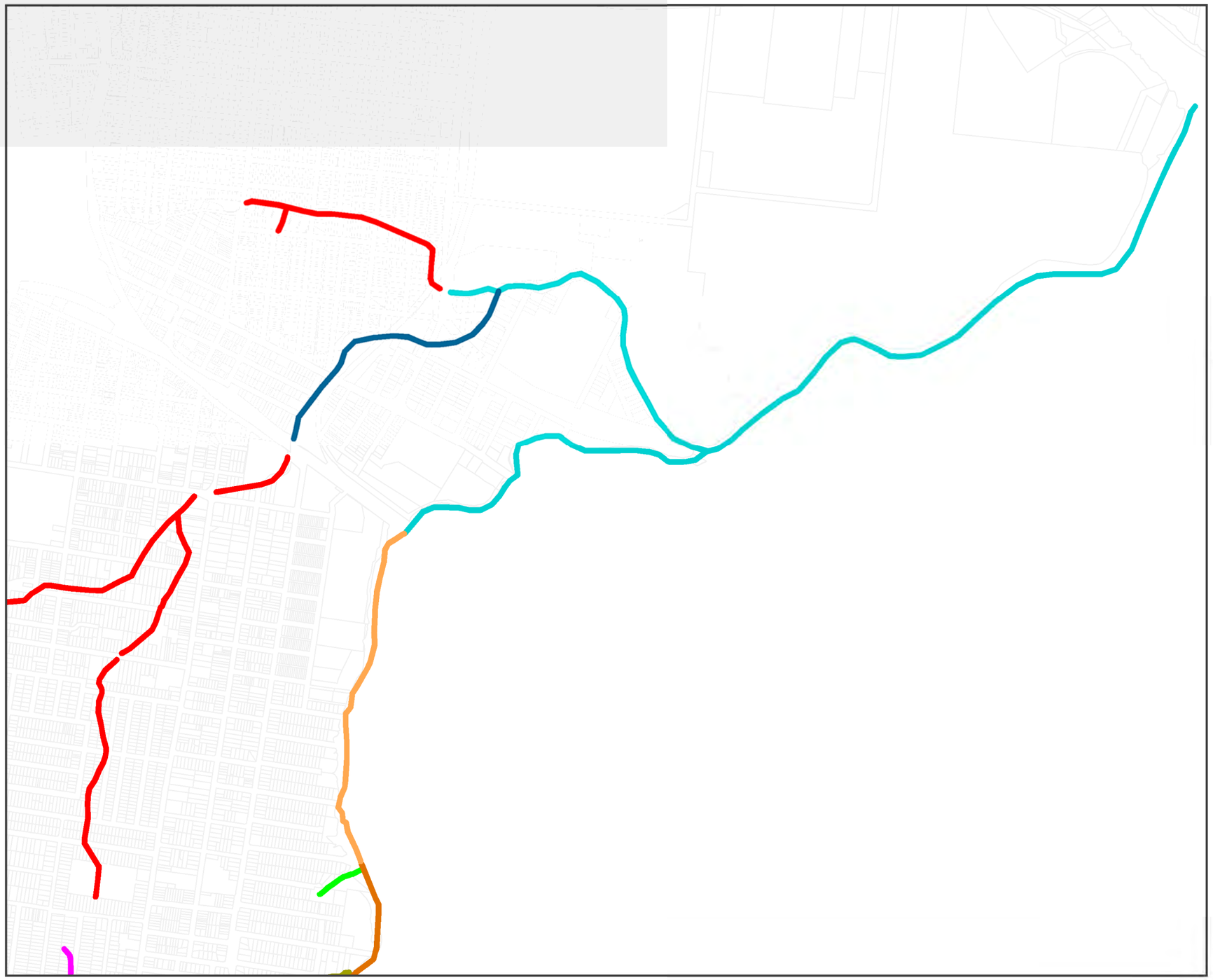
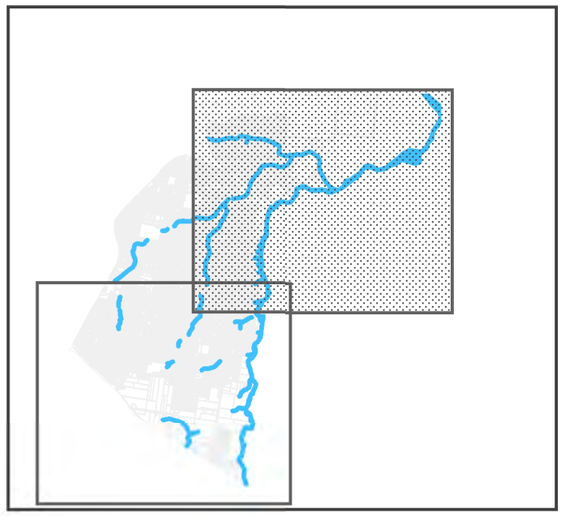
UNNAMED 8 GUILDFORD RD	Concrete lined	Concrete lined
UNNAMED 9 WENTWORTH RD	Stable	ephemeral

CHANNEL PROCESSES DUCK RIVER CATCHMENT PARRAMATTA LGA





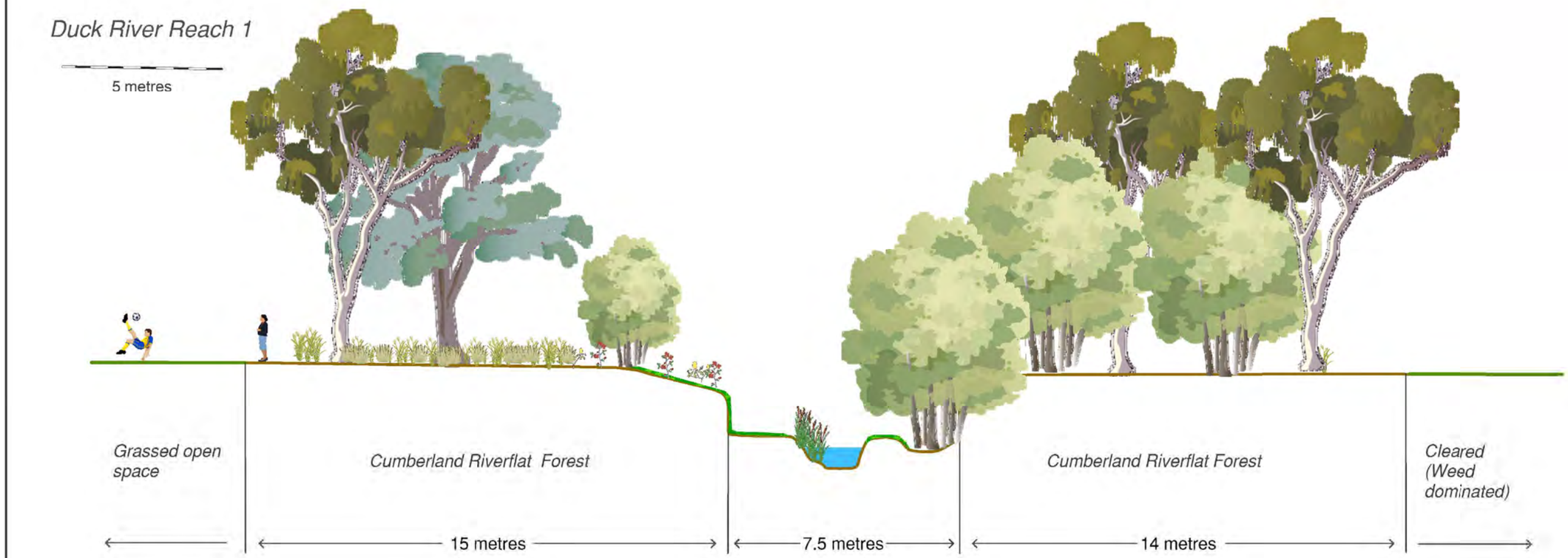
Cadastre

N

0 500
metres

concrete lined	(20)
ephemeral	(12)
pool	(4)
pool/impoundment	(6)
pools/pinch/vegetated	(2)
pools/pinches	(2)
riffles/glide	(4)
riffles/pools	(10)
riffles/pools/pinches	(2)
tidal	(10)
tidal/concrete	(2)
vegetated	(2)
vegetated/ephemeral	(6)

file: processesMP Map 1
date: 17/05/2012



DUCK RIVER REACH 1

CROSS SECTION

N
W E
S

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date: 16/05/2012

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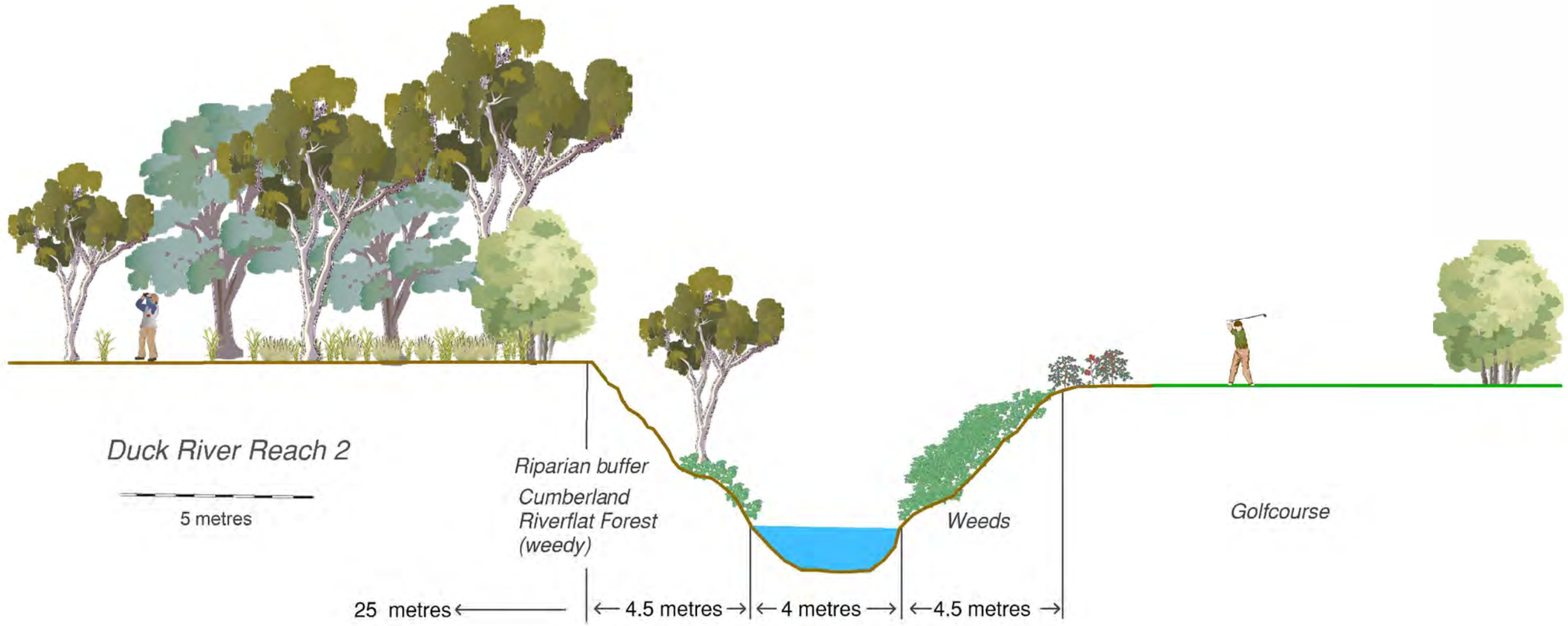
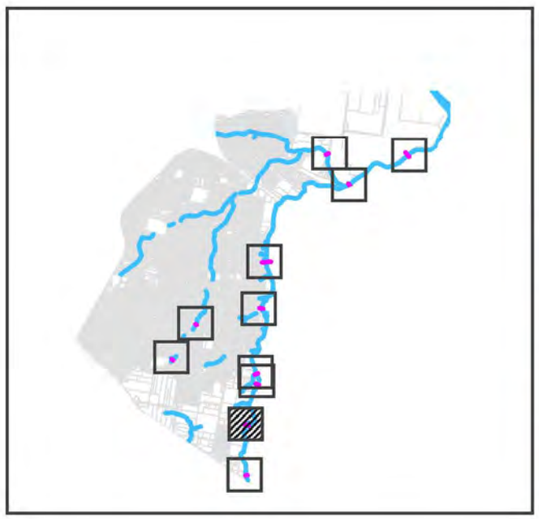




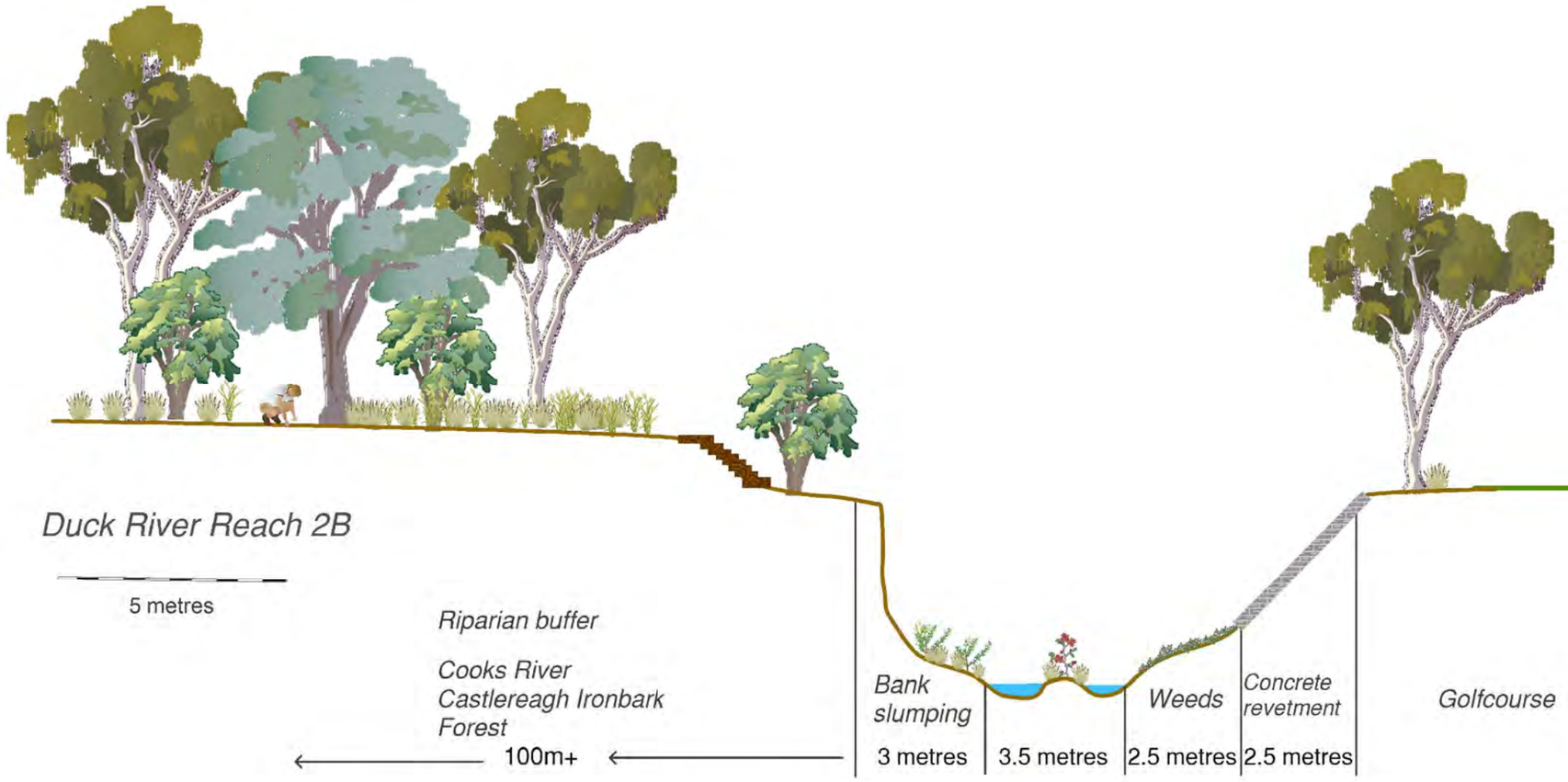
DUCK RIVER REACH 2 (A)

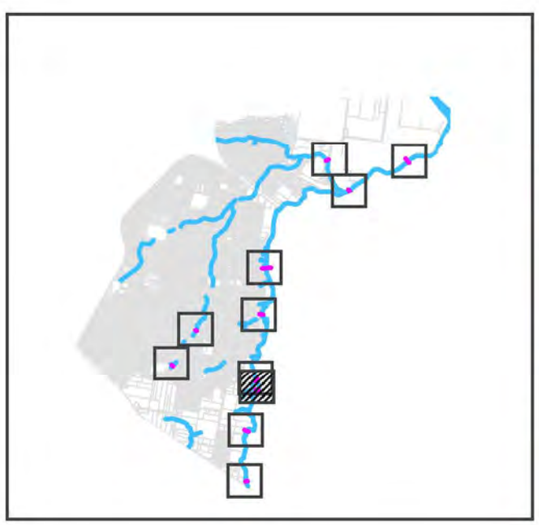
CROSS SECTION

N
W E
S

file: bathymetry/crosssections
date: 16/05/2012

appliedecology
appliedecology.com.au





DUCK RIVER REACH 2 (B)

CROSS SECTION

N
W
E
S

file: bathymetry/crosssections
date: 16/05/2012

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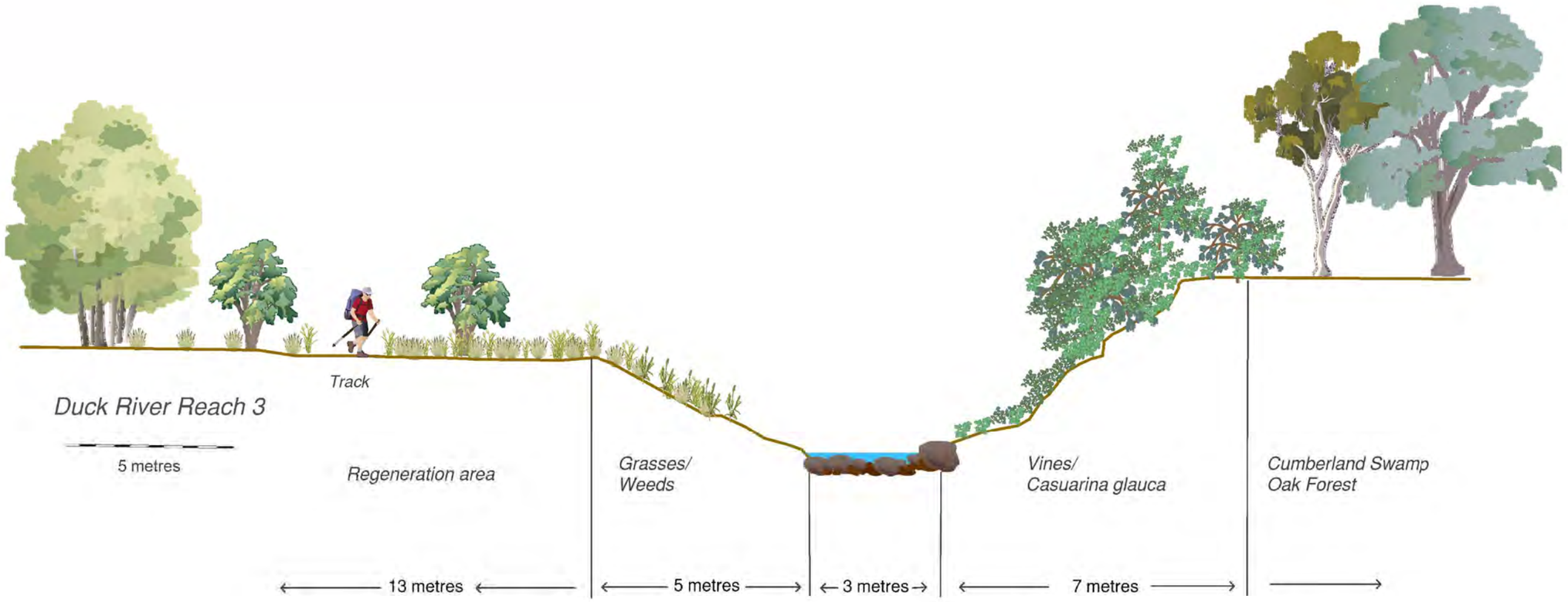
appliedecology.com.au



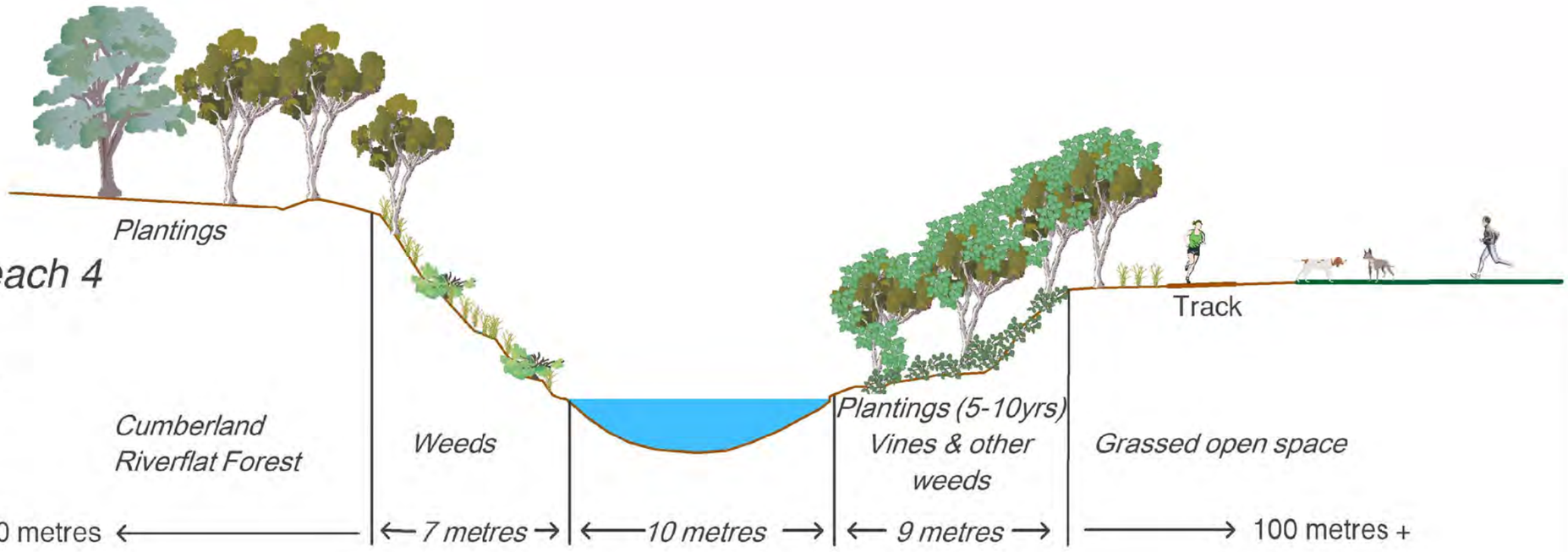
DUCK RIVER REACH 3

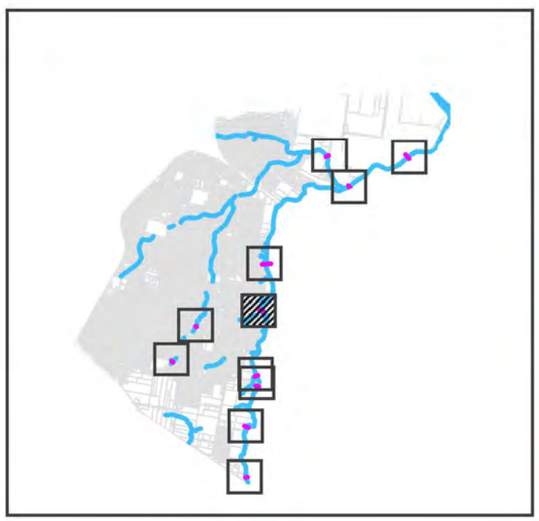
CROSS SECTION

N
W
E
S

file: bathymetry/crosssections
date: 16/05/2012

appliedecology
appliedecology.com.au





DUCK RIVER REACH 4

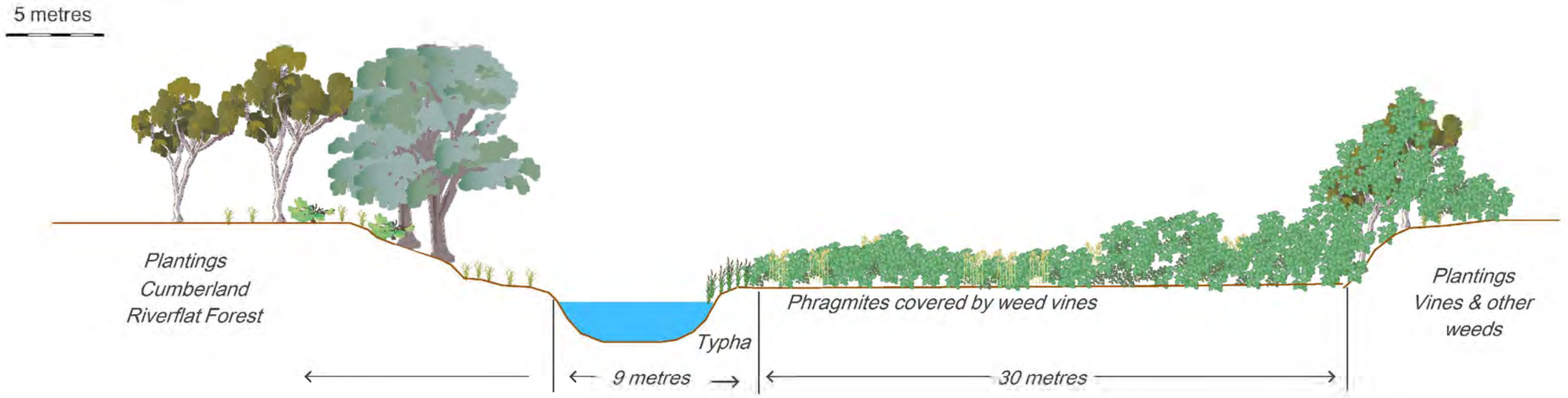
CROSS SECTION

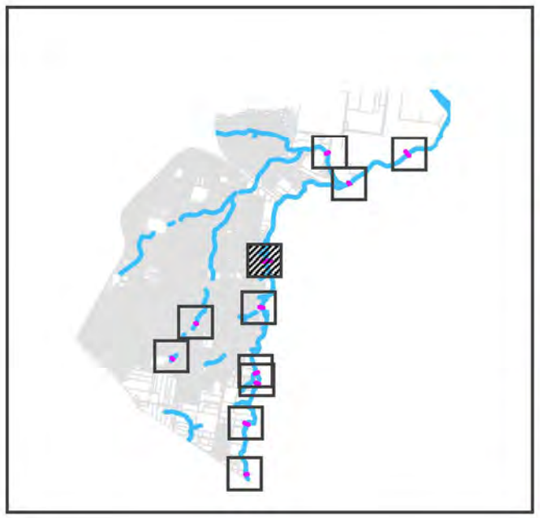
N
W
E
S

file: bathymetry/crosssections
date: 16/05/2012

applied ecology
appliedecology.com.au

Duck River Reach 5





DUCK RIVER REACH 5

CROSS SECTION

N
W
E
S

file: bathymetry/crosssections
date: 16/05/2012

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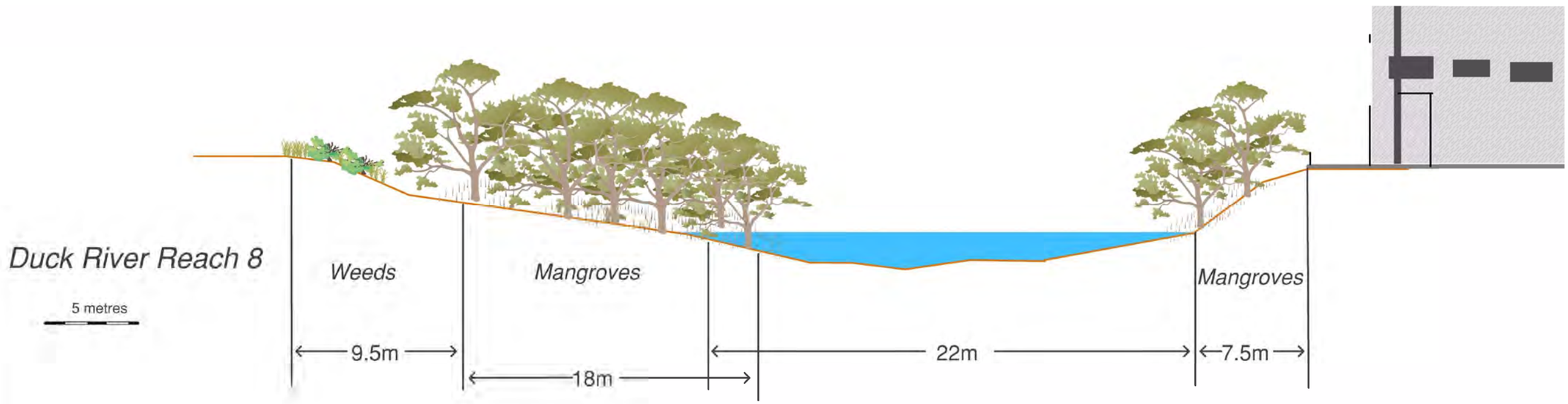

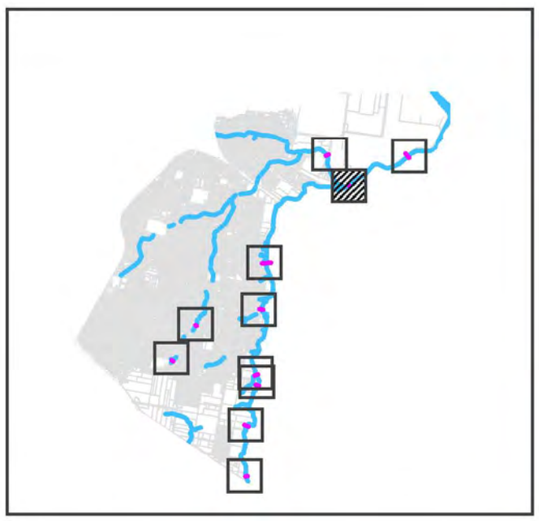

DUCK RIVER REACH 8 (2)

CROSS SECTION

N
W
E
S

file: bathymetry/crosssections
date: 16/05/2012

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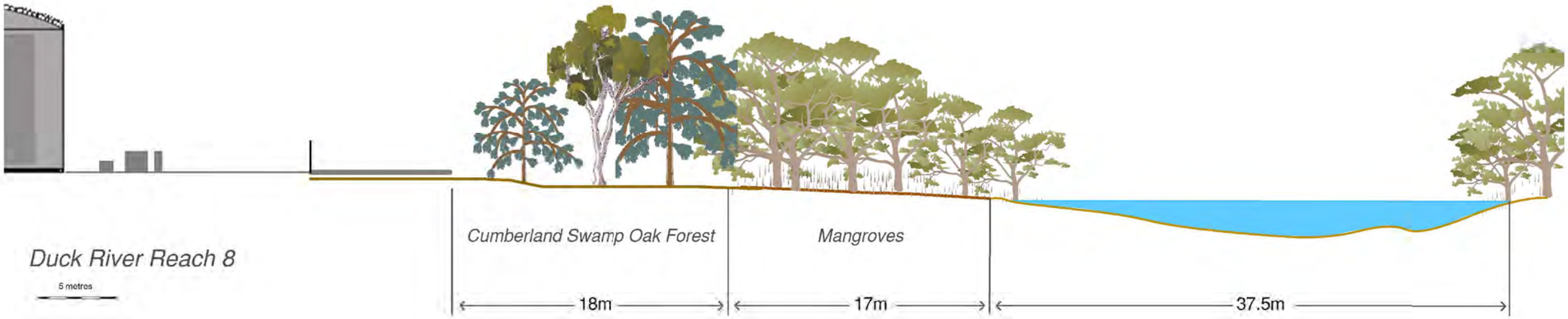
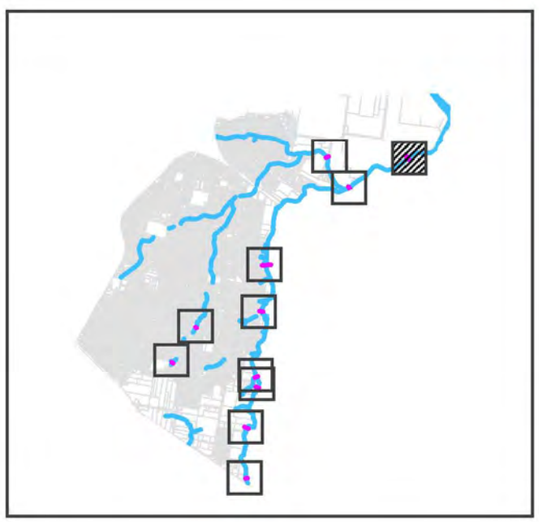




DUCK RIVER REACH 8 (1)

CROSS SECTION

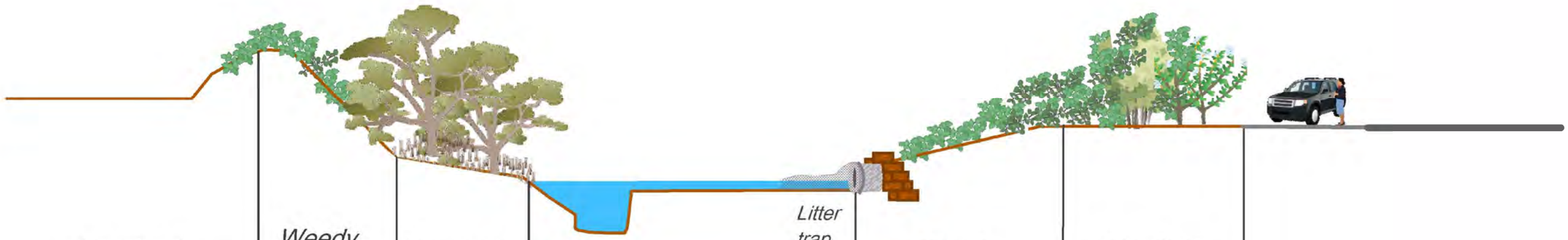
N
W
E
S

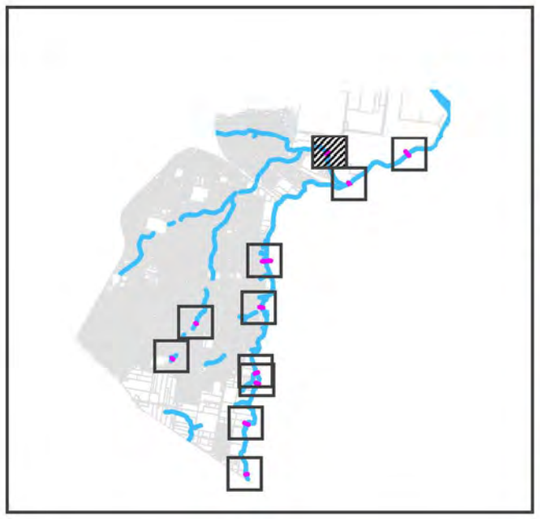
file: bathymetry/crosssections
date: 16/05/2012

applied ecology
appliedecology.com.au

Duck Creek 5

5 metres





DUCK CREEK 5

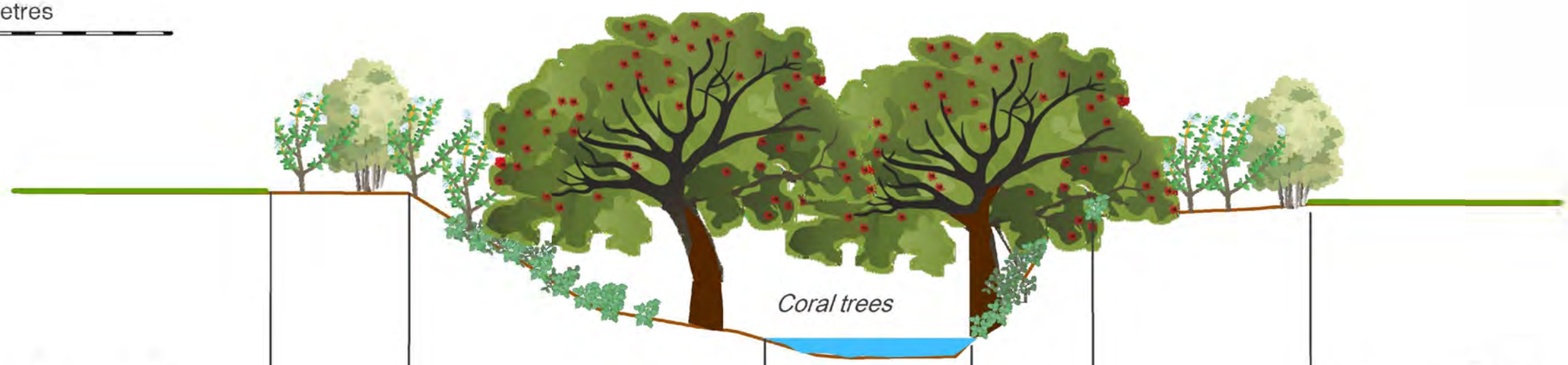
CROSS SECTION

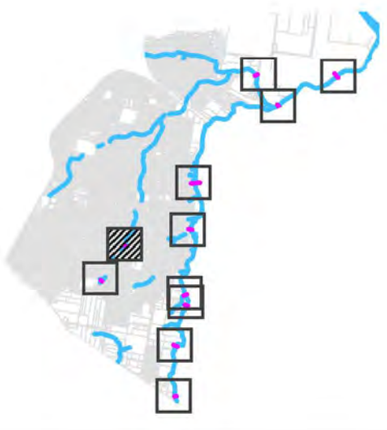
file: bathymetry/crosssections
date: 16/05/2012

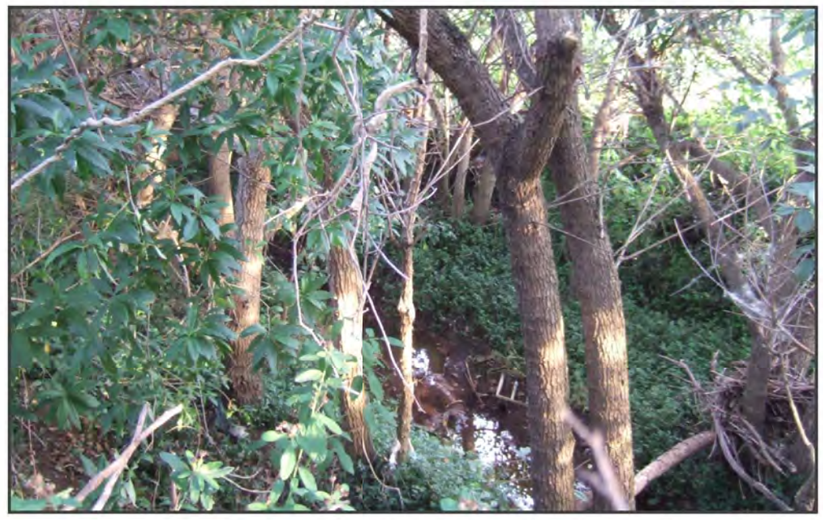
applied ecology
appliedecology.com.au

Little Duck Creek 2

5 metres







LITTLE DUCK CREEK 2

CROSS SECTION

file: bathymetry/crosssections
date: 16/05/2012

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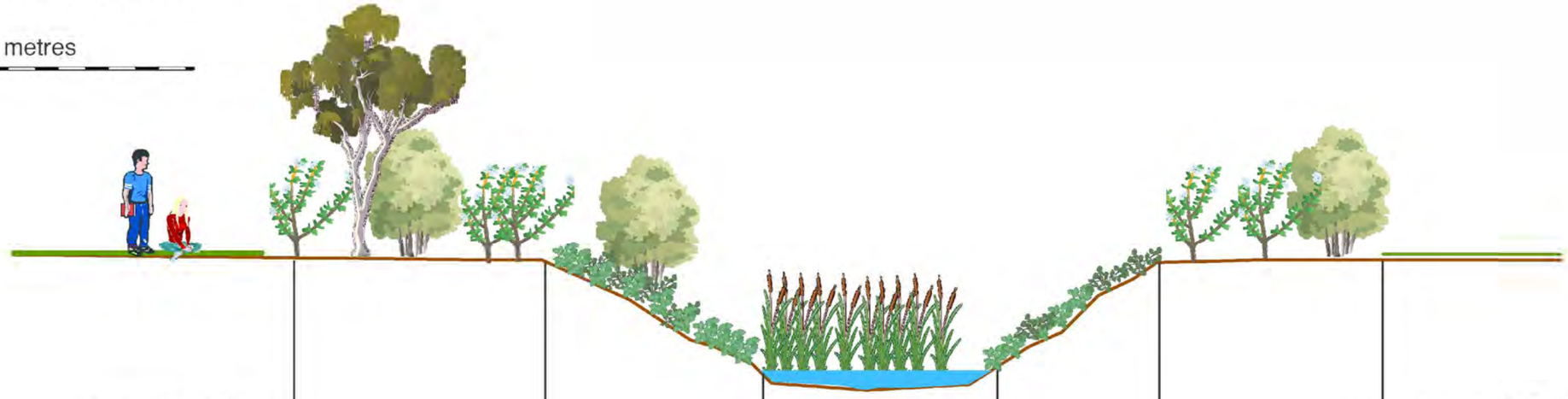
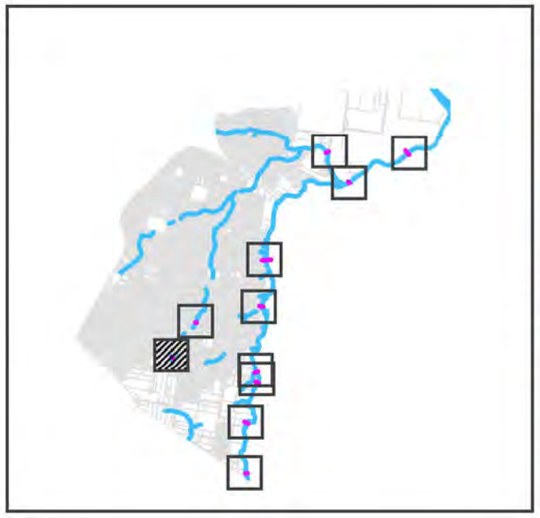
Little Duck Creek 1B

5 metres



Grassed Open Space	Plantings	Weeds	Typha	Weeds	Plantings	Grassed Open Space
←	4 metres	3.5 metres	3.5 metres	2.5 metres	3.5 metres	→



LITTLE DUCK CREEK 1B

CROSS SECTION

N
W E
S

file: bathymetry/crosssections
date: 16/05/2012

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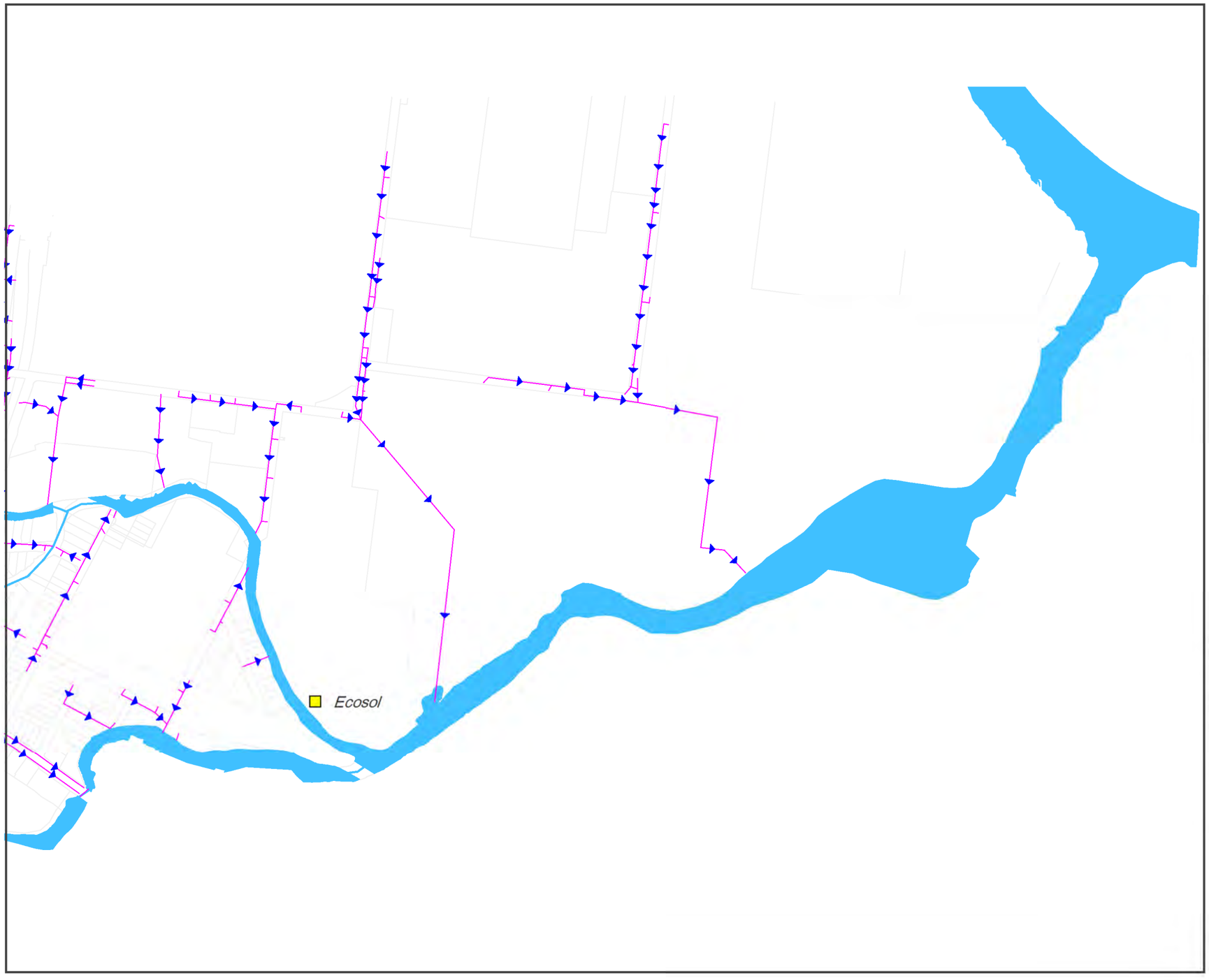
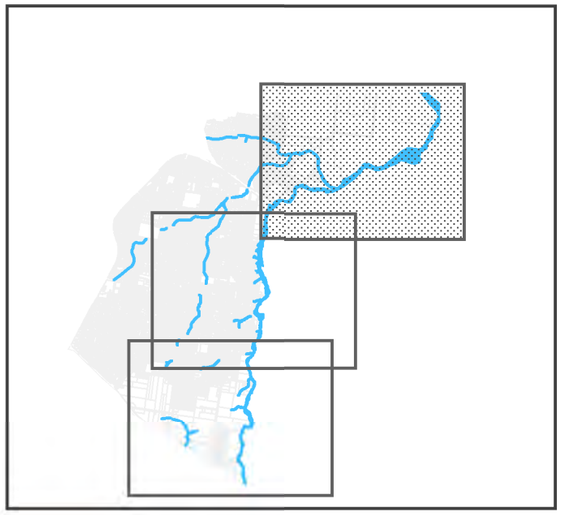
PIPE NETWORK, GPTS AND WEIRS - DUCK RIVER CATCHMENT PARRAMATTA LGA





Watercourse

Cadastre

N

0 250

metres

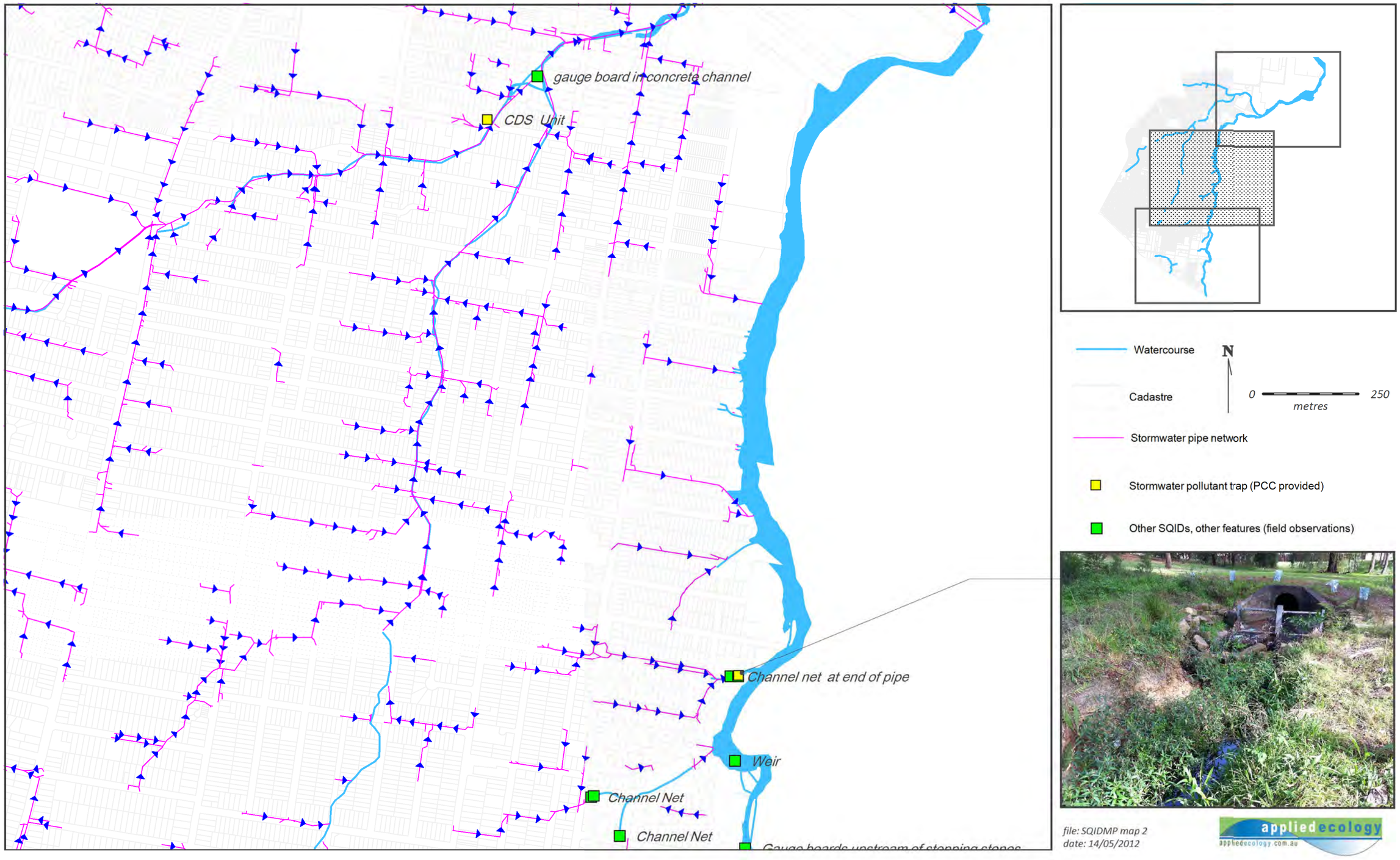
Stormwater pipe network

Stormwater pollutant trap (PCC provided data)

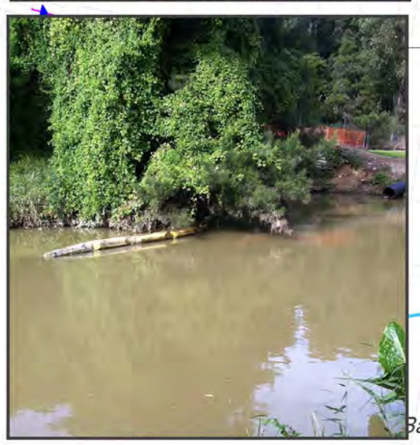
Other SQIDs, other features (field observations)

file: SQIDMP Map 1
date: 14/05/2012

PIPE NETWORK, GPTS AND WEIRS - DUCK RIVER CATCHMENT PARRAMATTA LGA



PIPE NETWORK, GPTS AND WEIRS - DUCK RIVER CATCHMENT PARRAMATTA LGA



Channel Net

Channel Net

Gauge boards upstream of stepping stones

Sediment basin

Litter Basket at end of pipe

Broken litter boom

Nets x2

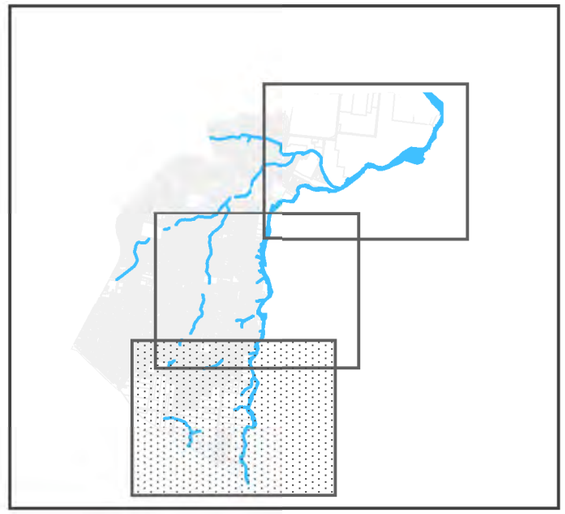
Sediment basin

Nettech/Litter Basket at end of pipe

Bankstown Council

Broken litter boom

Weir



Watercourse

N

Cadastre

0 300

metres

Stormwater pipe network

Stormwater pollutant trap (PCC provided data)

Other SQIDs, other features (field observations)

file:BushRegenMP map 3
date: 13/05/2012

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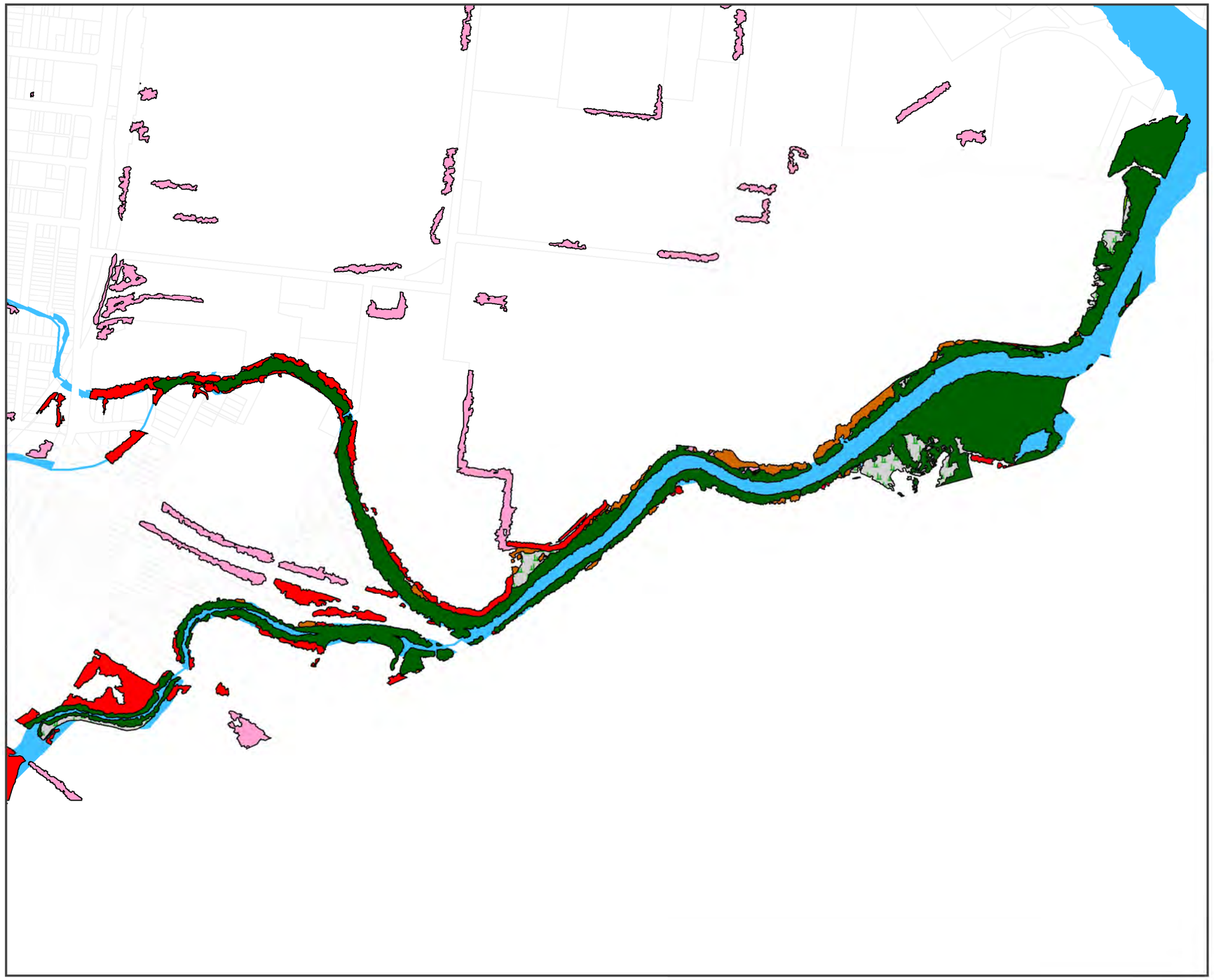
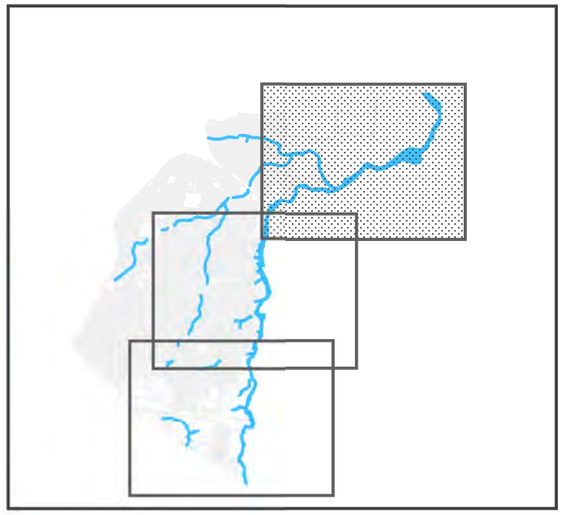
VEGETATION COMMUNITIES DUCK RIVER CATCHMENT PARRAMATTA LGA





Watercourse

Cadastre

N

0 250

metres

SMCMA Draft Vegetation Mapping 2009

- Castlereagh Ironbark Forest
- Castlereagh Shale-Gravel Transition Forest
- Cumberland Riverflat Forest
- Cumberland Swamp Oak Riparian Forest
- Estuarine Swamp Oak Forest
- Coastal Freshwater Reedland
- Estuarine Reedland
- Cumberland Shale Plains Woodland
- Estuarine Mangrove Forest
- Estuarine Saltmarsh
- Urban Remnant Trees
- Weeds

file: vegetationMP Map 1
date: 13/05/2012

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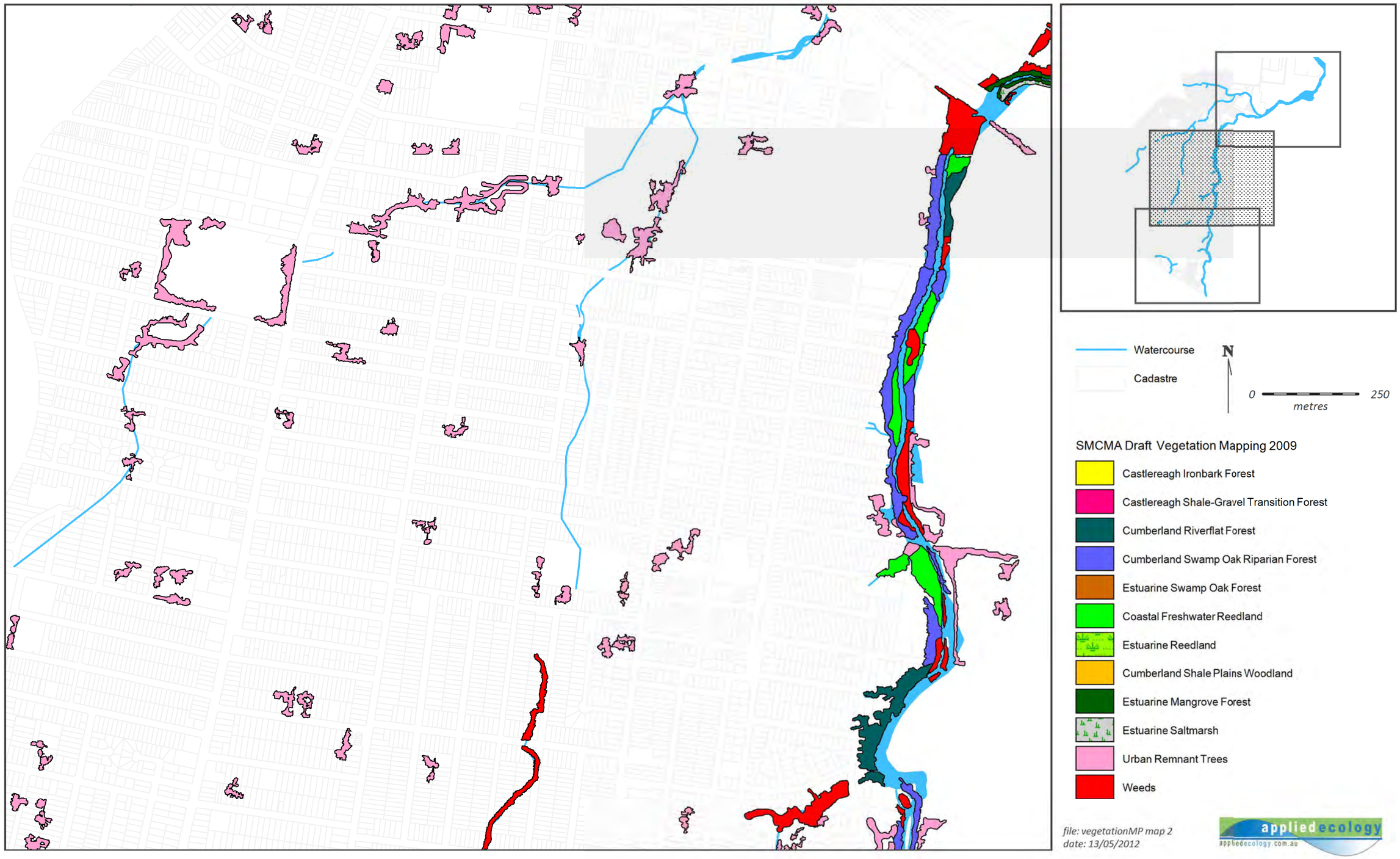
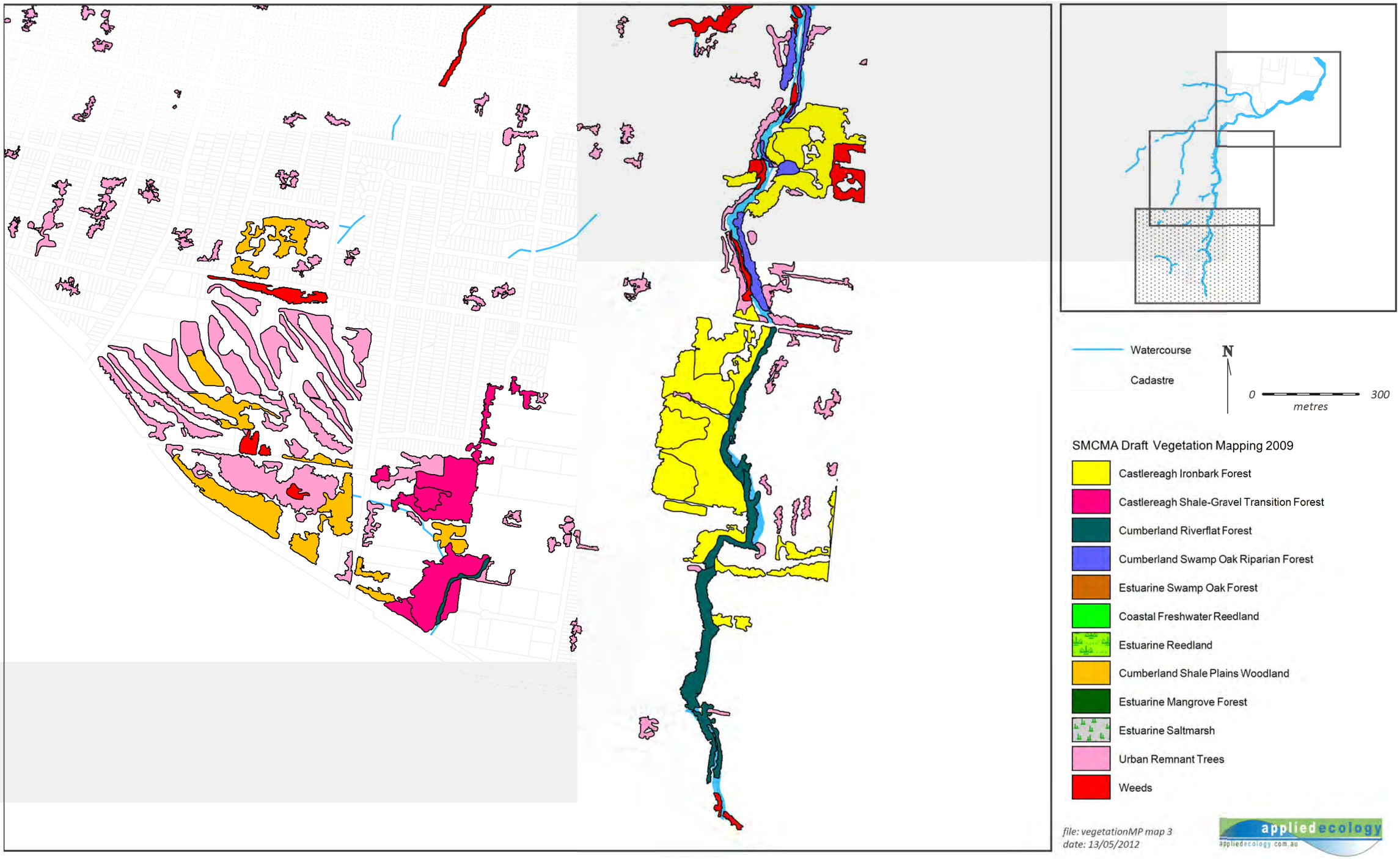
VEGETATION COMMUNITIES DUCK RIVER CATCHMENT PARRAMATTA LGA

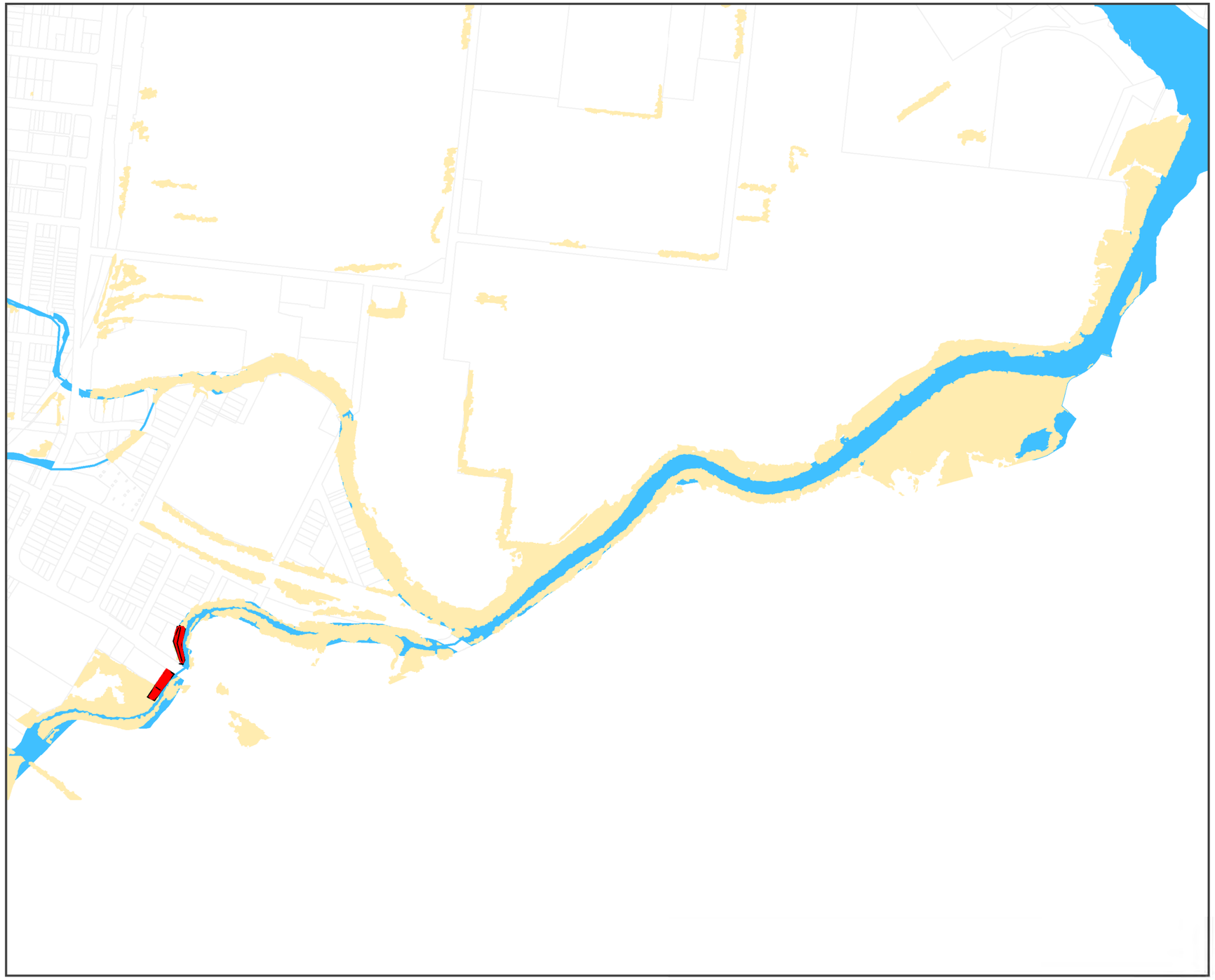


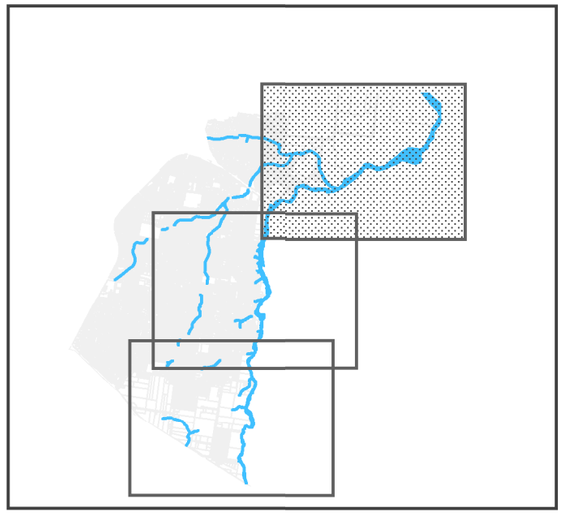
file: vegetationMP map 2
date: 13/05/2012

VEGETATION COMMUNITIES DUCK RIVER CATCHMENT PARRAMATTA LGA



BUSHCARE / CONTRACT WORK SITES DUCK RIVER MAIN CHANNEL PARRAMATTA LGA





Watercourse

Cadastre

N

0 250

metres

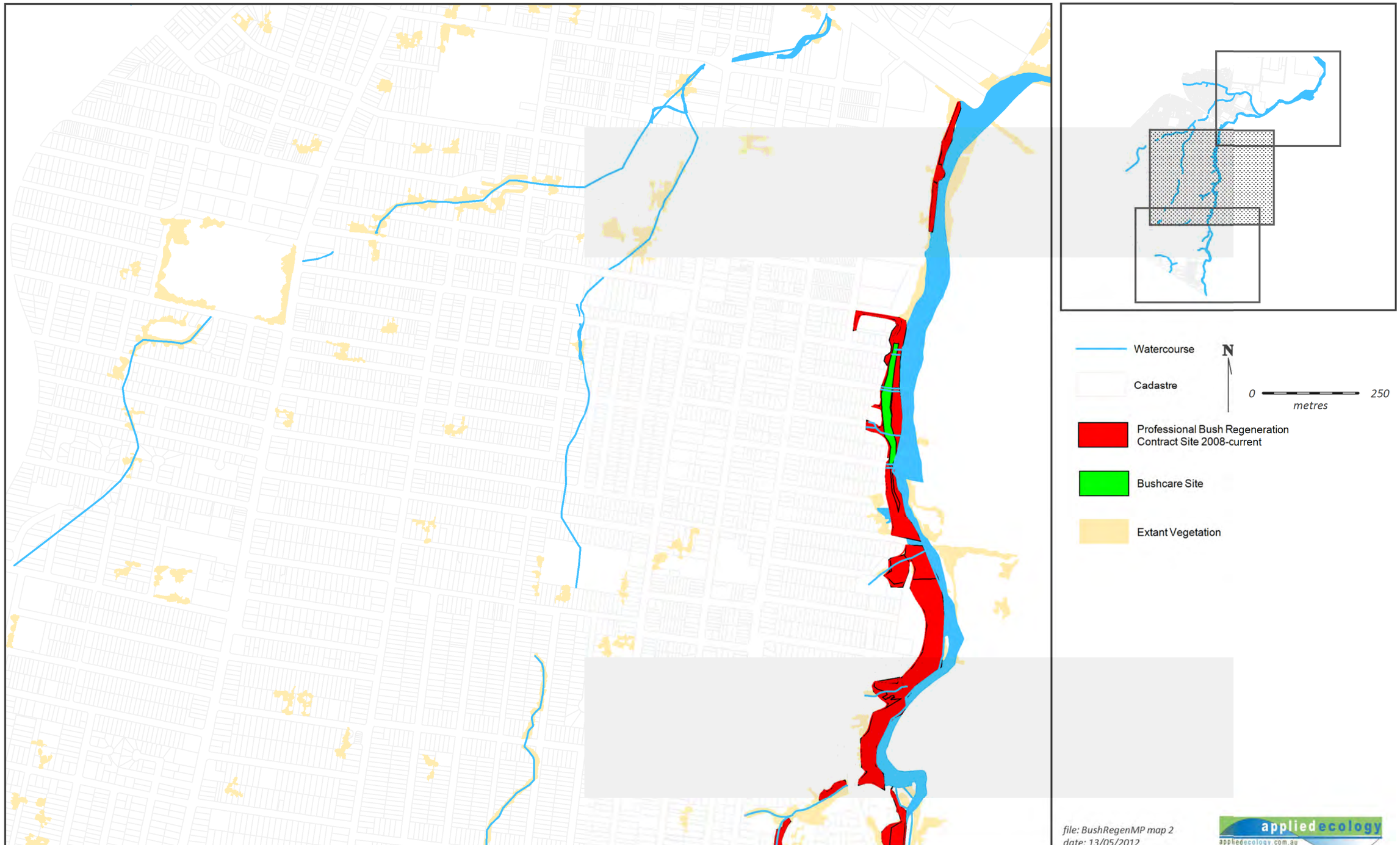
Professional Bush Regeneration Contract Site 2008-current

Bushcare Site

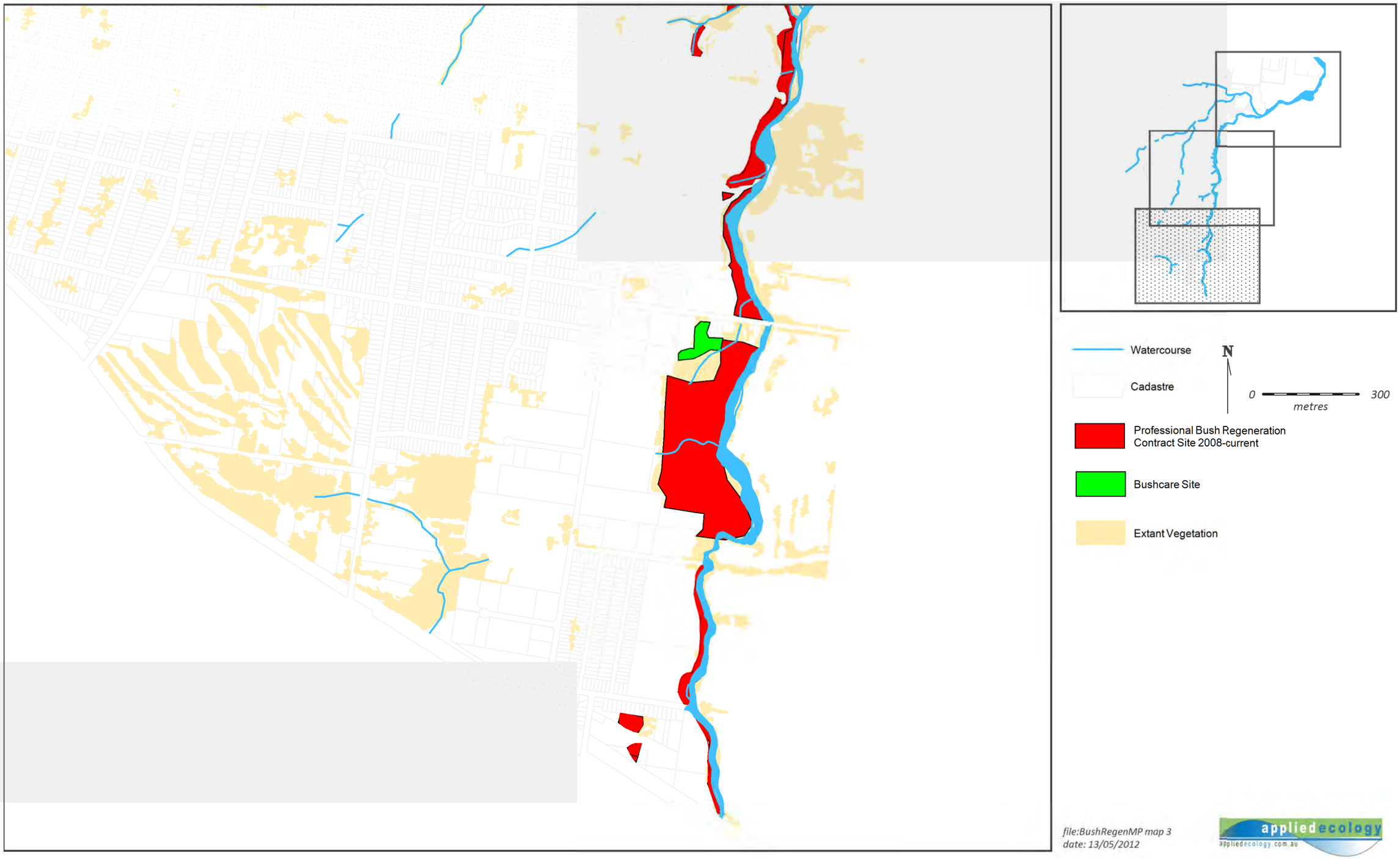
Extant Vegetation

file: BushRegenMP Map 1
date: 13/05/2012

BUSHCARE / CONTRACT WORK SITES DUCK RIVER MAIN CHANNEL PARRAMATTA LGA

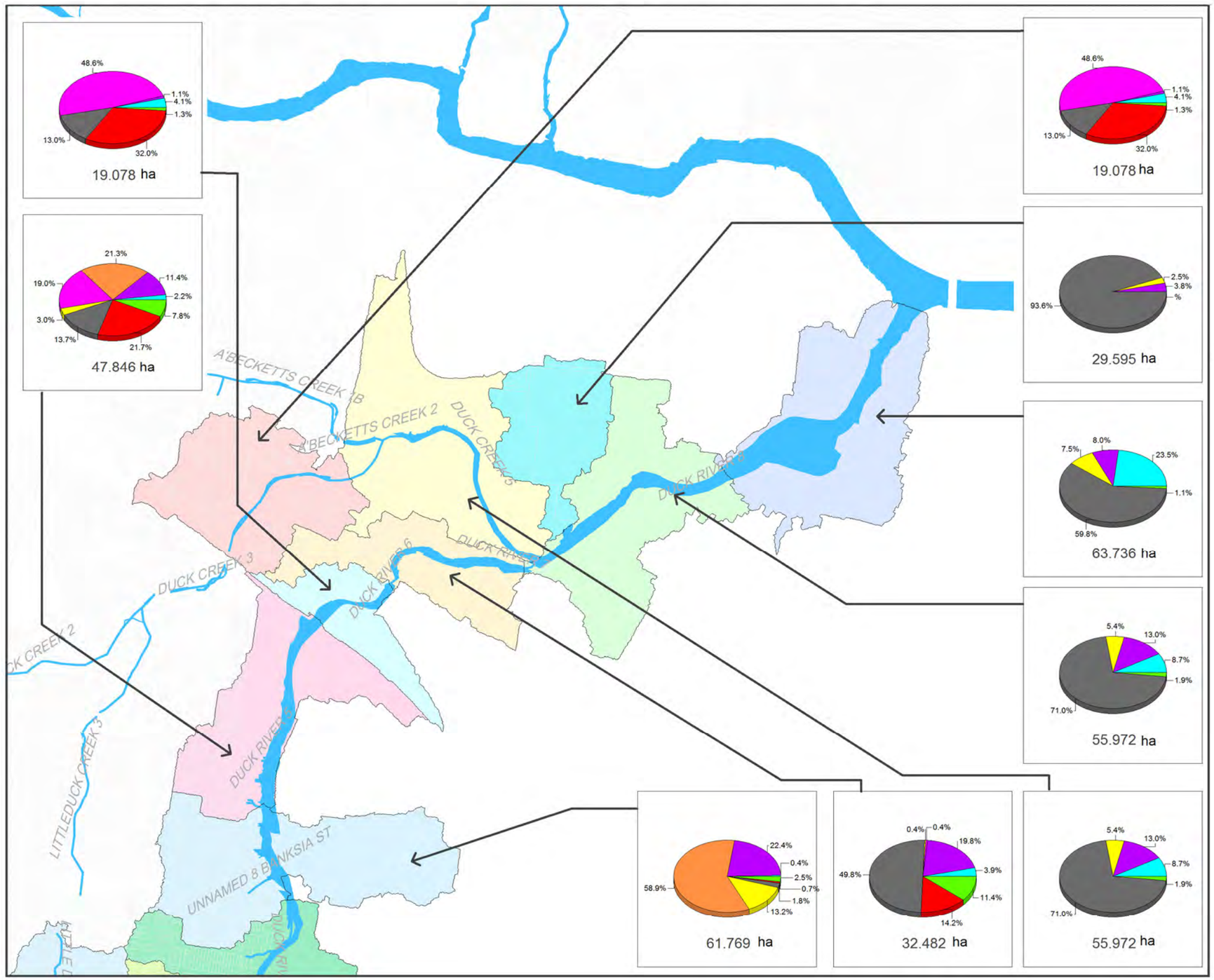


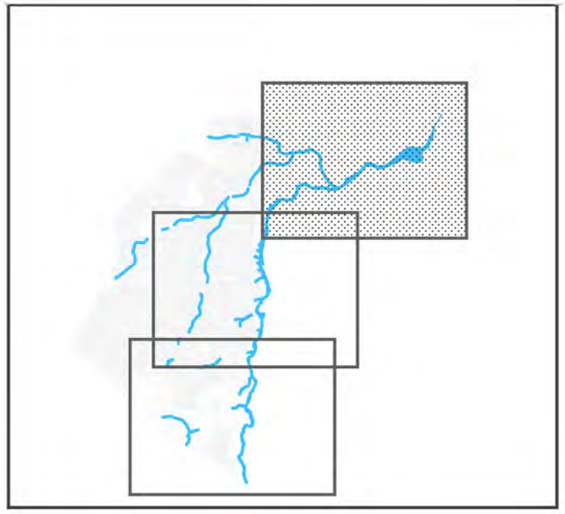
BUSHCARE / CONTRACT WORK SITES DUCK RIVER MAIN CHANNEL PARRAMATTA LGA



file:BushRegenMP map 3
date: 13/05/2012

LAND USE DUCK RIVER CATCHMENT PARRAMATTA LGA





N

WATERCOURSE

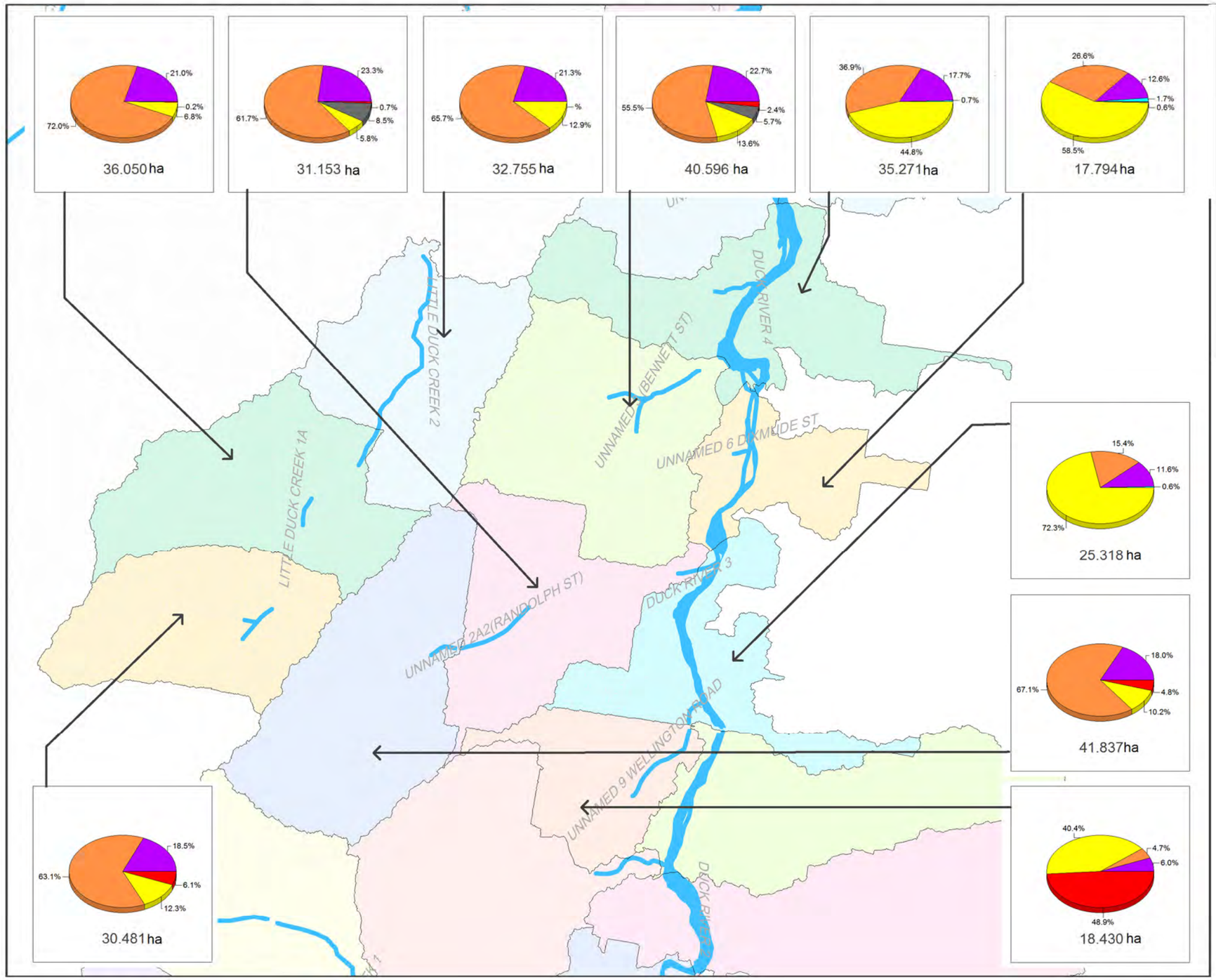
CADASTRE

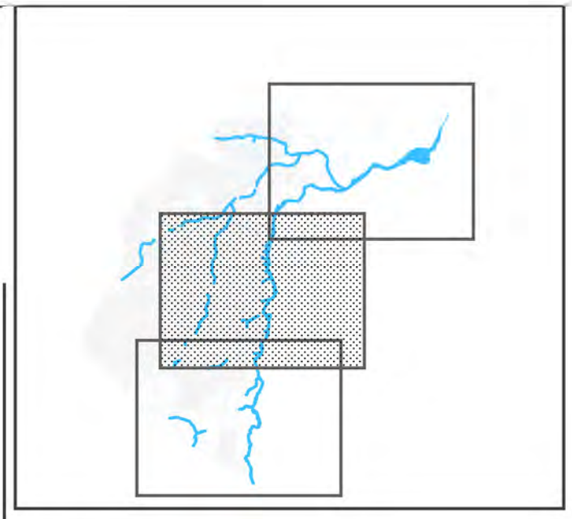
0 250 metres

- BUSHLAND
- COMMERCIAL
- INDUSTRIAL
- PARKLAND
- RAILWAY
- RESIDENTAL
- ROADWAY
- WATER

file: landuse MP Map 1
date: 17/05/2012

LAND USE DUCK RIVER CATCHMENT PARRAMATTA LGA





N

WATERCOURSE

CADASTRE

0 400 metres

- BUSHLAND
- COMMERCIAL
- INDUSTRIAL
- PARKLAND
- RAILWAY
- RESIDENTAL
- ROADWAY
- WATER

file: landuse MP Map 2
date: 17/05/2012

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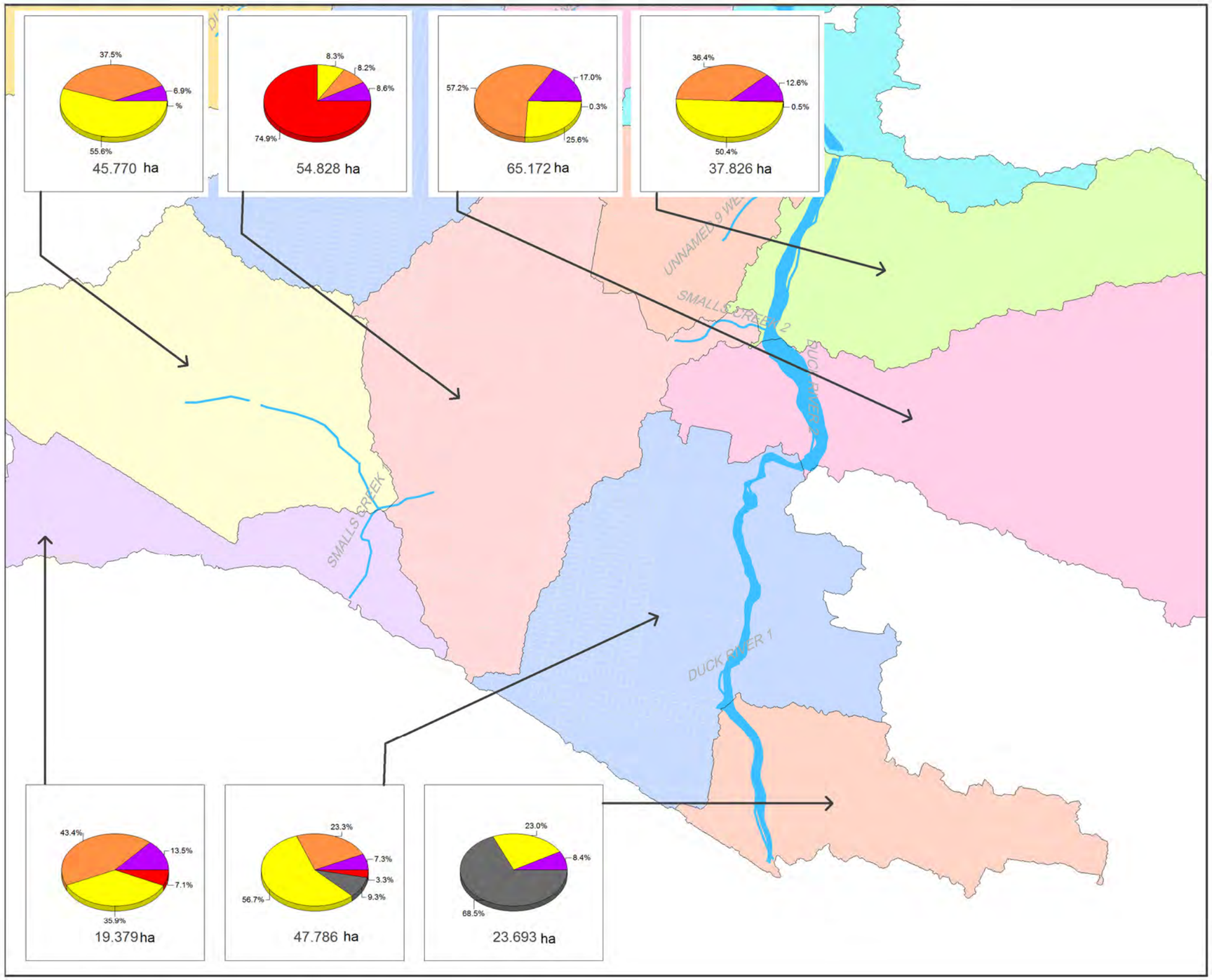
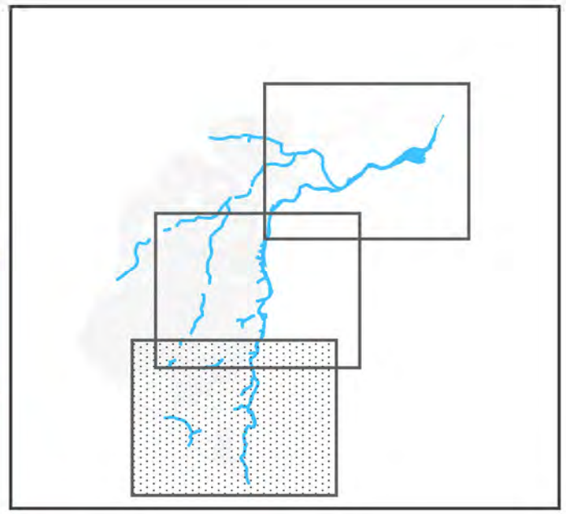
LAND USE DUCK RIVER CATCHMENT PARRAMATTA LGA





N

WATERCOURSE

CADASTRE

0 250 metres

- BUSHLAND
- COMMERCIAL
- INDUSTRIAL
- PARKLAND
- RAILWAY
- RESIDENTAL
- ROADWAY
- WATER

file: landuse MP Map 3
date: 17/05/2012

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AHIMs (INDIGENOUS HERITAGE)

OEH maintains the Aboriginal Heritage Information Management System which includes:

- information about Aboriginal objects that have been reported to the Director General, Department of Premier and Cabinet
- information about Aboriginal places which have been declared by the Minister to have special significance with respect to Aboriginal culture
- archaeological reports.

An Aboriginal site that is recorded on AHIMS could be:

- an Aboriginal object (as defined under the NPW Act)
- a group (i.e. a collection, scattering, deposit etc) of Aboriginal objects
- an area of land containing Aboriginal objects
- a "potential" archaeological deposit which is an area where, based on previous investigation, Aboriginal objects are likely to be present
- a declared Aboriginal place (as defined under the NPW Act), which may or may not contain Aboriginal objects
- an Aboriginal site that has been partially or completely destroyed under the conditions of a past consent.

The following lots were searched for AHIMs records:

LOT NO	DP NO	ADDRESS	ABORIGINAL SITE RECORDED	ABORIGINAL PLACE RECORDED
3	DP1063022	7 Hector ST Chester Hill 2163	0	
82	DP1098129	7 Hector Street CHESTER HIL		
81	DP1098129	7 Hector Street CHESTER HIL	1	
B	DP379153	1 Boundary Road CHESTER HILL		
A	DP379153	8 Everley Road CHESTER HILL	?	
1	DP222670	1 Everley Road CHESTER HILL	5	
B	DP415520	1 Everley Road CHESTER HILL	4	
1	DP217144	20 Wellington Road SOUTH GRANVILLE	8	
B	DP399373	20 Wellington Road SOUTH GRANVILLE	2	
A	DP407154	20 Wellington Road SOUTH GRANVILLE	2	
1	DP315287	20 Wellington Road SOUTH GRANVILLE	0	
5	DP192307	2A Erie Street SOUTH GRANVILLE		
6	DP192307	2A Erie Street SOUTH GRANVILLE		
7	DP192307	2A Erie Street SOUTH GRANVILLE		
8	DP192307	2A Erie Street SOUTH GRANVILLE		
1	DP514641	2A Erie Street SOUTH GRANVILLE	1	
279	DP8821	2A Erie Street SOUTH GRANVILLE	1	
280	DP8821	2A Erie Street SOUTH GRANVILLE	1	
4	DP226117	4 Namur Street SOUTH GRANVILLE	1	
2	DP509796	1B Mackay Road SOUTH GRANVILLE	1	
3	DP509796	1B Mackay Road SOUTH GRANVILLE	1	
185	DP8821	1B Mackay Road SOUTH GRANVILLE		
184	DP8821	2A Dixmude Street SOUTH GRANVILLE		
1	DP224184	1B Mackay Road SOUTH GRANVILLE		
147	DP8821	1B Mackay Road SOUTH GRANVILLE		
3	DP224184	1B Mackay Road SOUTH GRANVILLE		
4	DP224184	1B Mackay Road SOUTH GRANVILLE		
7	DP213194	1B Mackay Road SOUTH GRANVILLE		
6	DP213194	1B Mackay Road SOUTH GRANVILLE		
5	DP213194	1B Mackay Road SOUTH GRANVILLE		
C	DP408818	1B Mackay Road SOUTH GRANVILLE		
26	DP8821	1B Mackay Road SOUTH GRANVILLE		
25	DP8821	1B Mackay Road SOUTH GRANVILLE		
1	DP594805	1B Mackay Road SOUTH GRANVILLE		
1	DP512705	1A Byrnes Street SOUTH GRANVILLE	1	
1	DP633508	1 Banksia Street SOUTH GRANVILLE		
D	DP421599	124 Mona Street SOUTH GRANVILLE		
188	DP650719	131 Mona Street SOUTH GRANVILLE		
7	DP30910	1A Heath Street GRANVILLE		
159	DP6784	2 Neilson Street GRANVILLE		
2	DP204101	1A Neilson Street GRANVILLE		
117	DP6784	2 Mimosa Street GRANVILLE	1	
84	DP6784	1 Mimosa Street GRANVILLE	1	
83	DP6784	2 Myrtle Street GRANVILLE	1	
48	DP6784	1 Myrtle Street GRANVILLE		
47	DP6784	6A Seventh Street GRANVILLE		
25	DP6784	1 Seventh Street GRANVILLE		
2	DP707627	1B Factory Street GRANVILLE		
2	DP115286	1B Factory Street GRANVILLE		
1	DP1012953	2B Factory Street GRANVILLE		
101	DP619247	23 Factory Street GRANVILLE		
102	DP619247	1A Factory Street GRANVILLE		
2	DP775151	1A Factory Street GRANVILLE		
1	DP775151	2A Factory Street GRANVILLE		
4	DP803347	36 Railway Lands CLYDE		
	SP64725	13 Berry Street CLYDE		
1	DP220361	53 Rowley Road GUILDFORD	1	
1	DP22886	121 Rawson Road GUILDFORD		
21	DP27820	327 Excelsior Street GUILDFORD		
32	DP241618	327 Excelsior Street GUILDFORD		
40	DP2287	78 Guildford Road GUILDFORD		
11	DP2287	78 Guildford Road GUILDFORD		
20	DP868	53 Guildford Road GUILDFORD		
park	249			
21	DP868	52 Eve Street GUILDFORD		
2	DP626900	46 Eve Street GUILDFORD		
	reserve			
18	DP945	45 Eve Street GUILDFORD		

LOT NO	DP NO	ADDRESS	ABORIGINAL SITE RECORDED	ABORIGINAL PLACE RECORDED
24	DP945	110 Robertson Street GUILDFORD		
14	DP945	91 Robertson Street GUILDFORD		
32	DP945	87 Robertson Street GUILDFORD		
36	DP945	87 Robertson Street GUILDFORD		
41	DP945	30 Adam Street GUILDFORD		
28	DP945	31 Adam Street GUILDFORD		
32	DP945	58 Wolseley Street MERRYLANDS		
37	DP945	54 Wolseley Street MERRYLANDS		
40	DP945	54 Wolseley Street MERRYLANDS		
45	DP945	48 Wolseley Street MERRYLANDS		
1	DP136166	196 Blaxcell Street SOUTH GRANVILLE		
11	DP192747	196 Blaxcell Street SOUTH GRANVILLE		
102	DP794050	33 Lackey Street SOUTH GRANVILLE		
23	DP1788	34A Lisgar Street GRANVILLE		
3	DP1788	14 Stuart Street GRANVILLE		
B	DP367480	1 Abbott St Merrylands		
21	DP1788	39 Thomas Street GRANVILLE		
26A	DP947	34 Louis Street GRANVILLE		
72	DP998931	23 Louis Street GRANVILLE		
54	DP277	11A John Street GRANVILLE		
21	DP4978	9 Glen Street GRANVILLE		
4	DP16699	9 Glen Street GRANVILLE		
C	DP355997	1A Glen Street GRANVILLE		
1	DP794229	2 Blaxcell Street GRANVILLE		
1	DP430693	1 Memorial Drive GRANVILLE		
1	DP1010807	151 Railway Parade GRANVILLE		
200	DP752058			
1	DP336811	3 Onslow Street GRANVILLE		
15	DP850536			
6	DP850536	22 Hamilton Street CLYDE		
7	DP808181	1 Motorway M4 CLYDE		
71	DP800279	32 Wentworth Street CLYDE		
1	DP585919	21 Wentworth Street CLYDE	Not on data base	
21	DP817742	1A Unwin Street ROSEHILL		
2	DP864567	3-11 Shirley Street ROSEHILL		
1	DP109739	9 Devon Street ROSEHILL		
1	DP534905	9B Devon Street ROSEHILL		
2	DP224288	9 Devon Street ROSEHILL		
AUBURN				
51	DP 1081545	353 Chisholm Rd Auburn		
8	975170	Chisholm Rd Auburn		
6	192307	Chisholm Rd Auburn Princes Park		
A	397547	Peter Hislop Park	4	
B	65888	Golf course	4	
7	25613	Golf course		

LOT NO	DP NO	ADDRESS	ABORIGINAL SITE RECORDED	ABORIGINAL PLACE RECORDED
2	723928	Golf course	2	
9	10163	Golf course		
17	9380	Golf course		
21	13471	Golf course		
4	192307	Progress Park		
30	6713	Killeen Street Auburn		
29	6713	98 Chiswick Road Auburn		
1	938994	Auburn Community Picnic area		
7016	93911	99 Chiswick Road Auburn		
1	222366	99 Chiswick Road Auburn		
12	7097	Webbs Ave Auburn		
36	7097	Webbs Ave Auburn		
14	6338	Webbs Ave playing fields		
42	1463	Webbs Ave Auburn		
7014	93912			
43	1463	Webbs Ave Auburn		
1	514799	Arthur Street Auburn		
1	121657	Webbs Avenue		
28	8800	Edgar Street		
7020	93917	Edgar Street		
1	197476	Edgar Street		
2	197476	Edgar Street		
2	224387			
4	197476	Euston Road		
5	197476	Euston Road		
6	197476	Oriole Stadium		
8	197476	Euston Road		
9	197476	Euston Road		
3	197476	Euston Road		
7012	93894	Euston Road		
7050	93893	Chisholm Road		
6	975152	Bangor Street		
2	975152	Bangor Street		
33	975152	Bangor Park		
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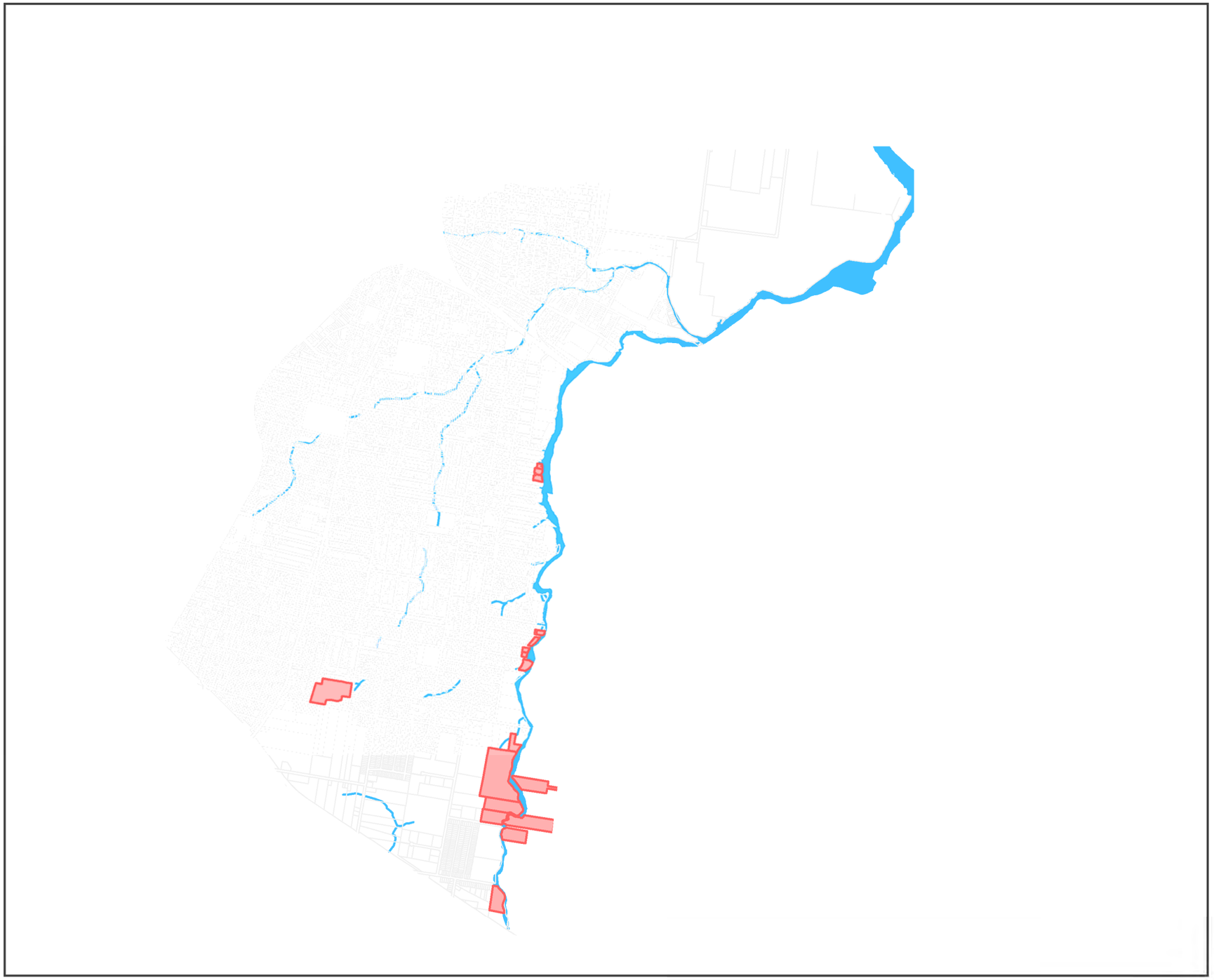
1	1007656	Railway Lands		
201	1007683	?		

AHIMs SEARCH DUCK RIVER CATCHMENT PARRAMATTA LGA



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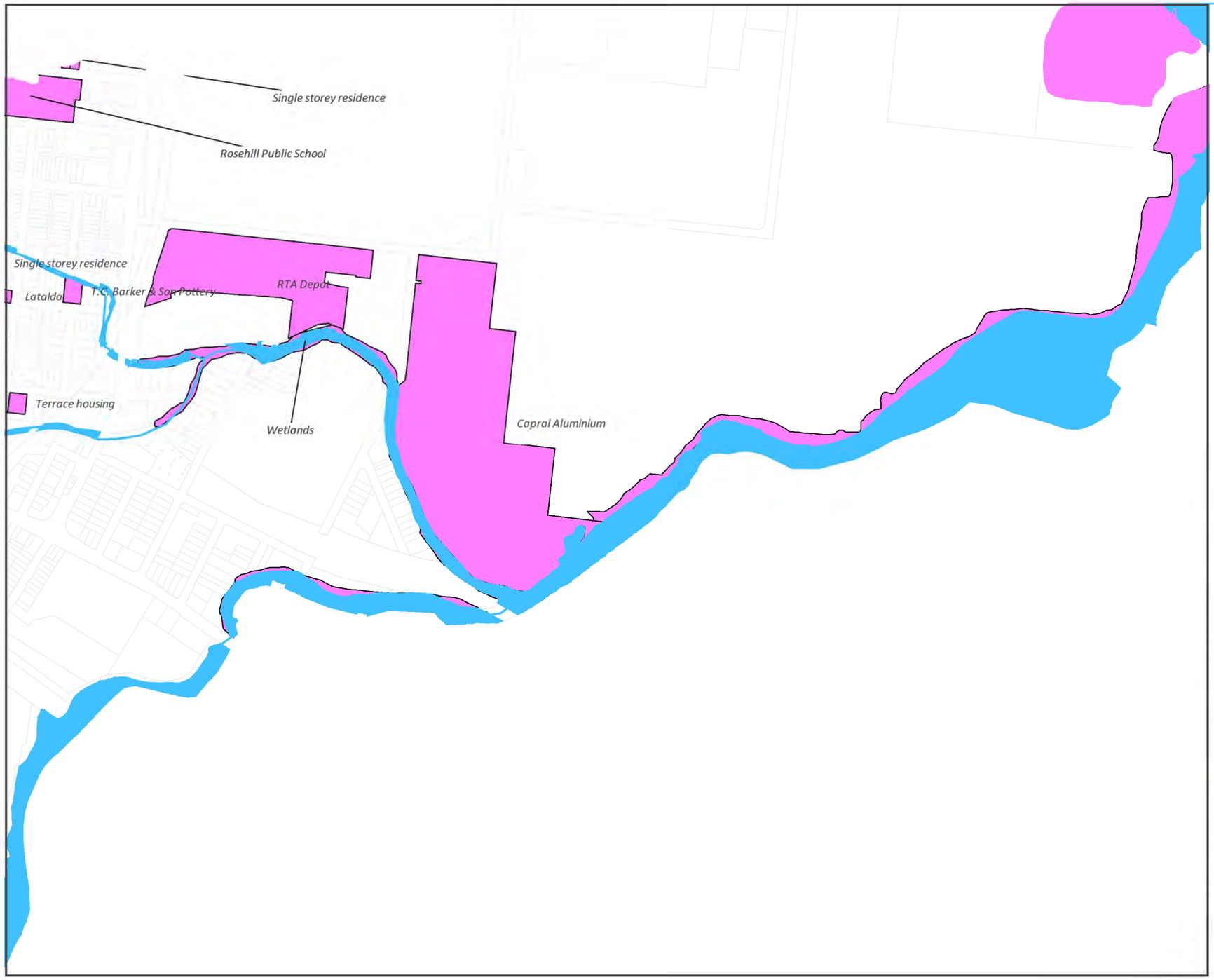
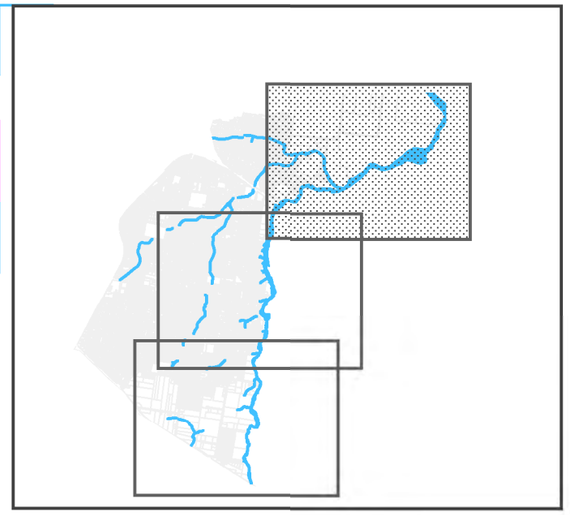
HERITAGE ITEMS (EUROPEAN /GENERAL) DUCK RIVER CATCHMENT PARRAMATTA LGA





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Heritage Item

Cadastre

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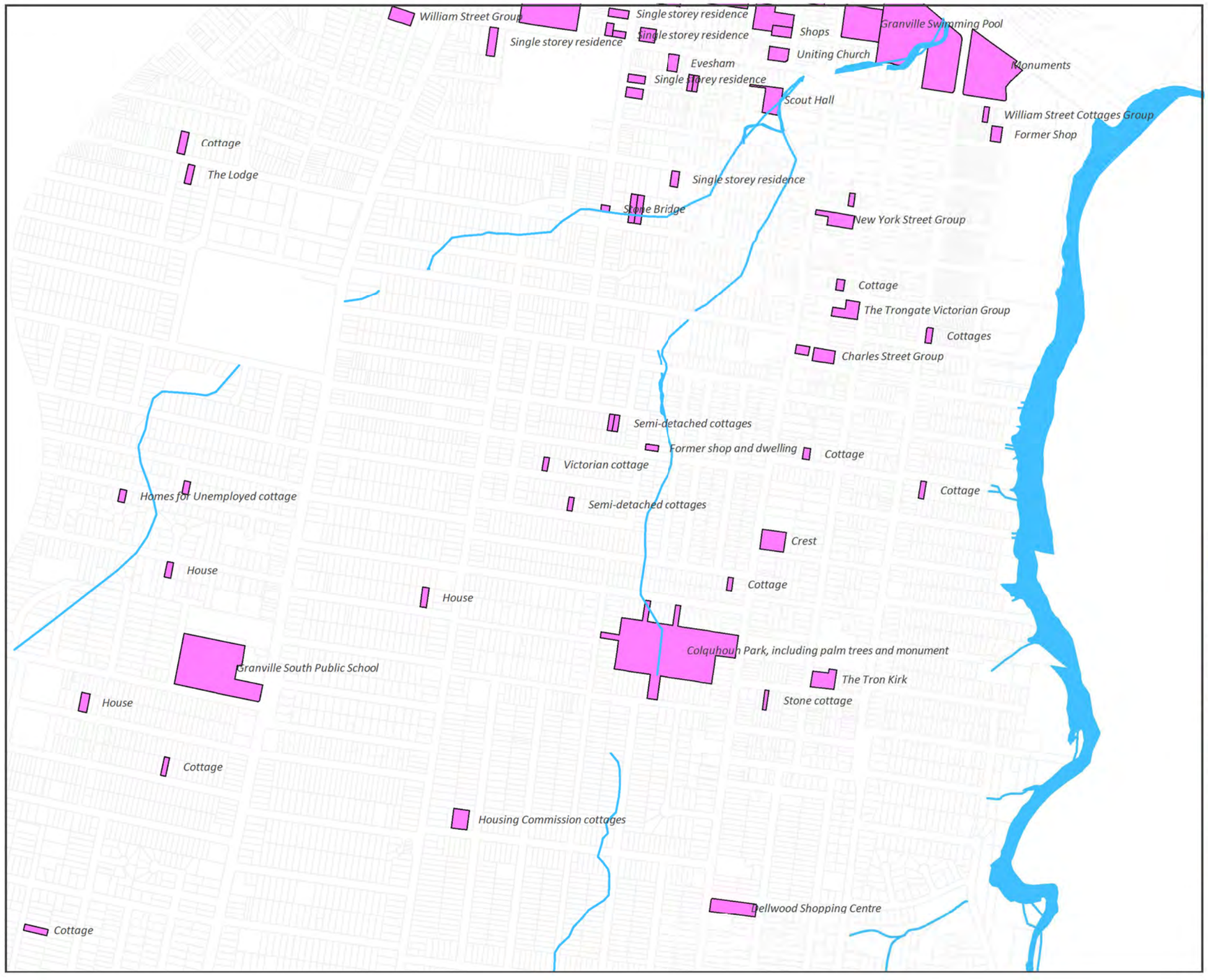
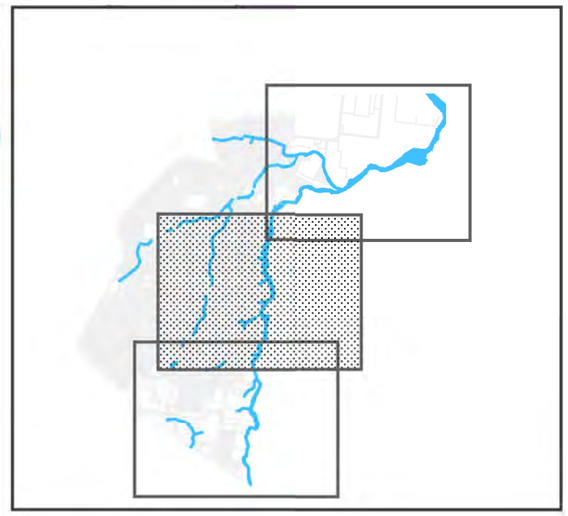
HERITAGE ITEMS (EUROPEAN /GENERAL) DUCK RIVER CATCHMENT PARRAMATTA LGA





Watercourse
Heritage Item
Cadastre

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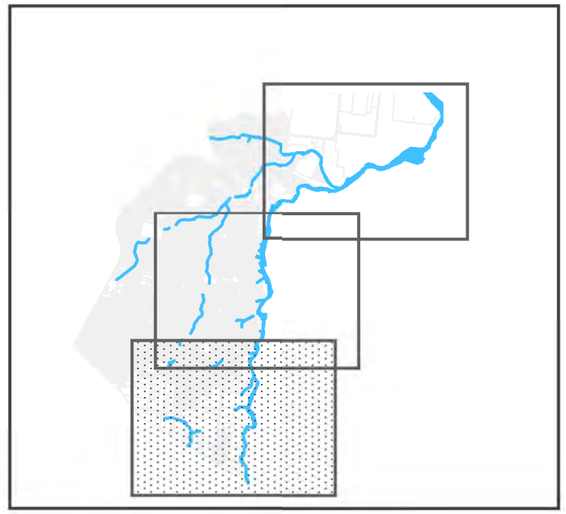

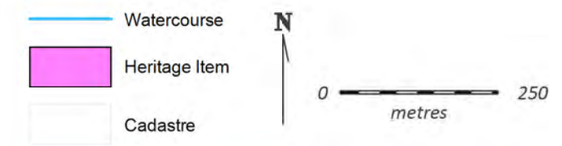

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Contaminated Land Register

Site contamination as a legacy of past site uses is not uncommon, particularly in an urban environment. The sites appearing on the 'List of NSW contaminated sites notified to EPA' indicate that the notifiers consider that the sites are contaminated and warrant reporting to EPA. However, the contamination may or may not be significant enough to warrant regulation by EPA. The EPA reviews the site, and makes a determination as to whether the site warrants regulation. Sites are allocated to a management class (Table 1). The list only contains contaminated sites that EPA is aware of, with regard to its regulatory role under the CLM Act (Table 2). An absence of a site from the list does not necessarily imply the site is not contaminated.

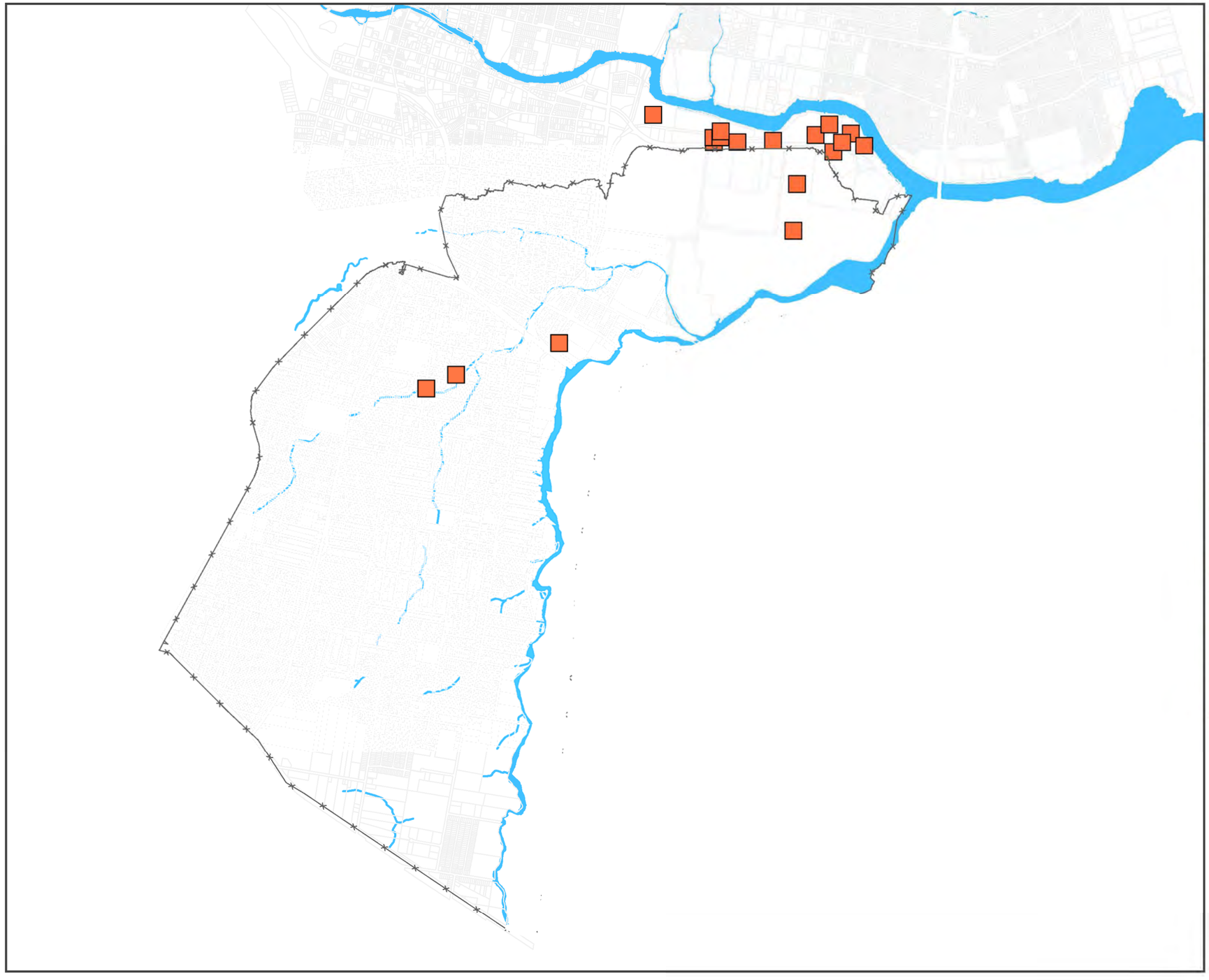
Table 4. EPA site management classes for sites notified to the NSW Contaminated Lands Register

EPA site management class	Explanation
A	The contamination of this site is being assessed by EPA. Sites which have yet to be determined as significant enough to warrant regulation may result in no further regulation under the *Contaminated Land Management Act 1997*.
B	EPA is awaiting further information to progress its initial assessment of this site.
C	The contamination of this site is or was regulated under the *Contaminated Land Management Act 1997*. Information about current or past regulatory action on this site can be found on the Record of EPA notices.
D	The contamination of this site is or was regulated under the *Protection of the Environment Operations Act 1997*. Information about current or past regulatory action on this site can be found on the POEO public register.
E	This is a premises with an operational underground petroleum storage system, such as a service station or fuel depot. The contamination of this site is managed under the *Protection of the Environment Operations Act 1997* and the Protection of the Environment Operations (Underground Petroleum Storage Systems) Regulation 2008.
F	The contamination of this site is managed by a planning approval process. The consent authority is either the local council or a government agency, such as the Department of Planning.
G	Based on the information made available to EPA to date, the contamination of this site is considered by EPA to be not significant enough to warrant regulatory intervention.
H	Initial assessment completed. The contamination of this site is to be regulated by EPA.

Table 5. Excerpt from the NSW Contaminated Lands Register of sites that may impact on the overall health of Duck River catchment

Suburb/City	Site Description	Site Address	Activity that caused the contamination	s60 Form Received	OEH Initial Assessment	OEH Management Class
Auburn	Former Ajax chemical factory	9 Short Street	Other Industry	Yes	Completed	C
Auburn	Janyon	Manchester Road	Other Industry	Yes	Completed	G
Camellia	Akzo	6 Grand Avenue	Chemical Industry	No	Completed	C
Camellia	Asciano Properties	39 Grand Ave	Chemical Industry	No	Completed	C D
Camellia	Bitumen Manufacturer	12 Grand Avenue	Other Industry	No	Completed	C D
Camellia	Council Reserve	11B Grand Ave	Metal Industry	No	Completed	G
Camellia	Hambear	14 Thackeray St	Metal Industry	No	Completed	G
Camellia	Hymix Concrete	14 Grand Ave	Metal Industry	No	Completed	C
Camellia	James Hardie Factory (former)	1 Grand Ave	Other Industry	Yes	Completed	C
Camellia	Maritime Services Board	33A Grand Ave	Metal Industry	No	Completed	G
Camellia	Mauri Foods	15 Grand Ave	Other Industry	Yes	Completed	H
Camellia	Railway Land	27 Grand Ave	Other Industry	No	Completed	G
Camellia	Sydney Water	41 Grand Ave	Chemical Industry	No	Completed	C G
Camellia	Veolia	37 Grand Ave	Chemical Industry	No	Completed	C
Camellia	Wrigg	13 Grand Ave	Metal Industry	No	In progress	A
Granville	Australand	15-17 Berry St	Other Industry	Yes	Completed	F
Granville	Caltex Service Station	144 Parramatta Rd	Service Station	No	In progress	B
Granville	Evans Deacon Ind	2B Factory St	Other Industry	Yes	Completed	C
Granville	Mobil Service Station	154-160 Parramatta Road	Service Station	Yes	In progress	B
Granville	Old Granville Depot	23 Elizabeth Street	Unclassified	Yes	In progress	A
Rosehill	Camellia, Shell Clyde Refinery	9 Devon Street	Metal Industry	No	Completed	D
Rosehill	James Hardie	Devon Street	Other Industry	No	Completed	C
Rosehill	Shell Clyde Refinery	Durham St	Other Petroleum	No	Completed	D
Silverwater	Silverwater Landfill	Carnarvon Road	Landfill	Yes	Completed	H

CONTAMINATED SITES DUCK RIVER CATCHMENT PARRAMATTA LGA



Cadastre

Watercourse

N

0 1
kilometres

Contaminated Lands Register
Registered Site

Catchment boundary

file: Contaminated_Lands
date: 13/05/2012

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CONSTRAINTS AND OPPORTUNITIES

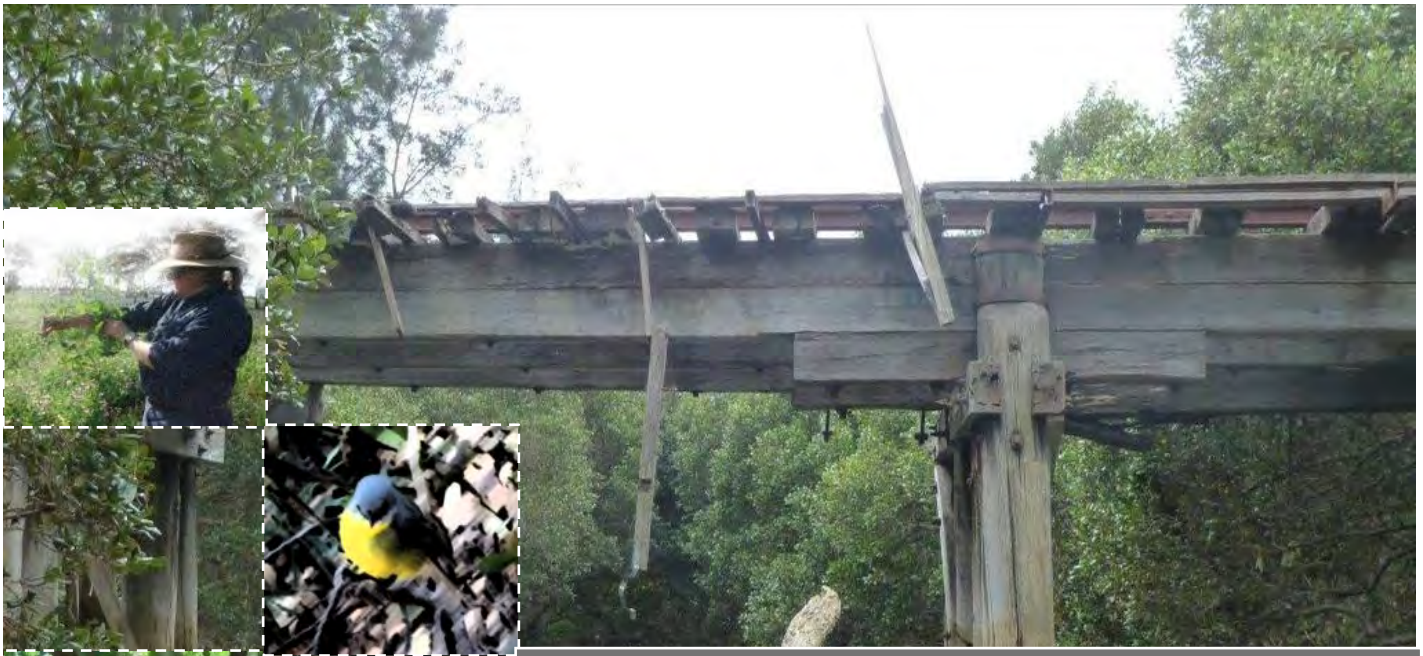
Based on the information gathered to provide detailed mapping for the Duck River Catchment, an opportunities and constraints assessment was undertaken to identify current issues/problems, assets/strengths of each reach.

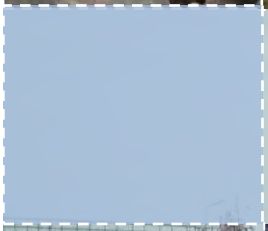
Table 6. Constraints and opportunities identified for reaches in the Duck River Catchment

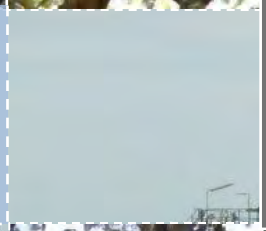
ISSUE	CONSTRAINTS	OPPORTUNITIES	APPLIES TO REACH #
Quality of vegetation in remnant EECs	• Generally small, with areas of good bush in highly degraded remnants • Ongoing impacts from weeds higher in the catchment, or outside the riparian corridor • Inappropriate use by visitors (eg. motorbikes, BMX, litter dumping, dogs off leash, faeces) • Cultural support and acceptance for non local indigenous plant species	• Recreate and extend the riparian understorey and canopy. • Restore complexity in vegetation, providing enhanced habitat resources • Re-establish a vegetative corridor of appropriate density and complexity for full length of study area, providing potential fauna corridor • Understorey management through bush regeneration programs	**Upper Duck River** DR#1, DR#2, DR#3, DR#4, DR#5 **Duck River Tidal** DR#6, DR#7, DR#8 **Smalls Creek** SC#1, SC#2 **Unnamed creeks** UN#1, UN#2B, UN#3, UN#5, UN#6, UN#7, UN#9
Quality of other riparian vegetation	• Significant areas of dense exotics and weeds • Weeds and other exotics provide stability and habitat resources in some areas	• Staged removal programs in conjunction with supplementary habitat resources (eg nest boxes) provide ongoing habitat during weed control activities • Better quality native habitat as a result of restoration activities provides resources for a wider range of native species	**Upper Duck River** DR#1, DR#2, DR#3, DR#4, DR#5 **Duck River Tidal** DR#6, DR#7, DR#8 **Duck Creek** DC#4, DC#5 **Little Duck Creek** LDC#1A, LDC#1B, LDC#2, **Smalls Creek** SC#1, SC#2 **Unnamed creeks** UN#1, UN#2A, UN#2B, UN#3, UN#4, UN#5, UN#6, UN#7
Naturally functioning stream ecosystem	• Bank stabilisation works may alter normal stream functions, including sediment deposition zones • Significant bed lowering has resulted in disconnection of the stream from the surrounding floodplain area • Significant sediment and nutrient loads are introduced from upstream areas • Toxic sediments impact on downstream and tidal environments • Tidal reaches function as estuarine ecosystems	• Manage woody debris as additional habitat resources • Improve aquatic health through control of introduced fish species • Supplementary plantings along waterway fringes, particularly in areas that are susceptible to erosion in peak flow events • Improvements to riparian corridor vegetation, provision of additional habitat options, enhancements to recreational amenity	**Upper Duck River** DR#1, DR#2, DR#3, DR#4, DR#5 **Duck River Tidal** DR#6, DR#7, DR#8 **Duck Creek** DC#4, DC#5 **Little Duck Creek** LDC#1A, LDC#1B, LDC#2 **Smalls Creek** SC#1, SC#2 **Unnamed creeks** UN#1, UN#2A, UN#2B, UN#3, UN#5, UN#6, UN#7, UN#9
Bank stability	• Bank erosion is occurring following high flow events, and large quantities of sediments are mobilised • Sediment transport can also carry weed propagules to areas downstream • Toxic sediments from past industrial activities are becoming disturbed and mobilised when banks are destabilised • Stormwater outlets create active erosion points in many places • Steep banks with weed vegetation coverage experiencing toe failure require immediate attention	• Possible provision of pool and riffle systems (rock chutes and rock weirs) as part of streambank and channel bed stabilisation will provide improved habitat, water quality enhancement and improved amenity • Stabilisation of streambanks will reduce sediment movement, improving flow behaviour and restricting transportation downstream • Use properly positioned rootwads as a stabilisation technique where appropriate	**Upper Duck River** DR#1, DR#2, DR#3, DR#4, DR#5 **Duck River Tidal** DR#6, DR#7 **Duck Creek** DC#4, DC#5 **Little Duck Creek** LDC#1, LDC#2 **Smalls Creek** SC#1, SC#2 **Unnamed creeks** UN#1, UN#2A, UN#2B, UN#3, UN#5, UN#6, UN#7, UN#9

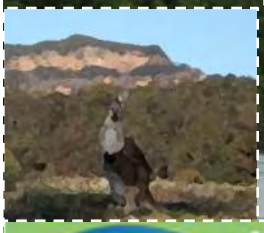
ISSUE	CONSTRAINTS	OPPORTUNITIES	APPLIES TO REACH #
Flood behaviour	• High proportion of impervious surfaces in the catchment has led to flashy storm flow events • Time of concentration is rapid, peak flows occur quickly and at higher levels than would be normal stream behaviour • Large quantities of litter and storm debris are transported and then deposited on vegetation, around in-channel piers, etc	• Improve management of peak flows in tributaries with alternating open channel and piped sections – options include provision of flood retardation basins • Improve capacity for lateral connection between stream and surrounding floodplain by removing flood sensitive structures • Improve management of litter to reduce impacts from deposition of storm debris	**Upper Duck River** DR#1, DR#2, DR#3, DR#4, DR#5 **Duck Creek** DC#4, DC#5 **Little Duck Creek** LDC#1, LDC#2 **Smalls Creek** SC#1, SC#2 **Unnamed creeks** UN#1, UN#2A, UN#2B, UN#3, UN#5, UN#6, UN#7, UN#9
Water quality	• Highly urbanised catchment is a constant source of litter in stormwater • High nutrient load generated in the immediate catchment and in upstream areas • Erosion leading to sediment mobilisation affects water quality • Carp populations feed on bottom sediments and constantly disturb and mobilise sediments and toxic material • Fertilisers and herbicide are used regularly on sporting grounds surrounding the river corridor	• Streambank stabilisation and erosion control will reduce sediment loads • Reduction in scouring through management of storm flows and removal of carp will reduce mobilisation of toxic sediments • Improved collection of litter and storm debris at stream inflow points • Education of grounds managers for sporting facilities to minimise the use of fertilisers and herbicides • Liaison with Bankstown City Council to better manage the quality of stream flows entering this part of the catchment	**Upper Duck River** DR#1, DR#2, DR#3, DR#4, DR#5 **Duck River Tidal** DR#6, DR#7, DR#8 **Duck Creek** DC#1, DC#2, DC#3, DC#4, DC#5 **Little Duck Creek** LDC#1, LDC#2, LDC#3, LDC#4 **A'Becketts Creek** ABC#1, ABC#2 **Smalls Creek** SC#1, SC#2 **Unnamed creeks** UN#1, UN#2A, UN#2B, UN#3, UN#4, UN#5, UN#6, UN#7, UN#8, UN#9
Width of riparian corridor	• For many of the smaller tributaries there is urban development within several metres of the normal water's edge • In other parts of these tributaries open space parks occupy the riparian corridor • In the main channel development is largely excluded from the immediate riparian area • Width of buffer allocated to riparian vegetation is often limited to 10-15m, outside this is grassed open space for sporting activities	• Revegetation in the main channel should include expansion of riparian buffer by planting to extend existing EEC vegetation • Revegetation in smaller tributaries should include expansion of riparian buffer through planting of canopy species that provide habitat resources without compromising the open space atmosphere • Some locations where buyback of riparian buffer should be considered	**Upper Duck River** DR#1, DR#2, DR#3, DR#4, DR#5 **Duck River Tidal** DR#6, DR#7, DR#8 **Duck Creek** DC#1, DC#2, DC#3, DC#4, DC#5 **Little Duck Creek** LDC#1, LDC#2, LDC#3, LDC#4 **A'Becketts Creek** ABC#1, ABC#2 **Smalls Creek** SC#1, SC#2 **Unnamed creeks** UN#1, UN#2A, UN#2B, UN#3, UN#4, UN#5, UN#6, UN#7, UN#8, UN#9
Land tenure for stream channel	• Large parts of many tributaries are concrete-lined trapezoidal drains owned and managed by Sydney Water as part of their stormwater management assets • Channels are managed to maintain their existing condition	• Limited opportunities for improvement of ecosystem health or habitat resources associated with concrete lined channels • No likelihood of "naturalisation" of these channels due to spatial constraints • Handover of channels from Sydney Water to Parramatta Council would require a major outlay of capital expenditure just to maintain their existing condition	**Duck Creek** DC#1, DC#2, DC#3, DC#4 **Little Duck Creek** LDC#3, LDC#4 **A'Becketts Creek** ABC#1 **Unnamed creeks** UN#1, UN#2A, UN#2B, UN#3, UN#4, UN#5, UN#6, UN#7, UN#9

ISSUE	CONSTRAINTS	OPPORTUNITIES	APPLIES TO REACH #
Land tenure for riparian corridor	• Some areas of private land ownership in the main channel • Many areas of private land ownership in the main tributaries significantly limit options for improving riparian extent and condition	• Consider buyback scheme or joint management plans with major industrial landholders, including Shell Refinery, Australia Post and others	**Upper Duck River** DR#5 **Duck River Tidal** DR#7, DR#8
Access and recreation	• Impacts on understorey and canopy continuity from informal pedestrian, bicycle and motorbike access • Continued need for mowing of open space areas, impacting on riparian corridor edge and damaging native grasses • Potential public safety issues in areas with dense understorey • Potential for damage to important cultural heritage items if location known and access improved	• Create interesting pedestrian and shared cycle circular paths around the Upper Duck River Wetlands riparian corridor • provide link to existing pathways and resources on both sides of the river • Provide educative and interpretive signage to highlight the importance of rehabilitation and maintenance activities. • Create educational opportunities associated with the main wetlands and riparian corridor • Identification and protection for important heritage items	**Upper Duck River** DR#1, DR#2, DR#3, DR#4, DR#5 **Duck River Tidal** DR#6, DR#7, DR#8 **Smalls Creek** SC#2 **Unnamed creeks** UN#3, UN#5, UN#6, UN#7, UN#9
Introduced animals	• Carp are destructive to stream banks and disturb stream bed sediments; outcompete native species for food and habitat resources • Gambusia are aggressive and very competitive species, predating tadpoles of native frog species • Introduced ducks and geese reduce food resources and defecate into the stream, contributing to poor water quality • Feral cats are implicated in predation of native birds and small marsupials	• Community information activities could include carp fishing as a way of reducing their numbers in the main channel, and education about the dangers of consuming fish caught in Duck River • Public education should include the damage done by introduced ducks and geese • Feral cats and uncontrolled domestic cats need to be controlled through a cat trapping program in conjunction with a cat curfew and micro-chipping program	**Upper Duck River** DR#1, DR#2, DR#3, DR#4, DR#5









WATERWAYS MAINTENANCE AND REHABILITATION MASTERPLAN FOR THE DUCK RIVER CATCHMENT

Prepared for Parramatta City Council

By Applied Ecology Pty Ltd

19/10/2012

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PARRAMATTA CITY COUNCIL

DOCUMENT VERIFICATION

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Document Title	**WATERWAYS MAINTENANCE AND REHABILITATION MASTER PLAN FOR THE DUCK RIVER CATCHMENT**
Client	**Parramatta City Council**
Client contact	**Pino Todarello**

Revision	**Prepared by**	**Reviewed by**	**Date**
Draft (D)	**MB/AC/JS**	**A. Collins, P. Todarello**	**May 2012**
Draft			
Final			**Issued 19th October, 2012**

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ACKNOWLEDGMENTS

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Anthony Collins Parramatta City Council
Greg Hodges Auburn City Council

Contents

List of Tables

A VISION FOR THE CATCHMENT

CONSULTATION FRAMEWORK

A range of stakeholders were consulted during the preparation of this Plan of Management. Representation was sought from local government, special interest groups, residents and the broader community. Around 350 people were invited to a public meeting as part of the plan development process. They were provided with alternatives for lodging comments and suggestions through online portals on Parramatta Councils' website, via email or mail.

Around 35 people attended the meeting, and participated in a vigorous brainstorming session. Many of the participants indicated that they had not previously taken the opportunity to be involved in the community consultative process, despite a number of these being held over the last 10 or 15 years. The issues discussed, opportunities identified, and desired outcomes identified are presented in detail in Appendix One, along with responses to a community survey questionnaire.

This was used to inform the development of the Vision for Duck River Catchment, below.

DEFINING THE VISION

Feedback from stakeholders was used to guide preparation of the Masterplan, particularly identifying the actions and their priorities. All of the suggestions were considered during the formulation of the Masterplan, and most were directly incorporated. Key findings from the community survey and consultation process are listed below:

- Need to reserve some areas specifically for nature conservation, with restricted access.
- A need was identified to conserve, maintain and improve the integrity of natural bushland.
- Strategies for managing the huge volume of rubbish in the catchment were discussed, and solutions included public education through specific programs in schools, for local businesses, cultural groups with non-English speaking backgrounds, and appointment of council rangers to specifically target littering and dumping of rubbish
- Manage water pollution including impacts from development and surrounding land use activities; better management of sediment traps and SQIDs
- The need for coordination between Auburn and Parramatta councils was highlighted; also the need to liaise with Bankstown Council to manage inputs from higher in the catchment.
- Programs to involve the local community more in the natural resources of the Upper Duck River Wetlands, increasing awareness of the assets and problems of the catchment through information brochures, signage, guided walks, schools programs, "Adopt a Reach" programs for local factories and corporate identities.
- Need for appropriate development controls to conserve the natural assets of Upper Duck River throughout ongoing urban development and population expansion in the area, including WSUD, BASIX, maintaining setbacks, buffer trees in the urban footprint

This formed the basis of the Vision for Duck River Catchment.

THE VISION FOR DUCK RIVER

A VISION FOR DUCK RIVER CATCHMENT

"is to improve the ecological health and value of the riparian corridor and wetlands ecosystems,

while enhancing a healthy, diverse and productive environment; and

ensuring that landuses within the catchment are developed and managed effectively for conservation of the natural environment and cultural heritage,

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

OBJECTIVES OF THE MASTERPLAN

The current condition of significant parts of the Duck River catchment is highly degraded, requiring significant resources of funding and time to achieve good ecological outcomes, in line with the Vision Statement. In recognition of this, the Masterplan proposes that rehabilitation be implemented progressively over a reasonable period time - five to ten years is recommended. The objectives are:

- Protect threatened species
- Rehabilitate endangered ecological communities and improve connectivity
- Improve water quality
- Stabilise sites of geomorphic degradation (bed or bank erosion)
- Protect known Aboriginal and European heritage items, and identify and record new ones
- Improve recreational facilities such as walking trails, rest areas, play areas and signage
- Increase community involvement in environmental management of the corridor, including offering opportunities for learning, and places to develop a connection with the natural environment
- Improve the connections between the Parramatta side of the river and the Auburn side
- Investigate, and if necessary, remediate contaminated land
- Repair important civil structural assets (e.g. stormwater, sewer and weir)
- Ensure all new development has appropriate environmental controls to minimise impact on the receiving ecosystem health

REACH APPORTIONMENT

Streams were divided into reaches based broadly on the method described by Rutherford et al (1999) in the Australian Streambank Rehabilitation Manual, and adapted from "A rapid riparian assessment tool for local council urban creek assessment: Ku-ring-gai Council, Sydney, NSW", (MP Taylor, S Findlay, A Fletcher, 2004. Fourth Australian Stream Management Conference, Launceston, 2004). Determination of reaches was conducted using the following steps:

1. **Division of longitudinal continuity:** Individual reaches are identified as being longitudinally bounded by a confluence or termination of the stream (including entry and exit from pipes).
2. **Division of different land use:** Changes in land use between bushland, urban areas and sporting fields/parks are used to further sub-divide the reaches. Land surface composition, in particular, area of impervious surfaces can greatly impact the quality and quantity of stormwater and thus affects stream condition.
3. **Division by buffer width:** For bushland and parkland stretches, the reaches are further divided according to width of riparian buffer (distance of vegetated zone before urban development). A substantive riparian buffer is in effect a "biophysical highway;" it provides effective filtration by trapping sediments and nutrients, attenuates flood impacts and provides habitat and wildlife corridors. The width of the riparian zone determines biophysical and ecological effectiveness and stream characteristics, an important factor to consider when defining representative reaches. Narrow corridors have greater relative 'edge effects' compared to larger buffers and these effects impact on their effectiveness as a refuge and a filter.

A total of 28 reaches were identified in the catchment, and are examined later in this report.

SHARED MANAGEMENT REACHES

A number of reaches have limited management recommendations because of existing management arrangements, or private ownership, including Sydney Water owned/managed concrete lined drains:

- A'BECKETTS CREEK 1
- DUCK CREEK 1
- DUCK CREEK 2
- DUCK CREEK 2A
- DUCK CREEK 3
- DUCK CREEK 4
- LITTLE DUCK CREEK 3
- LITTLE DUCK CREEK 4
- UNNAMED 4 A'BECKETTS ST
- UNNAMED 8 GUILDFORD RD

Other reaches that have private ownership of riparian lands include:

- DUCK RIVER 8
- DUCK CREEK 5
- SMALLS CREEK 1
- UNNAMED 7 BANKSIA ST

DEVELOPMENT OF A REHABILITATION WORKS PLAN

INTERPRETING THE CURRENT CONDITION OF THE CATCHMENT

A series of condition scores are provided to develop an overall understanding of the ecosystem health for that section of the catchment (Table 1). Each component of the overall condition is scored as indicated, with a maximum possible total of 26 for a reach. Contributing factors to these scores are explained in Table 1.

Table 1. Reach condition scores and how they are calculated

SCORE	CALCULATED FROM
GEOMORPHIC CONDITION (/5)	Geomorphology: score /2.5, deductions for overall extent of modification, erosion, sediment deposition Hydrology: score /2.5, deductions for modifications (eg. weirs, channelized, etc), storm damage, storm debris **Condition score = Geomorphology score + Hydrology score**
RIPARIAN VEGETATION (/5)	**Vegetation score = (Percent riparian vegetation cover) x (percent native species) x 5** eg. (70% cover x 60% native) x 5 = score of 2.1
INSTREAM HABITAT (/10)	Wetlands: score /4 for overall extent and condition of wetlands Habitat: score /4 with points added for complexity and extent of habitat elements present (see Table 18) Fish passage: score /2, deductions for barriers such as weirs, or partial barriers to passage eg. stepping stones weir **Habitat score = Wetlands score + Habitat score + Fish passage score**
SENSITIVITY (/6)	Endangered Ecological Communities: score 1 for each EEC present Threatened Species: score 1 for a species present Indigenous heritage: score 1 for an item present European heritage: score 1 for an item present **Sensitivity score = EEC score + TS score + Indigenous heritage score + European heritage score**
OVERALL SCORE	Overall score = sum of individual scores Maximum possible = 26

The overall score gives a useful ranking of stream condition. In general, higher ranked reaches should be worked first. Primary management objectives are determined from the individual condition scores (Table 2). This reflects the key values for that reach, and underpins targeted management objectives and actions.

A good hydro-geomorphology score is ≥ 3; a good riparian vegetation condition score is ≥ 2.5; a good instream habitat score is > 7; and a high sensitivity score is ≥ 5. Reaches that score in any of these ranges for condition categories need to be managed to maintain and improve these assets. Reaches that do not score in these ranges need to be managed to protect aspects of the downstream environment. In some cases, it is recommended that rehabilitation works target habitat creation or improvement, particularly in areas that have a direct impact on good habitat downstream.

Overall scores recorded ranged from 1.7 (A'Becketts Creek 2) to 22.2 (Duck River 8), providing an indication of the variation in condition of different reaches in the catchment.

Table 2. Individual scores, overall score and priority category for Duck River reaches

REACH NAME	HYDRO-GEOMORPHOLOGY SCORE	RIPARIAN VEGETATION SCORE	INSTREAM HABITAT SCORE	SENSITIVITY SCORE	OVERALL CONDITION SCORE	PRIMARY MANAGEMENT OBJECTIVE(S)
A'BECKETTS CREEK 1	1.5	0.5	1	0	3.0	REDUCE DOWNSTREAM IMPACTS
A'BECKETTS CREEK 2	0.5	0.1875	1	0	1.7	IMPROVE ESTUARY HEALTH
DUCK CREEK 1	1.5	0.0625	1	1	3.6	REDUCE DOWNSTREAM IMPACTS
DUCK CREEK 2	1.5	0.65	1	2	5.2	REDUCE DOWNSTREAM IMPACTS
DUCK CREEK 2a	1.5	0.225	1	0	2.7	REDUCE DOWNSTREAM IMPACTS
DUCK CREEK 3	1	0.4	1	0	2.4	REDUCE DOWNSTREAM IMPACTS
DUCK CREEK 4	1.5	2.1	6	0	9.6	REDUCE DOWNSTREAM IMPACTS
DUCK CREEK 5	4	3.6	7	3	17.6	IMPROVE ESTUARY HEALTH
DUCK RIVER 1A	2.5	1.75	5.2	4	13.5	PROTECT DOWNSTREAM HABITAT
DUCK RIVER 1B	3.5	2.75	5.8	2	14.1	GOOD RIPARIAN HABITAT, GOOD HYDROGEOMORPHOLOGY
DUCK RIVER 2A	2.5	2	7.2	2	13.7	GOOD INSTREAM HABITAT
DUCK RIVER 2B	3	2.6	7.3	6	18.9	HIGH SENSITIVITY, GOOD RIPARIAN HABITAT
DUCK RIVER 3A	4	1.1	7.5	3	15.6	GOOD INSTREAM HABITAT

REACH NAME	HYDRO-GEOMORPHOLOGY SCORE	RIPARIAN VEGETATION SCORE	INSTREAM HABITAT SCORE	SENSITIVITY SCORE	OVERALL CONDITION SCORE	PRIMARY MANAGEMENT OBJECTIVE(S)
DUCK RIVER 3B	4	1.25	7.4	3	15.7	GOOD INSTREAM HABITAT
DUCK RIVER 4A	3	0.75	6	4	13.8	GOOD HYDROGEOMORPHOLOGY
DUCK RIVER 4B	3.5	1.1	7.8	4	16.4	GOOD INSTREAM HABITAT, GOOD HYDROGEOMORPHOLOGY
DUCK RIVER 5A	3.3	1	7.5	4	15.8	GOOD INSTREAM HABITAT, GOOD HYDROGEOMORPHOLOGY
DUCK RIVER 5B	2.5	0.4875	7.8	6	16.8	HIGH SENSITIVITY, GOOD INSTREAM HABITAT
DUCK RIVER 6	3	1.125	7.8	5	16.9	HIGH SENSITIVITY, IMPROVE ESTUARY HEALTH
DUCK RIVER 7	4	2.4375	7.5	4	17.9	IMPROVE ESTUARY HEALTH
DUCK RIVER 8	4.8	3.4	8	6	22.2	HIGH SENSITIVITY, IMPROVE ESTUARY HEALTH
LITTLE DUCK CREEK 1A	3.5	2.475	3.5	0	9.5	GOOD HYDROGEOMORPHOLOGY, POTENTIAL HABITAT EXPANSION
LITTLE DUCK CREEK 1B	2.5	0.225	2	0	4.7	POTENTIAL HABITAT EXPANSION
LITTLE DUCK CREEK 2	2	1.35	3	1	7.4	POTENTIAL HABITAT EXPANSION
LITTLE DUCK CREEK 3	1.5	0.1	1	0	2.6	REDUCE DOWNSTREAM IMPACTS

REACH NAME	HYDRO-GEOMORPHOLOGY SCORE	RIPARIAN VEGETATION SCORE	INSTREAM HABITAT SCORE	SENSITIVITY SCORE	OVERALL CONDITION SCORE	PRIMARY MANAGEMENT OBJECTIVE(S)
LITTLE DUCK CREEK 4	1.5	0.75	1	2	5.3	REDUCE DOWNSTREAM IMPACTS
SMALLS CREEK 1	3.8	2.925	4	5	15.7	HIGH SENSITIVITY, GOOD RIPARIAN HABITAT
SMALLS CREEK 2	2.5	4.75	6	4	17.3	GOOD RIPARIAN HABITAT
UNNAMED 1A WADDANGALI	4	4.25	2	4	14.3	GOOD RIPARIAN HABITAT
UNNAMED 1B CAMPBELL HILL	3	3	6	4	16.0	GOOD RIPARIAN HABITAT
UNNAMED 2A RANDOLPH ST	3.5	1.6875	3	1	9.2	GOOD HYDROGEOMORPHOLOGY
UNNAMED 2B CHISWICK RD	3.5	1.75	5.5	2	12.8	GOOD HYDROGEOMORPHOLOGY
UNNAMED 3 BENNETT RD	3	3.325	7	3	16.3	GOOD RIPARIAN HABITAT, GOOD HYDROGEOMORPHOLOGY
UNNAMED 4 A'BECKETTS ST	1.5	1	1	0	3.5	REDUCE DOWNSTREAM IMPACTS
UNNAMED 5 DIXMUDE ST	3	3.5	2	1	9.5	GOOD RIPARIAN HABITAT
UNNAMED 6 MONS	2.5	2.1375	3	1	8.6	PROTECT DOWNSTREAM HABITAT

REACH NAME	HYDRO-GEOMORPHOLOGY SCORE	RIPARIAN VEGETATION SCORE	INSTREAM HABITAT SCORE	SENSITIVITY SCORE	OVERALL CONDITION SCORE	PRIMARY MANAGEMENT OBJECTIVE(S)
ST						
UNNAMED 7 BANKSIA ST	2.5	0.4	5	2	9.9	PROTECT DOWNSTREAM HABITAT
UNNAMED 8 GUILDFORD RD	1.5	0.1	1	0	2.6	REDUCE DOWNSTREAM IMPACTS
UNNAMED 9 WELLINGTON RD	4	3.5	2	5	14.5	HIGH SENSITIVITY, GOOD RIPARIAN HABITAT

DEVELOPMENT OF A PRIORITISED REHABILITATION PLAN

The prioritisation process

A prioritisation process should aim to

1) maintain and protect areas in good condition, or with specific important assets
2) maintain and improve areas in fair condition
3) reduce the impacts from areas in poor condition

Some broad rules for the prioritisation process are:

- **Rarity** (rare reaches have higher priority than common) and other High Conservation Value criteria
- **General condition** based on assessment of assets and problems (reaches in good condition are easier to fix than those in bad condition)
- **Trajectory** (deteriorating reaches should at least be stabilised before improving reaches that are improving on their own accord)*
- **Ease** (reaches that are easy to improve, before those that are hard)

(* Note: trajectory will also be affected by the condition of reaches immediately upstream)

A combination of field survey data and results from desktop surveys was used to inform decisions about the prioritisation process (Table 3).

Table 3. Deciding which works to do first for restoration activities

RANKING CRITERIA	SURVEY COMPONENT(S)
Rarity	• Threatened species present • EECs present • Migratory species present • Cultural heritage items present
General condition	Determined from the overall score (see previous section and site context drawing sheets)
Trajectory	Stream condition can be improving, remaining stable, or deteriorating. The reach trajectory summarises its probable pathway based on current condition and types of impacts currently operating in that reach. The trajectory was determined for the reach's ecological attributes (including riparian vegetation and instream habitat) and its hydrologic and geomorphic condition (based on presence of erosion, sediment deposition, deposition of storm debris).
Ease	Determined from additional data, including: • "good streams" are easier to fix than "bad streams" • Land tenure (public land is "easier" than private) • Presence of bushcare group (community support for ongoing works) • Accessibility, eg. for machinery for capital works

Identified works were then classified into works categories, based on the size and frequency of the activity, and this was also used to inform the works plans.

Works category

Proposed works fall into one, or occasionally more, of the following categories, depending on the size and frequency of the activity:

a) **Ongoing maintenance:** includes works that require repeating activities over time, such as regular mowing to reduce weed seed sources, monitoring programs, or other regular maintenance activities.
b) **Preservation requirements:** includes works that aim to prevent deterioration of existing assets, such as regular weeding in good bushland to retain its overall good health.
c) **Restoration works:** includes works that aim to improve the overall condition of an area or asset, such as primary weed control, carp control and other feral animal control activities.
d) **Minor capital works:** includes works with a budget <$20K, that provide minor additional infrastructure to improve the overall amenity or condition of the catchment, such as footpaths, seating, signage, minor bank stabilisation activities and small GPTs.
e) **Major capital works:** includes works with a budget >$20K, that provide major additional infrastructure to improve the overall amenity or condition of the catchment, such as major bank stabilisation works, trash racks, and pedestrian footbridges.

Works plans

A complete list of actions is provided in the following tables. Actions are grouped according to their management objective:

- **Biodiversity enhancement** actions aim to improve the overall health of the wetlands and riparian zones by removing or reducing a problem, or improving or expanding an asset
- **Water quality improvement** actions aim to improve the overall health of the wetlands by removing or reducing a problem
- **Erosion control** actions aim to improve the overall condition of riparian zones by stabilising channel banks and beds, and to improve the health of the aquatic environment by reducing the amount of sediment mobilised
- **Community and recreation** actions aim to improve the overall amenity of the wetlands and riparian corridor to encourage positive interactions that increase general awareness of the importance of the Upper Duck River wetlands and riparian corridor

Highest priority has been allocated to protecting, maintaining and restoring areas of high ecological and/or geomorphic resilience. The timetable for implementation is as follows:

- **Urgent priority** to be implemented as soon as possible
- **High priority** to be implemented within three years
- **Medium priority** to be implemented within six years
- **Low priority** to be implemented within ten years
- **Ongoing maintenance** refers to actions that are to be carried out for the duration of the Masterplan

Primary responsibility for implementation of the actions provided in the Masterplan falls to Parramatta City Council.

REHABILITATION WORKS AND ACTIVITIES

TYPES OF WORK

The following table provides a brief outline of the aims of activities that are recommended for restoration and management works (Table 4).

Table 4. A brief outline of the aims and activities included in recommended works

MASTERPLAN WORKS/ACTIVITY	BRIEF DESCRIPTION
Bush regeneration weed control	Removal of weeds in predominantly healthy bushland; also refers to follow-up weeding
Primary weed control of vines	Weed control targeting vines for eradication
Primary weed control	First cut weed control, often targeting woody weeds and noxious weeds; needs to have follow up weed control activities
Local provenance plant propagation	Cultivation of plants for revegetation using seed or propagules derived from local native species where possible
Infill planting for diversity	Supplementary planting for depauperate ecosystems – aims to provide increased habitat resources through increased plant diversity; species should be selected to improve vegetation structure and provide flowering and fruiting throughout the year
Planting for stabilisation	Supplementary planting using specifically selecting deep rooted, fast establishing species for planting in areas susceptible to erosion
Revegetation planting	Higher density supplementary planting to replace weeds that have been removed; select plant species that replicate original vegetation structure, improve habitat resources, maintain bank stability
Riparian buffer expansion planting	Preliminary plantings should be canopy species as these are slowest to establish, and Acacias to improve soil health
Plant fringing vegetation	Aims to provide a vegetative “shield” for sensitive vegetation through establishment of shrub and canopy species
Install jute matting with stabilisation planting	Soft engineering solutions to minor/localised erosion issues, and may include the use of jute matting, jute mesh, coir logs, or sandbags
Control/remove introduced ducks and geese	Aims to reduce impacts from utilisation of habitat resources, and pollution of waterways through defecation

MASTERPLAN WORKS/ACTIVITY	BRIEF DESCRIPTION
Control carp populations	Aims to reduce impacts on water quality and streambank erosion through agitation of sediments by bottom feeding behaviours, reduce competition with native fish species for food and habitat resources
Install end of pipe litter control device	Aims to reduce the volume of litter transported via Duck River in smaller channels at piped outflows
Install trash rack, trap or similar litter control device	Aims to reduce the volume of litter transported via Duck River in larger and smaller open channels
Install sediment trap/basin	Aims to reduce the volume of fine particulate pollution transported via Duck River in smaller channels
Install instream vegetated wetland or bioretention system	Aims to reduce the concentration of nutrients and fine sediments to improve water quality in the receiving environment; generally constructed offline or with a high flow bypass to protect the integrity of the system in peak flow events
Maintain mesh trash traps regularly; prepare and implement an Operations and Maintenance Plan	Aims to ensure ongoing correct functioning of gross pollutant control devices
Remove litter and debris from fringing reeds; consider installation of floating trash trap	Aims for an initial reduction in the volume of storm debris in reedland areas, and proposes an ongoing solution that should be implemented if installation of nets, traps and racks higher in the catchment fail to effectively control the pollutant load
Remove sediment plug and other rubbish/storm debris	Aims to provide an immediate solution to sediment and pollutant loading in a smaller channel; if regular maintenance of traps downstream fails to control future loads then ongoing cleaning will be necessary, and consideration should be given to relocating the traps
Water quality monitoring point	Aims to collect data that will help identify high pollution generating sub-catchments through a process of community involvement)
Toe protection works	eg. root wads, rock lining: aims to control erosion in areas where bank erosion is linked to toe erosion
Bank stabilisation works	eg. terracing, rebattering, geotextile lining, rock lining, retaining wall construction: aims to provide control of bank erosion from a number of possible causes

MASTERPLAN WORKS/ACTIVITY	BRIEF DESCRIPTION
Channel bed stabilisation works	eg. construction of rock riffles and/or rock chutes: aims to prevent further channel bed lowering and sediment mobilisation, leading to further disconnection of the main channel flows from the surrounding floodplain
Outlet protection	Aims to control localised erosion around stormwater discharge points
Install seating	Aims to provide facilities that encourage passive recreation/enjoyment of the natural environment
Install informative signage	Aims to provide facilities that encourage education and enjoyment of the natural environment
Install weather shelters	Aims to provide facilities that encourage passive recreation/enjoyment of the natural environment
Formalise existing path by constructing all weather crushed granite footpath for pedestrian access	Aims to improve access to some areas and improve public safety
Concrete footpath/cycleway to provide linkages with existing road and footpath network	Aims to improve access to some areas and improve public safety
Install pedestrian footbridge across river/wetlands	Aims to improve access to some areas and improve public safety
Manage as grassed open space	Aims to manage facilities that encourage passive recreation/enjoyment of the natural environment

See Appendix Two for a full description of works activities and recommended best practice methods.

WATERWAYS CORRIDOR RESPONSES TO MASTERPLAN WORKS AND ACTIVITIES

See Appendix Two for full description of works and recommended best practice methods.

POTENTIAL RESPONSES TO BIODIVERSITY ENHANCEMENT WORKS

Table 5. Potential geomorphic, hydrological and ecological responses to works activities proposed for biodiversity enhancement

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
Bush regeneration weed control removal of weeds in predominantly healthy bushland; also applies to follow-up weeding	• Potential for minor changes to sediment mobilisation and deposition regimes due to changes in plant cover • More closely aligned with naturally functioning waterway	• Minor localised changes during stabilisation following weed removal • Long term positive benefit in flood behaviour through re-establishment of healthy and resilient forested wetland	• Improvement in overall health of EECs • Improvement in diversity and quantity of habitat resources • Ecological for threatened species and endangered populations
Primary weed control of vines (weed control targeting vines for eradication)	• Potential for increased erosion during initial weed control phase. • Selection of the appropriate control methods and early establishment of native plants to replace vines is important to maintain bank stability during ecosystem transition and recovery phases	• Localised modification of flow behaviour through reduction in flow resistance due to intensive weed removal; this needs to be offset by replacement planting of native species • Long term positive reduction in adverse impacts from flood behaviour through re-establishment of healthy and	• Reduction/removal of ecosystem transforming invasive species (listed as key threatening process) • Potential short term loss of habitat resources (feeding and roosting) due to removal of weeds; this can be offset by using a staged removal process. • Long term improvement in

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
	• Long term reduction in mid and upper bank erosion	resilient forested wetlands	overall health of ecosystems and diversity and quantity of habitat resources
Primary weed control first cut weed control, removing the woody weeds and noxious weeds; needs to have follow up weed control activities	• Potential for increased erosion during initial weed control phase. • Selection of the appropriate control methods and early establishment of native plants to replace weeds removed is important to maintain bank stability during recovery phases • Long term reduction in mid and upper bank erosion	• Localised modification of flow behaviour through reduction in flow resistance due to intensive weed removal; this needs to be offset by replacement planting of native species • Long term positive reduction in adverse impacts from flood behaviour through re-establishment of healthy and resilient forested wetlands	• Reduction/removal of noxious weeds and environmental weeds in line with legislative requirements • Potential short term loss of habitat resources (feeding and roosting) due to removal of weeds; this can be offset by using a staged removal process. • Long term improvement in overall health of ecosystems and diversity and quantity of habitat resources
Local provenance plant propagation cultivation of plants for revegetation using seed or propagules derived from local native species where possible	• None anticipated	• None anticipated	• Improvement in overall health of wetland EECs • Supplementary plants of threatened species and endangered populations • Maintenance of biodiversity resources through active conservation of species and

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
			local genetic makeup
Infill planting for diversity supplementary planting for depauperate ecosystems	• Reduction in mid and upper bank erosion • Reduction in quantity of local sediment supply to stream system	• Potential minor 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	• Improvement in overall health of wetland EECs • Ecological for threatened species and endangered populations • Long term improvement in overall health of ecosystems through increases in the diversity and quantity of habitat resources • Maintenance of biodiversity resources through active conservation of species and local genetic makeup
Planting for stabilisation specifically selecting deep rooted, fast establishing species for planting in areas susceptible to erosion	• Resistance to mid and upper bank erosion. • Reduction in quantity of local sediment supply to stream system • Retention of diverse array of streambank habitats	• 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	• Improvement in overall health of wetland EECs • Ecological for threatened species and endangered populations • Long term improvement in overall health of ecosystems through increases in the diversity and quantity of habitat resources

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
			• Maintenance of biodiversity resources through active conservation of species and local genetic makeup
Revegetation planting higher density supplementary planting to replace weeds that have been removed; select plant species that replicate original vegetation structure, improve habitat resources, maintain bank stability	• Reduction in mid and upper bank erosion • Reduction in quantity of local sediment supply to stream system	• Potential minor 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	• Improvement in ecosystem health of wetland and forested EECs • Ecological support for threatened species and endangered populations • Long term improvement in overall health of ecosystems through increases in the diversity and quantity of habitat resources • Maintenance of biodiversity resources through active conservation of species and local genetic makeup
Riparian buffer expansion planting preliminary plantings should be canopy species as these are slowest to establish, and Acacias to improve soil health	• Improved mid and upper bank stability • Reduction in sediment mobilisation and deposition	• Localised modification in flood flow behaviour only • Negligible anticipated change in cross-section averaged flow velocities and associated flood behaviour	• Protection of EECs through buffer planting • Ecological support for threatened species and endangered populations • Long term improvement in

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
			overall health of ecosystems through increases in the diversity and quantity of habitat resources
Plant fringing vegetation aims to provide a vegetative "shield" for sensitive vegetation through establishment of shrub and canopy species	• Improved mid and upper bank stability • Reduction in sediment mobilisation and deposition	• Localised minor modification in flow behaviour; impacts of increase in planting density generally offset by reduction in weed infestation • Negligible anticipated change in cross-section averaged flow velocities and associated flood behaviour	• Protection of EECs through buffer planting • Ecological support for threatened species and endangered populations • Long term improvement in overall health of ecosystems through increases in the diversity and quantity of habitat resources
Install jute matting with stabilisation planting soft engineering solutions to minor/localised erosion issues	• 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	• Improvement in ecosystem health of wetland and forested EECs • Long term improvement in overall health of ecosystems through increases in the diversity and quantity of habitat resources • Improved stream ecosystem health through reduction in erosion and sediment

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
			mobilisation
Control/remove introduced ducks and geese reduce impacts from utilisation of habitat resources, and pollution of waterways through defecation	• Improved bank stability through reduction in degradation of bank vegetation by ducks and geese	• Improved water quality through reduction of pollutants from faecal deposition in the water	• Reduced competition with native birds for food and habitat resources • Improved aquatic ecosystem health through reduction in degrading processes
Control carp populations reduce impacts on water quality and streambank erosion through agitation of sediments by bottom feeding behaviours, reduce competition with native fish species for food and habitat resources	• Improved bank stability through reduction in undercutting of bank as a result of feeding behaviour by carp	• Improved water quality through reduction of sediment mobilisation and associated toxic compounds	• Improved aquatic ecosystems through reduction in degrading behaviours by carp • Reduced competition with native fish species for food and habitat resources • Reduction in competitive exclusionary behaviours by carp

POTENTIAL RESPONSES TO WATER QUALITY IMPROVEMENT WORKS

Table 6. Potential geomorphic, hydrological and ecological responses to works activities proposed for water quality improvement

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
Install trash rack aims to reduce the volume of litter transported via Duck River in larger channels	• Some potential changes to bank and channel bed form • Potential for increased erosion or sediment deposition in response to changes to channel form	• Possible flow modification due to in-channel debris buildup • Some reduction in flow velocities due to increased resistance, and associated flood level increases, up to overtopping flow	• Improved aquatic habitat through reduction of storm debris in peak flows • Improved riparian habitat through reduction in deposition of storm transported litter and debris • No net impact on fish passage for appropriately designed and located structures
Install end of pipe litter control device aims to reduce the volume of litter transported via Duck River in smaller channels at piped outflows	• Minor changes to sediment movements in response to changes in flow patterns	• Possible flow modification due to in-channel debris buildup • Some reduction in flow velocities due to increased resistance, up to maximum pipe flows • Possible back flooding higher in the catchment due to reduction in pipe's discharge capacity	• Improved aquatic habitat through reduction of storm debris in peak flows • Improved riparian habitat through reduction in deposition of storm transported litter and debris
Install trash trap or similar litter	• Minor changes to sediment	• Possible flow modification	• Improved aquatic habitat

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
control device aims to reduce the volume of litter transported via Duck River in smaller open channels	movements in response to changes in flow patterns	due to in-channel debris buildup • Some reduction in flow velocities due to increased resistance, and in associated flood level increases, up to overtopping flow • Minimal back flooding higher in the catchment as peak flows overtop the device	through reduction of storm debris in peak flows • Improved riparian habitat through reduction in deposition of storm transported litter and debris
Maintain mesh trash traps regularly; prepare and implement an Operations and Maintenance Plan aims to ensure ongoing correct functioning of gross pollutant control devices	• Reduction in destabilisation of sediments and banks by ensuring ongoing correct operations of gross pollutant traps	• Improvement in water quality by ensuring that devices are functioning correctly	• Improvement in aquatic and riparian habitats through improving bank stability and water quality • Reduced impacts from deposition of storm debris and sediments
Remove litter and debris from fringing reeds; consider installation of floating trash trap aims for an initial reduction in the volume of storm debris in reedland areas, and proposes an ongoing solution that should be implemented if installation of nets, traps and racks	• No net response to removal of litter and debris • Possible minor erosion or sedimentation associated with installation of floating trash trap	• No net response to removal of litter and debris • Possible minor changes in flow associated with installation of floating trash trap, although these are unlikely as the trap will float in response to changes in	• Improvement in aquatic and riparian habitats through reduction in a degrading process as a result of removing deposited storm debris and litter • Reduced impacts from deposition of storm debris

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
higher in the catchment fail to effectively control the pollutant load		flows; suitable for use in larger channels except where it can be a hazard to water craft	and sediments
Remove sediment plug and other rubbish/storm debris aims to provide an immediate solution to sediment and pollutant loading in a smaller channel; if regular maintenance of traps downstream fails to control future loads then ongoing cleaning will be necessary, and consideration should be given to relocating the traps	• 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 aquatic habitat through rehabilitation of riparian corridor • Improved riparian and fringing species diversity.
Water quality monitoring point aims to collect data that will help identify high pollution generating sub-catchments through a process of community involvement	• No response expected	• No response expected	• Potential for identifying adverse water quality impacts and addressing them; resulting improvement in overall health of aquatic ecosystems

POTENTIAL RESPONSES TO EROSION CONTROL WORKS

Table 7. Potential geomorphic, hydrological and ecological responses to works activities proposed for erosion control

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
Toe protection works eg. root wads, rock lining: aims to control erosion in areas where bank erosion is linked to toe erosion	• Potential change in flow resistance, depending on previous conformation of bank toe • Reduction in bank slumping through undercutting • Reduction in mid and lower bank erosion	• 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 • Short term lower flow resistance may induce higher velocity flows at bankfull levels	• Minor loss of habitat in degrading bank section(s) as a result of implementation • Improved habitat in immediate riparian area through reduction in degrading process, and through habitat creation associated with installation of complex habitat components, eg. rocks, logs, etc • Improved aquatic habitat through reduction in sediment sources • Improved riparian ecosystem health through planting for stability and diversity
Bank stabilisation works eg. terracing, rebattering, geotextile lining, rock lining, retaining wall construction: aims to provide control	• Minimising potential for toe failure and subsequent bank slumping and retreat – reduction in potential for	• Lower flow resistance in bank may induce higher velocity flows at bank full levels	• Minor loss of habitat in degrading bank section(s) as a result of implementation • Improved habitat in

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
of bank erosion from a number of possible causes	sediment loss to stream system • Less resistance to flow, leading to potential for additional bed scour downstream of structure • Resistance to mid and lower bank erosion • Minimising potential for mid-bank failure and bank retreat.	• Cross-section averaged flow velocities at rarer floods *(ie. higher than bankfull)* balanced through proposed dense riparian understorey and groundcover plantings in upper bank • Short term lower flow resistance may induce higher velocity flows at bankfull levels	immediate riparian area through reduction in degrading process, and through habitat creation associated with installation of complex habitat components, eg. rocks, logs, etc • Improved aquatic habitat through reduction in sediment sources • Improved riparian ecosystem health through planting for stability and diversity
Channel bed stabilisation works eg. construction of rock riffles and/or rock chutes: aims to prevent further channel bed lowering and sediment mobilisation, leading to further disconnection of the main channel flows from the surrounding floodplain	• Resistance to prograding bed and bank erosion, reducing bank 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	• 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 • No anticipated variation in flood level or risk to	• Improved aquatic ecology through water quality enhancement • Enhanced aquatic habitat through addition of habitat complexity components • Structure allows fish migration; no anticipated influence on fish breeding areas

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
		property	
Outlet protection aims to control localised erosion around stormwater discharge points	• Reduction in sediment supply to stream system • Resistance to upper bank erosion through maintaining a more stable surface downstream of outlets	• No response expected	• Improved aquatic ecology through water quality enhancement brought about by reduction in suspended sediments

POTENTIAL RESPONSES TO COMMUNITY AND RECREATION ACTIVITIES

Table 8. Potential geomorphic, hydrological and ecological responses to works activities proposed for community involvement and recreational activities

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
Install seating aims to provide facilities that encourage passive recreation/enjoyment of the natural environment	• No response expected	• No response expected	• Improved connection between users of the riparian corridor and the natural environment
Install informative signage aims to provide facilities that encourage education and enjoyment of the natural environment	• No response expected	• No response expected	• Improved connection between users of the riparian corridor and the natural environment
Install weather shelters	• No response expected	• No response expected	• Improved connection between users of the

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
aims to provide facilities that encourage passive recreation/enjoyment of the natural environment			riparian corridor and the natural environment
Formalise existing path by constructing all weather crushed granite footpath for pedestrian access aims to improve access to some areas and improve public safety	• No response expected	• No response expected	• Improved health of riparian habitat through reduction in creation in informal paths
Concrete footpath/cycleway to provide linkages with existing road and footpath network aims to improve access to some areas and improve public safety	• No response expected	• No response expected	• Improved connection between users of the riparian corridor and the natural environment
Install pedestrian footbridge across river/wetlands aims to improve access to some areas and improve public safety	• No response expected	• No response expected	• Improved connection between users of the riparian corridor and the natural environment
Manage as grassed open space aims to manage facilities that encourage passive	• No response expected	• No response expected	• Reduction in potential impacts from exotic grasses through adequate

MASTERPLAN WORKS/ACTIVITY	GEOMORPHIC RESPONSE	HYDROLOGICAL RESPONSE	ECOLOGICAL RESPONSE
recreation/enjoyment of the natural environment			management of potential propagules

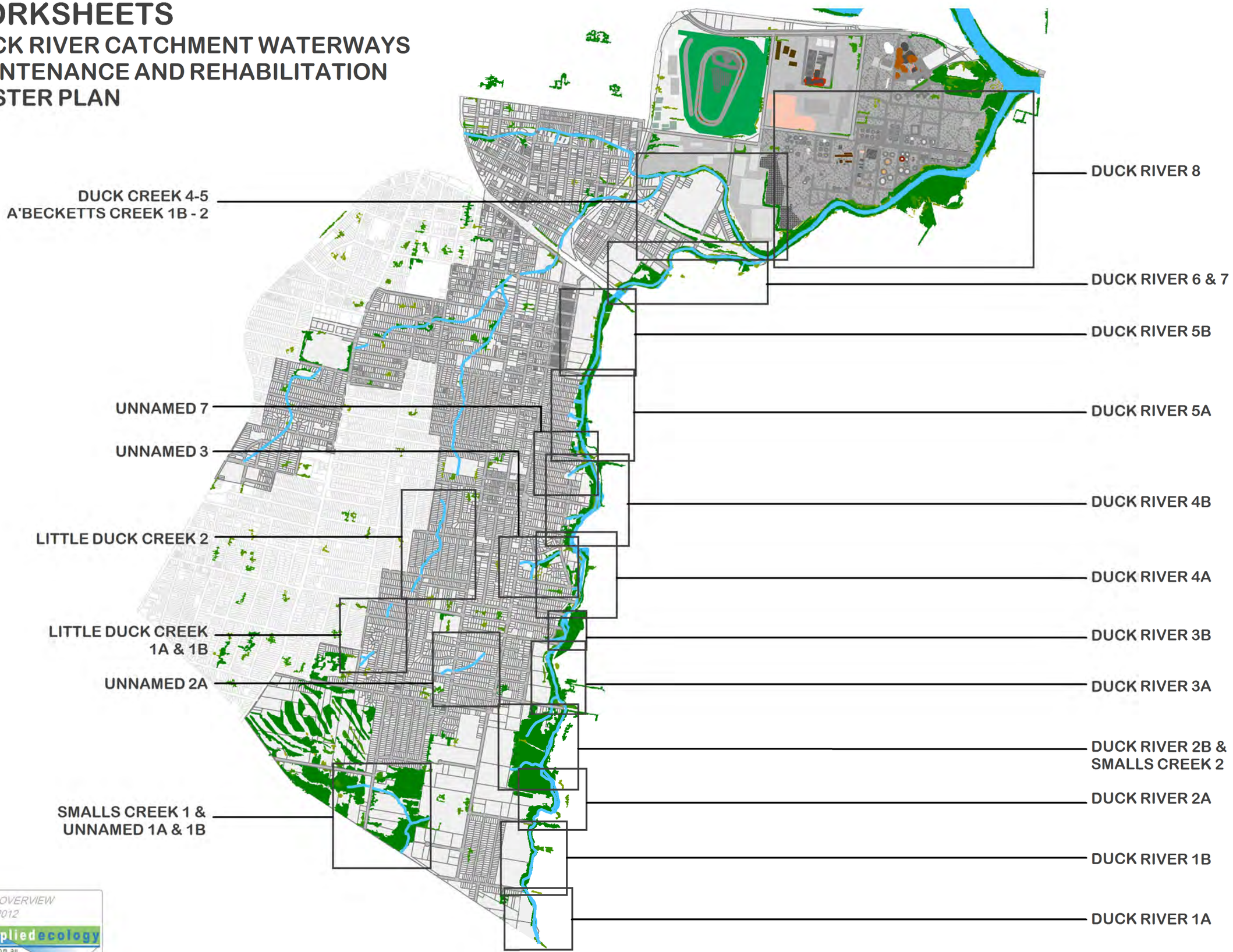
REHABILITATION WORKS AND ACTIVITIES – THE MASTERPLAN

OVERVIEW

See following pages

WORKSHEETS

DUCK RIVER CATCHMENT WATERWAYS MAINTENANCE AND REHABILITATION MASTER PLAN



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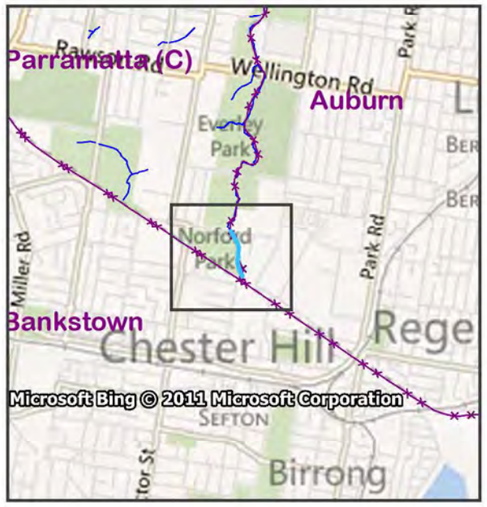
DUCK RIVER 1A

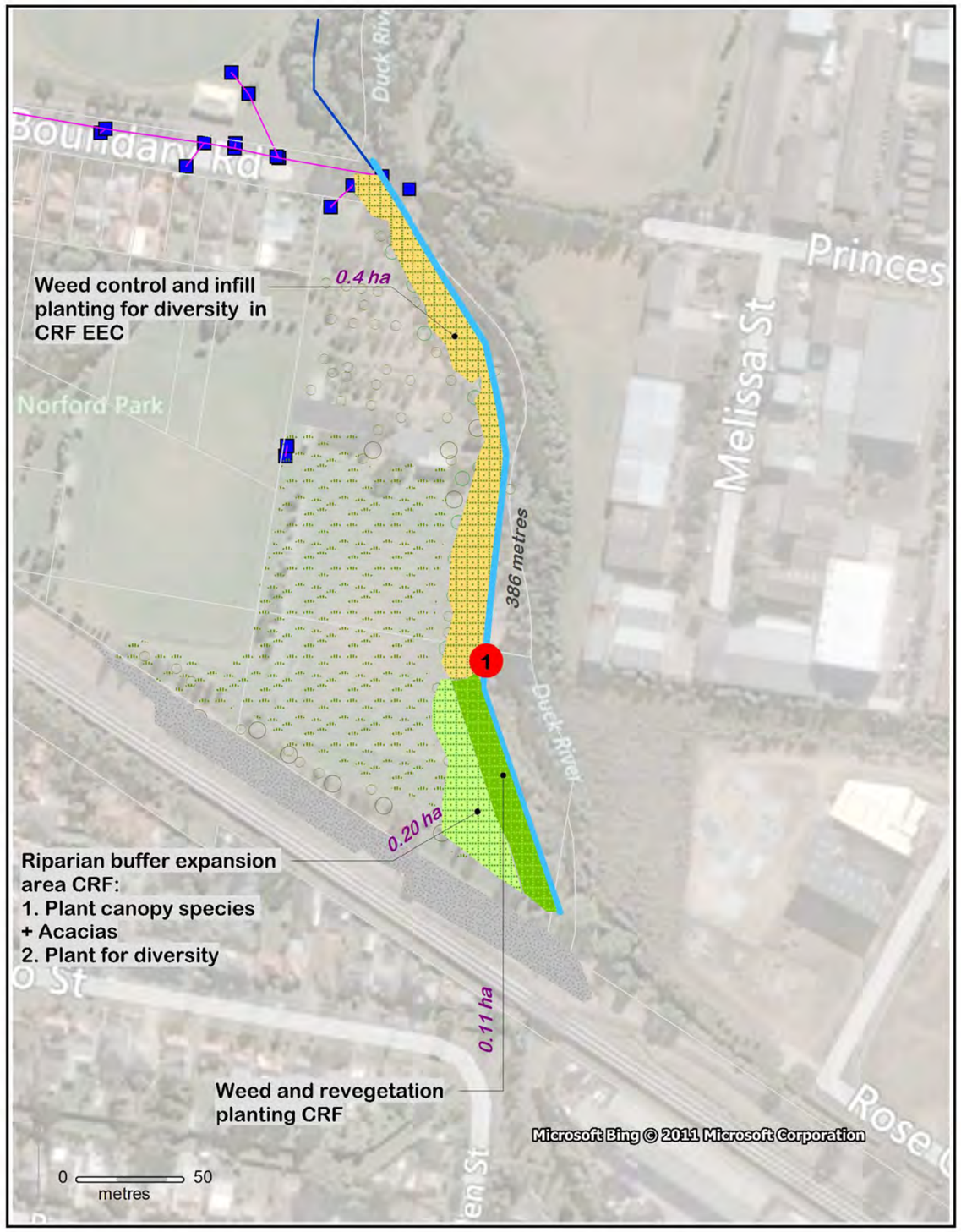
Table 9. Management actions and works required for reach DUCK RIVER 1A

REACH	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
DUCK RIVER 1A (1)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Water quality improvement: install trash rack	Urgent	N/A	$250-500K	$2-5K	PCC/ACC
DUCK RIVER 1A (2)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Riverflat Forest species	High	0.40ha	$2-6K	$500-1000	PCC
DUCK RIVER 1A (3)	Biodiversity enhancement: bush regeneration weeding and revegetation planting with Cumberland Riverflat Forest species	High	0.088ha	$1-3K	$500-1000	PCC
DUCK RIVER 1A (4)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control carp	Medium	N/A	$3-5K per event	ongoing	PCC/ACC
DUCK RIVER 1A (5)	Biodiversity enhancement: riparian buffer expansion planting with Cumberland Riverflat Forest species	Low	0.20ha	$4-6K	$500-1000	PCC




REACH: DUCK RIVER 1A



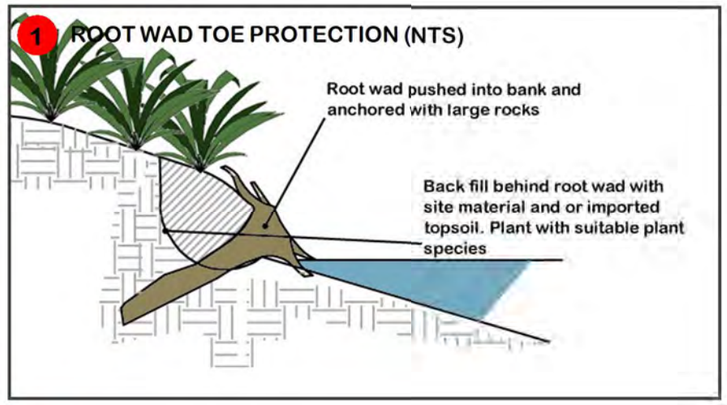


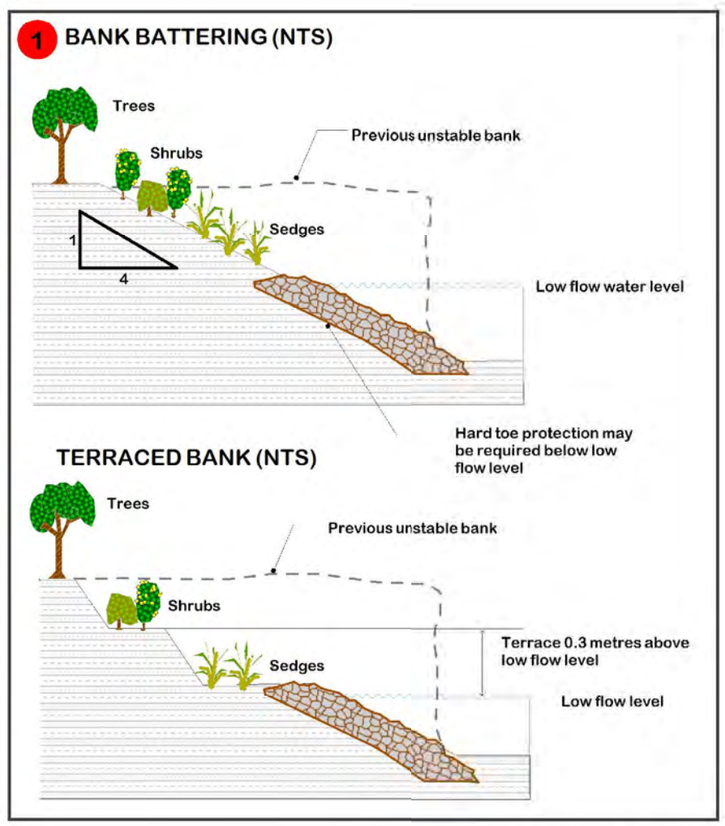
WORKS PLAN

VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)

Cumberland Swamp Oak Forest (CSOF)





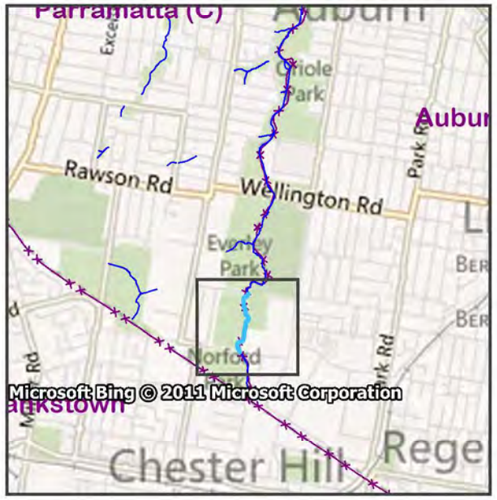
DUCK RIVER 1B

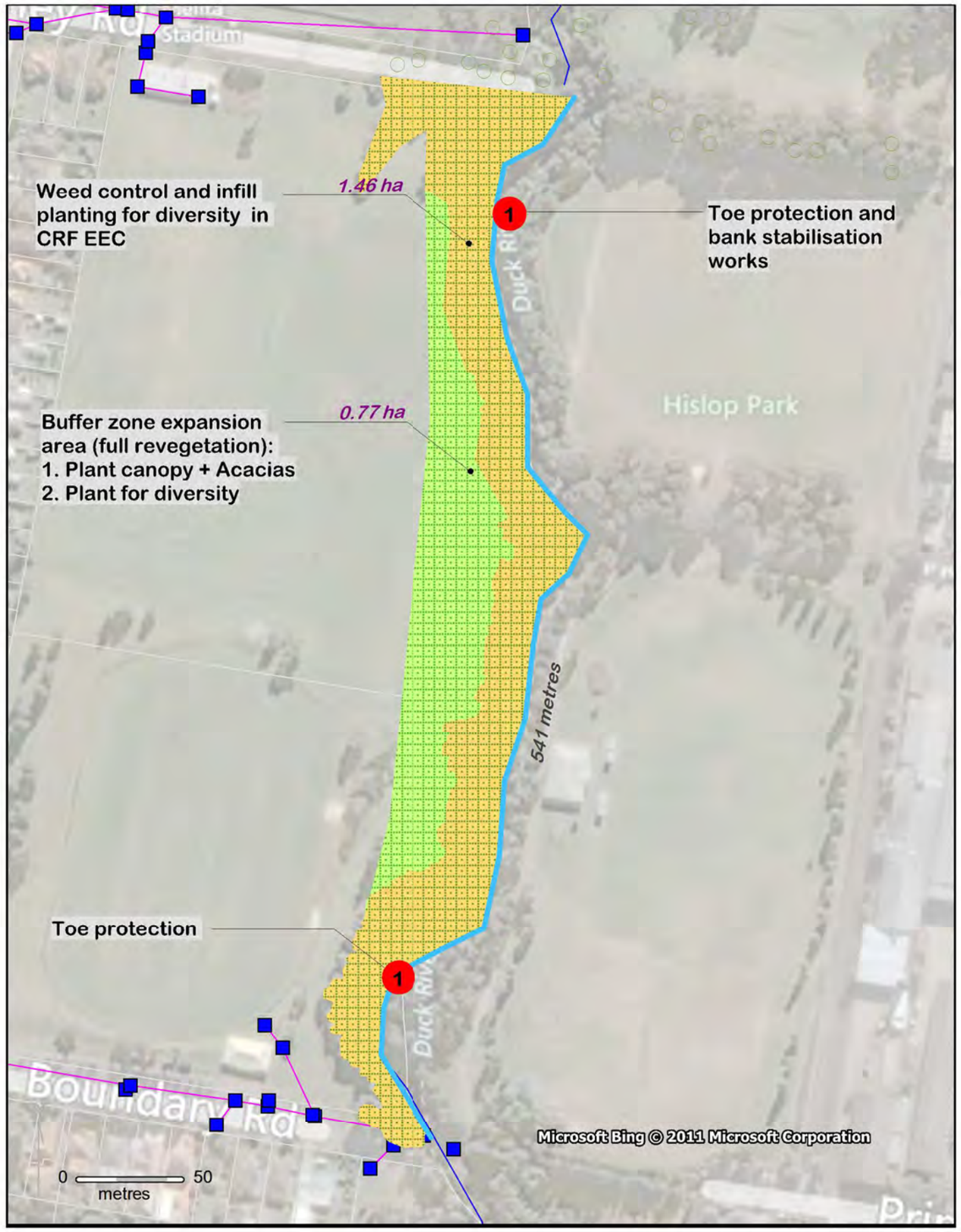
Table 10. Management actions and works required for reach DUCK RIVER 1B

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
DUCK RIVER 1B (1)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Water quality improvement: water quality monitoring point	Urgent/ongoing	N/A	$1-2K	$1-2K	PCC/ACC
DUCK RIVER 1B (2)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Riverflat Forest species	High	1.46ha	$10-20K	$3-5K	PCC
DUCK RIVER 1B (3)	Erosion control: toe protection works	High	30m	$20-30K	$1-2K	PCC
DUCK RIVER 1B (4)	Biodiversity enhancement: riparian buffer expansion planting with Cumberland Riverflat Forest species	Low	0.77ha	$20-25K	$5-8K	PCC




REACH: DUCK RIVER 1B

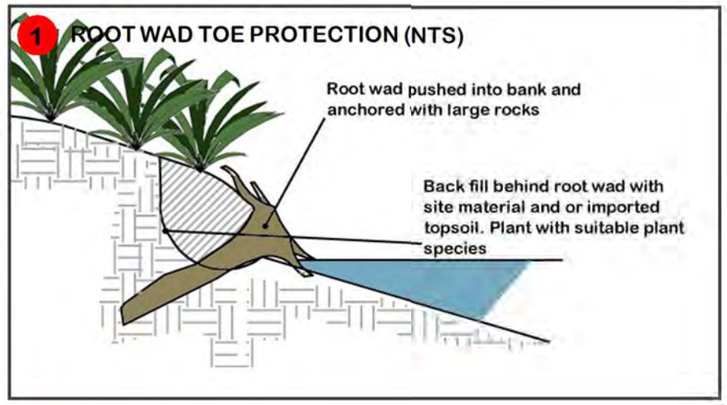


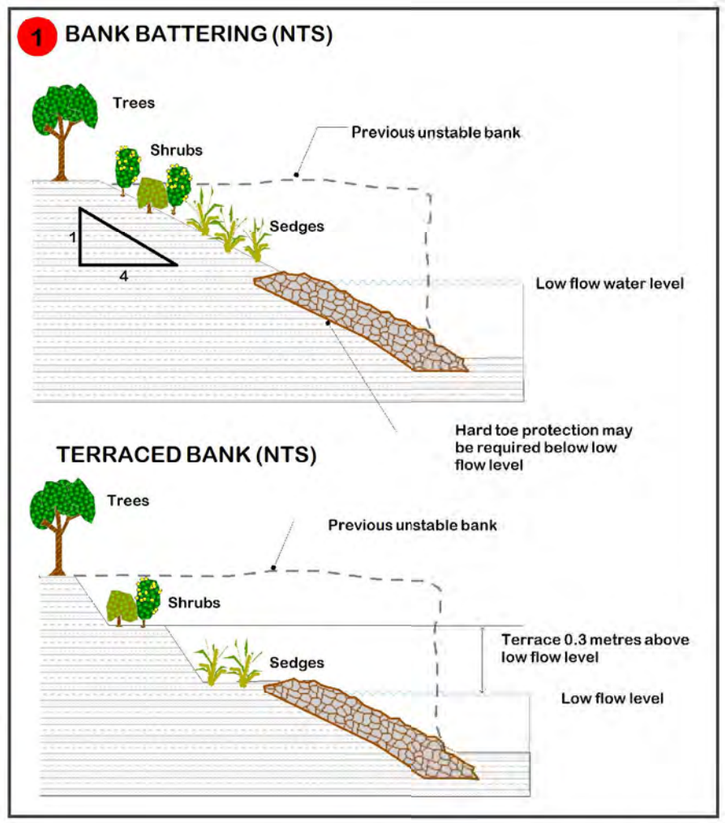


WORKS PLAN

VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)





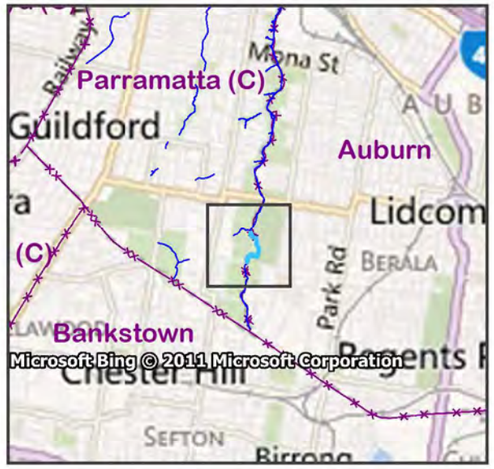
DUCK RIVER 2A

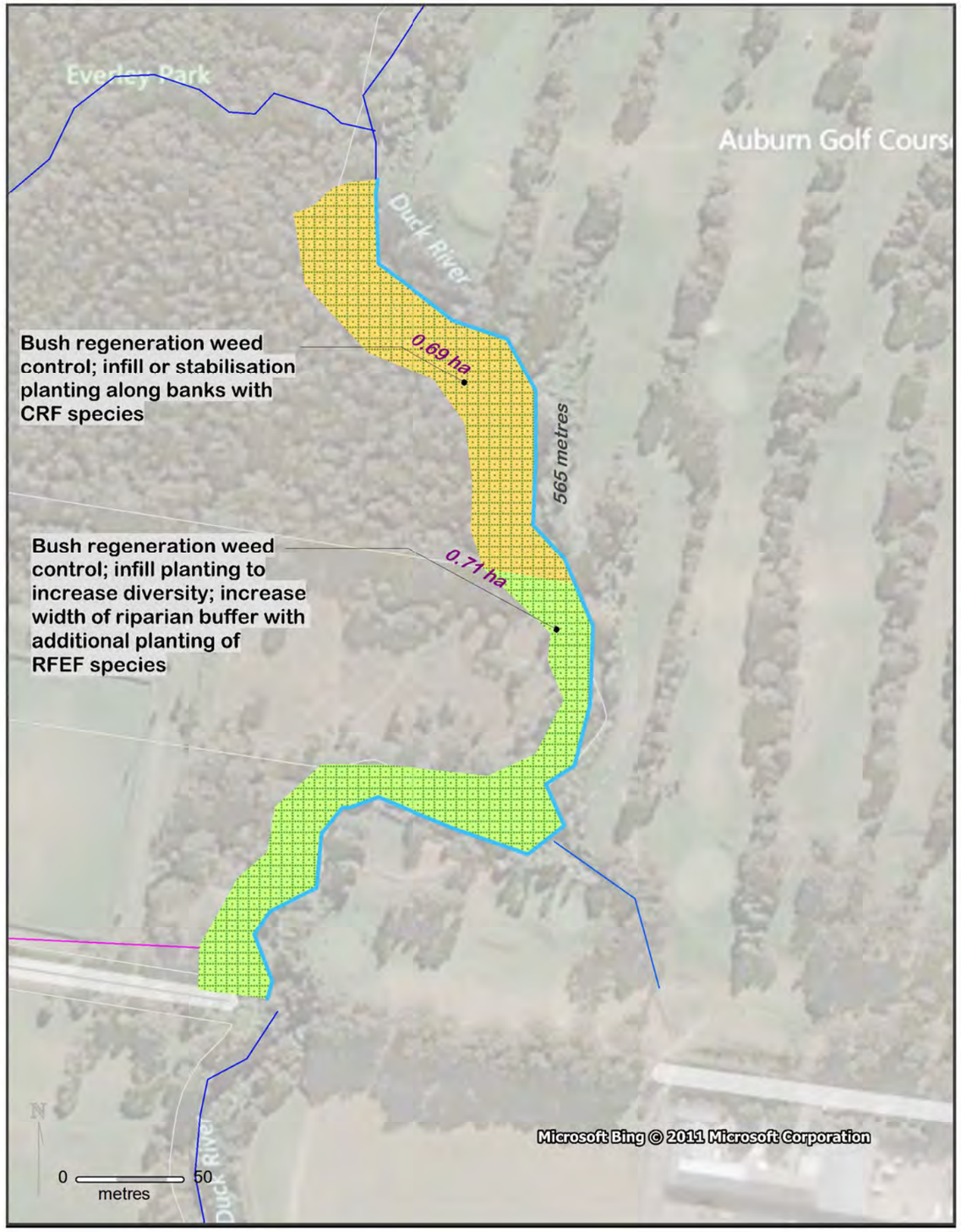
Table 11. Management actions and works required for reach DUCK RIVER 2A

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
DUCK RIVER 2A (1)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Riverflat Forest species	High	0.69ha	$5-10K	$1-2K	PCC
DUCK RIVER 2A (2)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Riverflat Forest species	High	0.71ha	$5-10K	$500-1000	PCC
DUCK RIVER 2A (3)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control carp populations	Medium	N/A	$3-5K/event	ongoing	PCC/ACC
DUCK RIVER 2A (4)	Biodiversity enhancement: riparian buffer expansion planting with Cumberland Riverflat Forest species	Low	0.71ha	$20-25K	$5-8K	PCC
DUCK RIVER 2A (5)	Erosion control: monitor bank stability and install jute matting with stabilisation planting as required; use Cumberland Riverflat Forest species	Ongoing	560m	$0-15K	$1-2K	PCC




REACH: DUCK RIVER 2A





WORKS PLAN

VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)

DUCK RIVER 2B

Table 12. Management actions and works required for reach DUCK RIVER 2B

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
DUCK RIVER 2B (1)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Water quality improvement: water quality monitoring point	Urgent/ongoing	N/A	$1-2K	$1-2K	PCC/ACC
DUCK RIVER 2B (2)	Biodiversity enhancement: bush regeneration weeding and stabilisation planting with Cumberland Riverflat Forest species	High	1.00ha	$10-20K	$1-5K	PCC
DUCK RIVER 2B (3)	Erosion control: monitor bank stability and install jute matting with stabilisation planting as required; use Cumberland Riverflat Forest species	Ongoing	470m	$0-15K	$1-2K	PCC
DUCK RIVER 2B (4)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control carp populations	Medium	N/A	$3-5K/event	ongoing	PCC/ACC

SMALLS CREEK 2

Table 13. Management actions and works required for reach SMALLS CREEK 2

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
SMALLS CREEK 1 (1)	Erosion control: scouring and undercutting protection for outlet control structure	Urgent	N/A	$150-250K	$2-4K	PCC
SMALLS CREEK 1 (2)	Erosion control: creek bank and bed stabilisation works	High	150m	$20-50K	$1-2K	PCC
SMALLS CREEK 1 (3)	Biodiversity enhancement: bush regeneration weeding and infill planting for stabilisation and diversity with Cumberland Riverflat Forest or Cooks River/Castlereagh Ironbark Forest species	High	1.6ha	$5-15K	$1-2K	PCC

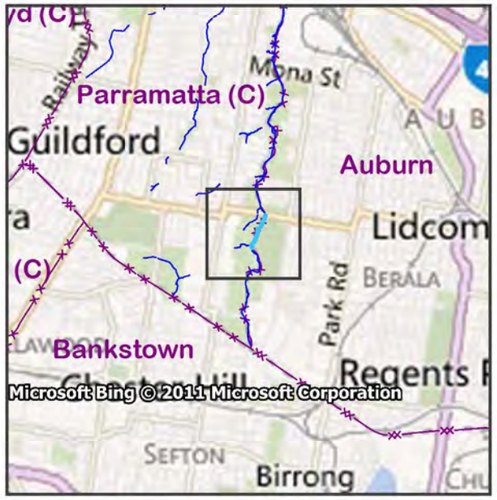
UNNAMED 9 WELLINGTON RD

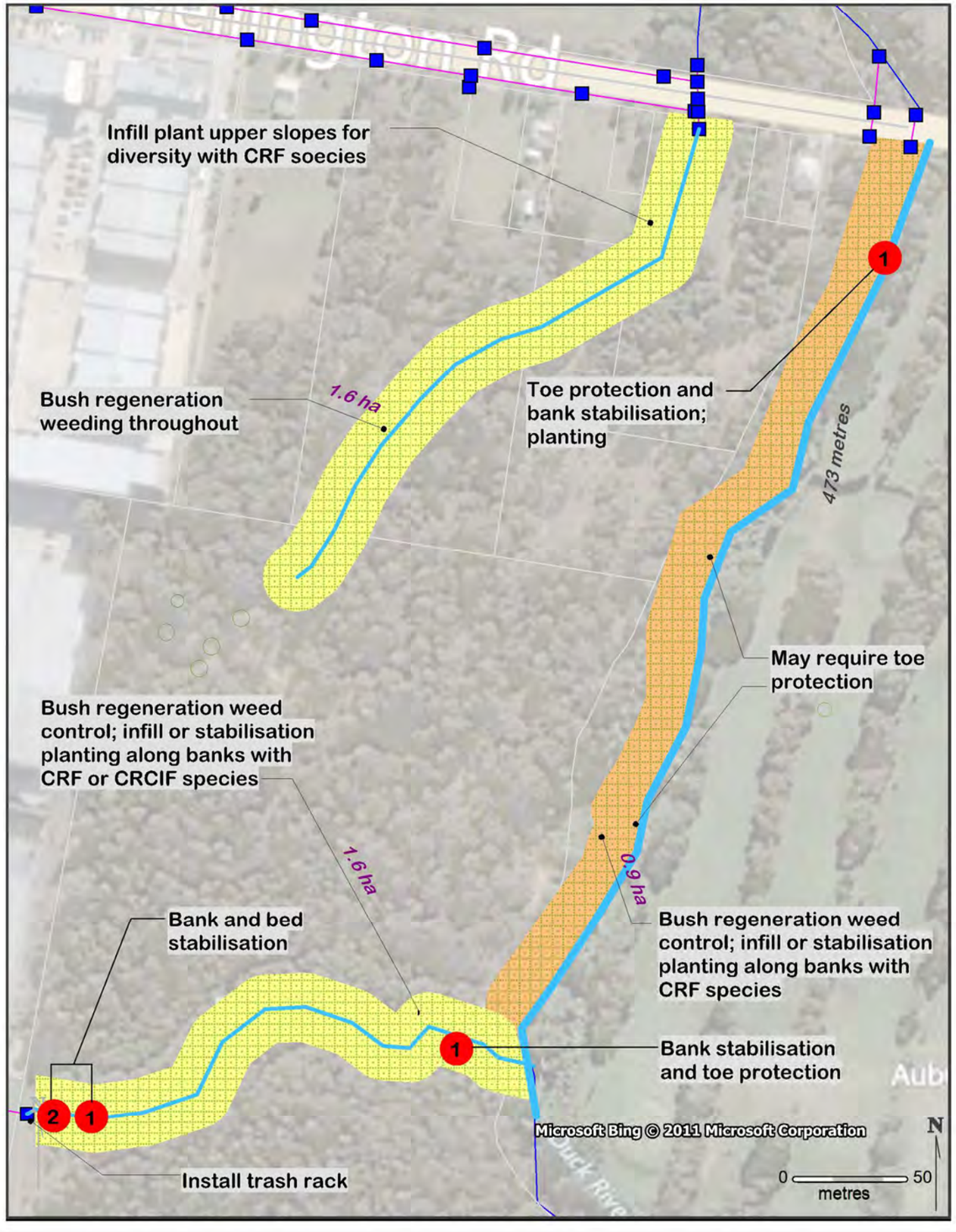
Table 14. Management actions and works required for reach UNNAMED 9 WELLINGTON RD

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
UNNAMED 9 (1)	Biodiversity enhancement: Bush regeneration weed control	High	1.6ha	$10-15K	manage with DUCK RIVER 2B	PCC
UNNAMED 9 (2)	Biodiversity enhancement: Infill planting along upper slopes for diversity with Cooks River/Castlereagh Ironbark Forest or Cumberland Riverflat Forest species	Medium	0.8ha	$5-10K	manage with DUCK RIVER 2B	PCC
UNNAMED 9 (3)	Biodiversity enhancement: Infill planting for stability with Cumberland Riverflat Forest species	Medium	0.4ha	$2-5K	manage with DUCK RIVER 3A	PCC




REACH: DUCK RIVER 2B & SMALLS CREEK 1





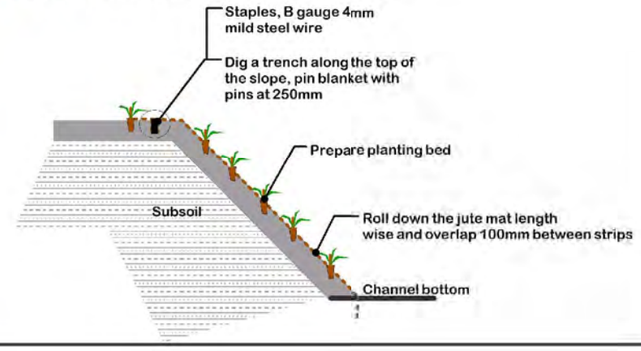
WORKS PLAN

VEGETATION COMMUNITIES

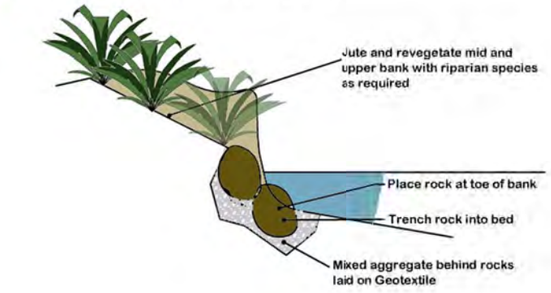
Cumberland Riverflat Forest (CRF)

Cooks river Castlereagh Ironbark Forest (CRCIF)

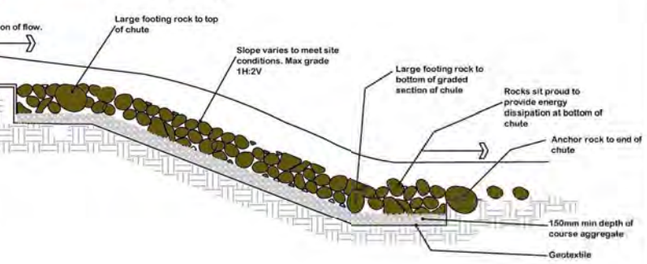
1 JUTE MAT BANK TREATMENT (NTS)



1 ROCK TOE PROTECTION (NTS)



2 ROCK CHUTE (NTS)



DUCK RIVER 3A

Table 15. Management actions and works required for reach DUCK RIVER 3A

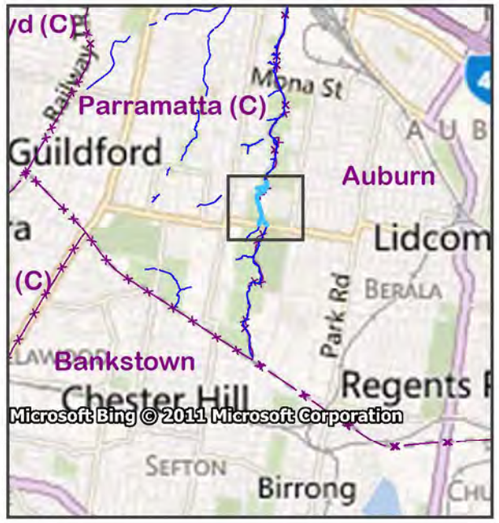
NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
DUCK RIVER 3A (1)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Community and recreation: install pedestrian footbridge across river/wetlands	High	N/A	$20-40K	$5-10K	PCC/ACC
DUCK RIVER 3A (2)	Biodiversity enhancement: primary weed control, revegetation for stabilisation with Cumberland Riverflat Forest species	High	0.19ha	$10-15K	$2-5K	PCC
DUCK RIVER 3A (3)	Biodiversity enhancement: primary weed control, revegetation for stabilisation and diversity with Cumberland Riverflat Forest species	High	0.52ha	$20-25K	$1-2K	PCC
DUCK RIVER 3A (4)	Community and recreation: install seating, informative signage and weather shelters	High	N/A	$15-30K	$500	PCC
DUCK RIVER 3A (5)	Community and recreation: formalise existing path by constructing all weather crushed granite footpath for pedestrian access	High	450m	$5-10K	$500	PCC
DUCK RIVER 3A (6)	Community and recreation: install informative signage	High	N/A	$2-5K	$500	PCC
DUCK RIVER 3A (7)	Biodiversity enhancement: primary weed control of vines	High	0.72ha	$30-40K	$5-10K	PCC
DUCK RIVER 3A (8)	Biodiversity enhancement: primary weed control of vines	High	0.24ha	$10-15K	$2-5K	PCC
DUCK RIVER 3A (9)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Riverflat Forest species	High	0.68ha	$10-20K	$2-5K	PCC
DUCK RIVER 3A (10)	Biodiversity enhancement: bush regeneration weed control	High	0.41ha	$5-10K	$1-2K	PCC
DUCK RIVER 3A (11)	Biodiversity enhancement: primary weed control and revegetation with Cumberland Riverflat Forest species	Medium	0.24ha	$10-15K	$2-5K	PCC
DUCK RIVER 3A (12)	Biodiversity enhancement: primary weed control and revegetation with Cumberland Riverflat Forest species	Medium	0.72ha	$40-50K	$5-10K	PCC
DUCK RIVER 3A (13)	Biodiversity enhancement: riparian buffer expansion planting with Cumberland Riverflat Forest species	Low	0.37ha	$10-12K	$2-3K one year only	PCC
DUCK RIVER 3A (14)	Erosion control: monitor bank stability and install jute matting with stabilisation planting as required; use Cumberland Riverflat Forest species	Ongoing	350m	$0-15K	$1-2K	PCC

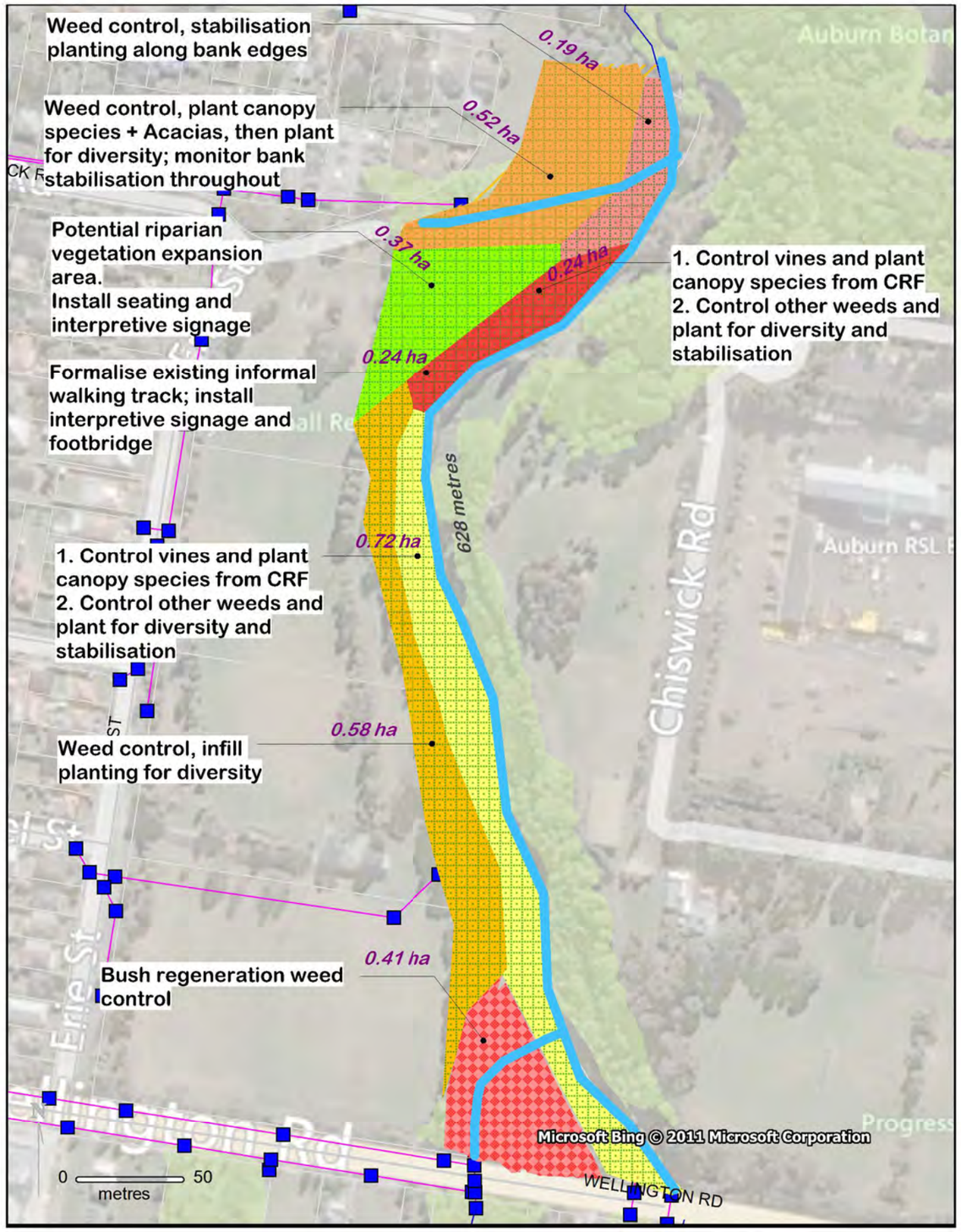
UNNAMED 2B CHISWICK ST

Table 16. Management actions and works required for reach UNNAMED 2B CHISWICK ST

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
UNNAMED 2B (1)	Erosion control: monitor bank stability – do not over clear. Stabilise steep slopes as required, eg. Jute mat and plant, rock line channel or toe	High	40m	$0-5k	manage with DUCK RIVER 3A	PCC
UNNAMED 2B (2)	Biodiversity enhancement: primary weed control, and plant canopy species (Cumberland Swamp Oak Riparian Forest)	High	0.4ha	$15-20K	manage with DUCK RIVER 3A	PCC
UNNAMED 2B (3)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Swamp Oak Riparian Forest species	Medium	0.4ha	$2-5K	manage with DUCK RIVER 3A	PCC

REACH: DUCK RIVER 3A





WORKS PLAN

VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)

Cumberland Swamp Oak Forest (CSOF)

DUCK RIVER 3B

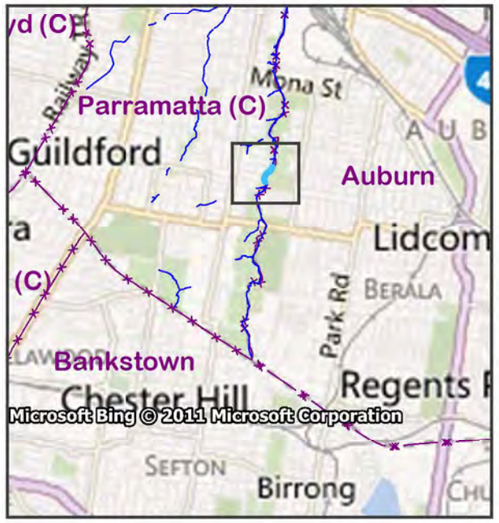
Table 17. Management actions and works required for reach DUCK RIVER 3B

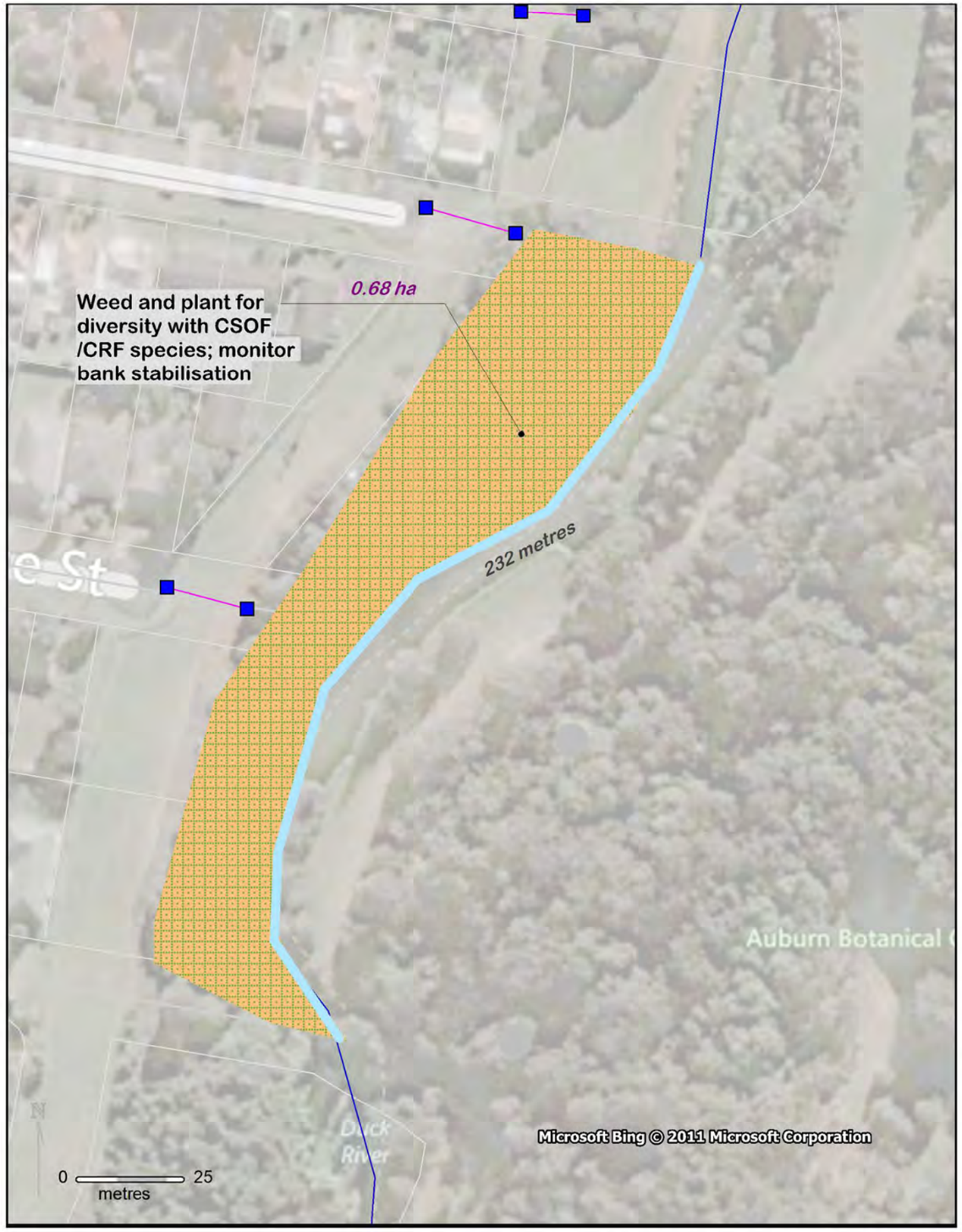
NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
DUCK RIVER 3B (1)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Riverflat Forest species	High	0.68ha	$8-12K	$1-2K	PCC
DUCK RIVER 3B (2)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control carp populations	Medium	N/A	$3-5K/event	ongoing	PCC/ACC
DUCK RIVER 3B (3)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control carp populations	Medium	N/A	$3-5K/event	ongoing	PCC/ACC
DUCK RIVER 3B (4)	Erosion control: monitor bank stability and install jute matting with stabilisation planting as required; use Cumberland Riverflat Forest species	Ongoing	130m	$0-10K	$1-2K	PCC




REACH: DUCK RIVER 3B

WORKS PLAN





VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)

Cumberland Swamp Oak Forest (CSOF)

DUCK RIVER 4A

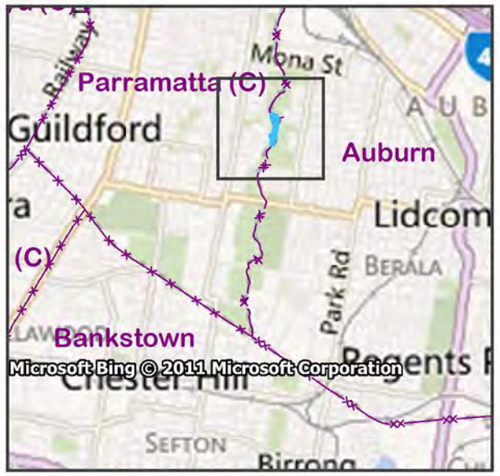
Table 18. Management actions and works required for reach DUCK RIVER 4A

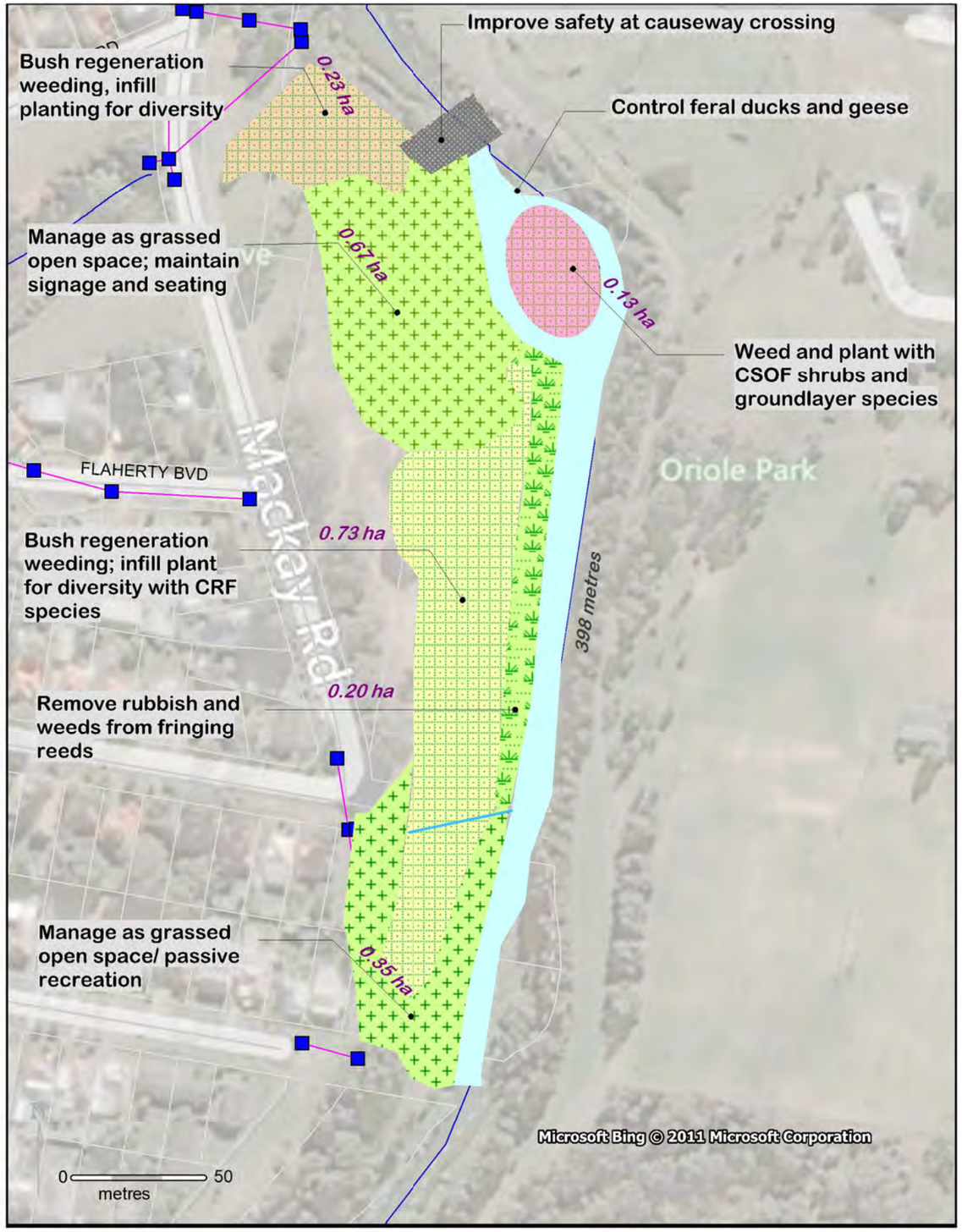
NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
DUCK RIVER 4A (1)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Community and recreation: improve safety at causeway crossing (stepping stones weir)	Urgent	N/A	$2-5K	$1-2K	PCC/ACC
DUCK RIVER 4A (2)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Riverflat Forest species	High	0.23ha	$5-10K	$500-1000	PCC
DUCK RIVER 4A (3)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Riverflat Forest species	High	0.73ha	$10-15K	$3-5K	PCC
DUCK RIVER 4A (4)	Water quality improvement: remove litter and debris from fringing reeds; consider installation of floating trash trap	High	N/A	$5-10K	$3-5K	PCC
DUCK RIVER 4A (5)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control carp populations (LOCATION 1)	Medium	N/A	$3-5K/event	ongoing	PCC/ACC
DUCK RIVER 4A (6)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control carp populations (LOCATION 2)	Medium	N/A	$3-5K/event	ongoing	PCC/ACC
DUCK RIVER 4A (7)	Community and recreation: manage as grassed open space	Ongoing	N/A	$2-5K/year	ongoing	PCC
DUCK RIVER 4A (8)	Community and recreation: maintain existing seating and signage	Ongoing	N/A	$2-5K/year	ongoing	PCC
DUCK RIVER 4A (9)	Community and recreation: manage as grassed open space	Ongoing	N/A	$2-5K/year	ongoing	PCC





REACH: DUCK RIVER 4A





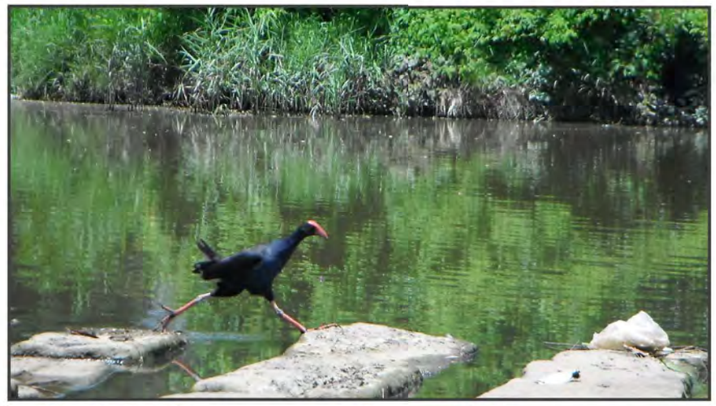
WORKS PLAN

VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)

Cumberland Swamp Oak Forest (CSOF)

Coastal Freshwater Reedlands



UNNAMED 3 CLYDE/BENNETT STS

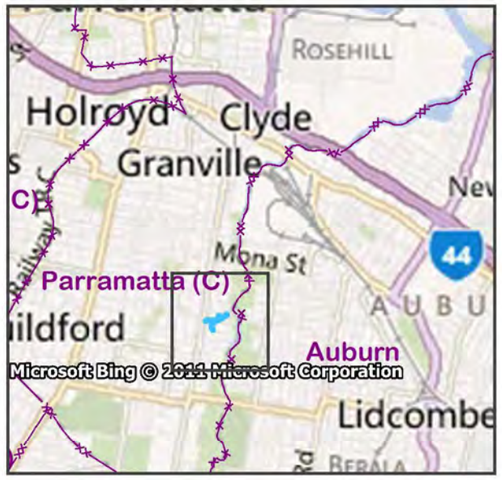
Table 19. Management actions and works required for reach UNNAMED 3 CLYDE/BENNETT STS

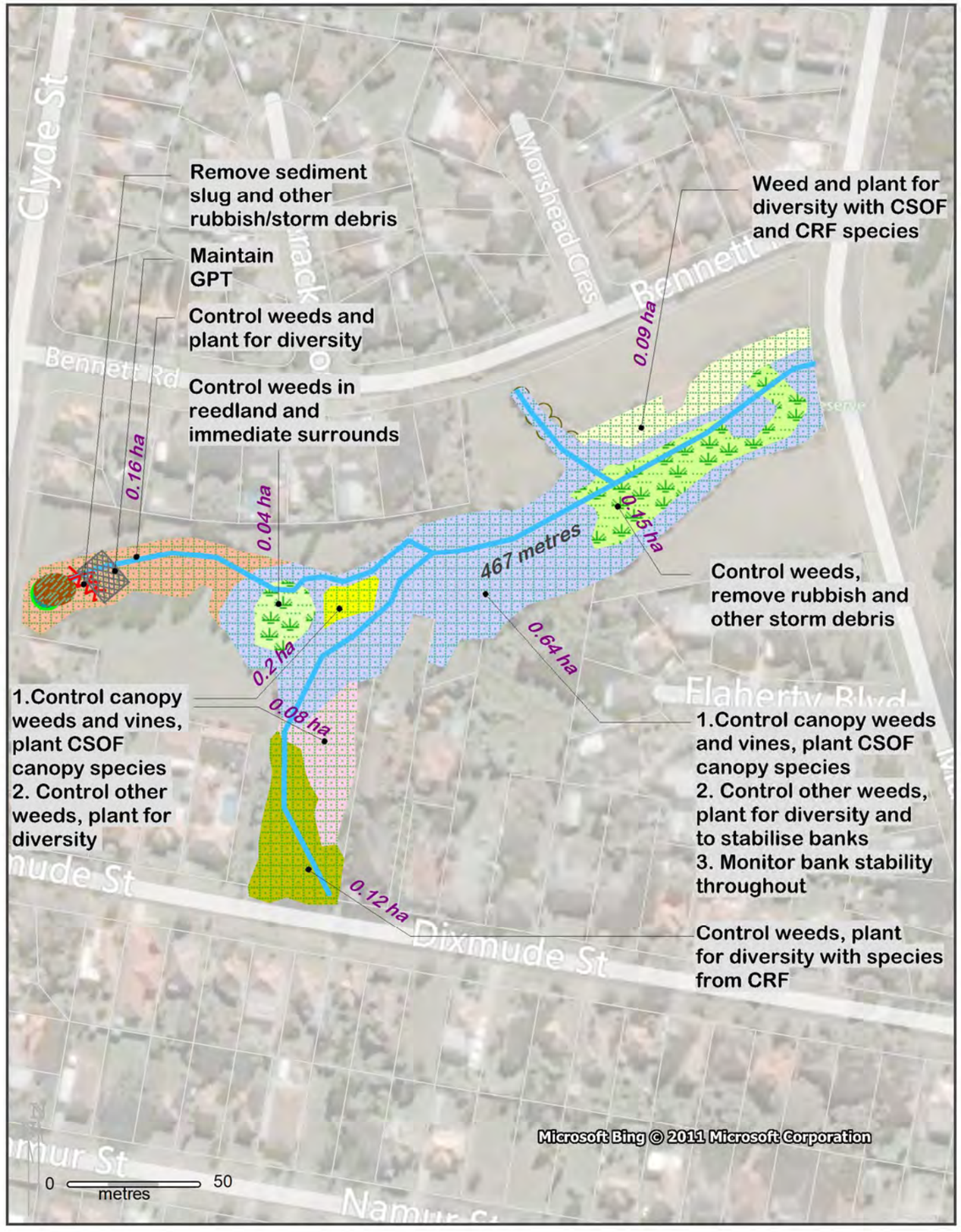
NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (pa)	RESPONSIBILITY
UNNAMED 3 (1)	Water quality improvement: remove litter and debris from fringing reeds	Urgent	N/A	$1-2K	event based	PCC
UNNAMED 3 (2)	Water quality improvement: remove sediment plug and other rubbish/storm debris	High	N/A	$3-5K	event based	PCC
UNNAMED 3 (3)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Swamp Oak Riparian Forest species	High	0.16ha	$10-15K	$1-2K	PCC
UNNAMED 3 (4)	Biodiversity enhancement: bush regeneration weeding and fringing planting for diversity with Cumberland Swamp Oak Riparian Forest species	High	0.04ha	$3-5K	$500-1000	PCC
UNNAMED 3 (5)	Biodiversity enhancement: primary weed control, and plant canopy species (Cumberland Swamp Oak Riparian Forest)	High	0.28ha	$15-20K	$2-4K	PCC
UNNAMED 3 (6)	Biodiversity enhancement: primary weed control, and plant canopy species (Cumberland Swamp Oak Riparian Forest)	High	0.12ha	$10-15K	$1-2K	PCC
UNNAMED 3 (7)	Biodiversity enhancement: primary weed control of vines, and plant canopy species (Cumberland Swamp Oak Riparian Forest)	High	0.64ha	$25-35K	$3-5K	PCC
UNNAMED 3 (8)	Biodiversity enhancement: primary weed control of vines and other weeds	High	0.15ha	$10-15K	$1-2K	PCC
UNNAMED 3 (9)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Riverflat Forest species	High	0.09ha	$8-10K	$500-1000	PCC
UNNAMED 3 (10)	Biodiversity enhancement: secondary weed control, revegetation by infill planting with Cumberland Swamp Oak Riparian Forest species	Medium	0.28ha	$15-20K	$1-2K	PCC
UNNAMED 3 (11)	Biodiversity enhancement: secondary weed control, revegetation by infill planting with Cumberland Swamp Oak Riparian Forest species	Medium	0.12ha	$10-15K	$1-2K	PCC
UNNAMED 3 (12)	Biodiversity enhancement: primary weed control, revegetation with Cumberland Swamp Oak Riparian Forest species	Medium	0.64ha	$25-35K	$3-5K	PCC
UNNAMED 3 (13)	Water quality improvement: maintain mesh trash traps regularly; prepare and implement an Operations and Maintenance Plan	Ongoing	N/A	$2-5K/year	ongoing	PCC
UNNAMED 3 (14)	Monitor bank stability and install jute matting with stabilisation planting as required; use Cumberland Swamp Oak Riparian Forest species	Ongoing	0.64ha	$0-15K	N/A	PCC




REACH: UNNAMED 3 BENNETT STREET

WORKS PLAN





VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)

Cumberland Swamp Oak Forest (CSOF)

Coastal Freshwater Reedlands

DUCK RIVER 4B

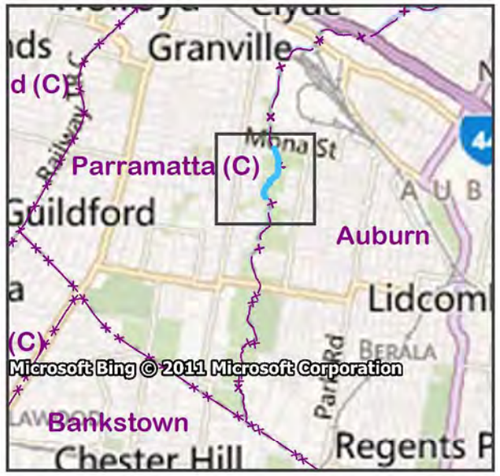
Table 20. Management actions and works required for reach DUCK RIVER 4B

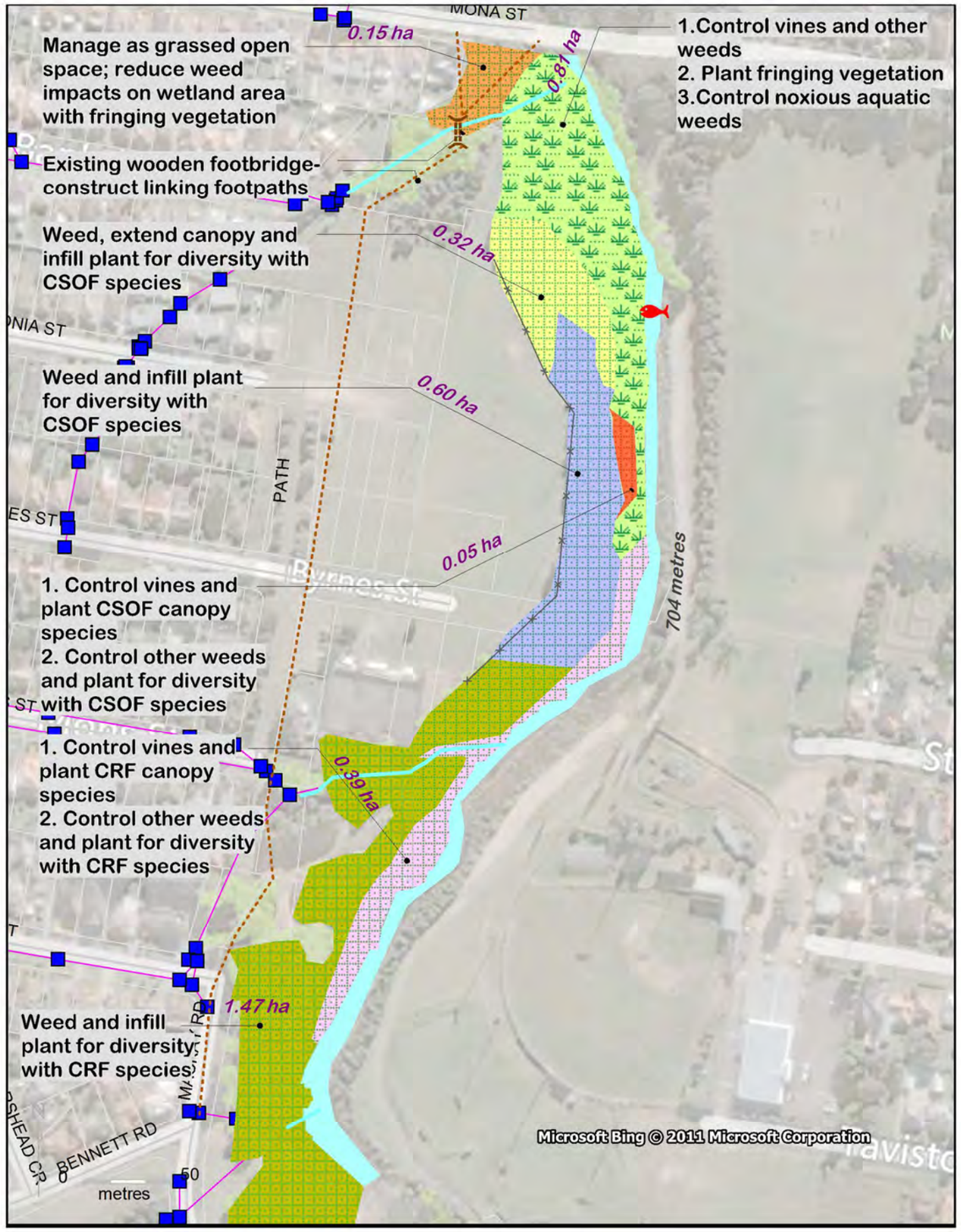
NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA / LENGTH	INITIAL COST	ONGOING COSTS (pa)	RESPONSIBILITY
DUCK RIVER 4B (1)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control aquatic noxious weeds	Urgent	0.02ha	$5-10K	$500-1000	PCC/ACC
DUCK RIVER 4B (2)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Water quality improvement: water quality monitoring point	Urgent/ongoing	N/A	$1-2K	$1-2K	PCC/ACC
DUCK RIVER 4B (3)	Biodiversity enhancement: fringing buffer planting with Cumberland Swamp Oak Riparian Forest species	High	0.15ha	$3-5K	$500 one year only	PCC
DUCK RIVER 4B (4)	Community and recreation: install concrete footpath/cycleway to provide linkages with existing road and footpath network	High	360m	$30-40K	$500-1000	PCC
DUCK RIVER 4B (5)	Biodiversity enhancement: primary weed control of vines, and plant canopy species (Cumberland Swamp Oak Riparian Forest)	High	0.32ha	$12-15K	$3-5K	PCC
DUCK RIVER 4B (6)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Swamp Oak Riparian Forest species	High	0.60ha	$5-10K	$500-1000	PCC
DUCK RIVER 4B (7)	Biodiversity enhancement: primary weed control of vines	High	0.05ha	$3-5K	$500-1000	PCC
DUCK RIVER 4B (8)	Biodiversity enhancement: primary weed control of vines	High	0.39ha	$15-20K	$5-8K	PCC
DUCK RIVER 4B (9)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Riverflat Forest species	High	1.47ha	$20-30K	$5-8K	PCC
DUCK RIVER 4B (10)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control carp populations (LOCATION 1)	Medium	N/A	$3-5K/event	ongoing	PCC/ACC
DUCK RIVER 4B (11)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control carp populations (LOCATION 2)	Medium	N/A	$3-5K/event	ongoing	PCC/ACC
DUCK RIVER 4B (12)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control carp populations (LOCATION 3)	Medium	N/A	$3-5K/event	ongoing	PCC/ACC
DUCK RIVER 4B (13)	Biodiversity enhancement: primary weed control and revegetation with Cumberland Swamp Oak Riparian Forest species	Medium	0.05ha	$3-5K	$500-1000	PCC
DUCK RIVER 4B (14)	Biodiversity enhancement: primary weed control and revegetation with Cumberland Riverflat Forest species	Medium	0.39ha	$15-20K	$3-5K	PCC
DUCK RIVER 4B (15)	Community and recreation: manage as grassed open space	Ongoing	N/A	$2-5K/year	ongoing	PCC





REACH: DUCK RIVER 4B





WORKS PLAN

VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)

Cumberland Swamp Oak Forest (CSOF)

Coastal Freshwater Reedlands

UNNAMED 7 BANKSIA ST

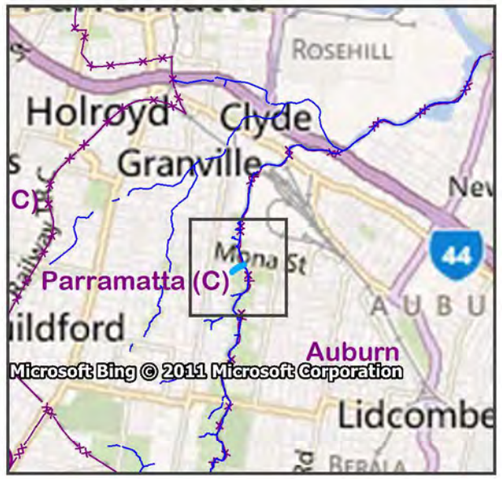
Table 21. Management actions and works required for reach UNNAMED 7 BANKSIA ST

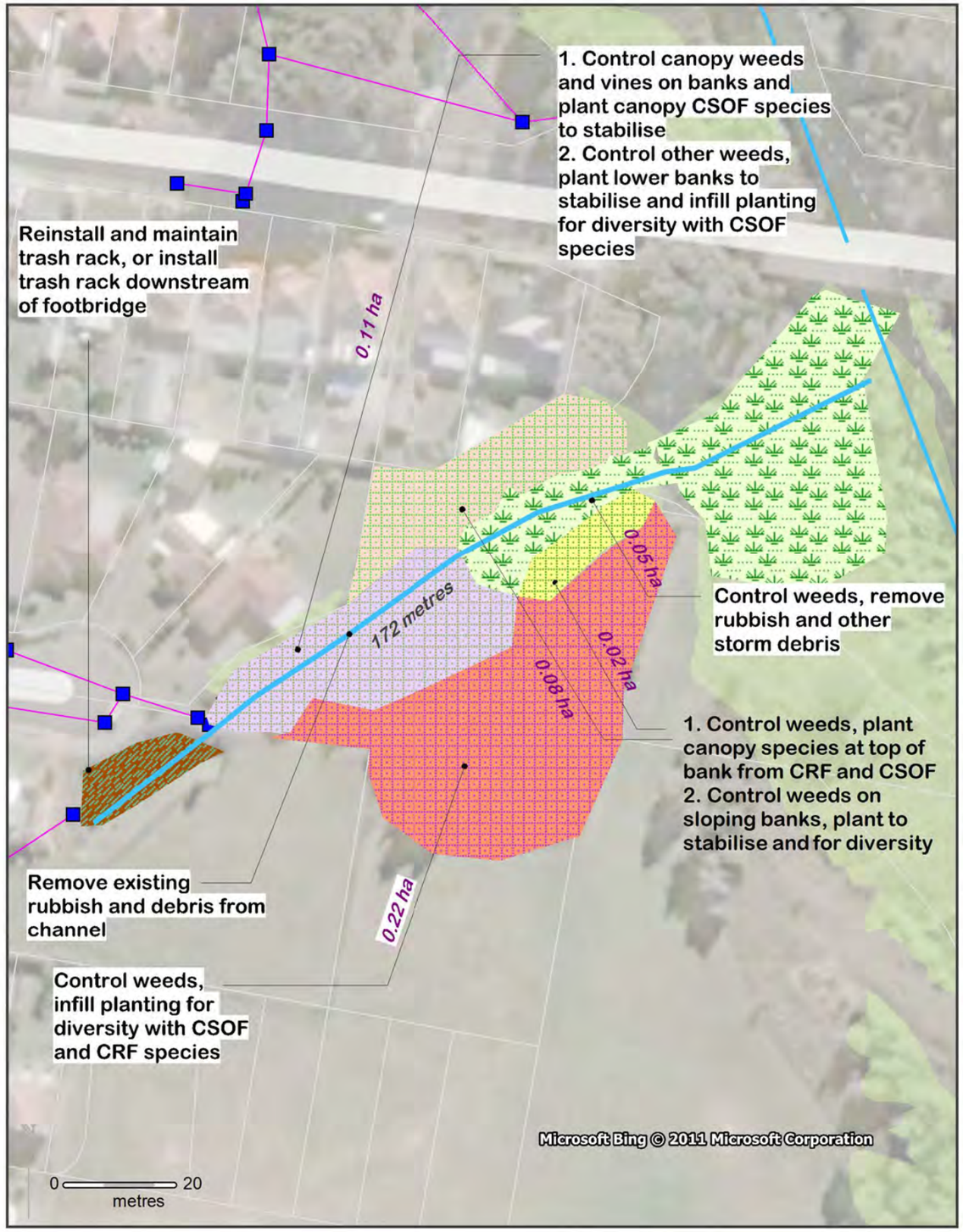
NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
UNNAMED 7 (1)	Water quality improvement: liaise with landholder to reinstall and maintain trash rack above detention basin, or install trash rack below footbridge	Urgent	N/A	$4-70K	$2-5K	Private landholder/PCC
UNNAMED 7 (2)	Water quality improvement: remove litter and debris from fringing vegetation upstream of reedlands	Urgent	N/A	$1-2K	manage with DUCK RIVER 4B	PCC
UNNAMED 7 (3)	Water quality improvement: remove litter and debris from fringing reeds	Urgent	N/A	$1-2K	manage with DUCK RIVER 4B	PCC
UNNAMED 7 (4)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Swamp Oak Riparian Forest species	High	0.22ha	$10-15K	manage with DUCK RIVER 4B	PCC
UNNAMED 7 (5)	Biodiversity enhancement: primary weed control of vines, and plant canopy species (Cumberland Swamp Oak Riparian Forest)	High	0.08ha	$5-10K	manage with DUCK RIVER 4B	PCC
UNNAMED 7 (6)	Biodiversity enhancement: primary weed control of vines, and plant canopy species (Cumberland Swamp Oak Riparian Forest)	High	0.11ha	$5-10K	manage with DUCK RIVER 4B	PCC
UNNAMED 7 (7)	Biodiversity enhancement: primary weed control of vines and other weeds	High	0.05ha	$3-5K	manage with DUCK RIVER 4B	PCC
UNNAMED 7 (8)	Community and recreation: install concrete footpath/cycleway to connect between footbridges	High	40m	$3-5K	manage with DUCK RIVER 4B	PCC
UNNAMED 7 (9)	Biodiversity enhancement: primary weed control, revegetation with Cumberland Swamp Oak Riparian Forest species	Medium	0.11ha	$5-10K	manage with DUCK RIVER 4B	PCC
UNNAMED 7 (10)	Biodiversity enhancement: primary weed control, revegetation for stabilisation with Cumberland Swamp Oak Riparian Forest species	Medium	0.10ha	$5-10K	manage with DUCK RIVER 4B	PCC
UNNAMED 7 (11)	Monitor bank stability and install jute matting with stabilisation planting as required; use Cumberland Swamp Oak Riparian Forest species	Ongoing	0.10ha	$0-5K	manage with DUCK RIVER 4B	PCC




REACH: UNNAMED 7 BANKSIA STREET

WORKS PLAN





VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)

Cumberland Swamp Oak Forest (CSOF)

Coastal Freshwater Reedlands

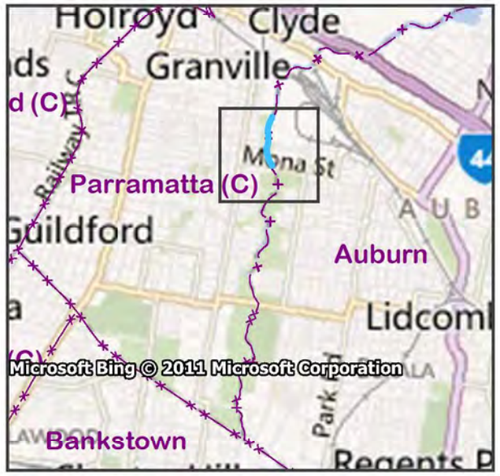
DUCK RIVER 5A

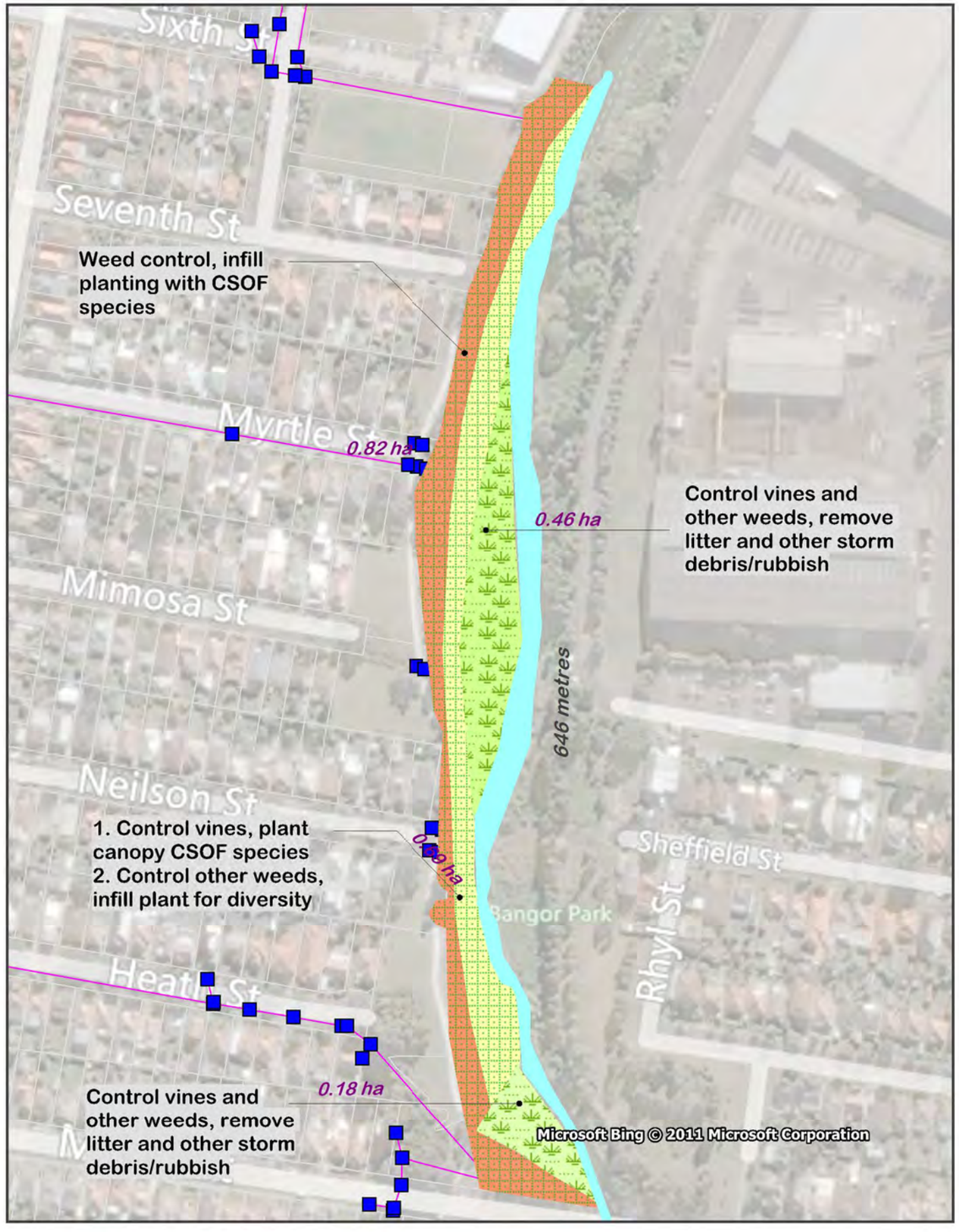
Table 22. Management actions and works required for reach DUCK RIVER 5A

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
DUCK RIVER 5A (1)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Water quality improvement: remove litter and debris from fringing reeds; consider installation of floating trash trap	Urgent	N/A	$5-10K	$1-3K	PCC
DUCK RIVER 5A (2)	Biodiversity enhancement: bush regeneration weeding and infill planting for diversity with Cumberland Swamp Oak Riparian Forest species	High	0.82ha	$40-50K	$5-10K	PCC
DUCK RIVER 5A (3)	Biodiversity enhancement: primary weed control of vines, and plant canopy species (Cumberland Swamp Oak Riparian Forest)	High	0.69ha	$30-40K	$5-10K	PCC
DUCK RIVER 5A (4)	Biodiversity enhancement: primary weed control, revegetation with Cumberland Swamp Oak Riparian Forest species	Medium	0.69ha	$30-40K	$5-10K	PCC
DUCK RIVER 5A (5)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control carp populations (LOCATION 1)	Medium	N/A	$3-5K/event	ongoing	PCC
DUCK RIVER 5A (6)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control carp populations (LOCATION 2)	Medium	N/A	$3-5K/event	ongoing	PCC




REACH: DUCK RIVER 5A





WORKS PLAN

VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)

Cumberland Swamp Oak Forest (CSOF)

Coastal Freshwater Reedlands

DUCK RIVER 5B

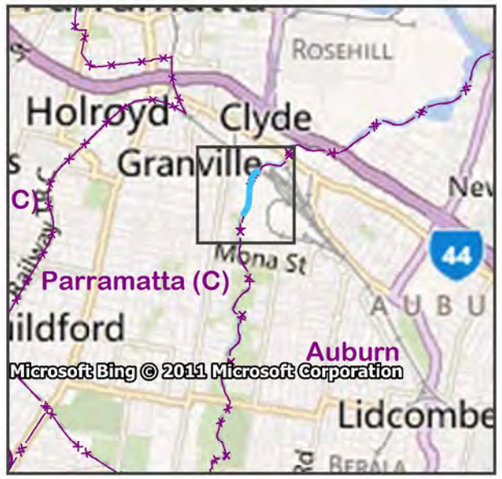
Table 23. Management actions and works required for reach DUCK RIVER 5B

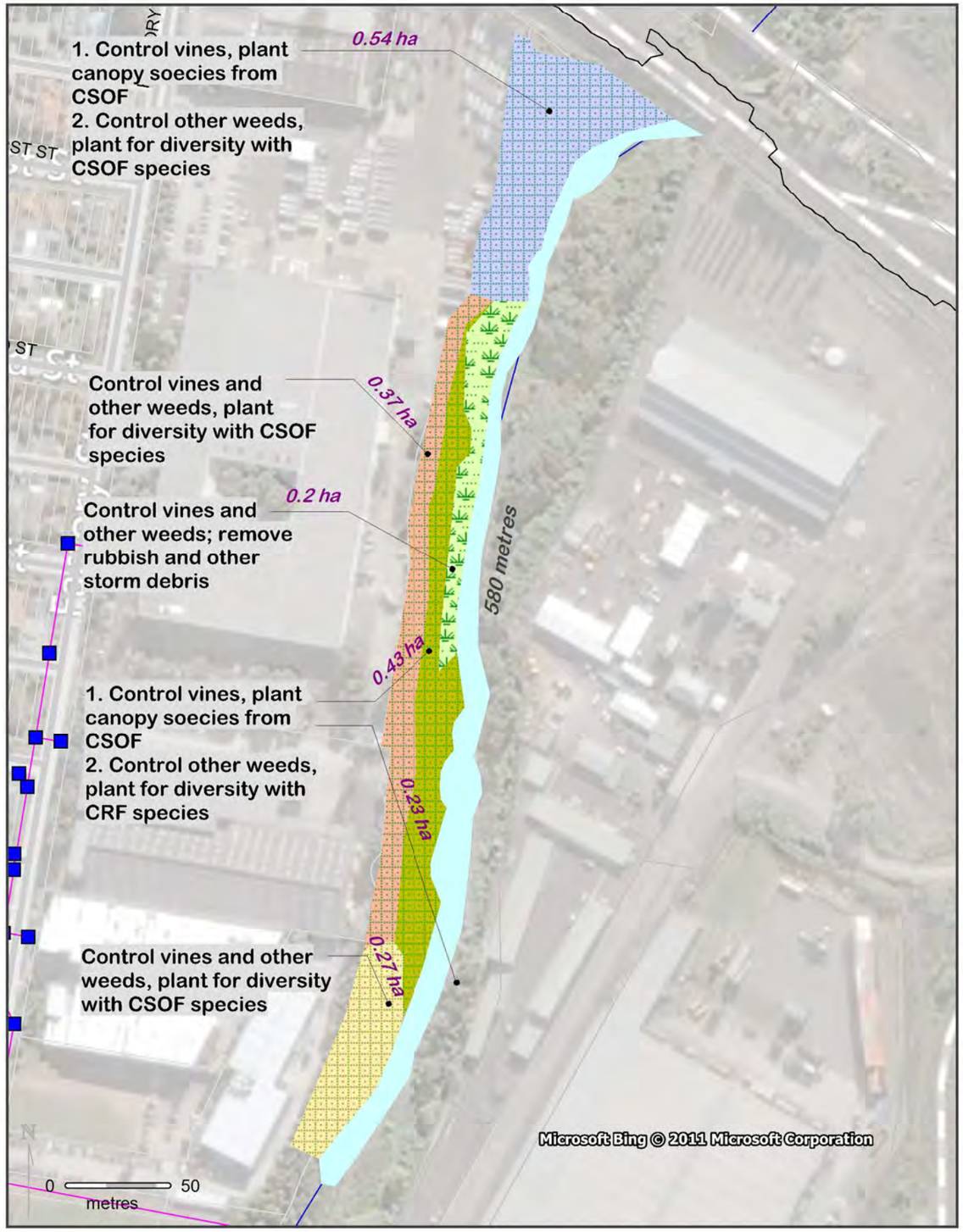
NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
DUCK RIVER 5B (1)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Water quality improvement: remove litter and debris from fringing reeds; consider installation of floating trash trap	Urgent	N/A	$5-10K	$1-2K	PCC/ACC
DUCK RIVER 5B (2)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Water quality improvement: water quality monitoring point	Urgent/ongoing	N/A	$1-2K	$1-2K	PCC/ACC
DUCK RIVER 5B (3)	Biodiversity enhancement: primary weed control of vines, and plant canopy species (Cumberland Riverflat Forest)	High	0.37ha	$20-30K	$5-7K	PCC
DUCK RIVER 5B (4)	Biodiversity enhancement: primary weed control of vines, and plant for diversity with Cumberland Swamp Oak Riparian Forest species	High	0.27ha	$15-20K	$5-7K	PCC
DUCK RIVER 5B (5)	Biodiversity enhancement: primary weed control of vines, and plant canopy species (Cumberland Swamp Oak Riparian Forest)	High	0.54ha	$25-35K	$5-7K	PCC/private landholders
DUCK RIVER 5B (6)	Biodiversity enhancement: primary weed control of vines, and plant canopy species (Cumberland Riverflat Forest)	High	0.43ha	$25-30K	$5-7K	PCC/private landholders
DUCK RIVER 5B (7)	Biodiversity enhancement: primary weed control, revegetation with Cumberland Swamp Oak Riparian Forest species	Medium	0.54ha	$25-30K	$5-7K	PCC/private landholders
DUCK RIVER 5B (8)	Biodiversity enhancement: primary weed control, revegetation with Cumberland Riverflat Forest species	Medium	0.43ha	$25-30K	$5-7K	PCC/private landholders
DUCK RIVER 5B (9)	Biodiversity enhancement: primary weed control of vines and other weeds	Medium	0.20ha	$10-15K	$2-5K	PCC/private landholders
DUCK RIVER 5B (10)	Joint actions with Auburn Council recommended in the Upper Duck River Wetlands and Riparian Management Plan: • Biodiversity enhancement: control carp populations	Medium	N/A	$3-5K/event	ongoing	PCC/ACC





REACH: DUCK RIVER 5B





WORKS PLAN

VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)

Cumberland Swamp Oak Forest (CSOF)

Coastal Freshwater Reedlands

DUCK RIVER 6

Table 24. Management actions and works required for reach DUCK RIVER 6

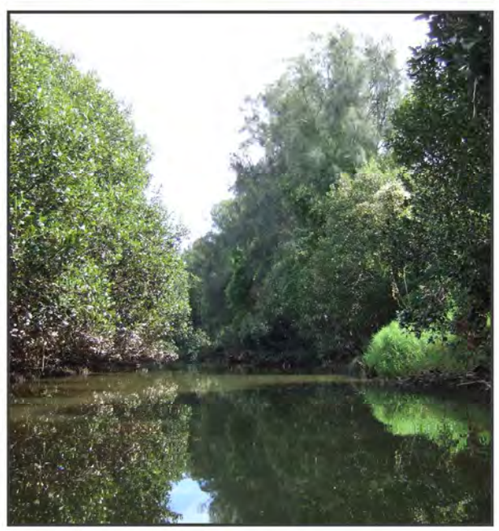
NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
DUCK RIVER 6 (1)	Biodiversity enhancement: primary weed control of vines and noxious weeds	High	1.79ha	$40-50K	$5-8K	PCC/private landholders
DUCK RIVER 6 (2)	Biodiversity enhancement: weed control and infill planting for stabilisation and diversity with Cumberland Swamp Oak Riparian Forest or Cumberland Riverflat Forest species	High	1.79ha	$40-50K	$5-8K	PCC/private landholders
DUCK RIVER 6 (3)	Erosion control: monitor bank stability, especially below railways bridges	High	120m	$0-5K	N/A	PCC/private landholders
DUCK RIVER 6 (4)	Biodiversity enhancement: possible riparian buffer expansion area: weed control and infill planting for stabilisation and diversity with Cumberland Swamp Oak Riparian Forest or Cumberland Riverflat Forest species	Medium	0.82ha	$10-15K	$1000-1500	PCC/private landholders

DUCK RIVER 7

Table 25. Management actions and works required for reach DUCK RIVER 7

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
DUCK RIVER 7 (1)	Biodiversity enhancement: primary weed control of vines and noxious weeds	High	1.66ha	$40-50K	$10-15K	PCC/private landholders
DUCK RIVER 7 (2)	Biodiversity enhancement: weed control and infill planting for stabilisation and diversity with Cumberland Swamp Oak Riparian Forest or Cumberland Riverflat Forest species	High	1.66ha	$15-20K	$2-5K	PCC/private landholders
DUCK RIVER 7 (3)	Erosion control: monitor bank stability, especially around Darcy Street	High	130m	$0-10K	N/A	PCC/private landholders

REACH: DUCK RIVER 6 & 7



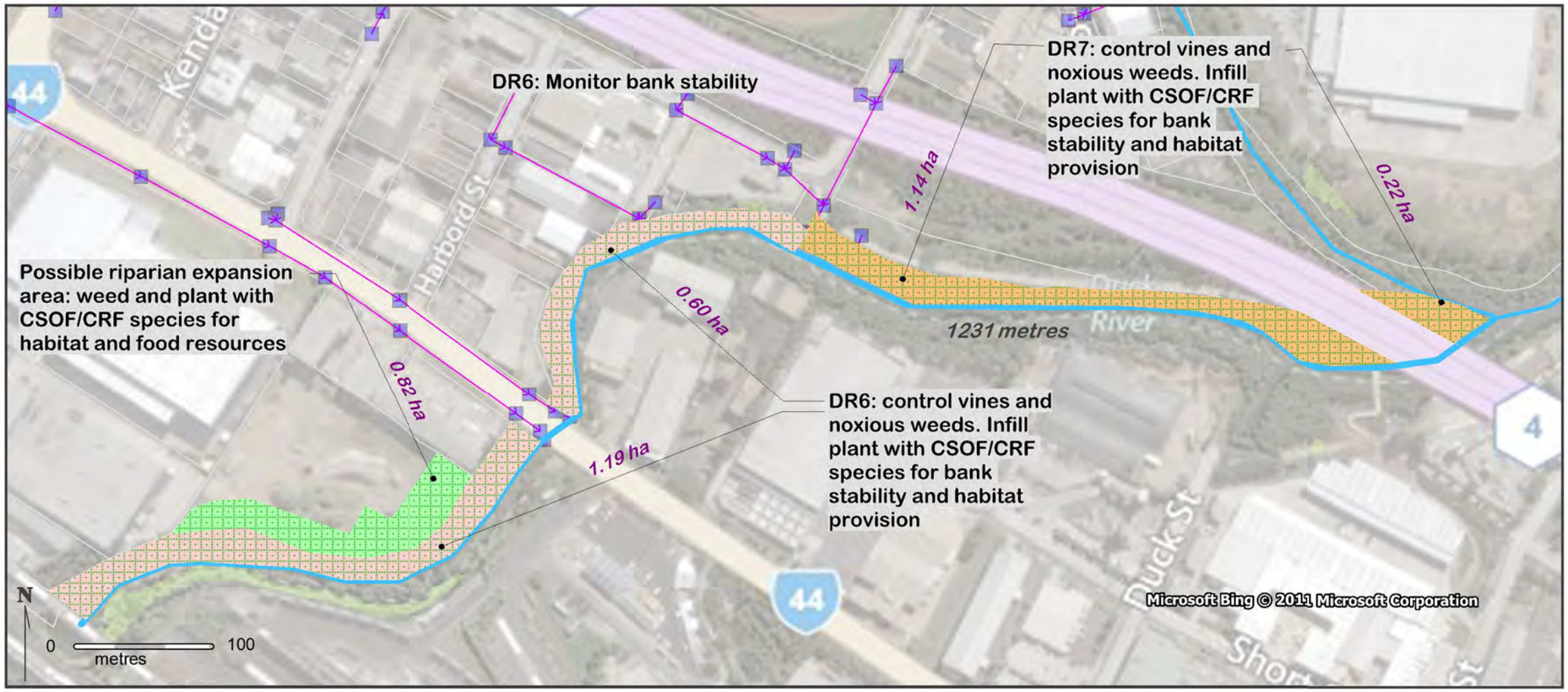
WORKS PLAN

VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)

Cumberland Swamp Oak Forest (CSOF)

Estuarine Mangrove Forest (EMF)



DUCK RIVER 8

Table 26. Management actions and works required for reach DUCK RIVER 8

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
DUCK RIVER 8 (1)	Community involvement Liaise with Shell Refinery to coordinate habitat restoration works	High/ongoing	N/A	N/A	N/A	Private landholders
DUCK RIVER 8 (2)	Biodiversity enhancement: primary weed control of vines and noxious weeds	High	20.6ha 2313m shoreline	$20-30K	$5-8K	PCC/Private landholders
DUCK RIVER 8 (3)	Biodiversity enhancement: bush regeneration weeding and infill planting for stabilisation and diversity with Cumberland Swamp Oak Riparian Forest or Cumberland Riverflat Forest species	Medium	20.6ha 2313m shoreline	$10-20K	$3-5K	PCC/Private landholders

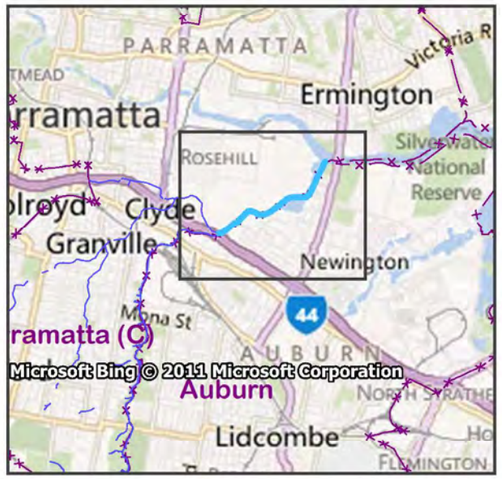


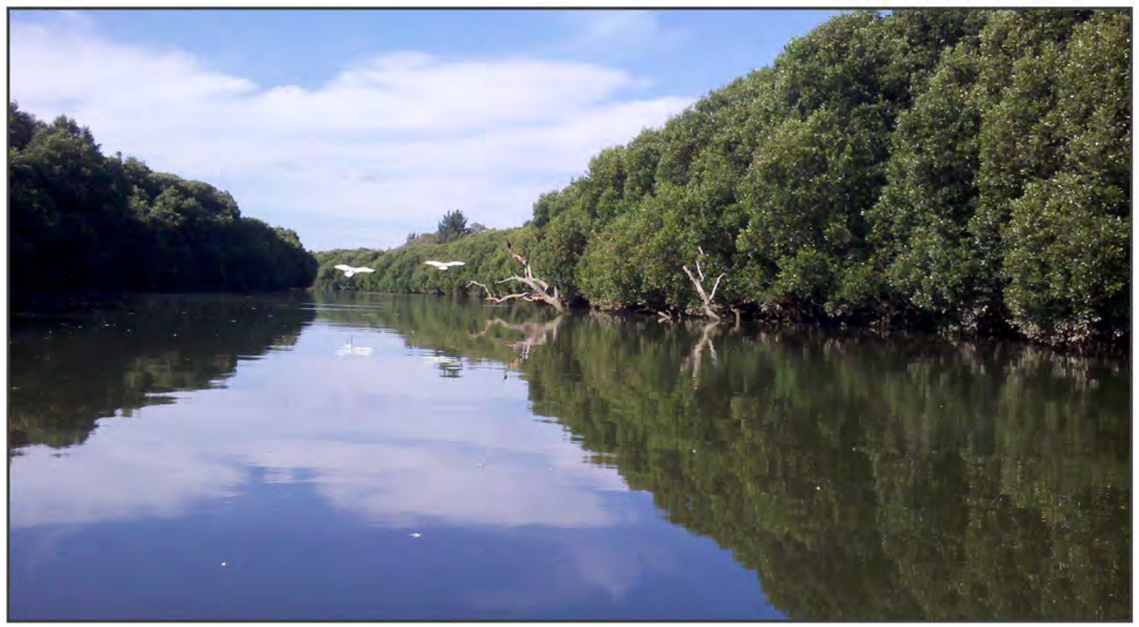





REACH: DUCK RIVER 8

WORKS PLAN



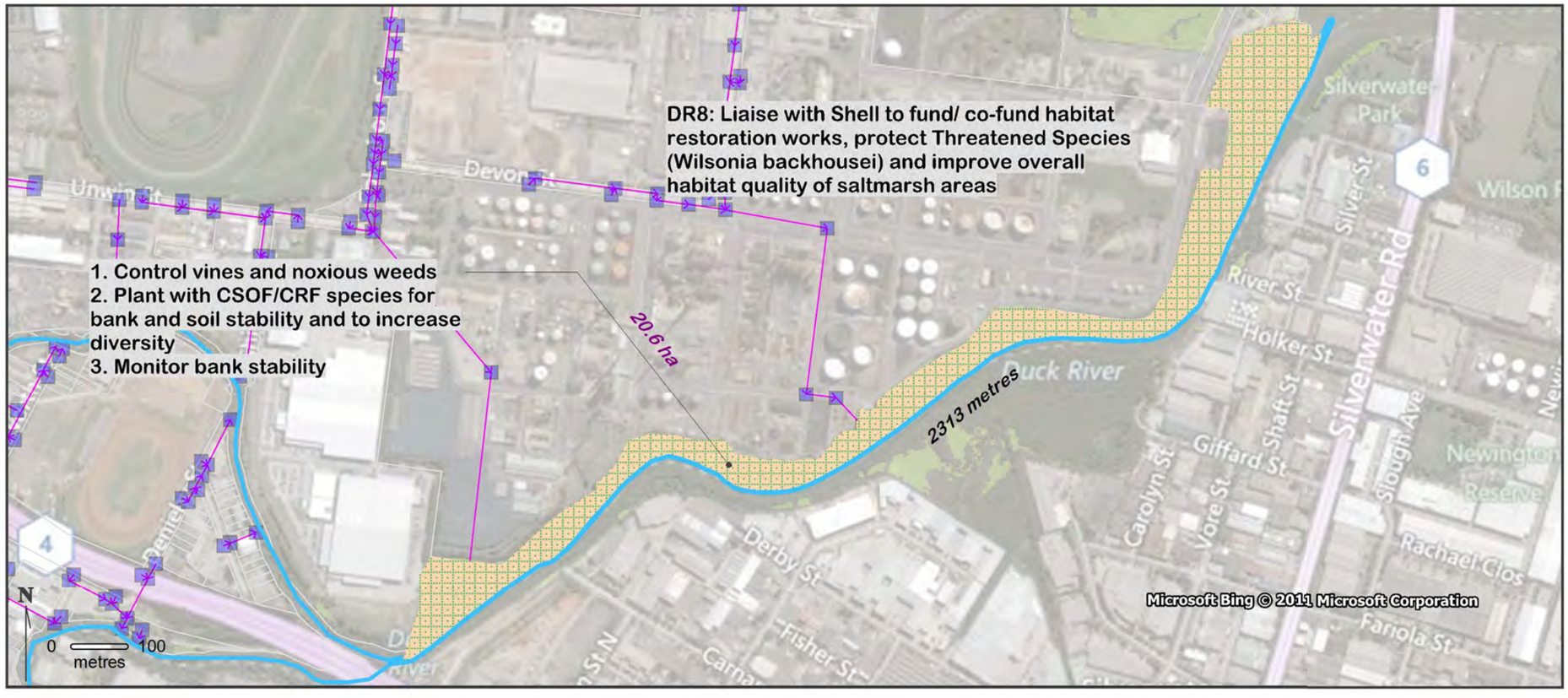


VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)

Cumberland Swamp Oak Forest (CSOF)

Estuarine Mangrove Forest (EMF)



DUCK CREEK 4

Table 27. Management actions and works required for reach DUCK CREEK 4

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (pa)	RESPONSIBILITY
DUCK CREEK 4 (1)	Biodiversity enhancement: primary weed control of vines and noxious weeds	High	1.3ha	$40-50K	$10-20K	PCC
DUCK CREEK 4 (2)	Biodiversity enhancement: stabilise steep slopes as required, eg. Jute mat and plant	High	300m	$0-10K	N/A	PCC
DUCK CREEK 4 (3)	Biodiversity enhancement: bush regeneration weeding and infill planting for stabilisation and diversity with Cumberland Swamp Oak Riparian Forest or Cumberland Riverflat Forest species	HIgh	1.3ha	$10-20K	$2-5K	PCC

DUCK CREEK 5

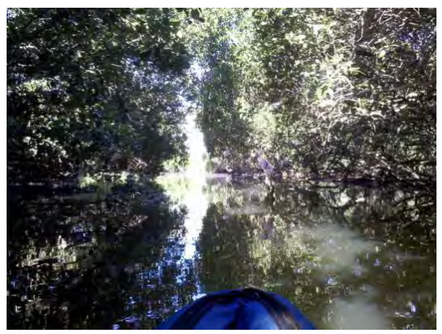
Table 28. Management actions and works required for reach DUCK CREEK 5

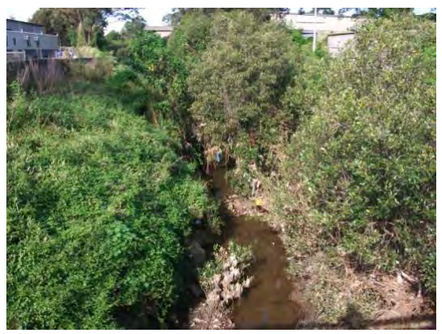
NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (pa)	RESPONSIBILITY
DUCK CREEK 5 (1)	Biodiversity enhancement: primary weed control of vines and noxious weeds	High	7.6ha	$40-50K	$10-20K	PCC
DUCK CREEK 5 (2)	Biodiversity enhancement: stabilise steep slopes as required, eg. Jute mat and plant, rock walls, rock groynes	High	1000m	$0-10K	N/A	PCC
DUCK CREEK 5 (3)	Biodiversity enhancement: bush regeneration weeding and infill planting for stabilisation and diversity with Cumberland Swamp Oak Riparian Forest or Cumberland Riverflat Forest species	High	7.6ha	$10-20K	$5-8K	PCC
DUCK CREEK 5 (4)	Community involvement: Liaise with local landholders to coordinate weed control; provide ongoing support as required	Medium/ongoing	N/A	N/A	N/A	Private landholders

A'BECKETTS CREEK 1 & 2

Table 29. Management actions and works required for reaches A'BECKETTS CREEK 1 & 2

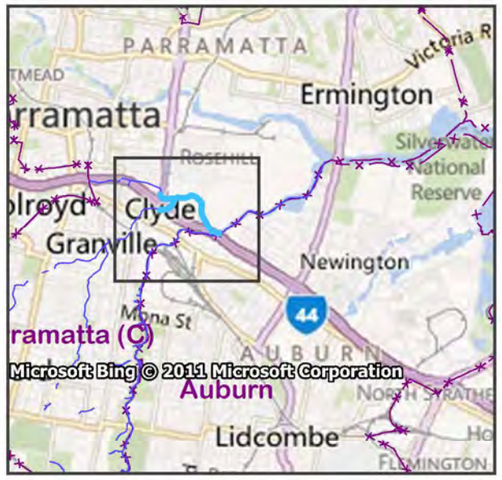
NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (pa)	RESPONSIBILITY
A'BECKETTS CREEK 1&2 (1)	Biodiversity enhancement: primary weed control of vines and noxious weeds	High	0.75ha	$30-40K	$4-6K	PCC/Sydney Water
A'BECKETTS CREEK 1&2 (2)	Biodiversity enhancement: stabilise steep slopes as required, eg. Jute mat and plant	High	150m	$5-7K	$500-1000	PCC/Sydney Water
A'BECKETTS CREEK 1&2 (3)	Biodiversity enhancement: bush regeneration weeding and infill planting for stabilisation and diversity with Cumberland Swamp Oak Riparian Forest or Cumberland Riverflat Forest species	Medium	0.75ha	$5-10K	$500-1000	PCC/Sydney Water

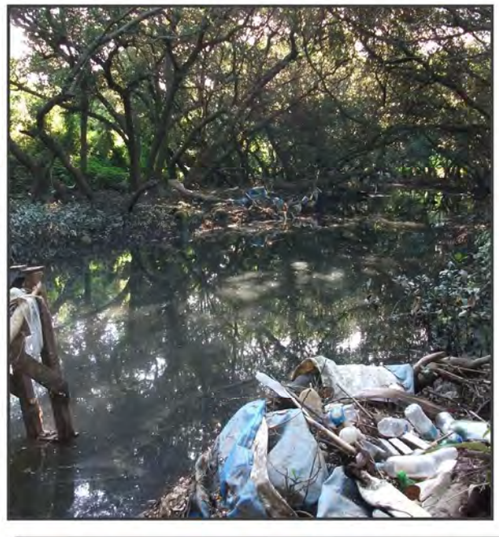




REACH: DUCK CREEK 4-5, A'BECKETTS CREEK 1B-2

WORKS PLAN

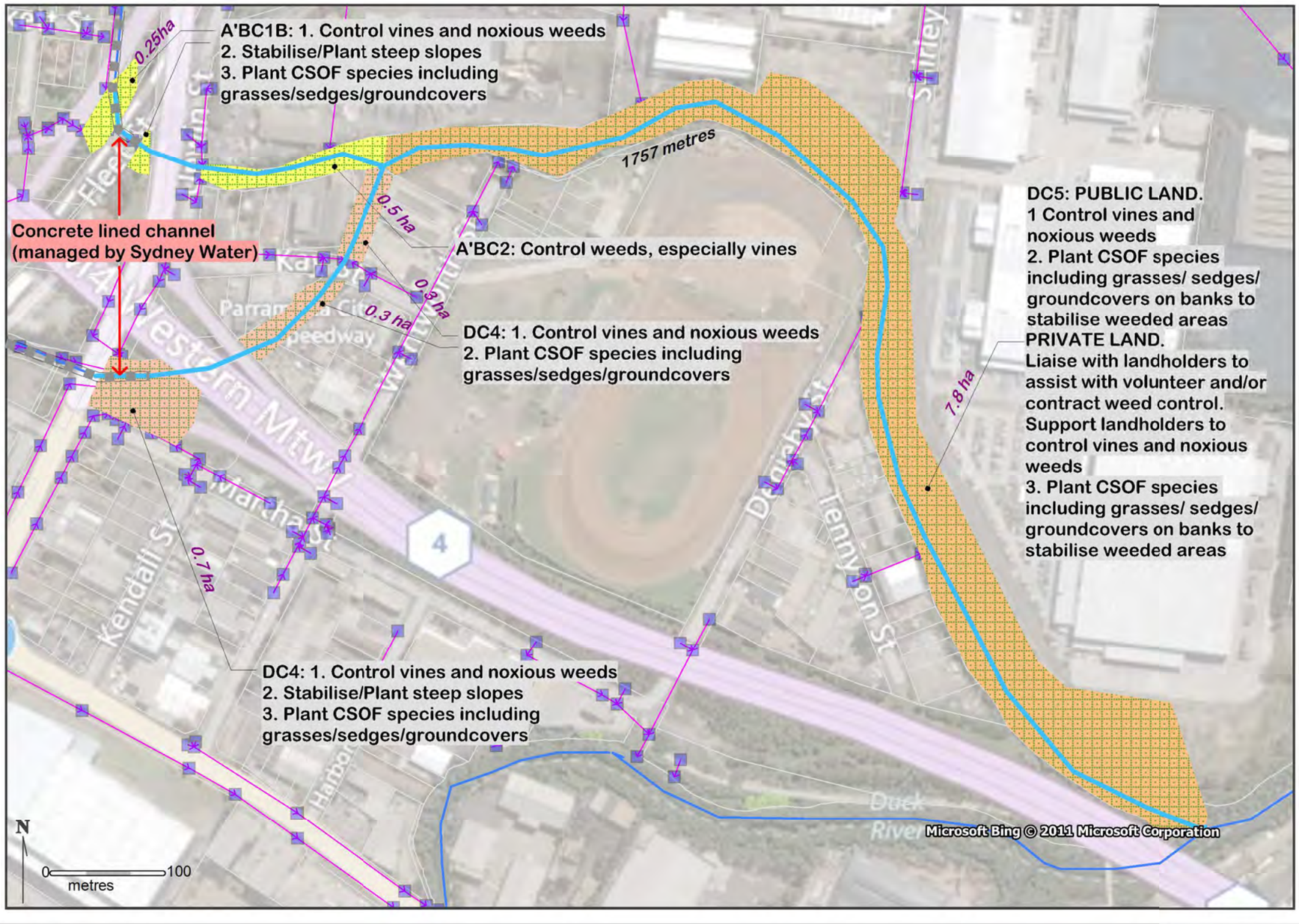




VEGETATION COMMUNITIES

Cumberland Swamp Oak Forest (CSOF)

Estuarine Mangrove Forest (EMF)



LITTLE DUCK CREEK 1A

Table 30. Management actions and works required for reach DUCK CREEK 1A

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
LITTLE DUCK CREEK 1A (1)	Erosion control: Rebatter banks where necessary in conjunction with weed removal	High	80m	$10-20K	$1-2K	PCC
DUCK LITTLE CREEK 1A (2)	Biodiversity enhancement: primary weed control of noxious and woody weeds in channel	High	0.3ha	$10-15K	$1-2K	PCC
DUCK LITTLE CREEK 1A (3)	Biodiversity enhancement: plant for stabilisation and habitat diversity with Cumberland Swamp Oak Riparian Forest or Cumberland Riverflat Forest species; target species that improve habitat resources for Grey-headed Flying Foxes	High	0.3ha	$5-10K	$1-2K	PCC
DUCK LITTLE CREEK 1A (4)	Biodiversity enhancement: riparian buffer expansion, targeting species for planting that improve resources for Grey-headed Flying Foxes	Medium	0.07ha	$2-5K	$500-1000	PCC

LITTLE DUCK CREEK 1B

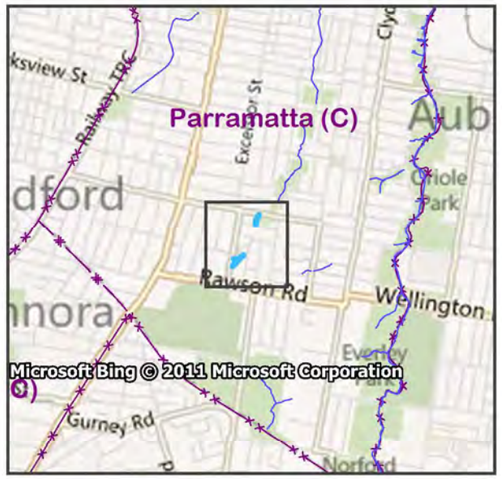
Table 31. Management actions and works required for reach DUCK CREEK 1B

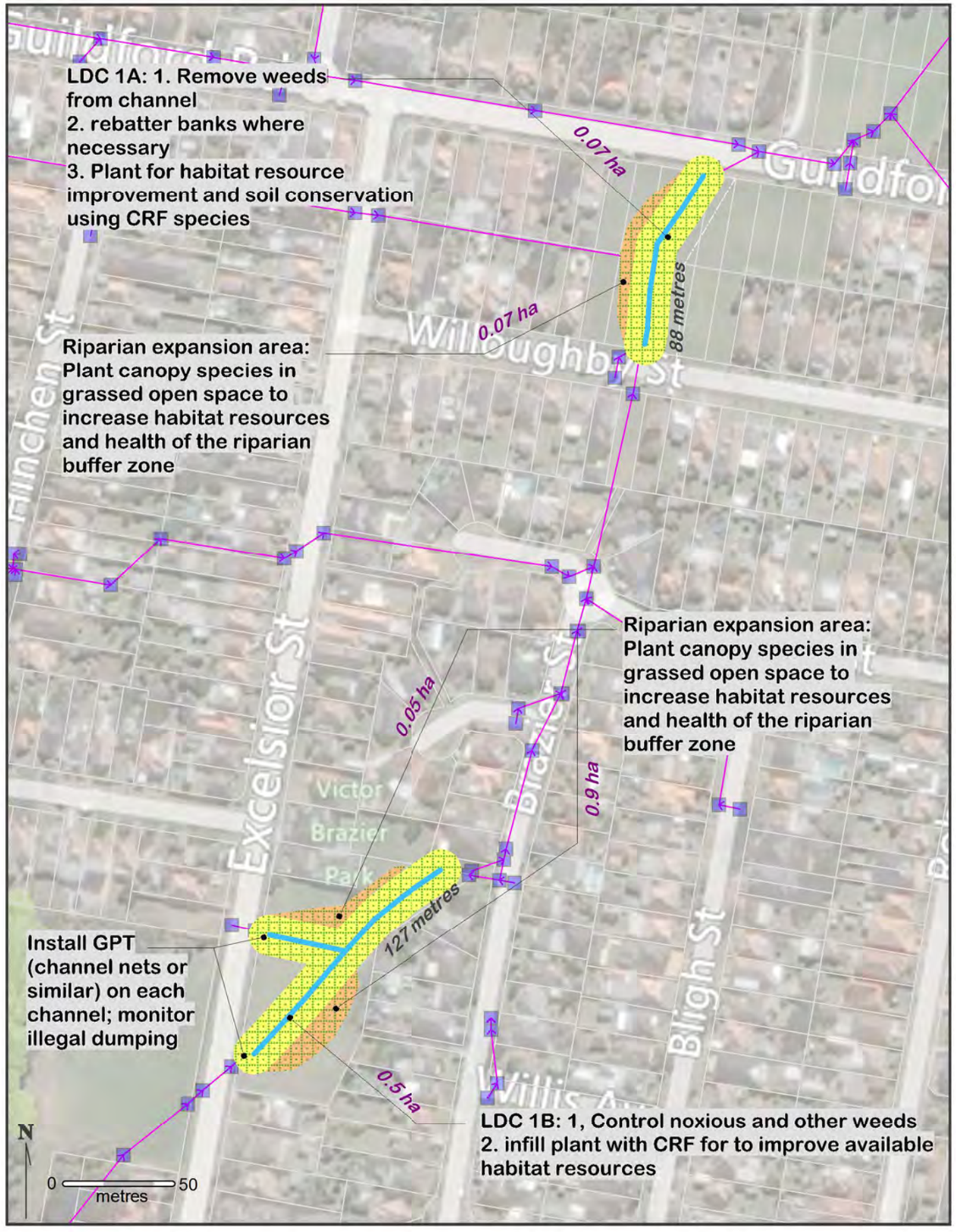
NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (per annum)	RESPONSIBILITY
LITTLE DUCK CREEK 1B (1)	Water quality improvement: install gross pollutant traps (channel nets or similar) on each channel inlet; monitor for illegal dumping	Urgent/ongoing	N/A	$20-50K	$1-2K	PCC
DUCK LITTLE CREEK 1B (2)	Biodiversity enhancement: primary weed control of noxious and woody weeds in channel	High	0.5ha	$20-25K	$5-7K	PCC
DUCK LITTLE CREEK 1B (3)	Biodiversity enhancement: plant for stabilisation and habitat diversity with Cumberland Swamp Oak Riparian Forest or Cumberland Riverflat Forest species; target species that improve habitat resources for Grey-headed Flying Foxes	High	0.5ha	$5-10K	$1-2K	PCC
DUCK LITTLE CREEK 1B (4)	Biodiversity enhancement: riparian buffer expansion, targeting species for planting that improve resources for Grey-headed Flying Foxes	Medium	0.14ha	$2-5K	$500-1000	PCC





REACH: LITTLE DUCK CREEK 1A & 1B





WORKS PLAN

VEGETATION COMMUNITIES

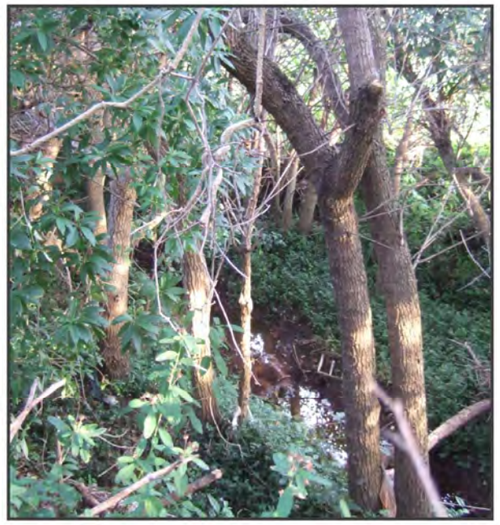
Cumberland Riverflat Forest (CRF)

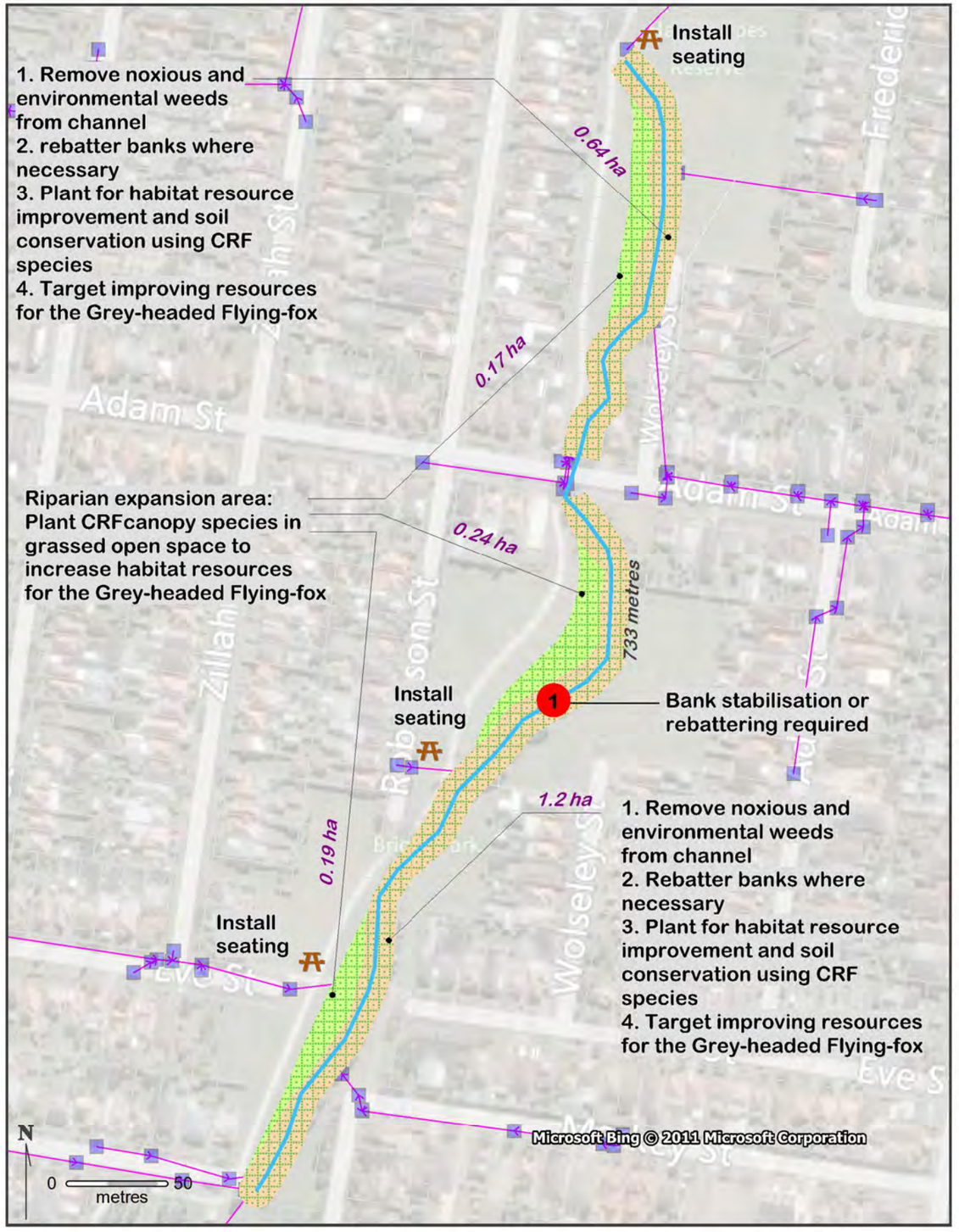
LITTLE DUCK CREEK 2

Table 32. Management actions and works required for reach DUCK CREEK 2

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (pa)	RESPONSIBILITY
DUCK LITTLE CREEK 2 (1)	Erosion control: Rebatter banks where necessary in conjunction with weed removal	Urgent	100m	$20-50K	$0-2K	
LITTLE DUCK CREEK 2 (2)	Biodiversity enhancement: primary weed control of noxious and woody weeds in channel	High	1.84ha	$60-75K	$5-10K	
DUCK LITTLE CREEK 2 (3)	Biodiversity enhancement: plant for stabilisation and habitat diversity with Cumberland Swamp Oak Riparian Forest or Cumberland Riverflat Forest species; target species that improve habitat resources for Grey-headed Flying Foxes	High	1.84ha	$40-50K	$5-10K one year only	
DUCK LITTLE CREEK 2 (4)	Biodiversity enhancement: riparian buffer expansion, targeting species for planting that improve resources for Grey-headed Flying Foxes	Medium	0.60ha	$10-15K	$1-3K one year only	

REACH: LITTLE DUCK CREEK 2

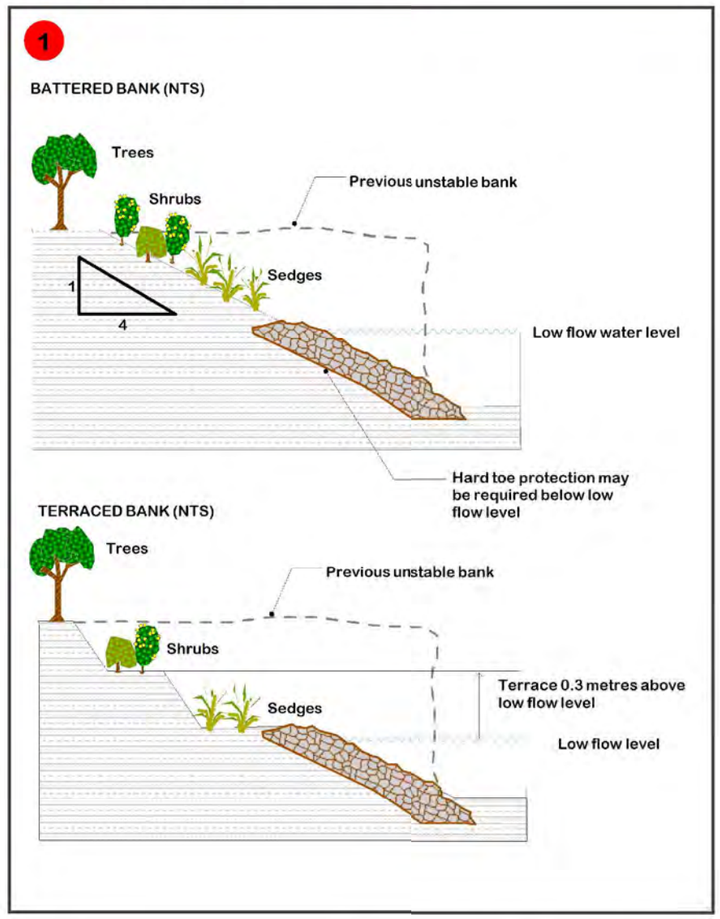




WORKS PLAN

VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)



SMALLS CREEK 1

Table 33. Management actions and works required for reach SMALLS CREEK 1

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (pa)	RESPONSIBILITY
SMALLS CREEK 1 (1)	Biodiversity enhancement: primary weed control of vines and noxious weeds	High	1.74ha	$40-50K	$5-10K	PCC
SMALLS CREEK 1 (2)	Biodiversity enhancement: bush regeneration weeding and infill planting for stabilisation and diversity with Cumberland Riverflat Forest species	High	1.74ha	$5-10K	$1-2K	PCC
SMALLS CREEK 1 (3)	Erosion control: monitor bank stability – do not over clear. Stabilise steep slopes as required, eg. Jute mat and plant, rock line channel or toe	High	200m	$0-10K	N/A	PCC
SMALLS CREEK 1 (4)	Biodiversity enhancement: control environmental weeds and infill planting as required with Cumberland Riverflat Forest species	Medium	0.7ha	$5-10K	$1-2K	PCC

UNNAMED 1A CAMPBELL HILL

Table 34. Management actions and works required for reach UNNAMED 1A CAMPBELL HILL

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (pa)	RESPONSIBILITY
UNNAMED 1A (1)	Water quality improvement: install trash rack or trash trap at inflow next to Campbell Hill Rd	Urgent	N/A	$20-25K	$1-2K	PCC
UNNAMED 1A (2)	Biodiversity enhancement: bush regeneration weeding and infill planting for stabilisation and diversity with Cumberland Plain Woodland species	High	1.35ha	$5-10K	$500-1000	PCC
UNNAMED 1A (3)	Erosion control: Monitor bank stability around new steps; increase planting density in this area; use stabilising plants from Cumberland Plain Woodland	High	0.1ha	$1-3K	$500	PCC
UNNAMED 1A (4)	Biodiversity enhancement: plant canopy species in grassed open space as a buffer for reed lined channel, use Shale Gravel Transition Forest species	Medium	0.25ha	$5-7K	$1000-1500 one year only	PCC

UNNAMED 1B WADDANGALI

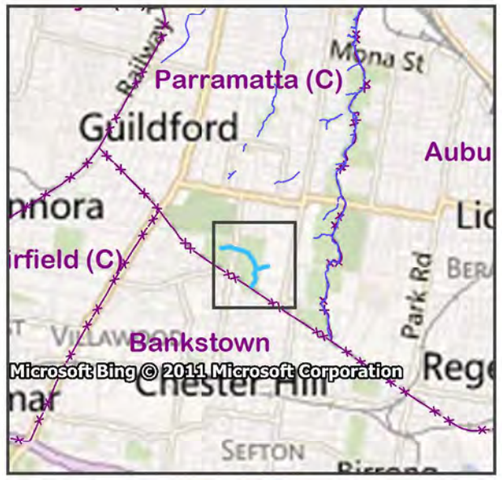
Table 35. Management actions and works required for reach UNNAMED 1B WADDANGALI

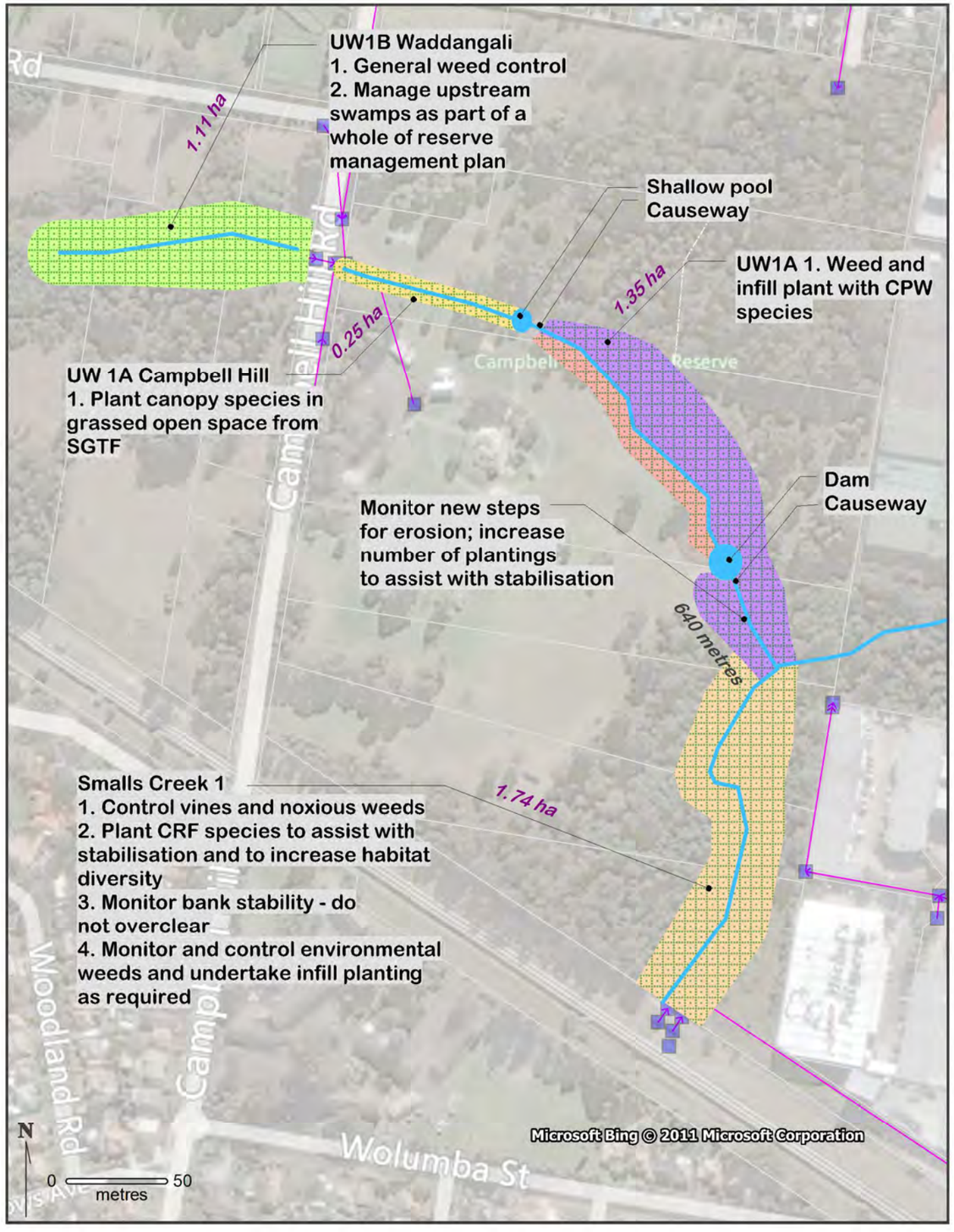
NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (pa)	RESPONSIBILITY
UNNAMED 1B (1)	Biodiversity enhancement: bush regeneration weeding and infill planting for stabilisation and diversity with Cumberland Plain Woodland species	High	1.11ha	$5-7K	$500-1000	PCC
UNNAMED 1B (2)	Biodiversity enhancement: develop whole of reserve management plan with staged removal of noxious and other weeds in swampy areas, and incorporate habitat replacement using Cumberland Plain Woodland species	High	N/A	$8-12K	N/A	PCC





REACH: SMALLS CREEK, UNNAMED 1A & 1B





WORKS PLAN

VEGETATION COMMUNITIES

Cumberland Plain Woodland (CPW)

Cumberland Riverflat Forest (CRF)

Shale-gravel Transition Forest (SGTF)

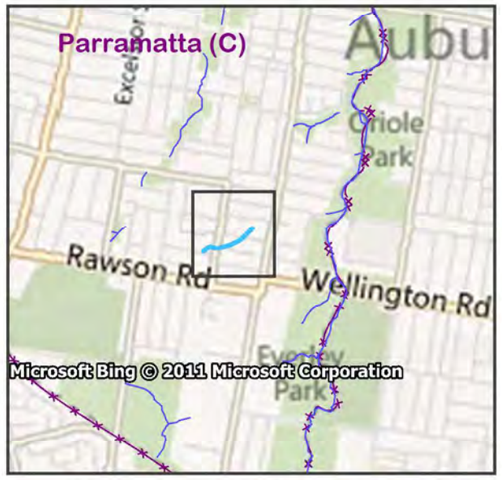
UNNAMED 2A RANDOLPH ST

Table 36. Management actions and works required for reach UNNAMED 2A RANDOLPH ST

NO.	ACTION/WORKS REQUIRED	PRIORITY	AREA (ha) / LENGTH (m)	INITIAL COST	ONGOING COSTS (pa)	RESPONSIBILITY
UNNAMED 2A (1)	Biodiversity enhancement: primary weed control of noxious and woody weeds	High	0.77ha	$10-15K	$1-2K	PCC
UNNAMED 2A (2)	Biodiversity enhancement: bush regeneration weeding and infill planting for stabilisation and diversity with Cumberland Swamp Oak Riparian Forest or Cumberland Riverflat Forest species	Medium	0.77ha	$2-5K	$500-1000	PCC
UNNAMED 2A (3)	Biodiversity enhancement: possible riparian buffer expansion area: weed control and infill planting for stabilisation and diversity with Cumberland Swamp Oak Riparian Forest or Cumberland Riverflat Forest species; target species that improve resources for Grey-headed Flying Foxes	Medium	0.16ha	$2-5K	$500 one year only	PCC

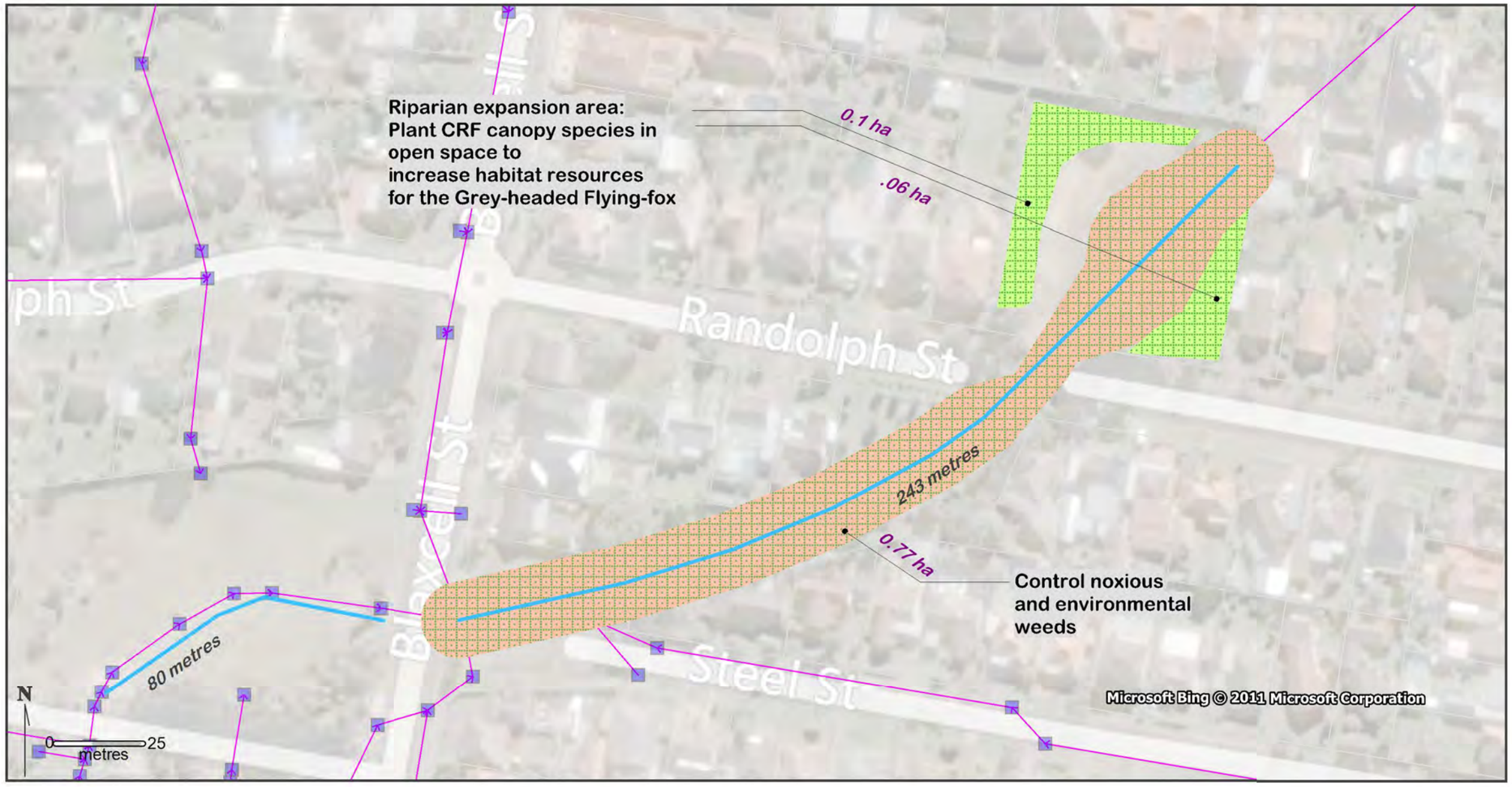
REACH: UNNAMED 2A

WORKS PLAN



VEGETATION COMMUNITIES

Cumberland Riverflat Forest (CRF)



REVIEW OF SETBACKS AND BUFFERS FOR NEW DEVELOPMENT

REQUIREMENTS FOR FLOOD PROTECTION

Molino Stewart (2011) estimated overfloor flooding for properties in the Duck River catchment. Floor levels were estimated from the height of the building floor above ground level and obtaining the ground level from the aerial laser survey provided by PCC. Floor height for non-residential properties (mainly industrial and large commercial premises in the lower part of the Duck River and Duck Creek catchments) was assumed to be 0.5m. Overfloor flooding of properties was estimated for probable maximum flooding events (PMF), and a series of flood average recurrence intervals (ARIs) ranging from 5 to 100 years (Table 37).

Table 37. Estimated overfloor flooding for properties in the Duck River catchment (from Molino Stewart, 2011)

SUB-CATCHMENT	PMF	100y ARI	50y ARI	20y ARI	5y ARI
Duck River	217	0	0	0	0
Duck Creek	906	93	63	35	6
Little Duck Creek	377	78	54	38	8
Commercial/ Industrial	220	39	28	17	7
TOTAL	1720	210	145	90	21

Key areas affected by flooding, even at shorter ARIs, are in Duck Creek, Little Duck Creek and the commercial and industrial areas in the lower part of Duck River. Residential properties affected by overfloor flooding in a 5 or 20 year event should be considered for voluntary buyback by PCC in areas where the channel is not under Sydney Water management. This will create opportunities for localised enhancement of biodiversity resources in these areas, as well as mitigating flood impacts.

BIOPHYSICAL REQUIREMENTS

The following vegetated riparian buffer requirements have been noted:

- Minimum distances to manage water quality processes in the riparian zone vary with rainfall intensity, soil type and land use characteristics. Connecticut River Joint Commission (1998) suggest a range of 38-46m for nutrient removal in forests with medium density groundcover on moderate slopes
- Ideal buffer widths for fauna habitat and movement are difficult to estimate, but a basic corridor linkage is recommended to improve the creek's value

- Minimum distances to attenuate overland flows for a catchment with gentle to moderate slope and medium to high groundcover are recommended to be 15m to 30m (MWH Australia P/L, 2003)
- LWA (2000) recommend a minimum width for riparian vegetation of 20m as being suitable for most situations, but needing to be wider where pollutant loads and slopes are greater

Based on this, an optimum width of 30m vegetated buffer – ideally with local native species from the appropriate vegetation community – is recommended, with a minimum of 20m to be enforced for all future developments.

The riparian zone may include existing developed areas – such as sporting fields, ovals, fences and even small buildings. In effect, these are part of the functional riparian zone, even though they are unnatural. From a land use management perspective, we suggest that the designation should not affect existing use rights, but that community education and landholder co-operation could be used by Council to actively support and encourage better management (such as joint rehabilitation projects and control of polluted runoff).

ZONING AND SETBACKS

The specific reference to provision of buffers in design principles in the Parramatta LEP 2011 refers to Clause 6.7 Foreshore Building Line and Clause 6.5 Water Protection. Consideration of the foreshore building alignment generally applies to foreshore downstream of the M4 motorway crossing. There is no specific reference to buffers or setbacks under Clause 6.5, Water Protection that may otherwise suggest a specific buffer distance or setback to riparian land and waterways.

Biodiversity design principles for development of land abutting land zones E2 and W1 in the LEP (2011) also recognise the need for "the requirement for provision of a buffer zone on the abutting land to protect the bushland area" although a specific distance/width is not specified. Molino Stewart (2011) suggests a riparian zone of between 20m and 40m on both sides of the Duck River based on the need for three specific zones:

1. Core riparian zone – land in and adjacent to the channel;
2. Vegetated buffer to protect the integrity of the core riparian zone; and
3. An asset protection zone for protection against bushfire damage.

Part 6 of LEP 2011 includes several sub-clauses that provide additional protection for lands in the riparian corridor. Part 6.4 Biodiversity protection aims to maintain terrestrial and aquatic biodiversity, and applies to a small parcel of land immediately downstream of Seventh Ave, Granville, and an unpiped section of Smalls Creek between factories.

Part 6.5 Water protection aims to maintain the hydrological functions of riparian land, waterways and aquifers, and applies to a small parcel of land immediately downstream of Seventh Ave, Granville, and small portions of residential blocks adjoining UNNAMED 3 CLYDE/BENNETT STS.

The recommended setbacks are congruent with the requirements under each relevant section of Parramatta LEP 2011.

TIMEFRAME FOR REVIEW

Review of the Masterplan should be conducted in two ways over different timeframes:

- Review of progress of works allowing for financial and environmental considerations
- Revision/rewriting of the Masterplan

REVIEW OF PROGRESS OF WORKS

Rate of progress of environmental restoration works are affected by a range of variables that are generally beyond the control of implementing authorities, including:

- Availability of funding
- Seasonal variables
- Rainfall regime
- Bushfire
- Vandalism
- Availability of local provenance tubestock suitably matured for planting

In the normal course of a rehabilitation program, works follow a sequential path, with each taking a period of time that may be affected by any of these variables. Thus the rehabilitation program is effectively a dynamic strategy, changing as works are completed, additional works are required, or new issues arise. Regular review should be conducted annually at a minimum to determine progress. An annual review will allow for modification of the implementation program as required.

REVISION/REWRITING OF THE MASTERPLAN

The Masterplan is considered current for a minimum period of 5 years. Annual review will extend the relevant lifespan of the plan, and retain a works focus on appropriate objectives and issues. The Masterplan should be updated as required, or within 3 years from completion or the last review.

Revision of the Masterplan should consider the following aspects:

- Results of bushland rehabilitation activities
- Results of water quality monitoring
- Whether short and medium term management objectives have been completed
- Whether any new issues arise that have not been previously addressed
- Whether existing management objectives are still current and appropriate

The Masterplan should be revised earlier if any of the following occurs:

- a significant change occurs in the catchment due to fire, flood or other catastrophic event
- additional information becomes available that changes the objectives or desired outcomes of management
- new issues are raised which require immediate attention
- additional funding for works becomes available
- data becomes available that indicates that the objections are not able to be achieved

APPENDIX ONE: COMMUNITY CONSULTATION

COMMUNITY WORKSHOP

Issues identified

Participants at the community consultation workshop identified the following issues:

- Pioneer reserve on a Sunday afternoon – terrible rubbish.
- Granville bridge on The Avenue...lots of rubbish.
- Community education on rubbish for people with a non English speaking background.
- Need to keep/maintain /improve the integrity of the natural bushland.
- Are the schools involved in Streamwatch?
- How do we engage culturally – other ethnic groups want to know.
- Water pollution from poor development and management.
- Verges that have been sprayed and eroded.
- We don't want a cycleway through the Duck River bushland.
- People in the football season – the football tape is all over the park.
- We don't really want to have people fishing....
- Maintenance of the sediment traps are supposed to be on a monthly cycle – some have not (ponds) been done in 9 months.
- Sediments very very poor quality – especially on the bed and banks.
- Mowing areas with alligator weeds = spread it.
- High turnover of parks grounds management staff, so they are not familiar with local issues
- Engaging community and industry – how do we achieve this?
- Purchase the land – department of housing owns some land? Identify areas for voluntary buyback.
- OHS concerns for self guided walks. Some raised walkways – some of it got burned up and removed.
- Bike jumps – cutting down trees for bikes jumps and bike paths. Need somewhere else to construct the ramps for the bikes.
- Dead end streets – people go up and dump in them.
- Fruit trees – tree nets. Fruit net in urban areas – have to look into the regulations.
- Trees that are cut down – on private land.
- Scar trees – important for indigenous heritage – an extra 60 trees that council does not know about.
- Planted out the island – and planted it out which was a significant aboriginal site. Japanese gardens built over a burial site where there was a massacre.

Opportunities identified

Participants at the community consultation workshop identified the following opportunities:

- Rangers for the rubbish. ??
- Education in schools.
- Contact local takeaways – educate about rubbish. Business products are all around the area. Put a bit of pressure on them.

- Maybe there needs to be something like cleanup Australia type day/s to clean up the rubbish.
- Start with schools and adopt some bushland. Pride in peoples kids and pride in the bushland.
- Five schools in the catchment doing environmental programs on the Duck River throughout the year.
- Need to have a plan that says that these are the places for nature and these are the places for mixed – the rest is urban.
- Fine the football clubs if they don't clean up their rubbish!
- Council does compliance – they do the surveys around shopping centres, not in areas. Rubbish is recyclable – it needs to be captured and recycled.
- Some guided walks in the Duck River bushland .
- Adopt a river section and linking it to pride – positive advertising when they look good.
- Auburn council – ":natural area coordinator" – got some new candidates and staff coming on. Mainly for the Duck River.
- Large community comes into the catchment every day - some corporate people are desperate to do something in the community – corporate responsibility every day volunteering in their work plan – large workforce available to get them in? "Cause some of the grief and does not stay". Massive workforce - companies come and wear their shirts - the whole thing is coordination – it costs a lot to coordinate.

Desired outcomes

Participants at the community consultation workshop identified the following as desired outcomes:

- Some areas for nature and not just universal access.
- Signage around the parks for litter.
- So little bushland – so little left. So precious – we just want to keep it nice!
- Protect the sacred sites and then educate other groups about the cultural law . i.e this is a women's birthing site etc.
- Building sites that have been managed properly.
- Better coordination between councils. One bit of work on one side but not the other. Council should know that if they start something they need to have a 10year commitment.
- Significant reduction in rubbish and resulting storm debris; fines for non compliance
- Sediment basins are emptied twice a year or as required.
- An education strategy or information booklet that targets parks services. Clearly identify areas that are managed as natural heritage and those that are mixed use.
- Catchment management programs – supporting programs that Council is doing – put the emphasis back on council to be systematic about how it is implemented. Need to know what all the peripheral plans say too. The masterplan needs to be the primary document.
- Council/businesses – sign off on an MOU?? Get some signatory agreement to assist with the management.
- River rewards scheme to highlight something positive.
- Sydney water plan – CMA catchment Action Plan – catchment wide targets etc. Important that the longer term goals in the broader strategies they need to be referred to.
- A Duck River Steering Committee for implementing the actions – constant feedback.

- The bushland is too small – we want to get into the urban footprint. They should be using street trees – local species etc – very rarely enforced. Eg factory developments. – peoples yards.
- Developments next to sensitive areas need to be triple checked and incorporate WSUD and any potential changes to the development. Population will increase in Parramatta. Feed into Councillors through a steering committee??

COMMUNITY SURVEY QUESTIONNAIRE

Community responses to questionnaires

A number of stakeholders completed the Community Consultation Survey Questionnaire. The responses from these questionnaires were collected to determine the key values and issues for the catchment. The following were identified as important for a vision for Duck River Catchment:

- Conserves natural qualities 15 responses
- Appealing, accessible and sustainable 13 responses
- Offers recreational opportunities (passive) 10 responses
- Improve water quality and waste management 8 responses
- Conserves heritage values 8 responses
- Important contribution to the character of the area 6 responses
- A sense of place for the community 4 responses
- Improve habitat 3 responses

APPENDIX TWO: FLORA FOR REVEGETATION

Cumberland Swamp Oak Riparian Forest, S_FoW07 (SMCMA, 2010)

The distinguishing feature is the prominent stands of swamp oak (*Casuarina glauca*) found along or near streams. Often these are relatively young trees, swarming amongst a mix of old and young eucalypts such as rough barked apple (*Angophora floribunda*), forest red gum (*Eucalyptus tereticornis*) and grey box (*Eucalyptus molucanna*). The understorey is typical of the open grassy and herbaceous characteristics of other riverflat forests.

Cumberland Swamp Oak Riparian Forest is a component of River Flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions, and is listed as an Endangered Ecological Community under the NSW Threatened Species Conservation Act 1995 (TSC Act).

Table A 1. Species recommended for revegetation in Cumberland Swamp Oak Riparian Forest

CORE SPECIES	ADDITIONAL SPECIES
TREES & SHRUBS	
Acacia decurrens	*Angophora floribunda*
Bursaria spinosa	*Breynia oblongifolia*
Casuarina glauca	*Eucalyptus baueriana*
Eucalyptus moluccana	*Eucalyptus crebra*
Maytenus silvestris	*Eucalyptus tereticornis*
Melaleuca decora	*Jacksonia scoparia*
Melaleuca nodosa	*Melaleuca styphelioides*
Ozothamnus diosmifolius	*Polyscias sambucifolia*
VINES & GROUNDCOVERS	
Alisma plantago-aquatica	*Adiantum aethiopicum*
Brunoniella australis	*Alternanthera denticulata*
Commelina cyanea	*Arthropodium milleflorum*
Damasonium minus	*Billardiera scandens*
Dichondra repens	*Carex appressa*
Echinopogon ovatus	*Centella asiatica*
Eclipta platyglossa	*Cheilanthes sieberi subsp. Sieberi*
Einadia hastate	*Clematis glycinoides var. glycinoides*
Eleocharis cylindrostachys	*Dianella longifolia*
Entolasia marginata	*Dianella revoluta var. revoluta*

CORE SPECIES	ADDITIONAL SPECIES
Glycine tabacina	*Dichelachne micrantha*
Pratia purpurascens	*Eragrostis leptostachya*
Senecio hispidulus	*Glycine microphylla*
Veronica plebeia	*Gonocarpus tetragynus*
Wahlenbergia gracilis	*Goodenia ovata*
	Hibbertia diffusa
	Juncus usitatus
	Lomandra longifolia
	Microlaena stipoides var. stipoides
	Oplismenus aemulus
	Oxalis exilis
	Oxalis perennans
	Persicaria decipiens
	Plantago debilis
	Poa labillardierei
	Poranthera microphylla
	Pseuderanthemum variabile
	Setaria distans
	Solanum prinophyllum
	Tetragonia tetragonioides

Coastal Freshwater Reedland, S_FrW03 (SMCMA, 2010)

Coastal Freshwater Reedland is found on poorly drained alluvial flats and sand depressions across the NSW east coast. These swamps are predominantly freshwater communities although some swamps may be brackish. The reedlands are tall sometimes reaching over 3 metres in height and are dominated by one or two species, predominantly common reed (*Phragmites australis*) and cumbungi (*Typha orientalis*). Other tall reeds include *Elaeocharis sphacelata*. The continous cover of reedlands may include a sparse cover of swamp oak (*Casuarina glauca*) or swamp paperbark (*Melaleuca ericifolia*) on the drier margins of the swamp.

Many of these remaining swamps in the SMCMA area are situated amongst intense urban landuses. In these environments drainage patterns have been altered and weeds are prolific at many sites. Where these swamps occur on muds, sands, silts and loams associated with coastal floodplains they forma component of Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney

Basin and South East Corner bioregions an Endangered Ecological Community listed under Schedule1 of the NSW Threatened Species Act, 1995.

Table A 2. Species recommended for revegetation in Coastal Freshwater Reedlands

CORE SPECIES	ADDITIONAL SPECIES
TREES & SHRUBS	
Melaleuca ericifolia	*Casuarina glauca*
	Melaleuca decora
	Melaleuca linariifolia
VINES & GROUNDCOVERS	
Blechnum indicum	*Baumea juncea*
Eleocharis sphacelata	*Bolboschoenus fluviatilis*
Hemarthria uncinata var. uncinata	*Carex appressa*
Hydrocotyle verticillata	*Gleichenia dicarpa*
Hypolepis muelleri	*Juncus continuus*
Isachne globosa	*Juncus planifolius*
Juncus kraussii	*Parsonsia straminea*
Phragmites australis	*Philydrum lanuginosum*
Typha orientalis	

Cumberland Riverflat Forest, S_FoW06 (SMCMA, 2010)

Cumberland Riverflat Forest is an open eucalypt forest that forms narrower ribbons alongside streams and creeks that drain the Cumberland Plain. Typically the canopy includes one of the rough-barked apple (*Angophora floribunda*) or broad-leaved apple (*Angophora subvelutina*) and one or both of forest red gum (*Eucalyptus tereticornis*) and cabbage gum (*Eucalyptus amplifolia*). However there are a wide variety of other interesting eucalypts that are highly localised.

Cumberland Riverflat Forest is a component of River Flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions and is listed as an Endangered Ecological Community under the NSW Threatened Species Conservation Act 1995 (TSC Act).

Table A 3. Species recommended for revegetation in Cumberland Riverflat Forest

CORE SPECIES	ADDITIONAL SPECIES
TREES & SHRUBS	
Acacia decurrens	*Eucalyptus amplifolia*
Angophora floribunda	*Eucalyptus saligna*

CORE SPECIES	ADDITIONAL SPECIES
Bursaria spinosa	*Exocarpos cupressiformis*
Eucalyptus baueriana	*Grevillea robusta*
Eucalyptus tereticornis	*Leucopogon juniperinus*
Hibiscus heterophyllus	*Persoonia linearis*
Ozothamnus diosmifolius	*Pittosporum undulatum*
	Trema tomentosa
VINES & GROUNDCOVERS	
Brunoniella australis	*Adiantum aethiopicum*
Cheilanthes sieberi subsp. Sieberi	*Cyperus laevis*
Commelina cyanea	*Dianella longifolia*
Clematis glycinoides var. glycinoides	*Echinopogon caespitosus var. caespitosus*
Desmodium varians	*Einadia trigonos*
Dichondra repens	*Eragrostis leptostachya*
Digitaria parviflora	*Microlaena stipoides var. stipoides*
Echinopogon ovatus	*Pratia purpurascens*
Einadia hastata	*Wahlenbergia gracilis*
Entolasia marginata	*Veronica plebeia*
Glycine clandestina	
Glycine microphylla	
Glycine tabacina	
Marsilea hirsuta	
Oplismenus aemulus	
Oxalis perennans	
Solanum prinophyllum	

Cooks River/Castlereagh Ironbark Forest S_DSF01 (includes Cooks River Clay Plain Scrub Forest) (SMCMA, 2010)

Castlereagh Ironbark Forest is associated with clay soils derived from Tertiary alluvial deposits. The structure ranges from a moderately tall open eucalypt forest or woodland to a low dense thicket of paperbarks with low emergent eucalypts. The latter is prevalent across the catchment of the Cooks River and is recognised in other classifications as Cooks River Clay Plain Scrub.

Broad-leaved ironbark (*Eucalyptus fibrosa*) is the most commonly recorded eucalypt although at some sites it may be absent. Other species such as woollybutt (*Eucalyptus longifolia*) is a more regular associate although sites often have a diverse canopy composition which reflects subtle grades between substrates sourced from tertiary sand, sandstone bedrock, shale and ironstone gravels. A prominent small tree layer of *Melaleuca decora* features above dense cover of shrubs that include *Melaleuca nodosa*, blackthorn (*Bursaria spinosa*) and peach heath (*Lissanthe strigosa*).

Castlereagh Ironbark Forest is a component of Cooks River/Castlereagh Ironbark Forest in the Sydney Basin an Endangered Ecological Community listed under Schedule 1 of the NSW Threatened Species Conservation Act 1995.

Table A 4. Species recommended for revegetation in Cooks River/Castlereagh Ironbark Forest

CORE SPECIES	ADDITIONAL SPECIES
TREES & SHRUBS	
Acacia decurrens	*Acacia falcata*
Acacia pubescens	*Acacia parramattensis*
Bursaria spinosa	*Daviesia ulicifolia*
Eucalyptus crebra	*Dillwynia parvifolia*
Eucalyptus fibrosa	*Dillwynia sieberi*
Leucopogon juniperinus	*Eucalyptus eugenioides*
Lissanthe strigosa	*Eucalyptus longifolia*
Melaleuca decora	*Eucalyptus tereticornis*
Melaleuca nodosa	*Exocarpos cupressiformis*
Pultenaea villosa	*Maytenus silvestris*
	Notelaea longifolia
	Ozothamnus diosmifolius
	Persoonia linearis
	Polyscias sambucifolia
VINES & GROUNDCOVERS	
Aristida vagans	*Austrostipa rudis*
Austrodanthonia tenuior	*Billardiera scandens*
Brunoniella australis	*Bossiaea prostrata*
Cheilanthes sieberi subsp. sieberi	*Calotis cuneifolia*
Desmodium varians	*Cymbopogon refractus*
Dianella revoluta var. revolute	*Dianella longifolia*

CORE SPECIES	ADDITIONAL SPECIES
Dichelachne micrantha	*Einadia hastate*
Dichondra repens	*Entolasia marginata*
Echinopogon caespitosus var. caespitosus	*Entolasia stricta*
Echinopogon ovatus	*Euchiton sphaericus*
Glycine clandestina	*Glycine tabacina*
Glycine microphylla	*Gonocarpus tetragynus*
Goodenia hederacea subsp. hederacea	*Hibbertia pedunculata*
Hardenbergia violacea	*Hypericum gramineum*
Hibbertia aspera subsp. aspera	*Lagenophora stipitata*
Lomandra filiformis	*Laxmannia gracilis*
Lomandra multiflora	*Lepidosperma laterale*
Opercularia diphylla	*Microlaena stipoides var. stipoides*
Oxalis perennans	*Olearia microphylla*
Panicum simile	*Poa labillardierei*
Poranthera microphylla	*Polymeria calycina*
Pratia purpurascens	*Pomax umbellata*
Setaria distans	*Veronica plebeia*
Themeda australis	
Vernonia cinerea var. cinerea	
Wahlenbergia gracilis	

Cumberland Shale Plains Woodland (S_GW03)

The gentle topography associated with the shale plains of Western Sydney carries an open grassy woodland dominated by grey box (*Eucalyptus moluccana*), forest red gum (*Eucalyptus tereticornis*) and ironbark (*Eucalyptus crebra/Eucalyptus fibrosa*). Localised patches of spotted gum (*Corymbia maculata*) may occur. Cumberland Shale Plains Woodland is the second of the grassy woodlands that comprise the Cumberland Plain Woodland endangered ecological community listed under the NSW Threatened Species Conservation Act, 1995. Like the related community Cumberland Shale Hills Woodland it is typified by a sparse to moderate cover of shrubs and a high cover of grasses and forbs.

Research has defined the primary habitat for the community as occurring at elevations less than 150 meters above sea level with some sites occurring at higher elevations where the landscape remains gently inclined. Rainfall is restricted to a narrow band between 750-950 millimetres per annum.

Table A 5. Species recommended for revegetation in Cumberland Shale Plains Woodland

CORE SPECIES	ADDITIONAL SPECIES
TREES & SHRUBS	
Bursaria spinosa	*Acacia decurrens*
Eucalyptus moluccana	*Acacia implexa*
Eucalyptus tereticornis	*Breynia oblongifolia*
	Daviesia ulicifolia
	Dillwynia sieberi
	Eucalyptus crebra
	Ozothamnus diosmifolius
VINES & GROUNDCOVERS	
Aristida vagans	*Austrostipa rudis*
Aristida ramosa	*Arthropodium milleflorum*
Brunoniella australis	*Asperula conferta*
Cheilanthes sieberi subsp. Sieberi	*Austrodanthonia racemosa var. racemosa*
Chloris ventricosa	*Austrodanthonia tenuior*
Cymbopogon refractus	*Dianella revoluta var. revoluta*
Desmodium varians	*Echinopogon caespitosus var. caespitosus*
Dianella longifolia	*Echinopogon ovatus*
Dichelachne micrantha	*Einadia hastata*
Dichondra repens	*Entolasia marginata*
Eragrostis leptostachya	*Eremophila debilis*
Euchiton sphaericus	*Fimbristylis dichotoma*
Glycine clandestina	*Goodenia hederacea subsp. hederacea*
Glycine microphylla	*Hypericum gramineum*
Glycine tabacina	*Hypoxis hygrometrica*
Hardenbergia violacea	*Juncus usitatus*
Lomandra filiformis	*Lachnagrostis filiformis*
Microlaena stipoides var. stipoides	*Lomandra multiflora*
Opercularia diphylla	*Panicum effusum*
Oxalis perennans	*Panicum simile*

CORE SPECIES	ADDITIONAL SPECIES
Setaria distans	*Phyllanthus virgatus*
Stackhousia viminea	*Plantago debilis*
Themeda australis	*Poa labillardierei*
Tricoryne elatior	*Poranthera microphylla*
Wahlenbergia gracilis	*Pratia purpurascens*
	Solanum prinophyllum
	Sporobolus creber
	Vernonia cinerea var. cinerea
	Veronica plebeia

Castlereagh Shale-Gravel Transition Forest (S_DSF02)

Castlereagh Shale-Gravel Transition Forest is recognised as a community associated with shale influenced sandy soils that support a component of ironstone gravels. The location of these soils can occur in remarkably different locations. Some are associated are with low lying tertiary alluvium overlying shale soils in the Bankstown area, whereas others occur on the northern Woronora Plateau where residual shale caps lie above bands of ironstone laterite and sandstone bedrock. The combination of the parent material produces a soil of relatively low fertility compared to the deeper Wianamatta Shale soils of the Cumberland Plain.

Together with a relatively low mean annual rainfall (800-900 millimetres) these conditions produce an open eucalypt forest with an understorey that may vary between dense shrubs to a low sparse shrub cover with an abundant groundcover of grasses.

Typically the canopy includes broad-leaved ironbark (Eucalyptus fibrosa) along with a wide variety of other eucalypts depending on location. The taller paperbark Melaleuca decora may be prominent above a lower open shrub layer of blackthorn (Bursaria spinosa) and gorse bitter pea (Daviesia ulicifolia). The ground cover is a mix of grasses, sedges and herbs. This community can be difficult to distinguish from the closely related Castlereagh Ironbark Forest on the basis of floristic composition alone. Within the SMCMA, mean species diversity for this community tends to be lower although this may be influenced by disturbance.

Table A 6. Species recommended for revegetation in Castlereagh Shale-Gravel Transition Forest

CORE SPECIES	ADDITIONAL SPECIES
TREES & SHRUBS	
Acacia falcata	*Acacia decurrens*
Bursaria spinosa	*Amyema gaudichaudii*
Daviesia ulicifolia	*Eucalyptus crebra*

CORE SPECIES	ADDITIONAL SPECIES
Eucalyptus fibrosa	*Eucalyptus globoidea*
Eucalyptus moluccana	*Melaleuca nodosa*
Eucalyptus tereticornis	*Ozothamnus diosmifolius*
Lissanthe strigosa	*Pultenaea villosa*
Melaleuca decora	
VINES & GROUNDCOVERS	
Aristida vagans	*Austrostipa rudis*
Atriplex semibaccata	*Bossiaea prostrata*
Brunoniella australis	*Brunoniella pumilio*
Cheilanthes sieberi subsp. sieberi	*Dianella longifolia*
Dianella revoluta var. revolute	*Echinopogon caespitosus var. caespitosus*
Dichelachne micrantha	*Echinopogon ovatus*
Dichondra repens	*Einadia hastata*
Glycine clandestina	*Entolasia stricta*
Glycine tabacina	*Eragrostis leptostachya*
Hardenbergia violacea	*Goodenia hederacea subsp. hederacea*
Lomandra filiformis	*Imperata cylindrica*
Lomandra multiflora	*Lepidosperma laterale*
Opercularia diphylla	*Microlaena stipoides var. stipoides*
Panicum simile	*Pimelea linifolia*
Themeda australis	*Pomax umbellata*
	Pratia purpurascens

APPENDIX THREE:

Best Practice guidelines for the following works activities are described in detail in Appendix Four.

WORKS ACTIVITIES FOR BIODIVERSITY ENHANCEMENT

Table A 7. Works activities recommended for biodiversity enhancement, with works category, guidelines and comments

SPECIFIC WORKS REQUIRED	WORKS CATEGORY	GUIDELINES AND COMMENTS
Bush regeneration weed control	Preservation requirements	Applies to bushland areas where there is existing native canopy with some native understorey and some native groundcover. These areas usually require removal of weeds to improve their overall condition; planting should not be required.
Primary weed control	Restoration works	Applies to bushland areas where there are considerable weed impacts in the canopy, midstorey and groundlayers. A staged removal of weeds is recommended, generally starting with woody weeds and shrubs, then groundlayer weeds. NOTE: noxious weeds should be treated as the first priority. In many cases, supplementary planting will be required (see below). A primary weed control program must include secondary and subsequent (followup) weed control activities. Most weeds are not effectively controlled by one treatment. Target weed species and floristic groups that have been identified as key threatening processes (NSW Dept Environment & Heritage): • Invasion and establishment of exotic vines and scramblers • Invasion and establishment of Scotch Broom • Invasion, establishment and spread of Lantana • Invasion of native plant communities by exotic perennial grasses

SPECIFIC WORKS REQUIRED	WORKS CATEGORY	GUIDELINES AND COMMENTS
Primary weed control of vines	Restoration works	Applies to bushland areas where there is significant impacts from exotic vines. NOTE: Invasion of exotic vines and scramblers is listed as a key threatening process. Control of vines should be followed by a reassessment of the ecological condition of the bushland. Generally, further primary weed control will be required. Vines must be controlled before any planting is commenced, as young plants can quickly become smothered. Ongoing control of vines should be implemented.
Local provenance plant propagation	Preservation requirements Restoration works	Local provenance species should be used for replanting where possible. When estimating the number of species, allowance should be made for replacement planting and on-going maintenance. A list of flora species for revegetation in each of the identified vegetation communities is provided in Appendix C.
Planting guidelines	Restoration works Ongoing maintenance	Undertake weed control activities first. Soil must be properly prepared before planting. Dig a hole that is big enough to loosen the soil around where the plant will go. Use native plant food and water retention crystals in the hole. Water in well and mulch or use a weed suppression mat. See section #
Infill planting for diversity	Restoration works	Dense weed infestations can suppress local native plant diversity. In areas where there are dense infestations over a large area, with little good bushland nearby, there is limited opportunities for improving floristic diversity by natural regeneration. Consider which vegetation layers need supplementing, and whether this can be achieved by direct seeding. Choose species from the appropriate vegetation communities provided in Appendix C.
Planting for stabilisation	Restoration works	Removal of a dense weed infestation can create bare areas. The best way to stabilise these areas is to establish a good vegetation cover as quickly as possible using local native species. Consider a combination of brush matting and tubestock planting. Brush

SPECIFIC WORKS REQUIRED	WORKS CATEGORY	GUIDELINES AND COMMENTS
		matting with native plant material that includes fruiting or seeding structures is a method of direct seeding that also provides temporary cover for potential erosion points. Brush matting should be installed to a depth of 0.5m. Monitor for compaction, erosion and vandalism. Choose nearby bushland areas as a source for the brush, and never over-harvest. A maximum of 10% of the whole plant should be harvested at any time. Do not reharvest for brush matting from the same plant for 5 years. Choose species from the appropriate vegetation communities provided in Appendix C. Give priority to species that develop deep roots quickly, or provide good groundcover – a mixture of these is best.
Revegetation planting	Restoration works	Applies to areas that have little or no native species present. These areas are generally targeted to improve connectivity between adjoining areas of better bushland. See comments for stabilisation planting and infill planting for diversity (above). Consider a staged planting program (see riparian buffer expansion planting). Choose species from the appropriate vegetation communities provided in Appendix C.
Riparian buffer expansion planting	Restoration works	Applies to areas where there is potential to expand the existing riparian buffer. Generally this buffer is currently narrow, and provides limited benefits to the wetlands. Riparian buffer expansion planting involves the complete recreation of native bushland. A staged planting program will achieve the best results. Plant colonising species first, along with canopy species. Generally accepted density for revegetation with trees is one per 5m2. These can be evenly distributed or clumped together; however, clumping can provide protection against wind and storms during the first five years of growth. Colonising species such as acacias help to promote soil heath which improves the establishment of eucalypts and other tree species. Faster growing shrubs also provide some protection for saplings. Once these plants are well established, infill plant with additional shrubs and groundcover species to improve the diversity of the buffer area.

SPECIFIC WORKS REQUIRED	WORKS CATEGORY	GUIDELINES AND COMMENTS
Plant fringing vegetation	Restoration works	Applies to areas with multiple use demands to be managed. Protection of wetland areas is best managed through the establishment of a fringing buffer of native vegetation. This is the normal condition for these wetlands. Width of this fringing buffer is determined by the availability of land for planting around the wetland perimeter.
Monitor bank stability and install jute matting with stabilisation planting	Restoration works Ongoing maintenance	Applies to areas with very steep banks. Weed control activities can create bare areas. In steeper areas, brush matting and tubestock planting may not be enough. Additional stabilisation can be achieved by installing jute mesh or jute matting, and planting into this at regular intervals (minimum 4 plants per m2). Where minor erosion points are apparent, consider the use of brush check dams and/or coir logs to provide temporary stabilisation during plant establishment. For more serious erosion, further consultation is recommended; these may require hard engineered solutions.
Control/remove introduced ducks and geese	Restoration works	This may require some community liaison before implementation. A number of local residents feed the ducks and geese as part of their regular activities. Contact a pest bird control company for removal of pest waterbird species. Engage the community in ongoing monitoring to ensure they do not become re-established in the area.
Control carp populations	Restoration works	A carp control program should be developed. This can include considerable community input, and may provide an effective way of engaging and educating additional members of the community. See section # for details.

WORKS ACTIVITIES FOR WATER QUALITY IMPROVEMENT

Table A 8. Works activities recommended for water quality improvement, with works category, guidelines and comments

WORKS REQUIRED	WORKS CATEGORY	GUIDELINES AND COMMENTS
Install trash rack, use appropriate height to accommodate flood flows	Major capital works	This needs to be properly sized and installed. Preparation and implementation of an operations and maintenance plan is a major component of the success of this type of structure. See section # for examples.
Install end of pipe litter control device	Minor capital works	This needs to be properly sized and installed. Preparation and implementation of an operations and maintenance plan is a major component of the success of this type of structure. See section # for examples.
Install trash trap or similar litter control device	Minor capital works	This needs to be properly sized and installed. Preparation and implementation of an operations and maintenance plan is a major component of the success of this type of structure. See section # for examples.
Maintain mesh trash traps regularly; prepare and implement an Operations and Maintenance Plan	Ongoing maintenance Preservation requirements	Prepare an Operations and Maintenance Manual and schedule for all GPTs and other SQIDs in the Upper Duck River catchment, and ensure the recommendations are implemented
Remove litter and debris from fringing reeds; consider installation of floating trash trap	Preservation requirements Major capital works	Use of booms to control litter in Duck River has proved unsuccessful. Netting, dragging and hand collection of litter/storm debris around wetlands can be conducted by boat. This will provide an initial clean up of the area; however, this needs to be maintained
Remove sediment plug and other rubbish/storm debris	Ongoing maintenance	Must be conducted by suitably qualified and experienced earthworks operator – type of machinery should be determined during a preliminary site inspection
Water quality monitoring	Preservation requirements	Liaise with local primary and high schools to implement a Streamwatch monitoring

WORKS REQUIRED	WORKS CATEGORY	GUIDELINES AND COMMENTS
point	Ongoing maintenance	program at a number of points along the main channel of Duck River. This will help to identify what the main pollution loadings are, and where they are coming from. Results of these monitoring programs can then be used to inform a targeted water quality improvement program.

WORKS ACTIVITIES FOR EROSION CONTROL

Table A 9. Works activities recommended for erosion control, with works category, guidelines and comments

WORKS REQUIRED	WORKS CATEGORY	GUIDELINES AND COMMENTS
Toe protection works	Minor capital works or Major capital works	This needs to be properly sized and installed. See individual works plans for examples.
Bank stabilisation works	Major capital works	This needs to be properly sized and installed. See individual works plans for examples.
Outlet protection	Minor capital works or Major capital works	This needs to be properly sized and installed. See individual works plans for examples.

WORKS ACTIVITIES FOR COMMUNITY AND RECREATION

Table A 10. Works activities recommended for community involvement and recreation, with works category, guidelines and comments

WORKS REQUIRED	WORKS CATEGORY	GUIDELINES AND COMMENTS
Install seating	Minor capital works	Must comply with relevant design standards and guidelines for urban infrastructure
Install informative signage	Minor capital works	Must comply with relevant design standards and guidelines for urban infrastructure
Install weather shelters	Minor capital works	Must comply with relevant design standards and guidelines for urban infrastructure
Formalise existing path by constructing all weather crushed granite footpath for pedestrian access	Minor capital works	Must comply with relevant design standards and guidelines for urban infrastructure
Concrete footpath/cycleway to provide linkages with existing road and footpath network	Minor capital works or Major capital works	Must comply with relevant design standards and guidelines for urban infrastructure
Install pedestrian footbridge across river/wetlands	Major capital works	Must comply with relevant design standards and guidelines for urban infrastructure
Manage as grassed open space	Ongoing maintenance	Create a clear delineation between grassed open space zones and bushland management zones. Use timber edging or similar method. Prevent the spread of exotic grasses and other environmental weeds to adjoining bushland. Avoid use of fertilizers and herbicides that may affect bushland health or water quality in nearby waterways.

APPENDIX FOUR: ADDITIONAL INFORMATION FOR GUIDELINES

These revegetation guidelines are designed to specify the processes, techniques and standards required for effective restoration of landscapes for biodiversity conservation. The emphasis is deliberately on restoration. They are designed to assist people and organisations planning revegetation at the landscape-scale as part of an integrated program of protection and repair of existing native vegetation.

WEED CONTROL TECHNIQUES

Cut and paint

This is suitable for coppicing and suckering weeds such as Camphor and Privet, or any weeds which are too large for hand-pulling or have long taproots such as Ochna. This method provides for no soil disturbance and weed eradication is successful.

1. Cut the stem/s 1-2 cm above (a cut stump or stem protruding above the ground can be dangerous to work around and the seed's ability to re-shoot is reduced), ground level using either secateurs, loppers, a pruning saw or a chainsaw, depending on the thickness and toughness of the stem.
2. Immediately apply glyphosate™ (generally 1:1 or 1:1.5 or 100%) to the cut surface of the stem or, with medium and large trees, to the outside edges of the cut surface. (Herbicides need to be applied immediately after the cut is made because the ability of the plant to transport fluids ceases as soon as the tissues are severed.))
3. Search through the leaf litter to locate any exposed stem or root surface. Scrape the exposed stem or root surface slightly with a knife until you can see a light green coloured layer. (Do not scrape too deeply.) Apply the herbicide to the scraped sections, either with a brush, injector or spray bottle.
4. Follow up as required.

Stem injection – Drill & frill

Drilling

A rechargeable drill with a 5mm drill bit, is used to drill holes in the tree. The battery life of the drill will not last very long, so make sure you have charged them up properly. 100mm deep holes are drilled into the sapwood at a downward sloping angle, drilling 1 to 2 holes at a time, then immediately (within 10 seconds) filling the holes with a glyphosate mix dependent on tree type. The holes are drilled approx. 15cm apart in a circular pattern around each and every multi-branch.The holes are easily filled using a drench gun. These are available from the Rural Co-op and Farmcare for approx. $110.00, and are easy to use. The drill method is good in difficult to get to spots (eg. multi-stemmed tree).

Frilling

Use a small axe to cut into the sapwood at a downward angle. Three rows of cuts are made in a brick pattern around all multi-branches, low to the ground. 1 to 3 cuts are made before immediately filling the cuts with a glyphosate mix dependent on tree type. The cuts need to be filled slowly to avoid chemical spills. The axe is easy to use in readily accessible spots. Note: The cordless drill and the axe

could be used together. The axe for the easily accessible trunks and the drill for the hard to get at multi-stems. This way the battery lasts a lot longer.

Scrape and paint

This is a variation of the cut, scrape and paint technique described above, the difference being the plant is not cut but left intact and scraped. This technique is suitable for Madeira Vine, Kudzu, saplings of Camphor Laurel and Privet as it ensures the translocation of the herbicide throughout the entire plant.

1. Scrape several sections of the stem along one side only, in lengths of at least 30 cm. The stem needs to be scraped firmly, exposing the fibres and/or light green coloured layer. Be careful not to sever the stem completely.
2. Each scraped section is immediately painted, prior to scraping the next section, with the recommended diluted glyphosate for the particular weed.

Crown grasses and herbs

Crowning: This technique is useful for weeds such as grasses and asparagus fern, which have their growing points below the surface of the soil. (corms, rhizomes or tufted fibrous root systems).

1. Grasp the leaves or stems of the plant and hold them firmly so that the base of the plant is visible. Any weeds with sharp leaves or stems should be cut back first.
2. Insert a knife close to the base of the plant at an angle, with the tip well under the root system.
3. Cut through the roots close to the base of the plant. Make sure that the hard crown or base of the plant where the roots begin is completely removed. It may require several cuts.
4. Hang the crowned plant matter up off the ground.
5. Follow up on a regular basis.

Manual removal (hand pulling)

Hand pulling: This requires holding the plant stem as close as possible to the base of the plant. Gently tug the plant. This will loosen the soil and allow the plant to come free. The plant may be hung up off the ground or piled in a heap.

Winding up: This process is suitable for plants with surface or climbing runners such as Morning glory.

1. You need to locate a runner, gently pull it along the ground towards you. Roll the runners up for easy removal. Continue doing this until all the runners have been rolled up. Small fibrous roots growing from the runners can be cut with a knife.
2. You should locate the main root system whilst removing the runners. When you do, remove it manually.
3. Do not leave any bits of stem or large roots, as these may reshoot.
4. Bag or compost the runners/roots.
5. Follow up on a regular basis.

Spray

Foliar spraying is a complementary or alternative method to some hand removal techniques. It is used in large areas of weed infestations that have a small native component or small dense areas of weeds with no natives. There are three different spraying techniques.

Spot spray

Spot spraying: is useful in areas with native seedlings present. In circumstances where solitary natives are scattered throughout a weed infestation, the individual trees may be covered or marked with a piece of bright coloured flagging tape. An area of about 10- 50 cm around the base of each native or clump of natives should be hand weeded. Spray units with adjustable nozzles should be set to produce a fine spray, at low to medium pressure. The weed clumps are sprayed with appropriate herbicide at the recommended strength plus a tracer dye. If a native is inadvertently sprayed, remove the affected leaves or immediately rinse off the herbicide with water.

Blanket or Area spray

Selective blanket spraying is used in areas with few or no native seedlings, where weeds have either formed a dense bed or have a large leaf size. Herbicides and concentration varies depending on the weed species, it is a good idea to use a Tracer dye so you can see where you have sprayed. Make sure you thoroughly check the area for natives prior to spraying. Any weeds close to natives should be removed by hand before starting to spray. Alternatively, young natives can be covered with cardboard prior to spraying. Spray units with adjustable nozzles should be set to produce a fine spray, at low to medium pressure

Splatter guns

The splatter gun (or gas gun) control technique involves the low volume, high concentration application of herbicide to the foliage of lantana, bitou bush and similar weeds using a specialised spray device.

This technique is particularly useful in areas of difficult access or sensitive vegetation because the tool is easily portable and causes limited off target damage. Like all management techniques, the splatter gun has limitations, but in general it provides a cheap and efficient method of managing dense infestations in places that are difficult to access, and that can be used as part of an integrated management program.

Herbicide use and requirements

Safety Gear

When using herbicides, it is essential to equip yourself with appropriate safety clothing.

Key items are rubber gloves, overalls, shoes or boots, eye goggles and a hat. An agricultural respirator is required for moderately and highly toxic herbicides. Avoid any parts of your skin being in contact with any herbicide. Immediately wash any parts of your body which come into contact with any herbicide, particularly your hands before eating.

Training, Certification

Weed control should be undertaken by appropriately qualified and experienced professional bush regenerators, or by volunteers under the direct supervision of a appropriately qualified and

experienced professional bush regenerator. Selecting the appropriate technique can be a matter of experience, both with local conditions, and the weed species being targeted.

Labels, Permits, MSDS

When using herbicides it is essential that you read the label on the container and follow the manufacturers' instructions. The label describes how the herbicide should be used (method and concentration, plus additives) for best results to control particular weeds. The permit describes the conditions under which the herbicide can be used in NSW. The MSDS describes a range of information about the chemical constituents in the herbicide, the most important of which is the safety measures required for use and first aid/medical treatment required following exposure.

Herbicides and additives

Glyphosate

Glyphosate is a systemic chemical which is inactivated upon contact with the soil. Roundup Bioactive™ and Weedmanster 360™ are products with improved surfactants, making them safer to use near waterways. Do not use Glyphosate within 6 hours of rainfall and where there is likelihood of rain within 24 hours.

LI 700®

LI 700® is a penetrant , which facilitates the transfer of the herbicide through the surface tissue and is often used for plants with waxy leaves, such as Madeira Vine and Wandering Jew. (Oils are also used for this purpose.) Manufacturer's instructions should be followed when using any penetrant.

This will help the chemical stick to the leaves, is rain-fast within minutes and helps spread the chemical evenly over the plant.

Tracer Dyes

Tracer Dyes are used with herbicides to improve efficiency and safety. The tracer allows areas/plants that have been treated to be identified. The tracer alerts anyone entering the treated area that a herbicide has been used for a short period of time. It also helps to ensure that the target plants are treated and non-target plants avoided.

Commonly used tracer is a red fluorescent dye such as Spraymate Marker Dye®. Manufacturer's instructions should be followed.

Metsulphuron Methyl

Metsulfuron is a non-residual herbicide, which is the active ingredient in Brushkiller® and Brushoff®.

Weed control – alternative methods

Repeated sprays with a knockdown herbicide (such as glyphosate) are effective in that they exhaust the soil weed seedbank, resulting in less weeds germinating after the planting. Residual herbicides prevent the weed seeds in the soil from germinating until the effect of the herbicide diminishes over time. Care should be used in the selection of herbicides: consider factors such as the development of herbicide resistance, residue in the soil, impacts on native plants and waterways. Alternatives to herbicides should always be considered.

Scalping (removing some of the surface soil) removes the majority of weed seeds and is very effective in a range of soils, although it may expose subsoils that are prone to cracking as they dry. Non-chemical methods include mulching with newspaper, straw, sawdust or similar; flaming; repeated cultivation and hand-chipping. Mowing reduces the vigour of the competing plants but is not as effective as complete removal. Many direct seeding machines have a built in scalping blade or disc to do weed control in a single pass. Most sites will still benefit from two-years of weed control prior to direct seeding.

Great care should be taken before exposing highly-erodible soils. Weed control should be in strips approximately one metre wide with a grassy strip retained between rows, or in spots one metre in diameter around each planting location.

Weed control and assessment

Weed control is usually the single most important factor in the success or failure of tree plantings. It is just as critical after planting as before and should be continued for at least one full growing season after planting and preferably for 2 years. A weed-free area of 1m diameter should be maintained around each plant for this period.

Weeds should be controlled when they are actively growing, before they set seed and before they begin to compete with your newly established plants. Different weeds will germinate at different times of the year so you will need to monitor your site regularly. Look at your site each month after planting and schedule weed control when you see actively growing weeds. It is much easier to control weeds before they get too big and before they set seed. If you have an annual program of revegetation planned, it pays to keep records of which weeds occur and when they emerge, as well as effective techniques for their control.

The Florabank website can help to identify weeds. It contains an interactive tool which enables you to select your area and look through a list of weed species known to occur in a particular region, with pictures and information about them. The Weeds CRC produced a range of weed management guidelines that may be helpful to tackle specific problem weed species. Another useful publication is 'Stop Bushland Weeds' by Meg Robertson. This publication also contains a table which shows the most effective times of year to control particular weeds.

Non-chemical methods such as hand weeding, mowing or mulching can also be used. For example, or weedy grass species, mowing when the exotic grasses flower, but before the native grasses do, gives the native grasses an advantage. If repeated over successive years, this method has been shown to increase the cover of native grasses and reduce the area of exotic grasses.

PLANTING

Local Provenance

It is generally accepted that for revegetation for conservation purposes, it is best to choose species that occur locally. Such species are well adapted to the environmental conditions of the site, and their pollinators, predators, symbionts and dependent wildlife are present. There are likely to be sources of seed available locally. Local provenance is principally about getting material that is adapted to local conditions, but also arises out of concerns about genetic pollution.

Florabank now recommends that provenance be considered in the following manner when collecting seed for revegetation:

Get the taxonomy right first

- Make sure you are dealing with the same species/subsp/variety or cultivar

Get the physical and genetic quality right

- Collect from 20-100 plants.
- Collect from plants at least 3 plant-heights apart

Only collect from large populations or pool multiple collections from smaller populations

Store seed under best conditions from collection right through to use

Match the site conditions

- Soil (texture and origin)
- Altitude
- Aspect
- Slope position
- Latitude (use bioregions as the boundary)

Then worry about proximity between collection and revegetation sites. Having said that, where possible, all revegetation works are to be conducted in accordance with current best practices. These include:

1) Collection of seed

a) Must be by appropriately qualified and licenced personnel
b) Must be local provenance seed stock (refer Florabank Guideline No.10)
c) Must be collected in a manner that maximises genetic quality of seeds (refer Florabank Guideline No.5)
d) No more than 20% of the fruit or 10% of plant material should be removed from one plant

2) Determining local provenance

a) Environmental conditions at the collection site should match the existing or desired environmental conditions at the proposed planting site
b) Consider the method is pollination and seed dispersal for the species concerned before deciding on local provenance boundaries (Figure 24).
c) While it is best to collect seed as locally as possible, care must be taken to maximise the genetic diversity of available seed stock to avoid problems associated with inbreeding

Collection Range					
Factors	**Narrow**		**Intermediate**		**Regional**
Pollination	self-pollinated	wind-pollinated	insect-pollinated	bird-pollinated	bat-pollinated
Seed dispersal	gravity			wind or water	bats and birds
Longevity	short-lived				long-lived
Extent	small number and small area				large number and large area
Density	low		medium		high
Fragmentation	low		medium		high

Figure 30. Collection ranges for determining local provenance areas (adapted from Florabank Guideline No.10).

3) Storage of seed

a) Seed must be stored appropriately (refer Florabank Guideline No.1)
b) Seed should be tested for viability before storage (refer Florabank Guideline No.8)

4) Propagation of plants

a) Plants should be propagated so that seedlings will be large enough to transplant onto site
b) Care should be taken that unexpected delays in construction do not cause seedlings to become root-bound
c) Propagation should be conducted in accordance with current best practices

5) References for plant propagation information:

- Wrigley, J.W. & Fagg, M. (1993) 'Bottlebrushes, paperbarks & tea trees: and all other
- plants in the Leptospermum alliance'. Angus & Robertson, Sydney. 352 pp.
- Wrigley, J.W. & Fagg, M. (1996) 'Australian native plants: propagation, cultivation &
- use in landscaping'. 4th ed. Reed. 696 pp
- Ralph, M. (1994) 'Germination of local native plant seed: for revegetation, tree
- planting & direct seeding projects'. Murray Ralph, Fitzroy, Vic. 42 pp.
- Ralph, M. (1997) 'Growing Australian native plants from seed'. Murray Ralph, Fitzroy,
- Vic. 156 pp.
- Ralph, M. (1994) 'Seed collection of Australian native plants for revegetation, tree
- planting and direct seeding'. Murray Ralph, Fitzroy, Vic. 121 pp.

Revegetation techniques

There are three techniques that are commonly used for revegetation: tubestock planting, direct seeding and natural or assisted regeneration.

DIRECT SEEDING	TUBESTOCK PLANTING	NATURAL REGENERATION
(+) Lower establishment costs	(+) More reliable	(+)Plants are well-adapted to the site
(+) Natural look and more diversely structured	(+) Uniform	(+)Establishes healthiest plants
(+) Establishes healthier plants	(+) Revegetation is visible to passers by	(-)May have to wait for a long time for results
(-) Long establishment times may lead to more maintenance such as weed control.	(-) Often results in unnatural looking rows	(-)Needs an adjacent or nearby seed source
(-) Ants have been known to take seed	(-) Higher establishment costs	(+)Lowest establishment costs
(-) Uses lots of seed	(+) Uses small quantities of seed	(-) Long establishment times may lead to more maintenance such as weed control.

Natural Regeneration

Natural regeneration is the term used to describe the growth of plants from seed naturally distributed to the site. Natural regeneration relies on existing seed sources, such as soil or canopy stored seed, or seed transported to the site by water, wind or animals in the area to be revegetated. This method of re-establishing vegetation is especially worthwhile for individuals and groups with limited resources. Natural regeneration is a good first choice, because native plants that grow from this method are likely to be well adapted to the site. If there is a good source of seed, natural regeneration can result in high species diversity, representing the original range of plant species.

Although the process of regeneration itself is 'passive', natural regeneration still usually requires facilitation and management. The areas to be revegetated are usually fenced to exclude stock and allowed to regenerate naturally. Some form of pre-treatment, such as a burn or herbicide treatment, may be applied to the site. If the regeneration fails or is poor, direct seeding or planting seedlings can be considered. As with other methods, implementation of a long-term weed management strategy is important.

Direct Seeding

Direct seeding involves sowing seed directly into prepared ground. Direct seeding generally is more efficient in terms of time, cost and labour, compared to tubestock planting. It also allows for a more diverse seed mix, leading to greater plant diversity. The main limitation with direct seeding is usually the availability of seed. Establishment of plants from direct seeding can be patchy and can take

several years, especially for hard-seeded species, but the plants that do establish are often robust and have developed a good root system. There are two main methods of direct seeding:

Hand Sowing: this method is useful for small areas or in inaccessible country. Handfuls of seed mixed with a bulking agent are thrown onto the prepared seed bed. Another method of hand-seeding uses cut stems of a plant with ripe fruit present, laid across a prepared site.

Mechanical direct seeding: this method involves the use of specialised direct seeding equipment, which is calibrated for different seed sizes and planting depths. Large areas can be seeded quickly using this method - up to 50 hectares in one day using one direct seeder.

As with other revegetation methods, ground preparation and weed control is critical. Because germinating seeds must compete with weed seeds that may be in the soil, a weed control program ideally should begin two years before direct seeding. The top layer of soil can also be scalped to remove weed seeds. Control of seed and shoot predators such as ants and red-legged earth mites is also important.

Tubestock Planting

'Tubestock' is the term for seedlings that have been raised in small nursery tubes, for transport to the planting site. Propagation of seedlings can be by seed, by cuttings, or through division. Seedlings can be planted by hand or with a mechanical seedling planter at the prepared site. As with direct seeding, site preparation is essential and will involve weed control and fencing.

Even though tubestock planting is more expensive and requires more labour than direct seeding and natural regeneration, it is a widely used method of revegetation. Results are reliable and immediate, and plant placement is controllable. Because of the labour-intensive nature of tubestock planting (both in propagation and planting), fewer species tend to be planted than with direct seeding.

General planting notes

Plants

Large healthy root systems, with no evidence of root curl, restriction or damage. Plants should be vigorous, well established, and free from disease and pests, of good form consistent with the species or variety. Before planting, plants should be hardened off, not soft or forced, and suitable for planting in the natural climatic conditions prevailing at the site.

General considerations

Replace damaged or failed plants with plants of the same type and size. Supply plants in weed-free containers of the required size. Label at least one plant of each species or variety in a batch with a durable, readable tag.

Deliver plant material to the site on a day to day basis, and plant immediately after delivery. Give notice of proposed changes to plant locations and spacing, for example, to avoid service lines, or to cover the area uniformly. Do not plant in unsuitable weather conditions such as extreme heat, cold, wind or rain. In other than sandy soils, suspend excavation when the soil is wet, or during frost periods.

Placement

Wherever possible, different species should be placed adjacent to each other. Trees and shrubs are to be planted to maximise the diversity of the upper canopy as much as possible.

Remove the plant from the container with minimum disturbance to the root ball, ensure that the root ball is moist and place it in its final position, in the centre of the hole and plumb, and with the top soil level of the plant root ball level with the finished surface of the surrounding soil.

Fertilising and water crystals

Slow release fertiliser pellets should be placed into the plant hole immediately before planting. Install water crystals with the fertiliser according to the manufacturer's recommendations. Best results are obtained if water crystals are soaked in water first.

Backfilling

Backfill holes after planting using topsoil. Lightly tamp down and water to eliminate air pockets. Ensure that topsoil is not placed over the rootball so that the plant stem remains the same height in the ground as it was in the container.

MANAGING THE SPREAD OF PHYTOPHTHORA

Phytophthora cinnamomi

Phytophthora cinnamomi is not visible to the naked eye. Under a microscope, its main body, the mycelium, looks like white hair-like threads. Sporangia (spore sacs) are produced on the mycelium in moist and aerobic conditions and at temperatures of 22-28ºC. In each sporangium 30-40 zoospores are formed and released. Zoospores are motile by way of two flagella, which enables Phytopthora to infect new and healthy root tips. Zoospores survive up to four days. When conditions for growth become less favourable, generally when the soil dries out, mycelium may form another type of spore, known as a chlamydospore. This resting spore has a thick cell wall and is able to survive in the soil or host tissue for many years, waiting for growth conditions to become suitable again. The mycelium can also survive on plant debris on or in the soil.

The most critical interaction in disease development is the simultaneous presence of Phytopthora zoospores and susceptible host plants. A range of factors determines the severity of the disease and its rate of spread. These include temperature, rainfall, soil type and characteristics, and microbial soil populations. Phytopthora is generally found in areas where:

- average annual rainfall is greater than 500 mm (20 inches)
- soils are acid to neutral with low amounts of nutrients and organic matter
- have few micro-organisms
- have poor drainage

Hot bushfires may destroy Phytopthora to a depth of 15 cm below the soil surface. However, the fire also lowers surface soil organic matter and microbial populations, making it more favourable for its growth.

Symptoms of disease

The roots and stems of plants affected by Phytophthora decay with root-rot and then disintegrate, destroying their ability to extract water and nutrients. An infected plant is then subject to water stress which is also known as 'internal drought'. The first visual symptoms of infection are generally shown as yellowing of the foliage (chlorosis) followed by dieback of the entire plant. Depending on local site and environmental conditions, this can occur in a matter of weeks for small shrubs or even several years for large shrubs or trees.

Symptoms vary between different plant species. Xanthorrhoea species for example, die rapidly and may collapse. Acacia species may die quickly but symptoms can be masked by other dieback causes such as general drought conditions. Leaves of Banksia species and Eucalyptus species show slower signs of dieback on their branch tips but may temporarily re-shoot. The Fabaceae, Acacia, Leptospermum and some Epacridaceae become yellow and die back in warm moist periods during spring and autumn. They may recover and form new growth during dry periods in summer or cold periods in midwinter. The cycle continues with dieback occurring again in spring and autumn.

Dieback may also be caused by factors other than Phytophthora. These may include chemicals, old age, fire, mechanical damage, insects, and environmental factors including drought, waterlogging, salt, frost and hail.

How the disease is spread

The single most important cause in the spread of Phytophthora appears to be through the transport of infested gravel, soil and plant material, which adheres to vehicles and heavy machinery. Such machinery is usually used in logging, firefighting, road construction and maintenance of roads and powerlines. A vehicle not cleaned after working in an infested area could easily spread the disease to another site many kilometres away. Phytopthora can also be spread in the following ways:

- through transport of soil and plant material adhering to bicycles, footwear, tools and camping equipment
- through water (as drain off, irrigation or moving ground water). Phytopthora will spread quickly downhill in surface and sub-surface water flows. If found along a watercourse, then surface water will most likely carry Phytopthora downstream into the catchment
- by transfer of infested gravel, soil, water or any other raw material
- from plant to plant through natural sub-surface root contact. The spread uphill and on flat ground is slower (approximately 1 metre per year) as it is confined to root contact from plant to plant
- by transferring infested plants to other sites
- by animals, particularly those with cloven hooves

Prevention of spread: Maintenance of vehicles and machinery

To prevent the spread of Phytopthora vehicles and machinery should be kept hygienically clean of soils which may be infected. A visual inspection should confirm that vehicles and machinery are free of clods of soil, slurry (water and soil mixture) and plant material. The cleaning procedure consists of two steps:

1. Dry brushing

- Remove all soil and plant material with a hard brush or tool. Pay particular attention to wheels, mudflaps and undercarriage.

2. Disinfection

- Disinfect vehicles (wheels, mudflaps and undercarriage in particular) and machinery with water containing a disinfectant until any remaining soil and mud is saturated.
- Allow disinfectant to penetrate for 10 minutes.
- Avoid recontaminating vehicles and machinery! The following disinfectants can be used:

A fungicide, such as Phytoclean®. Dilute 1 part in 50 parts water. Sodium hypochlorite (pool chlorine). Dilute 1 part in 1500 parts water.

Points to remember:

- Clean down on a hard, well-drained surface (such as an unsealed road) in high risk areas.
- Do not wash down with water only, as this will create a more suitable environment for infestation. Always use a disinfectant!
- Phytoclean® is preferred above sodium hypochlorite as it is a more effective disinfectant, as well as being biodegradable and noncorrosive.
- The use of a pressurised spray unit is preferred, as this will minimise the amount of water used.
- Do not drive through wash-down effluent.
- Do not allow mud and wash-down effluent to drain into bushland and surface waters such as rivers, creeks, reservoirs and dams.

Cleaning Footwear and Hand Tools

The fundamental hygiene principle to minimise the spread of Phytopthora is to keep footwear and hand tools hygienically clean and therefore free of Phytopthora. A hygiene kit should contain:

- hard brush
- bottle of disinfectant, such as methylated spirit (undiluted) or household bleach (dilute 1 part in 4 parts water)
- spray bottle

The cleaning procedure consists of two steps:

1. Dry brushing

Remove all soil and plant material from footwear and tools with the hard brush.

2. Disinfection

- Disinfect the entire sole of your footwear and tools using the spray bottle containing the disinfectant
- Allow the sole of the boot to dry for at least one minute
- Step forward to avoid recontamination of footwear
- Disinfect the hard brush!

Points to remember:

- Clean down on a hard, well-drained surface (such as an unsealed road) in high risk areas.
- Do not wash down with water only, as this will create a more suitable environment for infestation. Always use a disinfectant!
- Hand tools can also be disinfected by soaking for a few minutes in the bleach solution, then rinsing with distilled water and wiping dry with a clean paper towel. Clean down on a hard, well-drained surface.

Safety, Health and Welfare

Wear Personal Protective Equipment when handling or using disinfectants, wear, including gloves and safety goggles. All disinfectants are toxic to water organisms and extreme care must be taken in the use and disposal of undiluted, diluted and exhausted solutions.

Remember to:

- re-use containers where possible. Undiluted disinfectants and used containers must be disposed of in an approved refuse disposal site. Triple rinse and crush used containers before dispersal.
- dilute exhausted and diluted solutions an extra five times and spread over the ground a minimum of 50 metres away from surface waters. They may also be inactivated in a pit by addition of organic matter, such as sawdust, absorbing clay or paper.

CONTROL PROGRAMS FOR CARP

Carp are considered a pest species because it degrades the water quality of the ponds and limits the opportunity for native fish populations to become established. It is a prolific breeder and reduces the survival chances for native fish. Carp feed from the bottom of the pond, sucking in substrate (or material at the bottom of the pond) and water in search for aquatic organisms. This decreases water quality by increasing turbidity, consequently preventing light penetration into the water. Less light penetration affects plant growth, which is a valuable food source for native fish, and contributes to erosion of the banks of the ponds.

Although there is wide agreement that carp numbers should be reduced, control efforts are being hampered by a lack of information. Nonetheless, there are several options for reducing carp, and each has its benefits, disadvantages and costs.

Effective control of carp will require the application of a combination of techniques which include:

- **Environmental Rehabilitation** - This includes taking actions that will increase the numbers of native fish, such as creating fishways, and revegetating river banks, re-snagging rivers and looking at ways to release warmer water from dams. These are viewed as a necessary part of river management, but their direct effects on carp are unknown.
- **Physical Removal** - Catching large number of carp is already under way on a small scale and more licences are being issued. To be effective, at least 98% of carp must be removed, which may be very expensive, or impossible to achieve. Methods include netting and electrofishing.
- **Reduce Carp Reproduction** - This strategy involves reducing the numbers of carp eggs that have been laid in shallow habitats such as billabongs and wetlands where most spawning

activity occurs. This technique involves lowering the level of water by 45-60 cm to expose and dry out the carp eggs. The technique is being researched and could work well in wetland and billabong habitats.

- **Chemical Poisoning**: - While this is possibly an effective method, poisoning is very expensive and may only work in small or closed bodies of water. In addition, chemical poisoning would not be acceptable for the general environment, and would only be able to be used in habitats such as irrigation channels where the water quality is poor and the environment is no good.
- **Biological Techniques** - These include pathogens (usually viruses), immuno-contraception (interfering with reproduction) and interfering with the genetic make-up of the carp. None of these techniques are currently being used, but they are currently the subject of research and management studies.

Of the above control measures, the most suitable one for Upper Duck River Wetlands and Riparian Corridor is physical removal. The Centennial Park and Moore Park Trust (Trust) has an ongoing Carp eradication program aimed at eliminating carp from the Parklands' pond system, and to encourage native fish stocks to develop. This program has resulted in the removal of over 10 tonnes of carp from the pond system since 1998 – the largest fish weighing a record 24 kilograms.

Several activities under this program include:

- Electro-fishing program: a licensed procedure that stuns the fish which are then netted and removed from the ponds. The fish that are removed from the ponds are processed to make an organic liquid fertiliser.
- Line fishing: a dedicated volunteer-led program to selectively remove carp from the ponds using traditional fishing methods. Following removal from the ponds, the fish are then euthanased and used as bait for commercial fishing.
- Australian bass release: a system of gradually introducing Australian bass (Macquaria novemaculeata) - a native fish species - into the pond ecosystem to reduce carp numbers. 15,000 Australian Bass have been released into the Parklands ponds since 2005.

Key conditions of the Centennial Parklands' carp management program:

- Only the use of manufactured and purpose made barbless hooks is permitted. Barbless hooks are used to prevent any unnecessary suffering to Carp and will readily fall out if on the rare occasion a non-target species is hooked. Volunteers are supplied with approved hooks. No stainless steel hooks permitted.
- Fishing is only allowed in the designated area and at no time trampling of vegetation is allowed. One rod per person and rod is always to be held – no rod is to be left unattended nor is a rod holder permitted.
- Induction of all participants is provided as a prerequisite to participation. This induction prioritises the importance of protecting any non carp species from any action which might result in injury.
- A Fishing Coordinator has been recruited from the Australian National Sports Fishing Association a recognised leading industry body, to supervise all fishing activity undertaken in the Parklands to ensure effective quality control of the program.

- All volunteers are required to meet OHS requirements and are fully inducted on these requirements prior to participation.

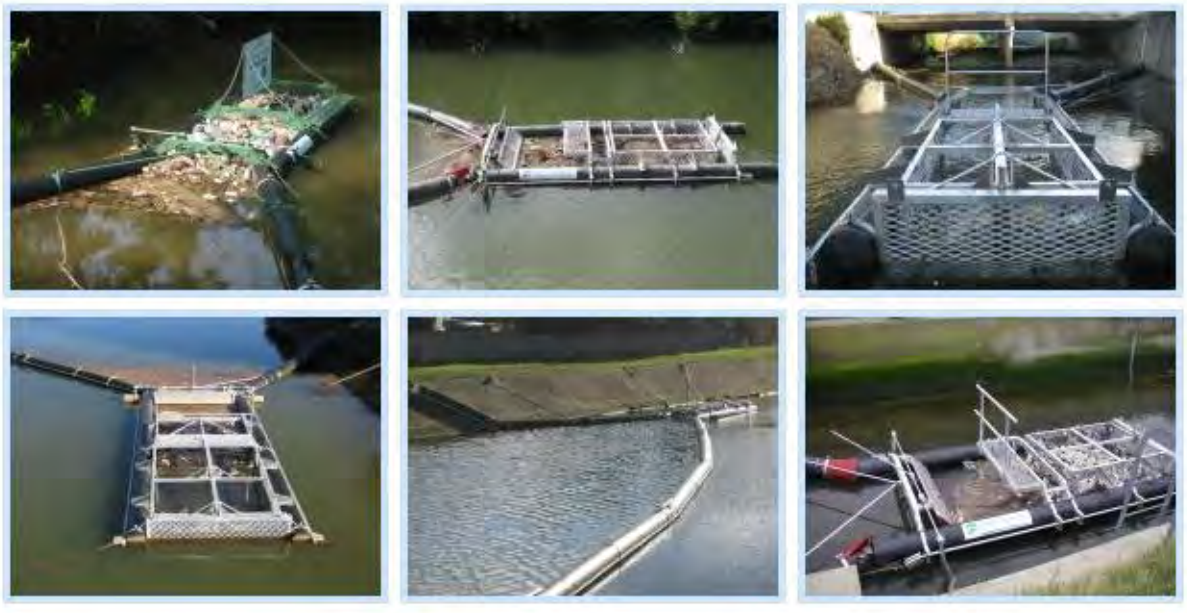
EXAMPLES OF LITTER CONTROL DEVICES

Trash rack

End of pipe control device

Trash trap

Floating trash trap

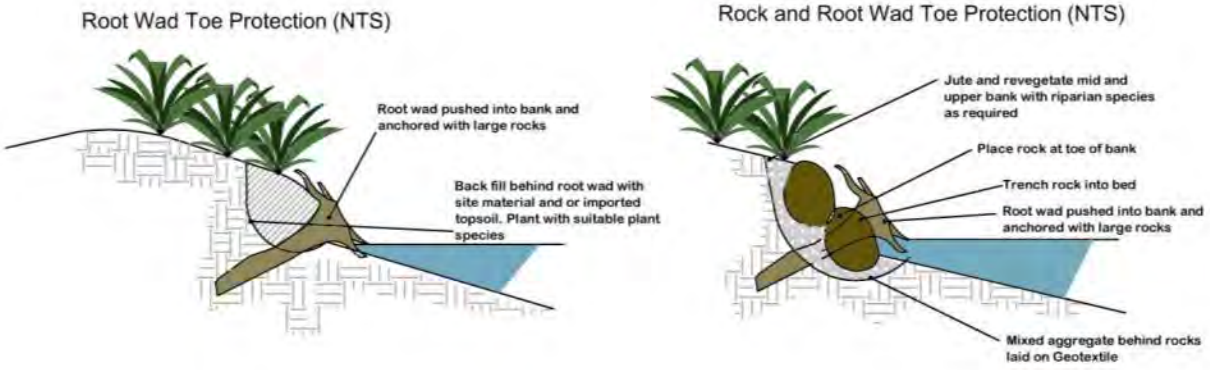


http://www.bandalong.com.au/products-and-services/bandalong-litter-trap/

http://wsud.melbournewater.com.au/content/treatment_measures/litter_traps/litter_trap_types.asp#floatingdebris

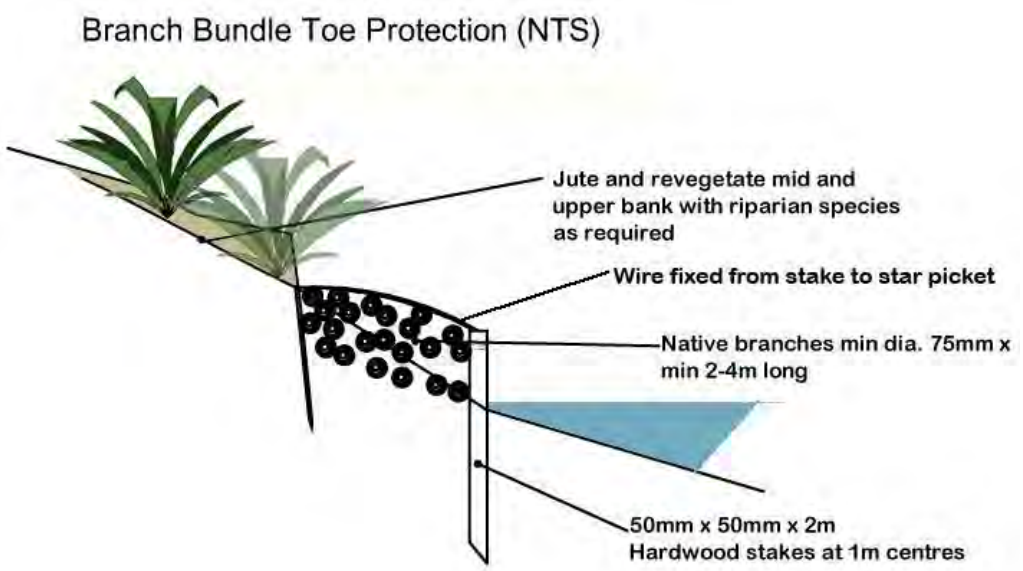
EXAMPLES OF EROSION CONTROL WORKS

Toe protection using root wads



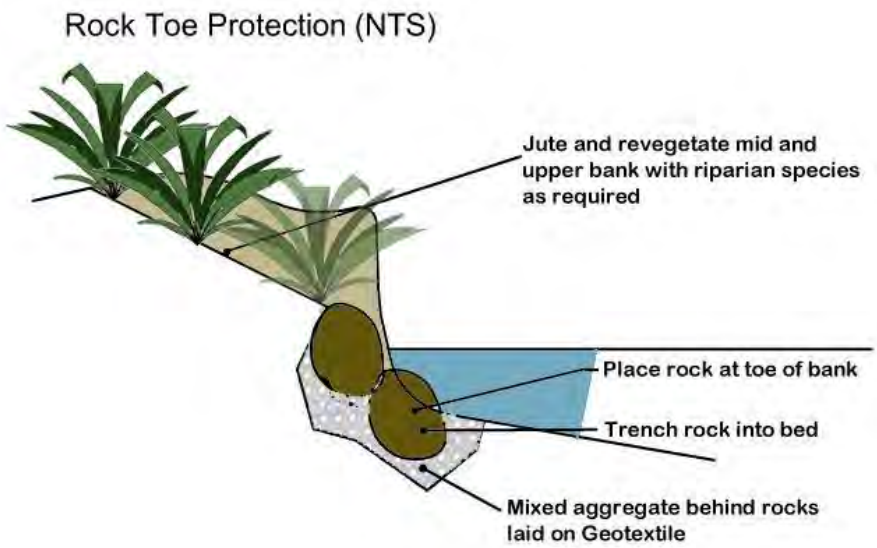
(Source: Sutherland Shire Waterways Prioritised Rehabilitation Plan, Applied Ecology 2012)

Branch bundle toe protection



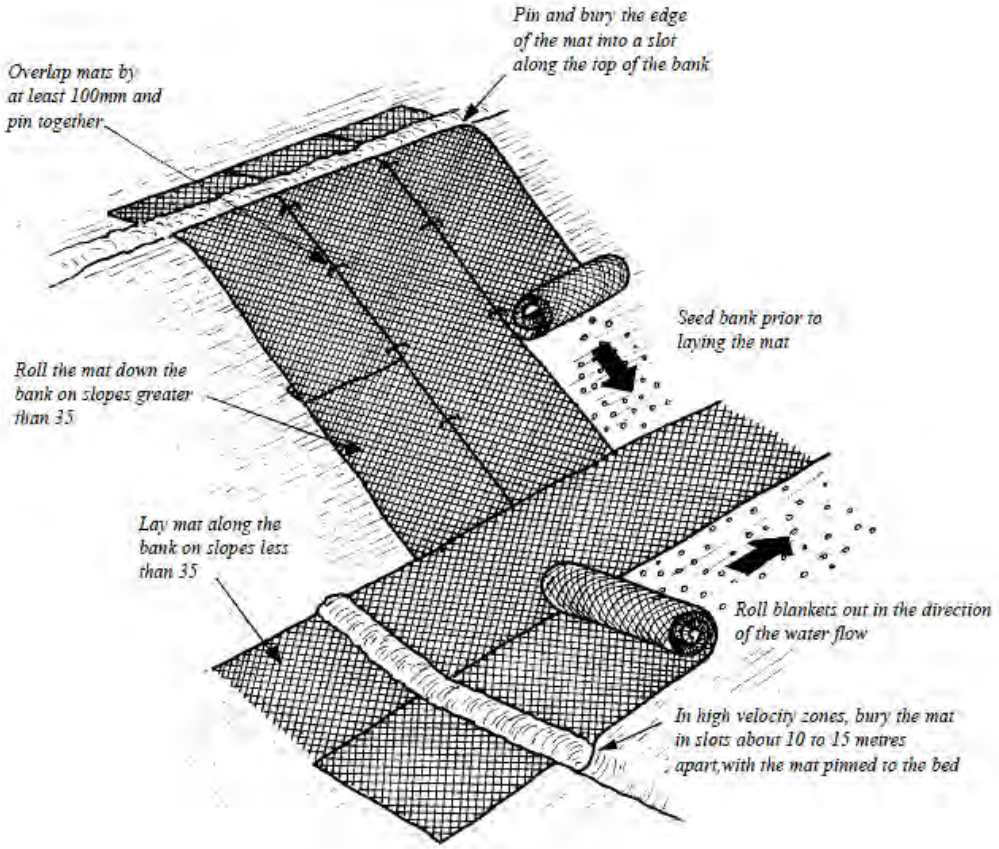
(Source: Sutherland Shire Waterways Prioritised Rehabilitation Plan, Applied Ecology 2012)

Rock toe protection

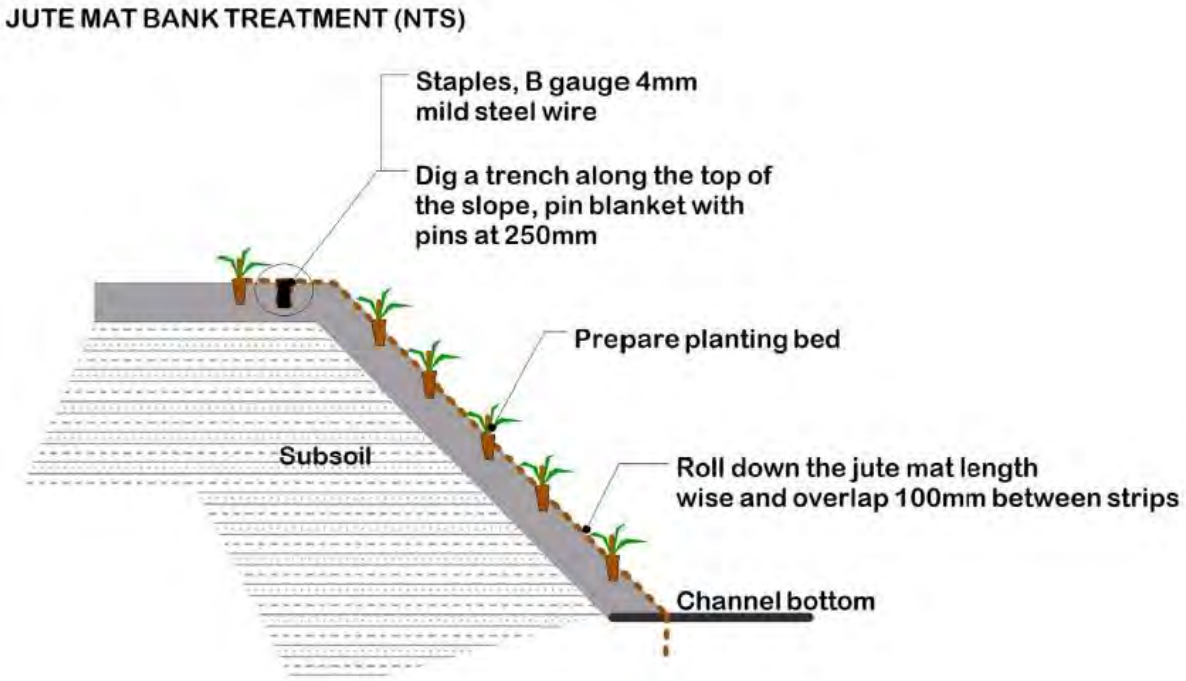


(Source: Sutherland Shire Waterways Prioritised Rehabilitation Plan, Applied Ecology 2012)

Jute matting bank stabilisation treatment

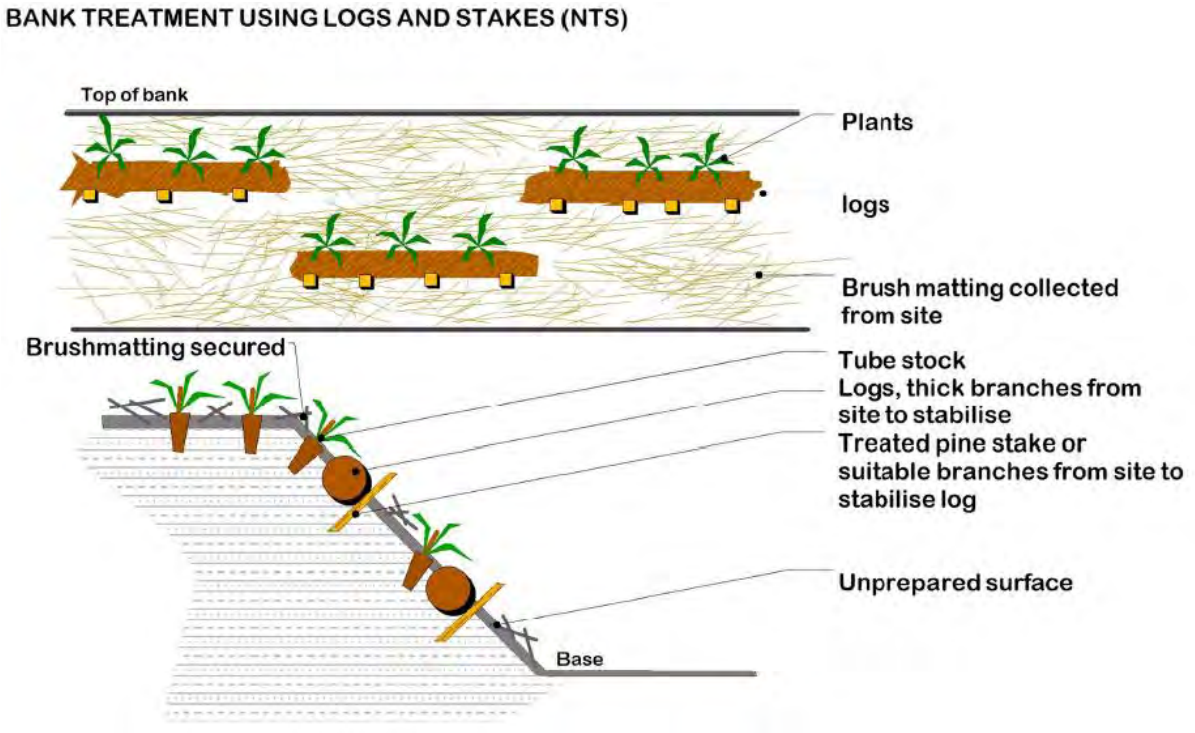


Jute matting bank stabilisation with planting



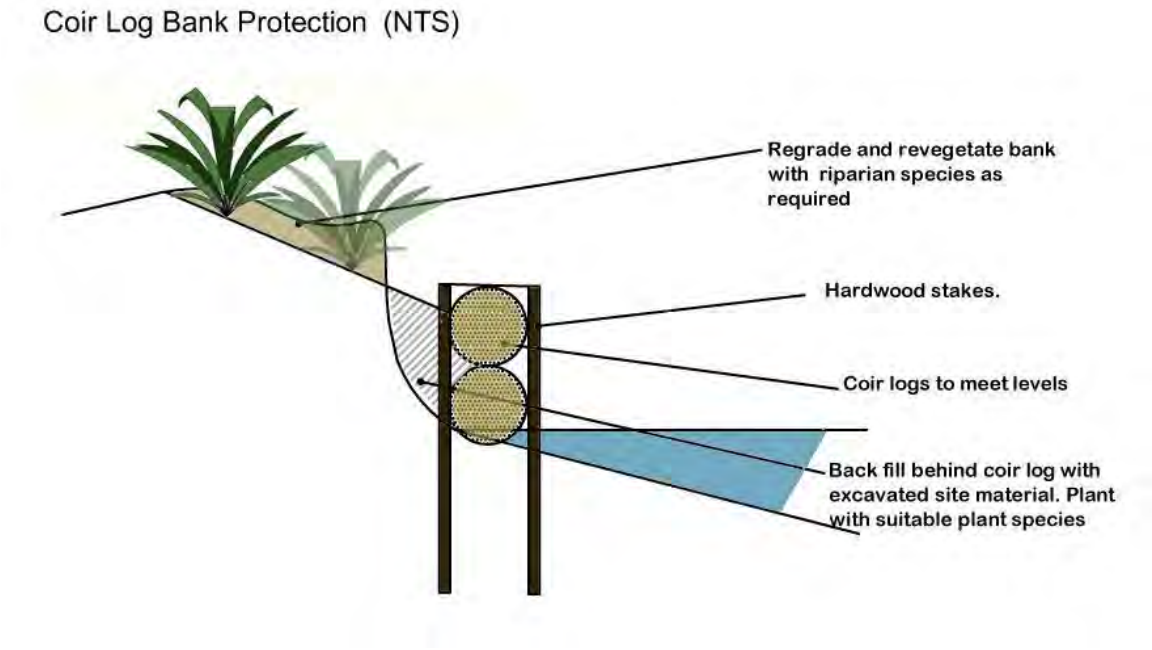
(Source: Sutherland Shire Waterways Prioritised Rehabilitation Plan, Applied Ecology 2012)

Bank stabilisation using brush matting with logs and stakes



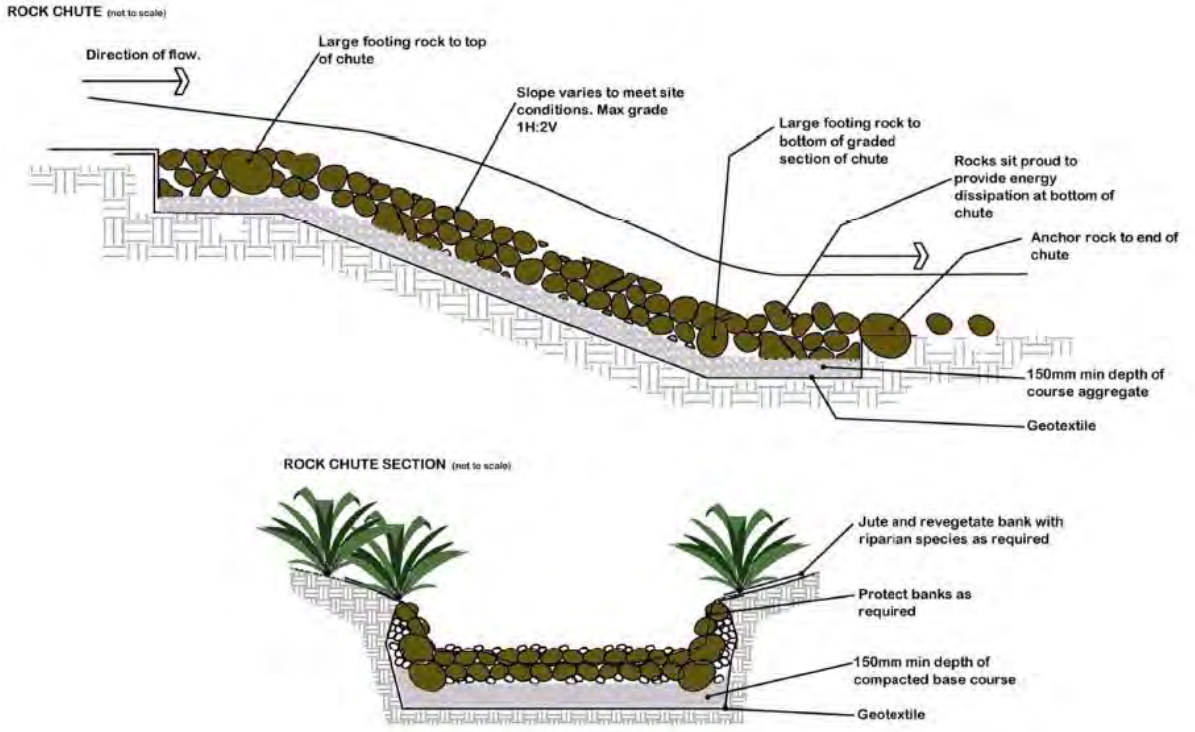
(Source: Sutherland Shire Waterways Prioritised Rehabilitation Plan, Applied Ecology 2012)

Coir log bank protection



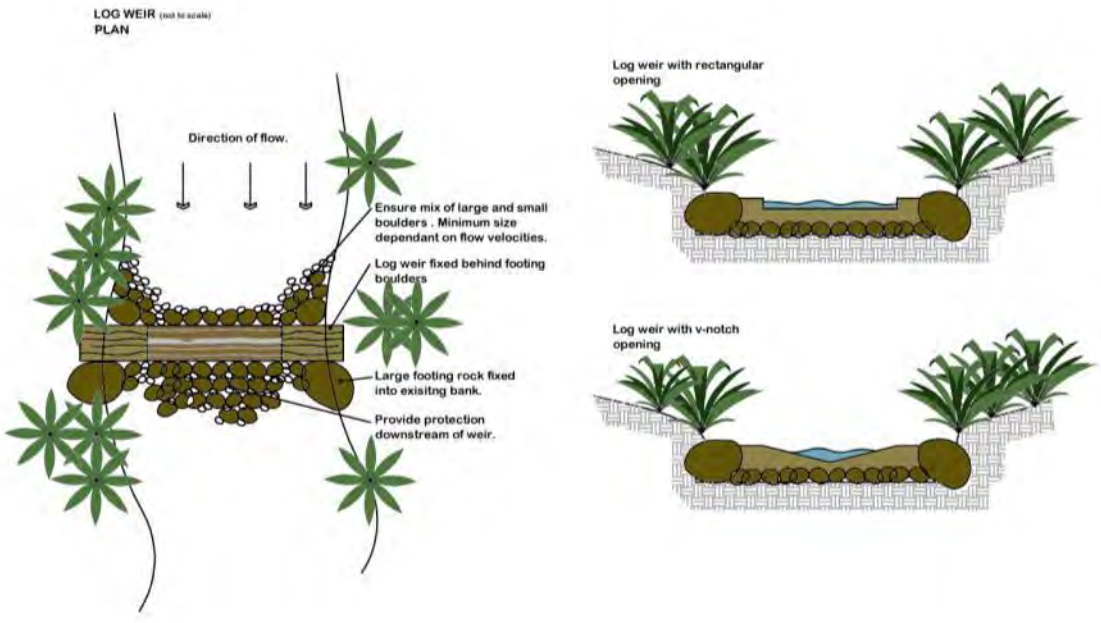
(Source: Sutherland Shire Waterways Prioritised Rehabilitation Plan, Applied Ecology 2012)

Rock chutes for channel bed stabilisation



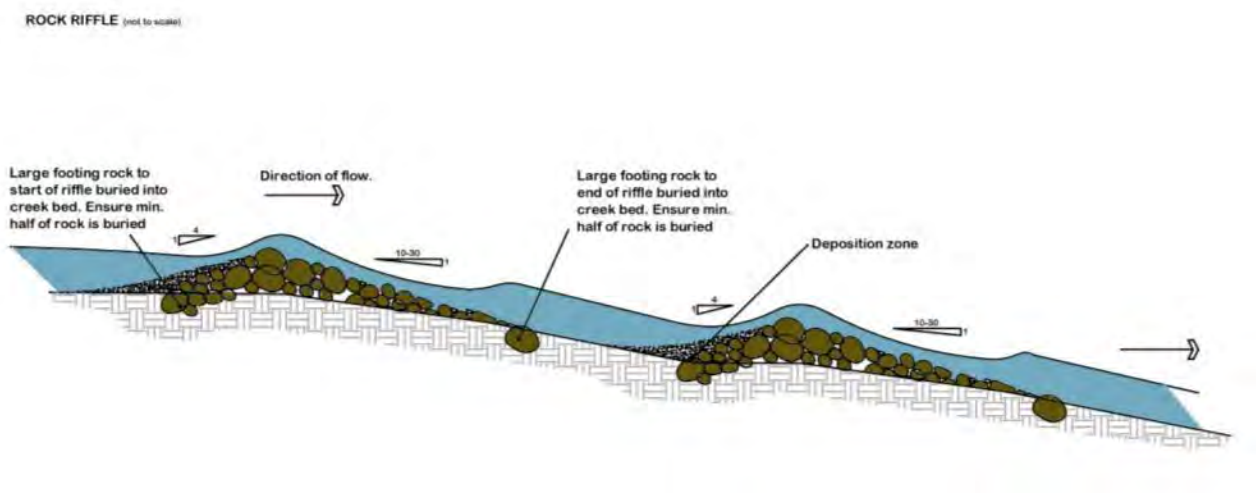
(Source: Sutherland Shire Waterways Prioritised Rehabilitation Plan, Applied Ecology 2012)

Log weirs for channel bed stabilisation



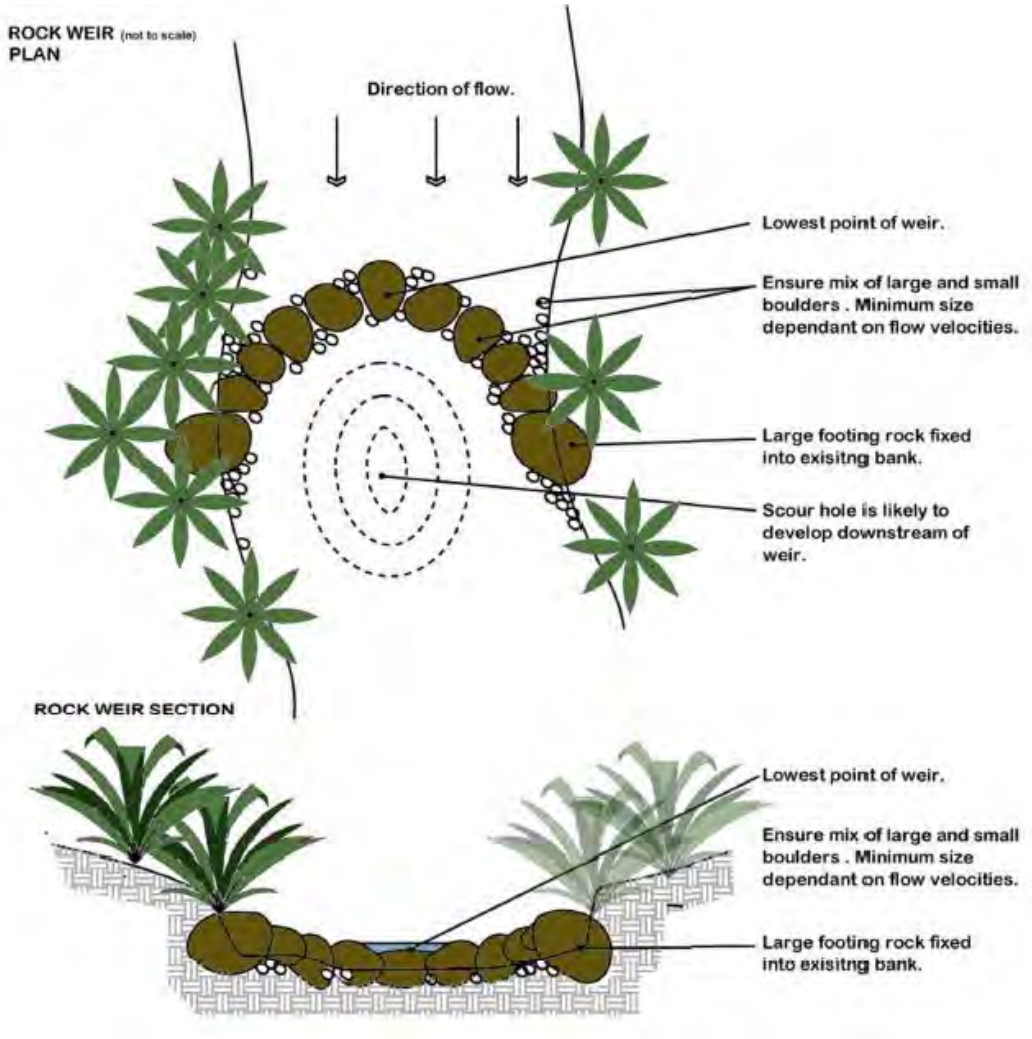
(Source: Sutherland Shire Waterways Prioritised Rehabilitation Plan, Applied Ecology 2012)

Rock riffles for channel bed stabilisation



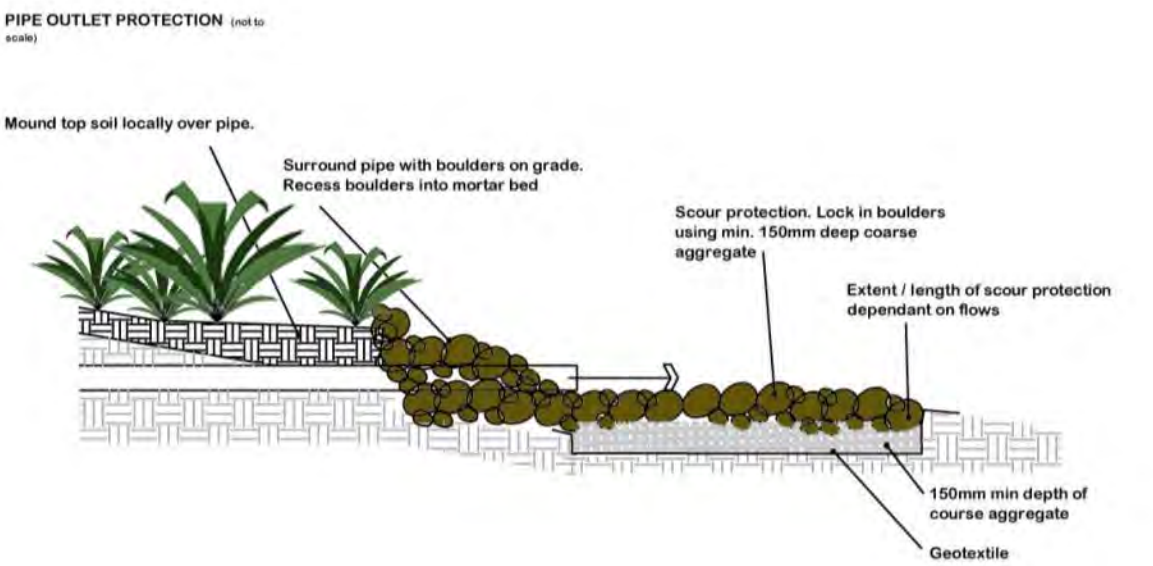
(Source: Sutherland Shire Waterways Prioritised Rehabilitation Plan, Applied Ecology 2012)

Rock weirs for channel bed stabilisation



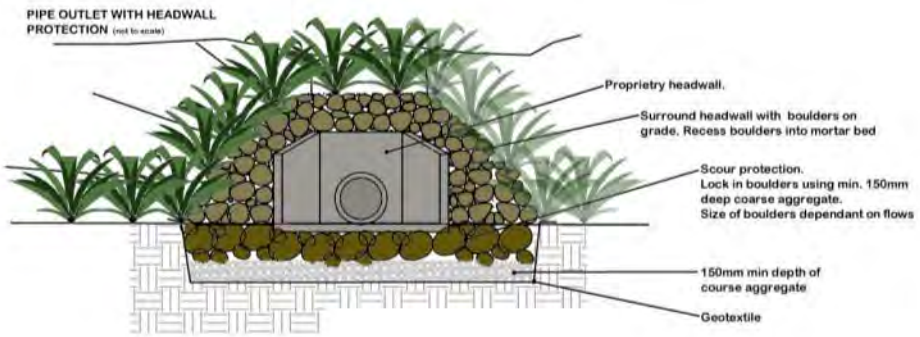
(Source: Sutherland Shire Waterways Prioritised Rehabilitation Plan, Applied Ecology 2012)

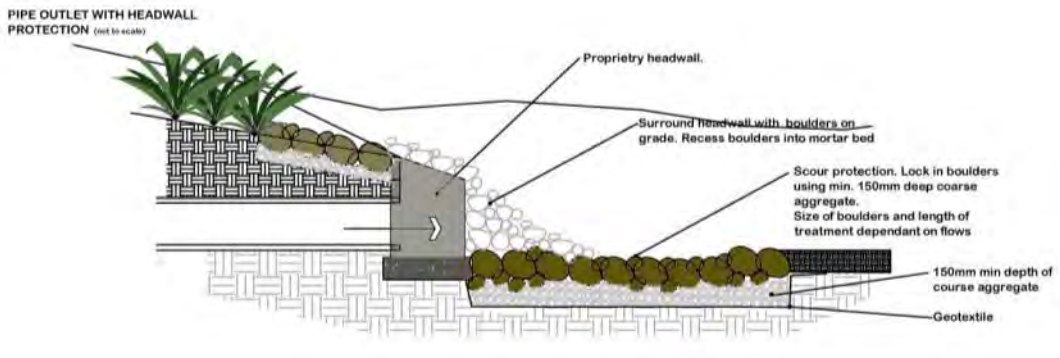
Pipe outlet protection



(Source: Sutherland Shire Waterways Prioritised Rehabilitation Plan, Applied Ecology 2012)

Headwall and outlet protection





(Source: Sutherland Shire Waterways Prioritised Rehabilitation Plan, Applied Ecology 2012)

DESIGN GUIDELINES FOR STREET FURNITURE

Elements of street furniture need to be co-ordinated with each other and with their surroundings. Designers should check the master plan, design guidelines and other planning documents relevant to the site for any requirements for street furniture styles, colours and finishes. Street and park furniture needs to:

- exhibit high resistance to vandalism
- be durable against weathering and deterioration
- be suitable for use by people with a wide range of needs including children, the aged and people with disabilities
- have a low whole-of-life cost.

Paint finishes should be selected on the basis of superior resistance to fading, vandal resistance and appropriateness for the surface they are coating. Graffiti coatings should be considered for surfaces likely to be affected by graffiti. Within these requirements, park furniture should be selected to enhance the unique design character of the space.

Park furniture positioning and selection should respond to the demands of the public and the physical location. The number of furniture items is a direct response to the requirements of the particular space. Park furniture should be positioned to focus on an activity or a view and take advantage of seasonal change, especially winter sun and summer shade. Where possible designers should site furniture in ways that provide shelter from the rain and other local weather patterns such as winter winds.

Seating is a major component in spaces that are created primarily for relaxing or resting. Seating in these spaces should be designed for longer duration sitting. Aggregations or multiples of seating may be required in central locations where they can be placed to encourage conversation or to generate a sense of place. This form of seating is normally inwardly facing, should be visible but not intrusive and sited in a manner that does not obstruct a view, activity or desire lines. Seats in secluded areas should be sited near or directly under street lighting. Avoid locating seats in grass where maintenance of the grass around and beneath the seat will be difficult. Also avoid placing seats around trees where they collect leaf litter and require increased maintenance.

Seats with an all metal framework, durable finish, armrests, slats perpendicular to the length of the seat are preferred. Seating surfaces should have ample space between slats; this type of surface tends to dry more quickly after rain. Seats should be designed to avoid entrapment hazards (see Australian Standard AS 1924.2 for head entrapment and Design Standard 15 Playgrounds and Playground Equipment for finger entrapment). Armrests and slats perpendicular to the length of the seat help to reduce vandalism; especially the danger and damage caused by in-line skaters and skateboard riders.