

Mittagong Creek Riparian Management Plan

Wingecarribee Shire Council (WSC)



AUSTRALIAN WETLANDS
CONSULTING PTY LTD

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1. Introduction

Australian Wetlands Consulting (AWC) has been commissioned to provide a Riparian Management Plan (The Plan) for a section the Mittagong Creek, Bowral. This Plan is put forward to ensure that the health of the creek, a major natural feature of the township is maximised providing increased biodiversity, stability, and improved water quality. The Creek is a significant community asset and has been classified as a Regional Site within the Wingecarribee Shire. In developing the management plan we have considered not only the needs of the creek from an environmental perspective but also the community's desire to develop a plan that can be implemented over the short and long term and increase environmental and community values and amenity.

Mittagong Creek runs through both council and private land and experiences a range of pressures along its length from rural farming practices to urban and industrial land uses and their associated activities. Weeds, bank stability and sediment loading within the riparian zone are key issues identified, culminating in a complex range of issues that require differing and unique design and management responses. There are also social issues to consider with several interest groups closely associated with the Creek. A section of the site contains the Bowral Vietnam War Memorial and associated Cherry Tree Walk, and The Bowral Urban Landcare group conducts maintenance work on previously revegetated riparian sections at varying locations.

Given the creeks importance and significance to the town and the various interest groups, the design response will not only need to address riparian health and biodiversity but it will also need to incorporate a social response.

WSC **Mission** Statement is:

“To create and nurture a vibrant and diverse community, growing and working in harmony with our urban, agricultural and natural environments”.

2. Site Context

The extents of the creek under this plan is located in the township of Bowral in the Southern Highlands, NSW, beginning at South Head Road to the East to Mittagong Road (Section 1) and from Mittagong Road through to the Sewage Treatment Works on the Western side of Mittagong Road (Section 2)(refer Figure 2.1).

For the purposes of clarity the entire length of the creek considered in this Plan is referred to as the Project. The project is broken into two Sections, section 1 and 2 as above. Specific areas within the sections are referred to as Sites. Sites are generally identified by geographic boundaries such as roads.

The creek passes through a number of land zone types, each typified by activities related to that particular land use allowed within the LEP, each requiring different riparian management strategies. The land use types are:

- E3 – Environmental Management
- IN1 – General Industrial
- IN2 - Light Industrial
- R2 – Low Density Residential
- R3 – Medium Density Residential
- R5 – Large Lot Residential
- RE1 – Public Recreation
- RE2 – Private Recreation
- RU4 – Rural Small Holdings
- SP2 - Infrastructure

Permitted activities will need to be determined as part of the implementation of this plan as well as consultation and the involvement of/ with landowners and interest groups to ensure successful outcomes.

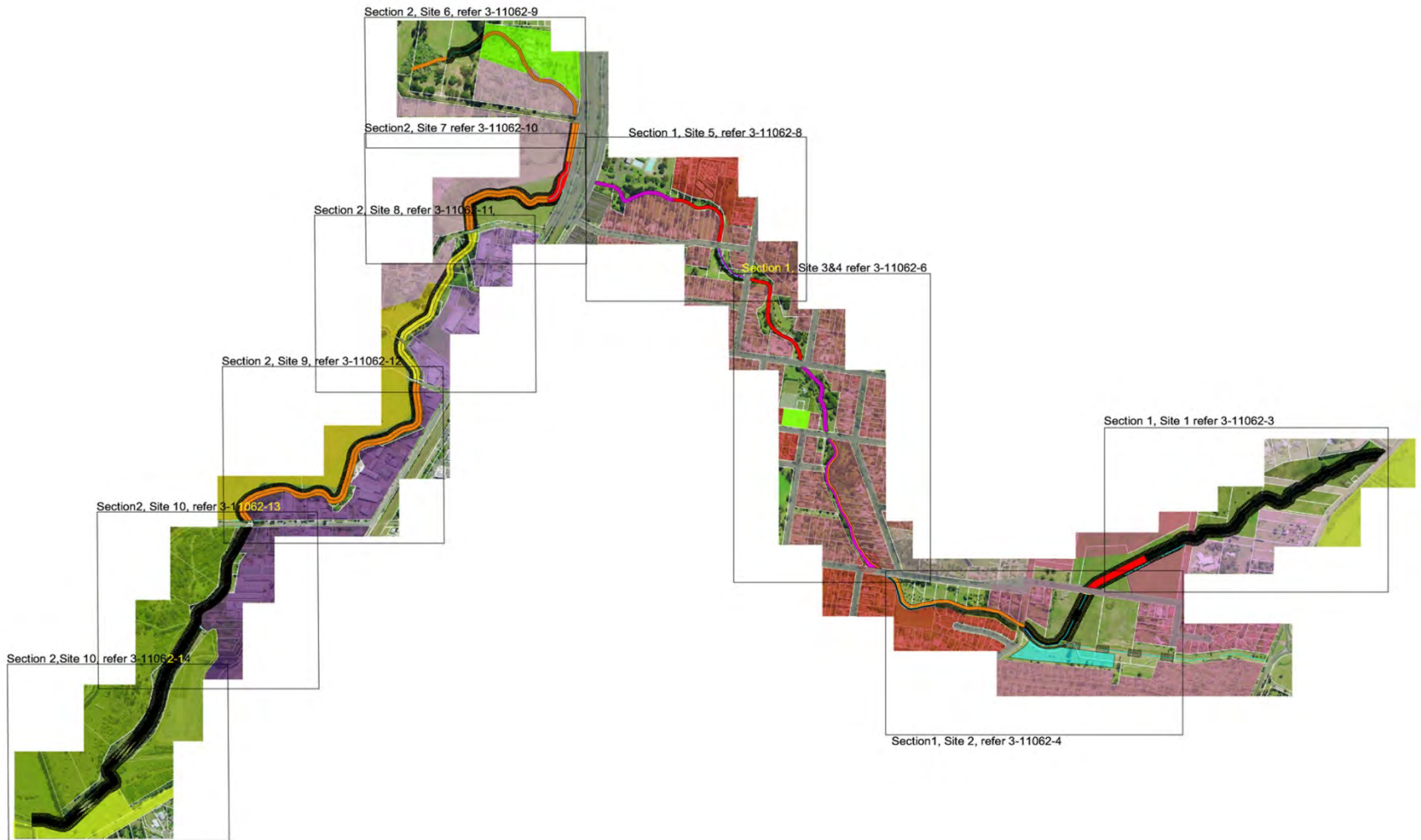


Figure 2-1: Locality map, Mittagong Creek

3. Project Objectives

A Plan of Management for Mittagong Creek Reserve was adopted by Wingecarribee Shire Council in July 2008. This plan satisfies Wingecarribee Shire Council's (WSC) requirements to manage this portion of community land under the Local Government Act (1993). The Plan of Management covers only a small portion of the Mittagong Creek corridor from Bowral Street through to Mittagong Road.

Several high priority measures were recommended in this study, one of which was to "improve management of riparian corridor, by establishing a creek maintenance program and by preparing a Mittagong Creek Riparian Corridor Management Plan to guide rehabilitation of the creek corridor in a way compatible with hydraulic, environmental and recreational objectives." This was also a key recommendation of the Bowral Floodplain Risk Management Study and Plan (Flood Study), Bewsher 2009.

In 2010 Wingecarribee Council commissioned the Wingecarribee Shire Council Stormwater Management Plan 2010 to 2031. This plan also identifies the need for the development of a Mittagong Creek Riparian Management plan. It calls for common sense guidelines to be developed to resolve issues between habitat and flood risk in riparian zones of the Wingecarribee.

The key objective of the current study is to build upon work completed to date by developing a Mittagong Creek Riparian Vegetation Management Plan (The Plan) which addresses the restoration and ongoing management of the Mittagong Creek Riparian Corridor. It is hoped the plan can be used to stage future works in manageable portions and as a tool that assists Council in seeking grant funding for these works.

Identified in the Mittagong Creek Reserve Plan (Issue B) are Legislative and Statutory Requirements for Community Lands and also the Core Objectives of council for the future management of Community lands. As the creek is on both council and private land not all of these are applicable to the full extent of the site but private participation in the implementation of the Riparian Management Plan is a key objective.

Key objectives nominated within section 2.7 of the Mittagong Creek Reserve PoM for riparian areas are to:

- Provide bed and bank stability,
- Protect water quality,
- Maintain viability of riparian vegetation,
- Integration with floodplain processes,
- Manage edge effects at riparian/ urban interface,
- Protect natural values within the creek,
- Provide adequate access,
- Vegetation to reflect public open space usage,
- Does not promote pest vegetation/ fauna,
- Provide continuity and connectivity.

WSC Vision for the future.

In 2031 we will be...

"A healthy and productive community, learning and living in harmony, proud of our heritage and nurturing our environment"

Building on the PoM we will nominate a set of design and management responses that provide basic habitat and preserve or emulate as much as possible a natural functioning stream as well as providing for and accommodating, the needs and wishes of the local community.

4. Legislation and Environmental Planning Instruments

There are several key environmental planning policies and strategic plans relevant to the preparation and implementation of this Plan. A number of Federal and State statutes, policies and plans influence the management of riparian resources. These policies and plans are not explored in detail in this Plan but state and local metropolitan strategies specifically related to the site and the participating LGA are utilised in the preparation of this Plan

At the Commonwealth level, environmental planning policies and strategic plans include:

- Environment Protection and Biodiversity Conservation Act 1999, and
- Australian Heritage Commission Act 1975.

At the State level these include:

- Environmental Planning and Assessment Act 1979;
- Local Government Act 1993;
- Threatened Species Conservation Act 1995;
- National Parks and Wildlife Act 1974;
- Noxious Weeds Act 1993;
- Native Vegetation Act 2003;
- Catchment Management Authorities Act 2003;
- Fisheries Management Act 1994;
- Water Management Act 2000;
- Natural Resource Commission Act 2003;
- Protection of the Environment Operations Act 1997
- Water Industry Competition Act 2006
- Drinking Water Catchments Regional Environmental Plan No. 1 (now deemed a SEPP as of 1 July 2009)
- LEP – Wingecarribee Shire Council 2010
- Illawarra Regional Environmental Plan No.1
- The Sydney-Canberra Corridor Regional Strategy (DoP 2008)
- Wingecarribee Strategic Plan 2002

4.1 NSW Targets

The NSW Government State-wide natural resource management targets, as referenced in the state plan Protecting our native vegetation, biodiversity, land, rivers and coastal waterways (NSW Government 2010), provide the structure for the NSW Monitoring, Evaluation and Reporting (MER) program. The MER Strategy was endorsed by the NSW Government in 2006 and has now been revised (DECCW 2010a). The MER Strategy was established to focus the resources of NSW natural resource and environment agencies and coordinate their efforts with Catchment Management Authorities (CMAs), local government, landholders and other natural resource managers to establish a system of monitoring, evaluation and reporting on natural resource condition.

The MER Strategy, citing NRC (2007), identifies State-wide natural resource management targets to be achieved as listed in Table 4-1. Relevant targets developed for River Health as part of the Hawkesbury Nepean Catchment Management Authority Action Plan 2008-2017 are also provided.

TABLE 4-1: NSW STATE-WIDE NATURAL RESOURCE MANAGEMENT TARGETS

TARGETS	
Biodiversity	
Macro-environmental	1. By 2015 there is an increase in native vegetation extent and an improvement in native vegetation condition.
	2. By 2015 there is an increase in the number of sustainable populations of a range of native fauna species.
Specific priorities	3. By 2015 there is an increase in the recovery of threatened species, populations and ecological communities.
	4. By 2015 there is a reduction in the impact of invasive species.
Water	
Macro-environmental	5. By 2015 there is an improvement in the condition of riverine ecosystems.
	6. By 2015 there is an improvement in the ability of groundwater systems to support groundwater dependent ecosystems and designated beneficial uses.
	7. By 2015 there is no decline in the condition of marine waters and ecosystems.
Specific priorities	8. By 2015 there is an improvement in the condition of important wetlands, and the extent of those wetlands is maintained.
	9. By 2015 there is an improvement in the condition of estuaries and coastal lake ecosystems.
Land	
Macro-environmental	10. By 2015 there is an improvement in soil condition.
Specific priorities	11. By 2015 there is an increase in the area of land that is managed within its capability.
Community	
Macro-environmental	12. Natural resource decisions contribute to improving or maintaining economic sustainability and social well-being.
Specific priorities	13. There is an increase in the capacity of natural resource managers to contribute to regionally relevant natural resource management.

Relevant targets developed for River Health as part of the Hawkesbury Nepean Catchment Management Authority Action Plan 2008-2017.

State wide Targets:	
<ul style="list-style-type: none"> • Improving condition of riverine ecosystems, and condition and extent of important wetlands; • reducing decline in the condition of marine waters and ecosystems; • improving the ability of groundwater systems to support groundwater-dependant ecosystems and designated beneficial uses; • improving estuary condition. 	
CT RH1 Riparian Lands: Improving the health of riparian lands	MT RH1-1 Riparian conservation: Increasing the length of river and stream banks being managed primarily for conservation to 23% or 150 of reaches in this category.
	MT RH1-2 Riparian Vegetation Regeneration: Increasing the length of river and stream banks being managed under assisted regeneration so that 18% or 260klm of these riverbanks are improved.
	MT RH1-3 Riparian Vegetation Rehabilitation: Establishing 600 000 plants on reaches that have been identified to need revegetation.
CT RH2 Aquatic Biodiversity: Improving sustainability of key native aquatic populations and the recovery of threatened aquatic species.	MT RH2-1 Restoration of in-stream habitat: Increasing the length of improved in-stream habitat using appropriate in stream works. E.g. large woody debris, removing barriers to fish passage
CT RH3 Wetlands: Understanding, maintaining and improving wetlands function (in peat-based swamps; and sandstone based upland, riverine floodplain and estuarine wetlands)	MT RH3-1 Important Wetlands: Increasing the area of important wetlands with recovery.
CT RH4 Groundwater: Improving the ability of groundwater systems to support groundwater-dependent ecosystems	

and beneficial uses.

4.2 Local Strategies and Plans

There are a number of management plans, the Local Environmental Plan (LEP), the Development Control Plan (DCP), studies and strategies that have been prepared for the LGA and the study area addressing Stormwater, Biodiversity, Cultural and Community Facilities and Open Space. These provide the framework for implementation of planning controls and on-ground works.

➤ **Wingecarribee Local Environmental Plan 2010**

Clause 7.4 Natural resources sensitivity—biodiversity

(1) The objective of this clause is to maintain terrestrial and aquatic biodiversity, including:

- protecting native fauna and flora, and
- protecting the ecological processes necessary for their continued existence, and
- encouraging the recovery of native fauna and flora, and their habitats.

(2) This clause applies to land identified as “Regional Wildlife Habitat Corridor” on the Natural Resources Sensitivity Map. This map identifies riparian land of the subject site as Category 3 – Bank Stability and Water Quality which limits development to within 10m of the top of bank.

➤ **Wingecarribee Environment Strategy 2010-2015** outlines a number of initiatives by Council regarding best practice decision making to reduce the impacts on natural resources. The Plan identifies the following programmes specific to the site and receiving waters downstream.

- **The Wingecarribee River Riparian Restoration Programme** - Hawkesbury Nepean Catchment Management Authority Action Plan 2008-2017.

The key objective of the programme is to:

- Protect and rehabilitate the riparian zone of the Wingecarribee River and any tributaries and creeks entering the river by fencing, regenerating and revegetating with local native plants;
- **Mittagong Creek Rehabilitation Maintenance** - Hawkesbury Nepean Catchment Management Authority Action Plan 2008-2017.

Key objective(s) of the programme are:

- Removal of noxious and environmental weeds;
- Protect and maintain all previous environmental works;
- Support and build on community based activities increasing capacity for creek and riparian restoration;
- Decrease sediment and erosion impacts on riparian health and stormwater quality;
- Further develop and support community participation in conservation activities;
- Negotiate with private owners with view to extending riparian restoration works downstream;
- Revegetation with riparian vegetation in appropriate bare areas with no natural regeneration potential;

- Improve in stream health through removal of rubbish and revegetating stream banks with wetland species.

Additional detail is given in these plans for specific sites or issues as listed below:

- Wingecarribee Open Space, Recreation, Cultural and Community Facilities Needs Study, 2004;
- Wingecarribee Environment Strategy 2010-2015;
- Mittagong Creek Reserve Plan of Management Issue B - 2008
- Bowral Flood Plain Risk Management Study and Plan – 2009
- Stormwater Management Plan 2010-2031
- Riparian Management Guidelines for the Wollondilly and Wingecarribee Rivers - 2002

5. Existing Site Characteristics

5.1 Reach Description

5.1.1 Section 1

Site 1: Old South Road – Bowral Street – Intersection with Constructed Channel. Drawing 3-11062-3

Starting from Old South Road, Mittagong Creek runs through open fields with grazing the dominant land use. Non-native deciduous trees and willows provide canopy, shade and root stability to banks but also trap other debris impeding flows. A small disused bridge also crosses the creek, impeding flows in large events as do several stock fences with evidence of trapped debris.

Bank stability is generally sound but poor in some locations due to stock movements in and along the creek banks. Where trees are located within the stream rather than the banks, scouring is seen as the trees force flows to be directed around the trunks and into banks. There is also evidence of bed lowering with some banks over 2m tall and nearly vertical.

There is very little native vegetation (approx. 6 trees) along the length of the reach with pastoral grasses to top of bank the only riparian vegetation. Blackberry and Ivy were also present in small quantities. *Juncus sp.* was evident within the boggy area adjacent to the culvert at Old South Road.

From Bowral St to the junction with the constructed channel the creek has become disconnected from the surrounding grazing land by the deposition of material, presumably from cleaning the creek line. This material has been deposited directly on the top of bank effectively separating this section of creek from the floodplain.

Stormwater runoff from Bowral Street is running along unformed, unplanted drains/ swales that are washing sediment into the creek.



Site 2: Bowral Street – via Stanley Park and Constructed channel. Drawing 3-11062-4

The creek here has been realigned and converted into a trapezoidal drain engineered to efficiently convey flows. Shallow battered banks slope down to the channel bottom. There are no trees along the entire length of the channel with mown batters along the southern bank, adjacent to the park/ open space. On the north side of the channel, pastoral grasses and blackberry dominate. The channel floor is dominated by dense growth of *Typha*, providing a water quality function and slowing flows. There are little or no in-stream morphological features (pools or riffles) or variation.



Immediately downstream from the confluence of the channel and Site 1, there is bank instability, particularly on the southern side adjacent to the park/ open space area. This is on the outside of a stream bend and erosion and bank slumping are evident. The internal side of the bend is covered with un-kept pastoral grasses and blackberry but the banks are intact. There are no trees along this section of the creek. A small concrete access point, imbedded with large rocks has been constructed adjacent to the confluence of a storm water drain. This acts as a small drop down/ riffle. The stormwater drain enters from the south and scouring of the banks is evident at this point. From the drain to the small foot bridge accessing Stanley Park there is bank erosion and increased weed occurrence, particularly on the northern bank. There is an increase of trees and riparian vegetation along the northern bank from this point as opposed to the open grasslands of the previous sites.

Stanley Park is a Bush Care site with the northern or True Right (when looking down stream) bank showing improved bank stability and occurrence of native, riparian vegetation. The southern bank (True Left – when looking downstream) borders private property and is devoid of significant native riparian vegetation, with only weedy tree species and mown grass evident. Bank instability on the true left is also evident. A growth of bamboo (likely *Phyllostachys* spp.) is evident in the property adjacent to Bowral St and the creek and appears to be spreading. There is also an increased occurrence of *Typha* from this point along the length of the creek excluding the constructed channel.



Site 3: Bowral Street – Shepherd Street. Drawing 3-11062-6

The Cherry Tree Walk and walking track closely follows the remainder of the creek through to Mittagong Road from this point on.

There is a significant increase in the occurrence of weed species on the true right of the creek as the system enters the urban environment and private land bordering the creek. Weed species include *Vinca major*, Japanese Honeysuckle, Ivy, Blackberry, thistles, fennel and privet. Bank erosion is an issue along the true left of the creek in this section primarily due to the lack of riparian vegetation at the top of bank. This is due to current management practices whereby riparian areas are mown to the top of the bank. There is good canopy cover within this site with large old stand trees and groupings of *Acacia* bordering the creek and adjacent open space.

There is significant erosion adjacent to a stormwater pipe out let near Bowral Street with large sediment slugs evident at the outlet and downstream. This is more evident at the Shepherd St Bridge where there is significant *Typha* growth. This is probably due to flow velocities being slowed at this point by the alignment of the creek with the bridge causing sediment to accumulate which are then colonised by *Typha*. Upstream from Bowley St a rock weir and bank armoring have been implemented by the Bowral Urban Landcare Group as part of the Mittagong Creek Restoration Project.



Site 4: Shepherd Street – Merrigang Street – Rose Street. Drawing 3-11062-6

This site contains the best example of urban riparian management, structure and care along the entire Project. The bank, riparian vegetation and in stream condition are all very good as presented by its highest ranking for potential successful rehabilitation (57%). Existing works to stabilise the banks with rip rap and planting have proved successful and there is good canopy cover along the length of the site apart from a small section between the footbridge and the Merrigang St Bridge. There is also a V-notch weir constructed between Merrigang St and the pedestrian footpath and a rock weir immediately downstream of Shepherd St.

Sediment slugs are evident within the channel and these have again been colonised by *Typha* and *Phragmites*. Small slugs appear within the section but significant sedimentation and weed cover is found upstream of the Merrigang St Bridge again due to the slowing of flows due to the alignment of the creek with the bridge, and the subsequent deposition of material.

The width of the riparian buffer is quite narrow due to proximity of the pathway on the true left but there is an opportunity to increase the width on the true right by utilising the adjacent open space. Other issues identified

are a pipe crossing the creek between the foot bridge and Merrigang St Bridge and the occasional discharge of water from an underground water tank associated with the neighbouring bowls club.



Site 5: Rose Street – Victoria Street – Mittagong Road. Drawing 3-11062-8

Rose Street - Victoria Street

This is the most degraded and complex site along the creek. While parts of the creek within this site are in relatively good condition bar weed and minor bank stability issues (up and down stream of Rose Street) there are several locations where severe bank instability and erosion are expressed. This is complicated also by the proximity of the existing and the contaminated site adjacent to the Gas Works. Vertical cut erosion and large woody weed species along with the occurrence of in stream weeds (*Typha*) are the major issues. Much of this section requires further detail in the way of survey, flow analysis and construction solutions and is beyond the scope of this plan.



Victoria Street – Mittagong Road. Drawing 3-11062-8

Again this site is in relatively good condition aside from weed and minor bank stability issues, however there are several locations where severe bank instability and erosion are expressed. This is particularly evident on the outside of bends which are subject to higher energy flows during storm events. Conversely, the internal bends exhibit sediment slugs and deposition that are colonised by weedy riparian species (*Typha*).

There is little riparian vegetation along this entire length with mown grass, open space areas occurring to the top of the bank. On privately owned land adjacent to the creek there are significant weed species including *Vinca major*, Japanese Honeysuckle, Ivy, Blackberry, thistles, fennel and privet.

Immediately upstream of Mittagong Road and adjacent to the Vietnam Veterans War Memorial the banks are stable and intact with very little weed infestation due to weed management. There is however little or no riparian vegetation along or adjacent to the bank. The banks in this location are also very steep with large deciduous trees planted near the top of the bank.



5.1.2 Section 2

Site 6: Northern Tributary. Drawing 3-11062-9

The majority of this site runs through private property and was unable to be accessed for assessment. The area adjacent to the Centennial Park Dog Park however has significant large weed tree species, namely Privet with smaller weeds species including *Vinca major*, Japanese Honeysuckle and Blackberry present. Another large tree thought to be 'White Poplar' also occurs adjacent to the creek. Bank stability along this section is generally very good with only minor erosion evident. There is a good mix of canopy trees both native and exotic observed on neighbouring private property.



Site 7: Centennial Road – Mount Road. Drawing 3-11062-10

There is a large amount of sediment build up on the western side of the culvert to Mittagong Road and significant scouring immediately downstream of the culvert with 2m vertical banks exposed. This zone, to approximately 100m downstream of the culvert will require further detailed investigation and is beyond the present scope. Works in this area are also complicated by the amount of large existing trees at the top of bank which are currently maintaining bank integrity.

Downstream of the above site the banks and vegetation are generally in good order with the only main issue being the presence of large woody weed species, namely Privet and under storey weeds such as Blackberry. Bank stability will need to be assessed and will be dependent on the amount of weeds to be removed (trees). As there is also a significant number of native tree species along the bank, bank battering may not be appropriate. Several in stream sediment slugs were identified and also impediments to stream flow due to trapped debris. Excessive sediment build up was observed at the Mount Rd Bridge with flows restricted to one section of the under bridge structure. Removal of sediments at this location will require extensive protection of the toe of the bank to prevent scouring around the bridge structure.



Site 8: Mount Road – Willow Road. Drawing 3-11062-11

Immediately downstream of Mount Road there is evidence of riparian planting with the occurrence of *Lomandra* and *Acacia* sp amongst weedy grass species. The native plantings are presumably as a condition of consent associated with neighbouring industrial development. There is a lack of successional canopy species near Mount Road and the occurrence of weeds such as Blackberry and Privet increases further downstream while tree canopy cover from *Casuarinas* and Eucalypt species also increases. Bank stability in this site is generally good with only a small number of locations expressing any threat of erosion. There is evidence of bed lowering due to the narrowing of the channel caused by vegetated sediment slugs that form benches adjacent to the toe of the bank. In stream obstacles caused by trapped debris and dams created by local children were observed.

Adjacent land practices of grazing and agriculture have limited the width of the riparian zone on the true right while on the true left, industrial activities have generally been limited to property boundaries and the riparian zone, although weedy is a fairly wide Council Reserve on the true left with considerable scope for rehabilitation. This section was previously the focus of a local Landcare group's rehabilitation activities, including Willow control and revegetation, though little maintenance has been carried out in recent years. There is some evidence of dumping of material from the industrial sites and windblown rubbish within the riparian zone, although this wasn't as bad as might be expected and was limited to only a couple of locations.



Site 9: Willow Road – Oxleys Hill Road Drawing 3-11062-12

This site is extensively weedy with Privet and Willow the dominant weed species punctuated with native canopy species. Bed and bank stability is generally good and supported by native trees and weedy undergrowth. The significant threat in this section is the occurrence of large amounts of debris caught in stream, inhibiting flows. Sediment slugs were also identified along with bank erosion. But again banks are generally stable.



Site 10: Oxleys Hill Road – Sewage Treatment Plant. Drawings 3-11062-13, 14

This site is generally free of canopy weed species with Blackberry, Honeysuckle and grassy weeds the dominant weeds. Bank stability through this section is generally very good with low, shallow batters. Bed condition is also good with only a handful of sediment slugs observed. There are also a number of drop downs and pools helping this site rank highly in the ranking assessment (49%). This is primarily due to the lack of weedy trees increasing the potential for successful rehabilitation.

Rubbish and drains were observed on the Industrial side of the creek with unchecked (no scour protection, trash racks etc) flows from pipes noted. Again this was only noted in a couple of instances and in general it appears that industrial activities are not contributing significantly to in stream or embankment rubbish accumulation.



Quarry – Sewage Treatment Plant

The creek has been altered through this site due to quarrying activities and has been straightened with pools and riffles created. There is no issue with bank stability through this section as the creek breaks out into an open flood plain over constructed riffles. There has been significant native tree species planted in this area. A large number of young Willows are starting to establish within the rock riffles and Blackberry is the dominant terrestrial weed species. This area shows very good potential for rehabilitation.



5.2 Threatening Processes

The major threats were: weed encroachment, sedimentation and bank erosion, however their implications for successful riparian rehabilitation vary throughout different parts of the study area.

Other issues include urban encroachment (proximity of Cherry Tree Walk, private land maintenance/management) and adjacent recreational land use, limited riparian buffer vegetation and with some potential threat from land use such as grazing (cattle access to banks) and industrial zone activities.

An important part of successful rehabilitation is the management of threatening processes. Management actions need to address the threats at each site as they may affect the capacity of a site to regenerate.

5.2.1 Weeds

Plants that are out of place or unwanted due to their invasive nature are considered weeds. They are mostly introduced species, but can include native plants from a different geographic area – e.g. Typha. Weeds are spread by animals, wind, water, humans and vehicles. They characteristically produce large amounts of seed compared to native endemic species and are the first to invade disturbed areas. Thus, places such as roadsides, urban areas and cleared landscapes generally have a greater abundance of weeds. In addition, riparian zones are at threat of weed invasion due to:

- Concentrated use by animals and humans;
- More favourable conditions for weed production (e.g. moisture and flood disturbance);
- They are often the only remaining remnants in urban areas;
- Riparian zones often have a narrow longitudinal shape, so there is a greater proportion of patch-edge that is exposed to adjacent land uses and associated weeds.

Weeds have the potential to out-compete native plants for resources (soil, water, nutrients and light). They often form dense stands, smother native plants and provide refuge to feral animals.

The weed seed bank in existing riparian soils also poses a threat in that as mentioned, weeds are generally first to colonise disturbed land. Any weed removal strategy will need to consider whether the weeds;

- are providing and or adding to the riparian environment in the absence of native vegetation or in the absence of a suitable alternative,

- are providing needed habitat and,
- whether, weed removal will result in ongoing and extended maintenance.

It must be remembered that the establishment of a full riparian vegetation community with canopy, sub canopy and ground layer will ultimately outcompete weed species.

Field observations indicate that many of the weeds tabulated below grow around waterways, often dominating one or more vegetation layers. The urban/rural land uses of the study area are susceptible to weed invasion and pose a threat to the ongoing health of riparian native vegetation communities and ecosystems.

TABLE 5-1: ENVIRONMENTAL WEEDS OF THE SOUTHERN HIGHLANDS

Environmental Weed		
Form	Common Name	Scientific Name
Tree	Monterey Pine Silver Poplar Tree of Heaven Willows Sycamore Box Elder Strawberry Tree Desert Ash Olive Cootamundra wattle,	<i>Pinus radiata</i> <i>Populus alba</i> <i>Ailanthus altissima</i> <i>Salix</i> spp. (except <i>babylonica</i>) <i>Acer pseudoplatanus</i> <i>Acer negundo</i> <i>Arbutus unedo</i> <i>Fraxinus angustifolia</i> <i>Olea europaea</i> ssp. <i>Europaea</i> <i>Acacia baileyana</i> & its cultivars
Shrub	Barberry Cherry Laurel Cotoneasters Privets. Fennel Firethorns Hawthorns Holly Montpellier Broom Sweet Briar Butterfly Bush Lavender Cherry Plum Boneseed Thorn apple Blackberry	<i>Berberis vulgaris</i> <i>Prunus laurocerasus</i> <i>Cotoneaster</i> spp. <i>Ligustrum</i> spp. <i>Foeniculum vulgare</i> <i>Pyracantha</i> species <i>Crataegus</i> spp. <i>Ilex aquifolium</i> <i>Genista</i> spp. <i>Rosa rubiginosa</i> <i>Buddleja davidii</i> <i>Lavandula stoechus</i> <i>Prunus cerasifera</i> <i>Chrysanthemoides monilifera</i> <i>Datura</i> spp. <i>Rubus fruticosus</i>
Climber	Banana Passionfruit Bridal Creeper / Baby Smilax English Ivy Honeysuckle Turkey Rhubarb Cape Ivy Cats claw creeper Bluebell Creeper Madera vine Moth vine	<i>Passiflora</i> sp. <i>Myrsiphyllum asparagoides</i> <i>Hedera helix</i> <i>Lonicera japonica</i> <i>Acetosa sagittata</i> <i>Delairea odorata</i> <i>Macfadyena unguis-cat</i> <i>Sollya heterophylla</i> <i>Anredera cordifolia</i> <i>Araujia sericifera</i>
Lily	Formosa Lily Monbretia / Crocosmia, Freesia Arum Lilly	Formosa Lily Monbretia / Crocosmia, Freesia Arum Lilly
Ground cover	Blue Periwinkle Kikuyu Bamboo spp. Forget-me-not Soursob Ox-eye daisy African Daisy Variegated thistle Agapanthus	<i>Vinca major</i> <i>Pennisetum clandestinum</i> Mint <i>Mentha</i> spp. <i>Myosotis sylvatica</i> <i>Oxalis pes-caprae</i> <i>Leucanthemum vulgare</i> <i>Osteospermum fruticosum</i> <i>Silybum marianum</i> <i>Agapanthus praecox</i>

5.2.2 Sedimentation and Erosion

Sedimentation is the process in which particulate matter carried from its point of origin by either natural or human-enhanced processes is deposited elsewhere on land surfaces or in water bodies. Sediment is a natural product of stream erosion; however, the sediment load may be increased by human practices. Such enhanced sources of sediment in a catchment include unvegetated streambanks and uncovered soil regions, including construction sites, deforested areas, and croplands.

In the context of stream hydrology, sediment is inorganic and organic material transported by, suspended in, or deposited by streams. Sediment load, which is the quantity of sediment transported by a stream, is a function of stream discharge, soil and land-cover features, weather conditions, land-use activities, and many other factors. Sediment load carried by streams and rivers can be composed either of fine materials, mostly silts and clays, or larger materials such as sand.

Solid sediment load can be divided into two components on the basis of the mode of sediment transport: suspended sediment, and bedload sediment. Suspended sediment consists of silt-sized and clay-sized particles held in suspension by turbulence in flowing water. Bedload sediment consists of larger particles which slide, roll, or bounce along the streambed by the force of moving water. Dissolved load consists of inconspicuous material in solution moving downstream. It is produced by chemical weathering processes, and does not settle out of water.

Additional erosion damages in both rural and urban areas include reduced property values, deteriorated water quality, and increased costs of removing sediment from roadways, roadside ditches, and surface-water supplies.

One of the principal causes of degraded water quality and aquatic habitat is the depositing of eroded soil sediment in waterbodies. Excessive amounts of sediment resulting from natural or human-induced causes can result in the destruction of aquatic habitat and a reduction in the diversity and abundance of aquatic life.

If the river cross-section is sufficiently reduced by sediment buildup, sedimentation can increase downstream flooding. In addition, some metal ions, pesticides, and nutrients may adhere to sediment particles and be transported downstream.

Erosion is simply the opposite of sedimentation. Erosion is the removal of material/ sediments out of the system. Although erosion is a natural process human land use practices also have an effect on erosion, especially when associated with agriculture, deforestation, and urban sprawl. Land use for these purposes generally experiences a significantly greater rate of erosion than that of land under natural vegetation.

Erosion is natural and, in fact, healthy for the ecosystem. For example, gravels continuously move downstream in watercourses. Excessive erosion, however, causes serious problems, such as receiving water sedimentation, ecosystem damage and outright loss of soil.

6. Threatened Species and Communities

6.1 Threatened Flora

A database search was completed to determine the potential for threatened flora to occur in the locality of the subject site. A search of the NSW Wildlife Atlas based on the Wingecarribee LGA recorded 15 threatened flora species within the LGA. Of these only 1, the Buttercup Doubletail, *Diuris aequalis* is found within 5km of the subject site.

A search of the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC) Protected Matters database recorded 6 Vulnerable or critically endangered species or species habitat likely to occur within 5klm of the study area.

6.2 Endangered Ecological Communities

The *Southern Highlands Shale Woodland* is an endangered ecological community which would have, at one time, existed within the study area. Presently less than 5% of this original community remains. The *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* is listed as critically endangered in DSEWPC database and is noted as likely to occur within the area.

Common threats to the remaining these communities are:

- Disturbance and clearance of remnants during road maintenance and upgrades.
- Continued clearing, degradation and fragmentation of remnants for agricultural activities (including pine plantations), and infrastructure and residential development.
- Degradation of condition, with aging trees, lack of regeneration and weed invasion.
- Continuous heavy grazing and trampling of remnants by grazing stock, resulting in ringbarking and losses of plant species (simplification of the understorey and ground layer and suppression of overstorey), erosion and other soil changes (including increased nutrient status).
- Harvesting of firewood (either living or standing dead, including material on the ground).
- Invasion of remnants by non-native plant species, including noxious weeds, pasture species and environmental weeds.

6.3 Threatened Fauna

Searches of relevant databases were completed for records of threatened fauna on the subject site. The NSW Wildlife Atlas holds records of 8 threatened fauna species within the LGA although none are noted as being found within the vicinity of the subject site.

A search of the DSEWPC database found 17 fauna species (including Mammals, Fishes, Reptiles, Birds and Frogs) that are either Vulnerable or Endangered species or species habitat that are likely, known or may occur within 5klm of the site. The search also picked up 14 Migratory species that are likely, known or may occur within 5klm of the site.

7. Flooding

Consistent with the Bowral Floodplain Risk Management and Plan (Flood Study) prepared by Bewsher 2009, this Plan will address riparian restoration for improved functionality, both hydraulically and environmentally. While not specifically addressing recommended measures in the flood study one high priority measure is the preparation of this Plan as an outcome of the flood study;

-Improved management of the riparian corridor, by establishing a creek maintenance program and by preparing a Mittagong Creek Riparian Corridor Management Plan to guide rehabilitation of the creek corridor in a way compatible with hydraulic, environmental and recreational objectives.

Findings in the flood study state that in the event of a 100 year ARI flood event, 76 houses and 23 businesses would be flooded at an approximate cost of \$10 million. Most of the residential properties are located East of Mittagong Road with the business located on the West. Several properties (approx. 25 houses and businesses)

are affected in 10 year flood events. As noted in the flood study the flood affected houses and businesses are dispersed along the creek so there is no, one fix solution.

Areas up and downstream of Old South Road have been identified as possible sites for flood mitigating detention basins. During field investigations the open parkland area located to the south of the constructed channel (Refer to drawing 3-11062-4) also showed potential as a possible detention basin. The proximity to existing residential housing and pedestrian walkways however lends itself not only to flood mitigation but also to the establishment of a designed, offline wetland/ chain of ponds for aesthetics and habitat creation. This could be designed to provide a valuable community asset, providing improved water quality, flood mitigation in peak events and valuable habitat. It is recommended that further study and dialogue be undertaken to realise the sites potential.

Community consultation (Section 5 of the Flood Study) undertaken during the flood study indicated concerns over excessive reed growth and dumping of rubbish and identified sections of the creek that required Channel clearance (Figure 5.2 of the Flood Study). The community's suggested flood management measures for channel clearance are consistent with our field work observations although there was very little 'dumped rubbish' in the creek line (1 occurrence of a car tyre, dumped rubbish in the riparian zone adjacent to the industrial area).

Vegetation issues noted within the flood study are:

- To remove exotic plant species from the creek corridor to improve the hydraulic function of the creek;
- To provide for the rehabilitation of the creek with endemic plant species which are tolerant of riverine conditions;
- To create an environment which is sympathetic to the ecology of the creek, and in particular, fauna habitat;
- To create a rehabilitated creek corridor which allows for access by the general community for recreation and education;
- To ensure that the potential for soil erosion and destabilisation of the creek banks is addressed by providing for the management and staged rehabilitation of the creek.

All rehabilitation measures outlined in this plan are not aimed at reducing flood risk. The objective of this Plan is to improve riparian health. However, by increasing the cross sectional area of the creek, improving flows and by nominating management practices/ actions that remove in-stream obstacles, there is not likely to be an increase in flood risk over present levels.

8. Site Assessment and Ranking of Sites

The assessment of vegetation health and the prioritisation of sites was based upon the Rapid Assessment Method (RAM). Rather than a fluvio-geomorphic assessment method such as AUSRIVAS, it is felt the RAM selected is better placed to rank and prioritise the priority issues stated. The assessment has been used successfully for numerous studies by the project team, and provides an informed and detailed assessment of the current character and issues of the riparian zone without undertaking a detailed geomorphic assessment.

A rapid ecological assessment was also conducted to identify significant native and weed species. Budget limitations did not allow for a complete ecological assessment and identification of flora and fauna species along the 6 km Project length.

Details of the RAM methodology are as follows;

Two parameter types will be recorded for the assessment, non-ranking and ranking:

Non-ranking assessment parameters

These parameters are recorded to provide descriptive, qualitative information about the sites and include:

- Site number – Sites are numbered progressively from upstream to downstream.
- Photo numbers – The photo numbers are recorded in the Riparian Assessment Matrix to ensure correct allocation of photographs to sites for reporting.
- Section length – The approximate length of each site is indicated in metres based on changes in vegetation or obvious landmarks as identified on maps.
- Vegetation community code – endangered ecological community mapping codes (if available)
- Vegetation community ground-truthed – Ground-truthing of each mapped vegetation community is undertaken. Landscaped sites and remnant communities too small to be picked up by the RE mapping are also noted.
- Dominant terrestrial weeds – The dominant terrestrial weed species for each site are recorded.
- Dominant threat type – The dominant perceived threat is recorded for each site (eg. grazing, weed invasion, stormwater pollution, erosion, sedimentation etc).
- Current adjoining land use – The current adjoining land use is recorded based on field observations.
- Significant species/habitat – The presence of any rare/endangered species is noted.

Ranking assessment parameters

The following parameters are scored to provide a quantitative assessment at each site. This assessment enables the calculation of the regeneration potential of each site based on each site’s sum of scores. Each ranking assessment parameter is rated using a Likert scale where a score between 1 and 10 is assigned to each parameter. A score of 10 indicates excellent conditions and a score of 1 indicates the poorest conditions.

Parameters include:

- Bed condition – A score is given to best describe streambed condition, where: 1 = poor condition (eg. flat meandering and shallow with large sediment slugs sometimes colonised by vegetation and with no pools and no large woody debris); 10 = excellent condition (eg. pools, runs, riffles, large woody debris and no sediment slugs present).
- Bank stability – A score is given to best describe bank stability based on the following:

Score	Condition
1	Poor condition with active severe erosion
3	Unstable
5	Becoming unstable
8	Good condition
10	Excellent condition (not likely to erode)

- Weed cover – The proportion of weed cover to native cover is estimated where: 1 = all weed species and no natives; 10 = no weeds present at the site.
- Density (vegetation) – The density of vegetation (including riparian trees, shrubs and forbs) is estimated where: 1 = no vegetation; 10 = maximum riparian vegetation density that could be expected at that site relative to the vegetation communities present.
- Diversity – The diversity of vegetation (including trees, shrubs and forbs) is estimated where: 1 = no native species; 10 = the maximum diversity which could be expected at that site relative to the vegetation communities present.
- Vegetation community age – The relative age of riparian vegetation community establishment is scored for each site. The scores are based on the following:

Score	Community Age
1	Yet to regenerate (recently cleared or disturbed), no old growth trees.
3	Seedlings actively regenerating in a cleared/disturbed area, few to no old growth trees.
5	Saplings, indication of a young vegetation community, older disturbed area with few old growth trees.
8	Established regenerated community – no obvious recent disturbance, some old growth trees.
10	Old growth community – no disturbance.

- Threats – This score indicates the likelihood of each site to ecologically degrade due to an active process or a combination of processes. Threats will likely include grazing, erosion, sedimentation, stormwater pollution and weed invasion. Scores: 1 = very high threat likely to heavily impact on the ecological value of the site; 10 = no apparent threat.
- Width (of riparian vegetation) – The width of the riparian vegetation zone is estimated for each site. The score describes the range of the extent of riparian vegetation from the edge of the creek. Score allocation is described in the table below:

Score	Width of Riparian Zone Vegetation (m)
1	1 – 5
2	5 – 10
3	10 – 15
4	15 – 20
5	20 – 25

Score	Width of Riparian Zone Vegetation (m)
6	25 – 30
7	30 – 35
8	35 – 40
9	40 – 45
10	> 45

- Connectivity (riparian) – Connectivity with other riparian areas up and down stream is estimated where: 1 = no connectivity to other riparian forest areas; 5 = either one side of creek has good riparian connection, or both banks have intermittent connection; 10 = unbroken connectivity with adjoining riparian forest on both banks.
- Connectivity (adjacent) – Connectivity with adjacent forest areas is estimated where: 1 = no connectivity to adjacent forest areas; 10 = continuous connectivity with adjacent forest areas of > 250m width.
- Access for rehabilitation – The availability of access for rehabilitation is estimated where: 1 = no access possible; 10 = unrestricted access for rehabilitation available.

8.1 Riparian Rehabilitation Prioritisation

Following assessment of riparian zone, the project requires prioritisation of riparian rehabilitation works and protection to:

- Address in-stream geomorphic processes that lead to increased risk of instability;
- Address weed issues;
- Protect and enhance the riparian zone; and
- Protect and enhance the ecological health of the creek and its tributaries.

The following methods are proposed for the achieving these requirements. Rehabilitation sites were prioritised based on the calculation of each site's regeneration potential and threat score derived from the results of the site assessment. The regeneration potential is the score designed to reflect a remnant area's resilience or ability to recover to a stable self sustaining state from a degraded state given that active threatening processes are controlled. This can be expressed as:

Regeneration Potential (%) = (Bed Condition + Bank Stability + Weed Cover + Density + Diversity + Vegetation Community Age + Threats + Width + Connectivity Riparian + Connectivity Adjacent + Access for Rehabilitation) / 110 x 100.

Regeneration potential is derived using the sum of the eleven scores given for the ranking assessment parameters, expressed as a percentage. The lowest percentages reflect sites with the lowest regeneration potential, and the highest percentages reflect sites with the highest regeneration potential.

Threats may inhibit a site's ability to regenerate. If a site's regeneration score exceeds the threat score it is more likely to require less effort to regenerate than a site where the threat score greatly exceeds the regeneration potential.

The individual sites have been scored using the methods described above, and the results tabulated below (Table 8-1). The results divide the creek into high to low priority sites with respect to rehabilitation works based on a percentage score. The % score indicates the regeneration potential but this can be interpreted in a number of ways. A low percentage score or regeneration potential may in fact be a priority site as the need to implement rehabilitation at these locations is obviously needed. Whereas high regeneration potential scores are either more intact or have some degree of existing management. This is evident with the Stanley Park and Bowral St – Shepherd St sites where Bushcare activities occur, increasing the regeneration potential score of the site. Access for Rehabilitation can also skew results, elevating rehabilitation potential scores however these scores can be easily assessed on site and do not really influence a sites ecological rehabilitation potential

Council will need to assess each site on its merit with the above in mind to determine where funds are best spent. Council also need to look at the creek as whole as certain management activities need to be undertaken along the entire length of the creek and within the catchment. As an example, although several sites have low recovery potential scores there are high priority management activities that need to occur within them. The removal of Willows will be noted as a priority action regardless of a sites recovery potential. These priority actions needing to occur along the whole of the subject site are listed in Table 13-1.

Another limitation of the RAMS method is that it does not consider the social context when ranking regeneration potential. This is evident when looking at individual sites associated with the pedestrian walkway and Cherry Tree Walk. Some of these sites exhibit low regeneration potential compared to sites downstream of Mittagong Rd. From an ecological perspective this seems appropriate but from a social perspective, when

the Cherry Tree Walk and pedestrian path are used daily by many, funds may be more appropriately spent in these high use, high visibility areas.

Council will need to reconcile these points when implementing the actions to follow in this report and firmly establish and document a protocol for decisions around riparian management and expenditure.

TABLE 8-1: RANKING OF SITES – SECTION 1

Non-ranking Assessment Parameters								Ranking Assessment* Parameters Scores (1 – 10)											Total
Site	Location	Photo Numbers	Approx. Section Length (m)	Dom Terrestrial Weed	Dom Aquatic Weed	Dom Threat Type	Curr Adj Land Use	Bed Cond	Bank Stability	Weed Cover	Density (veg)	Diversity (trees, shrubs, forbs)	Veg Comm Age	Threats	Width (rip veg)	Connectivity riparian	Connectivity adj	Access for rehab	% Regeneration Potential
1	Old South Rd – Canal	301-317	1100	-Pastural grasses	-Typha -Willow -Unidentified deciduous exotic	-Grazing -Stock -Weeds -In-stream trees	-Grazing	5	3	1	5	4	1	6	1	1	1	10	33%
2	Canal	318-322	300	-Pastural grasses	-Typha	-Channel blockage	-Grazing -Public open space	6	9	1	5	1	1	3	1	1	1	10	35%
2	Canal – Stanley Park foot bridge	323-330	310	-Pastural grasses -Privet -Willow	-Typha	-Erosion -Bank Slumping -Slugs -In-stream trees	-Grazing -Public open space -residential	6	1	1	5	1	1	1	2	1	1	10	27%
2	Stanley Park	331	290	-Pastural grasses -Privet -Willow	-Typha	-Weeds	-Public open space -residential	7	7	5	5	5	5	5	2	4	1	10	51%
3	Bowral St – Shepherd St	332-341	450	-Vinca -Ivy -Honeysuckle -Blackberry -Privet	-Typha	-Bank stability -Weeds -Slugs	-Public open space -residential	6	7	3	6	5	5	6	1	7	3	8	52%

Non-ranking Assessment Parameters								Ranking Assessment* Parameters Scores (1 – 10)											Total
Site	Location	Photo Numbers	Approx . Section Length (m)	Dom Terrestrial Weed	Dom Aquatic Weed	Dom Threat Type	Curr Adj Land Use	Bed Cond	Bank Stability	Weed Cover	Density (veg)	Diversity (trees, shrubs, forbs)	Veg Comm Age	Threats	Width (rip veg)	Connectivity riparian	Connectivity adj	Access for rehab	% Regeneration Potential
4	Shepherd St – Merrigang St	342-348	220	-Pastural grasses	-Typha -Phragmites	-Slugs	-Public open space	3	7	8	7	6	5	7	2	7	3	8	57%
4	Merrigang St – Victoria St	349-352	260	-Vinca -Ivy -Honeysuckle	Typha	Weeds	-Residential -Public open space	3	1	2	5	1	1	6	1	1	1	10	29%
5	Victoria St – Mittagong Road	354-365	475	-Vinca -Ivy -Honeysuckle -Blackberry -Privet	-Typha -Ranunculus	-Weeds -Bank Erosion -Slugs	-Residential -Public open space	3	3	2	4	2	1	7	1	1	1	10	32%

TABLE 8-2: RANKING OF SITES – SECTION 2

Non-ranking Assessment Parameters								Ranking Assessment* Parameters Scores (1 – 10)											Total
Site	Location	Photo Numbers	Approx. Section Length (m)	Dom Terrestrial Weed	Dom Aquatic Weed	Dom Threat Type	Curr Adj Land Use	Bed Cond	Bank Stability	Weed Cover	Density (veg)	Diversity (trees, shrubs, forbs)	Veg Comm Age	Threats	Width (rip veg)	Connectivity riparian	Connectivity adj	Access for rehab	% Regeneration Potential
6	Northern tributary		620	-Privet -Blackberry -Grasses -Jap. Honeysuckle -Vinca	-Typha	-Erosion -Weeds	-Residential -Public open space	3	3	2	6	3	5	3	4	6	4	5	40%
7	Mittagong Rd- Mount Rd	366-369	425	-Privet -Blackberry	-Typha	-Erosion -Weeds -Slugs	-Grazing	3	3	4	5	3	5	3	2	7	2	7	40%
8	Mount Rd – Willow Rd	370-378	520	-Privet -Blackberry -Grasses	-Typha	-Erosion -Weeds -Slugs	-Grazing -Industrial	3	4	2	4	3	5	3	2	5	2	8	37%
9	Willow Rd – Oxley Hill Rd	379-385	780	-Privet -Blackberry -Grasses	-Typha	-Erosion -Weeds -Slugs	-Grazing -Industrial	4	5	2	7	3	6	3	2	7	2	3	40%
10	Oxley Hill Rd – Start of Quarry		440	-Blackberry -Grasses	-Typha	-Weeds	-Industrial -Horticulture	7	9	2	5	2	2	7	3	7	2	8	49%
10	Start of Quarry - STP	386	610	-Blackberry -Grasses -Willow	-Typha	-Weeds	-Grazing -Horticulture -Open Space	8	9	4	4	3	2	6	5	6	4	8	49%

9. Riparian Zone

9.1 Role of Vegetation

The role of riparian vegetation in ecological and environmental restoration is well documented. A well developed and structured riparian zone is critical in providing physical assistance to restoration in the form of providing and enhancing bank stability and protection (Abernathy & Rutherford 1999; Lovett & Price 1999). Riparian vegetation also aids in reducing solar heating of a waterway and in the case of a forested riparian zone, cooling of soil water and shallow groundwater through evapo-transpiration (Tabacchi *et al.* 1998). Other benefits developed over the longer term include an increase in the carbon supplies and enhanced nutrient cycling in the riverine zone (Marsh *et al.* 2005).

The Plan will serve to achieve the desirable outcomes of enhanced riparian vegetation. The planted riparian zone will be integrated with existing, desirable riparian species and further protect species of significance. In all instances the riparian enhancement will be a multi-tiered approach, with species composition, complexity, density and structure reflecting, where possible, species indigenous to the area.

9.2 Riparian Buffer Zones

A Water Quality Buffer is an area of the riparian vegetation parallel to the waterway that is planted with the aim of improving water quality by removing sediment and sequestering nutrients and other pollutants from overland flow, while increasing the stability of the creek banks. Four types of Water Quality Buffers are discussed further in this plan; grass buffer strips, pioneer species planting, structural reconstruction and designed landscape response. A conceptual image contrasting the existing degraded condition and a revegetated Water Quality Buffer is provided in Figures 12.1 – 12.4.

Areas classified as 'Low' recovery potential are generally not likely to be prioritised for restoration due to the poor quality of the vegetation and significant investment required; however these areas can be maintained as a Water Quality Buffer which will provide direct improvements to water quality while increasing the area of riparian vegetation at less cost than full ecological restoration. This as an important component of achieving long term water quality objectives for the riparian zone. In general, buffers protect a system component from the effects of change within another part of the same or an adjoining system. Riparian buffer zones are very

Water Quality Buffers are a cost effective solution for low priority ecological zones ('Low recovery potential'), where poor water quality associated with landuse is a significant challenge.

The vegetation structure required to deliver water quality outcomes is much simpler than that required for full ecological restoration.

Water Quality Buffers attempt to improve the condition of land that may otherwise not be prioritised for any form of restoration.

important for a number of reasons: they often contain diverse vegetation communities which provide a habitat heterogeneity for terrestrial and semi-aquatic organisms; they can influence water flow, both surface and subsurface, thereby improving water quality; they provide shade, which in turn helps control water temperature, algal growth and provides cover for aquatic species; they are a source of leaf matter for foraging, and woody debris for habitat; they increase bank stability; and they provide corridors for movement of native fauna and flora between geographically separate areas. Riparian zones can also act as a buffer to noise and light pollution from nearby roads or urbanized regions.

The effectiveness of a riparian buffer at achieving each of the abovementioned functions varies depending on several key factors, namely bank slope, vegetation species composition and age, and sediment type (Parkyn, 2004). Slope gradient appears to be the most important variable in removal of sediment or particulate pollutants, whereas buffer width is most important for the effective removal of dissolved nutrients (Parkyn, 2004).

Riparian buffers comprising grassed buffer strips (referred to as vegetated filter strips) are effective at trapping sediments and nutrients adsorbed to sediments (such as phosphorus), but tend to be relatively poor at trapping dissolved nutrients, or for the provision of shade, food sources, in-stream structure or corridors for many species (Parkyn, 2004). Riparian buffers comprising taller, woody vegetation are typically good at;

- providing shade,
- as a source of food and woody habitats,
- as a screen for light and noise,
- as corridors for terrestrial fauna (to a varying extent depending on species composition), and
- as a means for reducing soluble nutrient inputs.

Designed riparian buffers often incorporate multi-tiered systems of both native woody vegetation to enhance ecological function, and vegetated filter strip for the management of water quality. In essence, this approach seeks to mimic the complexity and effectiveness of a natural riparian buffer system, and often the best approach is to provide the required buffer width to enable a self-sustaining buffer of native vegetation (Parkyn, 2004).

It is difficult to derive a general 'rule of thumb' regarding buffer width, as this will vary depending on the desired functions of the buffer, volume of water and sediment being transported, and vegetation composition. Whilst a 5-10m vegetated filter strip buffer may be adequate for removing the majority of sediment and adsorbed nutrients, it has been shown to be insufficient for removing soluble nutrients (Parkyn, 2004), and would likely serve limited ecological value. A combination of 10m of grass buffer and 10m of natural vegetation adjacent to the stream has been recommended as effective in many Australian situations from a water quality perspective, (Land and Water, 2004). When the objective is the protection and enhancement of bank stability, riparian buffer width should be determined by the height and steepness of the eroding bank

profile; the higher and steeper the bank the greater the width of the protective buffer (Abernathy & Rutherford 1999). However the minimum width requirement to achieve some level of enhanced bank stability and protection is five meters (Abernathy & Rutherford 1999).

All of these factors must be balanced by existing and potential site constraints at the location of the restoration activities. Due to a number of site constraints along the creek, ideal widths of the riparian revegetation zone will not always be achievable, however the five (5) meter minimum width (from the toe of bank) will be achieved in the majority of cases and where possible, consistent with the “Regional Wildlife Habitat Corridor” a 10m minimum riparian buffer should be aspired to.

This project also involves in-stream protection works, specifically boulders and root wads. These additional in-stream works will serve to supplement the riparian restoration in areas where the width may be less than desirable. In locations where the Cherry Tree Walk or any other feature limits a continuous buffer, plant up to the edge of the path or feature and beyond if appropriate.

10. Habitat Protection and Creation

10.1 The role of large woody debris

Large Woody Debris (LWD) is a natural feature of all river systems. The creation of LWD in river systems forms as a result of overhanging trees dying or through destabilisation via natural erosion or channel avulsion. These dead or destabilised trees fall into the adjacent watercourse and are an important feature of natural streams. LWD is responsible for the creation of habitat, increasing channel roughness and reducing near bank velocities (Washington 2002, Lovett & Price 1999). LWD has historically been removed from watercourses because of its mistaken implication in increasing flooding (BCC 2003, Washington 2002, Lovett & Price 1999) and because of a reduction in the navigability of a watercourse (Washington 2002).

In revegetation or bank stabilisation projects the addition of LWD has been shown to enhance other bank stabilisation techniques, such as rock groynes and walls. It performs this roll directly, by reducing near bank velocities and by aiding in the creation of a depositional environment and indirectly by enhancing the fully and semi aquatic habitat that would otherwise be left deficient if rock structures alone were used (Washington 2002).

Wood should be oriented to capture additional woody debris and, if possible with a portion of the wad above the flood flow level. This aids in the capture of additional debris at times of flood when debris transport is greatest (Washington 2002). Where possible positioning LWD in a variety of orientations to the flow; i.e parallel, perpendicular, angled will lead to a greater variety of habitats; i.e pools, bars or islands surrounding the LWD (Lovett & Price 1999, Rutherford *et al.* 1999)

No fixed rule seems to have been adopted by all practitioners in relation to the amount and type of wood used for LWD structures. However it is generally accepted that the amount of LWD placed should reflect what would be observed in that system naturally. Two manuals suggest that if that data is unavailable the amount of LWD should be 0.01m³ for every 1m² of channel bed (Price & Lovett 1999, Rutherford *et al.* 1999). With respect to the wood used; it should, wherever possible be of the same species that would make up the LWD naturally and of a density to ensure a longevity of many years (Price & Lovett 1999, Rutherford *et al.* 1999, Washington 2002). Weed species, particularly willows should never be used because of the ability of these species to regenerate and reinfest (Price & Lovett 1999) decay rapidly and are unsuitable for invertebrate and biofilm colonisation (Rutherford *et al.* 1999).

The concept design drawings, drawing set AWC 3-11062-1 to 14, illustrate that the LWD used in this stabilisation project will be positioned so as to enable capturing of additional LWD. The variety of orientations, while generally parallel to the flow, will ensure a variety of Instream habitats forming around the LWD.

Every attempt will be made to preserve existing LWD. If the progress of the works must disturb this existing LWD it will be removed, preserved and incorporated it into the rehabilitation works where possible.

11. Riparian Management

11.1 Managing Vegetation – Weeds and Natives

Native vegetation will be managed by enhancing the existing desirable species on-site. While revegetation will focus on a dense community of plants the preliminary species nominated within the drawings are a combination of vegetation observed during site visits and species used successfully on previous projects. To the greatest extent practical, preference should be given to the use of local provenance plant material, which in this context would mean as close to site as possible, or at least from the Mittagong Creek catchment.

In a bio-engineering response to stream erosion, vegetation plays an integral role in the sites long-term stability, by binding soils and limiting erosion; enabling succession in large trees to mature then fall into the water; and to provide food sources and shelter for aquatic and terrestrial fauna.

Weeds have a variety of significant impacts, affecting not only the environment but also the economy and social values. They are an important factor that needs to be controlled during the restoration and stabilisation process.

The success of one technique over another for control can vary significantly depending on a variety of factors, including:

- the size of the standing population or level of infestation;
- time constraints imposed on the management regime;
- the constraints of the surrounding environment or the site; and

- the proximity of populations that can re-establish a site.

On-going success in weed management requires a detailed understanding of the target species, with a focus on factors such as:

- life history;
- fecundity or size of seed bank; and
- dispersal mechanisms.

There is a need to undertake weed control in a staged manner. Whilst undesirable, many of the weed species provide shelter and food, and contribute to corridors for wildlife. Care must be taken to ensure that the environmental benefits provided by adult trees are retained until the native revegetation is able to replace these functions. A detailed weed assessment is needed to ascertain if native fauna are using weed species as habitat and if so careful consideration of a staged weed removal and replacement will have to be considered.

The planting densities nominated in the concept design drawings are focussed on providing a dense cover at all revegetation layers. A dense ground cover layer is a useful, passive strategy for crowding out and preventing the establishment weed species (BCC 2003).

12. Restoration of Native Vegetation

Management responses for the rehabilitation of native vegetation will vary according to the condition of the subject site and types of weeds and other pressures being managed. For the purpose of this plan two primary types of weed control are assumed under the broader term of bushland regeneration – assisted regeneration and reconstruction.

Assisted regeneration of riparian buffers assumes appropriately qualified bushland regenerators or restoration practitioners employing recognised strategic weed control methods within remnant native vegetation with a high recovery potential. The purpose is to guide a site's ecological trajectory to recovery via strategic weed control methods and stimulating seed banks. Planting is generally not a part of assisted natural regeneration and would only be in response to observations made around vegetation structure and species representation over time.

The assumed weed control management within assisted regeneration areas would involve works being undertaken over a 12 month to 36 month period with a sequence of works likely to include:

- 0 – 6 months – preliminary/primary weed control
- 6 – 12 months – follow up weed control
- 12 – 36 months – maintenance weed control

Maintenance does not necessarily end after 36 months. The aim is to get the site to a level of minimal maintenance. Some sites will require maintenance in perpetuity, perhaps being treated once or twice per annum.

12.1.1 Structural weeds

The most commonly encountered weeds along the creek are Willow, Privet, Blackberry, *Vinca major* and Pastural grasses. Each of these weeds impacts on riparian rehabilitation as they form a structural component of the riparian vegetation.

Vines

Vines are particularly invasive plants. They are destructive, prolific and persistent, often able to adapt to a vast range of soils and conditions and difficult to control. Identified along the creek during site investigations as part of the study's rapid riparian vegetation assessment, three weeds of major significance present in the catchment are Ivy (*Hedera helix*), Honeysuckle (*Lonicera japonica*) and Blue Periwinkle (*Vinca major*). Control of invasive vine weed species is recommended throughout the remnant vegetation of the riparian zone as part of a coordinated approach to weed management between landowners.

Canopy Weeds

Planning for removal of canopy weed trees requires consideration of the role of the tree in riparian stabilisation framework. The riparian canopy consists of trees between 5m and 30m. Root systems of riparian trees are a central dense root mass about five times the diameter of the trunk. The root system provides the framework for the physical strength of the bank. The tree roots hold the bank together, facilitate drainage through the bank and prevent water logging and slumping.

The major canopy weed of riparian zone is Willow (*Salix spp.*). Willow is considered one of the twenty worst weeds (<http://www.environment.gov.au/land/publications/pubs/bush-may04-article-5.pdf>). These weedy trees are dominant species often forming monocultures on creek banks. Where no other species are assisting in bank stabilisation and the vegetation zone is narrow, the bank can eventually become unstable from deep undercutting and the tree falls into the water. Although serious degradation is caused the trees still provide riparian function which needs to be considered in weed control programs. They provide shade on the waterway, reducing water temperature and provides limited canopy habitat for fauna. A program of staged removal and replacement is the best approach to management.

Midstorey

The major mid-storey weed is Small-leaved Privet (*Ligustrum sinense*). Although midstorey weeds provide shelter and shade on the waterway and may provide bank stabilisation functions, they also compete with less vigorous native seedlings and block their regeneration.

Understorey

Weeds such as Paspalum, *Vinca major* and Blackberry are dominant in the riparian understorey. Understorey weeds in riparian zones block regeneration of native seedlings through competition but they also contain bank sediments during flood events. Understorey weeds also inhibit natural litter cycling and reduce habitat for reptiles and amphibians. Removal of understorey weeds is essential to reinstate riparian function, but consideration of the erosion potential following weed removal is required.

Aquatic weeds

The most significant aquatic weed is *Typha* in the slow flowing, sedimentation zones. While an Australian native, *Typha* in this situation is by definition a weed. It is reducing the hydraulic capacity of the creek, effectively damming large sections of the channel. It is however providing a water quality function trapping nutrients and sediments. The return of a functional riparian canopy will reduce the cover of this weed through shading of the water way in certain locations i.e. through urban areas but *Typha* could be retained in the constructed channel to provide an effective water quality improvement function.

Weed specific programs on a catchment basis are required to deal with more serious aquatic weeds. These programs follow an integrated approach of chemical control, follow up and revegetation.

12.2 Riparian Buffer Options

Riparian Buffer options could include one or a combination of many treatments ranging from fencing an ephemeral lateral gully and undertaking seasonal weed control to a possible end goal of full ecological restoration. Options include:

- fencing + weed management
- fencing + grass buffer strip + weed management
- fencing + pioneer planting + weed management
- fencing + eventual ecological restoration
- natural assisted regeneration

12.2.1 Fencing

Uncontrolled use of riparian lands around the main channel and ephemeral lateral gullies by stock can contribute greatly to the amount of sediment, nutrients and animal wastes moving into the creek. In addition, uncontrolled access can lead to excessive run-off, bank erosion, loss of productive land, decline in important wildlife habitat and damage to in-stream

ecosystems. As domestic stock favour riparian frontages and low-lying gullies, these areas can become over-grazed, eroding the bank soils allowing weed invasion and eroding stock tracks which result in increased sediment, nutrients and animal wastes being washed into the main creek channel.

The simplest way of regulating stock access to riparian land is to fence the area between the lateral gully and/or the creek and the rest of the property. Riparian fencing requires careful planning as flooding is a potential threat to conventional fence lines. There are several alternative fence options including hanging fences, electric fences and drop fences.

12.2.2 Weed Management

Once an area is fenced off, it will require maintenance to prevent weed invasion. The maintenance of Water Quality Buffers will be required several times each year, however with water quality as a primary objective, it

The fencing and planting of a grass buffer strip could be seen as the first stage of improving riparian vegetation throughout the catchment. A progressive goal could be full ecological restoration should landowner interest be forthcoming in subsequent years.

is seen as acceptable that these buffers may receive a reduced level of maintenance without compromising their key function. Weed control may range from slashing periodically or allowing seasonal grazing within a grass buffer, through to routine assisted regeneration of reconstructed areas such as spot spraying and hand weeding. Although some of these options are not consistent with best practice management bushland regeneration, we recommend this as a compromise, if necessary, that upholds the principle that some vegetation cover is more beneficial to the health of the creek than none, particularly as the Water Quality Buffer could be viewed as Stage 1 of further ecological restoration.

While undertaking weed control, erosion needs to be managed by maintaining some vegetation cover to avoid exposed soils along ephemeral drainage lines and on the banks of the creek. Retaining some vegetation cover should also prevent an increase in weed species.

Follow up maintenance is an integral part of regeneration and needs to be funded as part of the initial planning for each site. Any follow up works requiring more highly skilled regenerators will require funding for professional contractors or trained Council staff.

12.2.3 Grass Buffer Strip

Grass buffer strips should to be established and maintained along landscape depressions where overland flow concentrates and enters small channels or gullies to reduce sediment and nutrients entering the creek. The aim is for a broad, well-grassed strip covering the entire area of flow concentration if possible, to protect against times of heavier rainfall. Eg.



It is important to keep livestock out and to maintain the buffer to ensure there is almost complete ground cover and a good height of vegetation (grasses should be at least 10-15 cm) to maximise the capacity for sediment and nutrient entrapment. The ideal width and management practice for grass buffer strips depends on the volumes of water and sediment being transported and the nature of the adjacent landscape, however it is generally recommended that an ideal combination of 10m of grass buffer and 10m of natural vegetation

adjacent to a stream will be effective in most situations (Prosser and Karssies, 2001). Width will be subject to landowner negotiation, however between 10m and 20m is recommended.

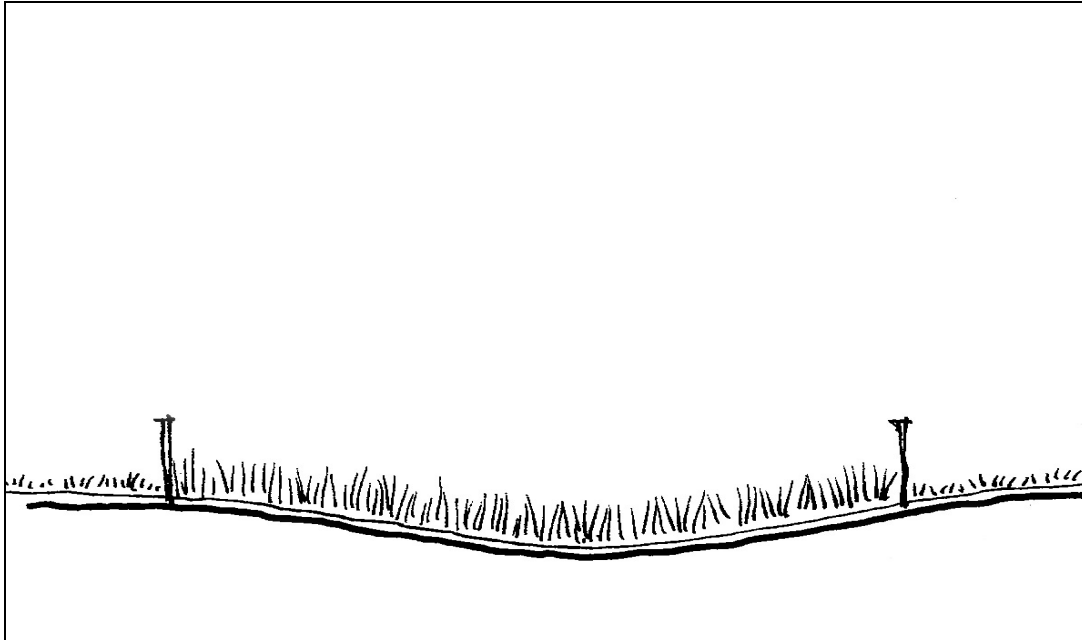


figure 12-1. Grass buffer strips trap sediment and protect the ephemeral gully and main creek channel from sediment, nutrients and animal wastes. (Australian Wetlands, 2008).

12.2.4 Pioneer Planting

Pioneer planting is a thick density of fast-establishing pioneer riparian species that will quickly encourage soil binding and canopy shade to deter weed infestation. This is likely to include species such as Acacias, Eucalypts, and Casuarina but will not be particularly structurally complex or have high species richness.

The primary aim of the planting is to improve water quality, however this style of planting has potential additional value a woodlot or carbon sink without its water quality function being compromised. Similar to grass buffers, it is recommended that this planting type be at least 5m wide and be situated to ensure that ephemeral and overland flow paths are intercepted.

Establishment of this buffer would involve fencing to exclude livestock, slashing and spraying of pasture grass, planting of appropriate native species at a density of between one and two tubestock per square metre, initial watering and periodic follow up weeding until the native plants are sufficiently established to suppress weed growth.

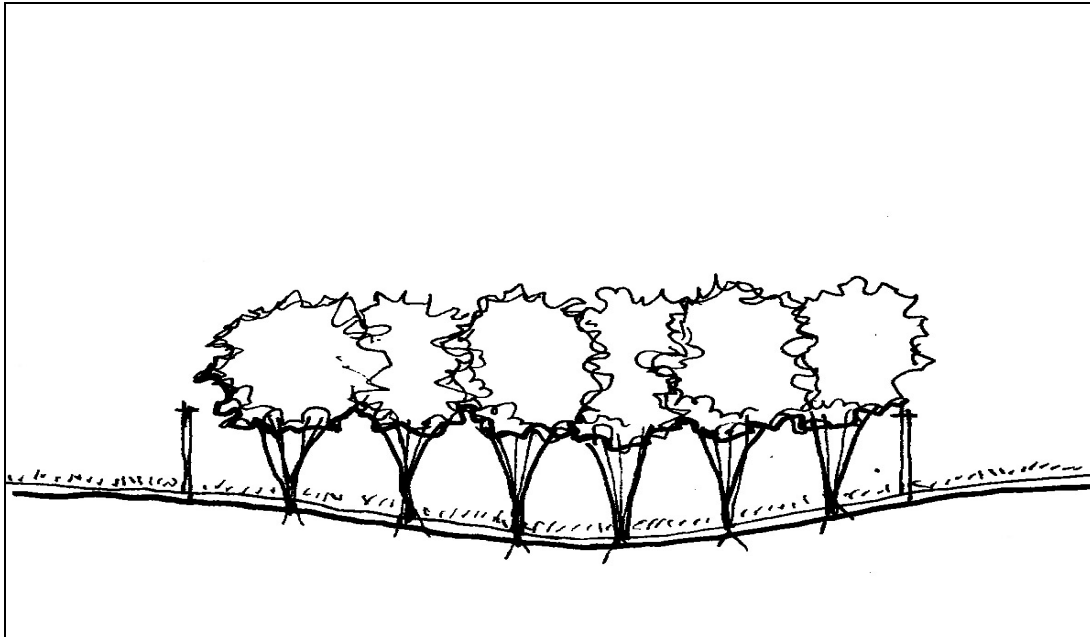


Figure 12-2. Conceptual image of pioneer planting (Australian Wetlands, 2008).

12.2.5 Structural Planting / Reconstruction

In areas where native vegetation is so degraded that assisted natural regeneration or rehabilitation alone is unlikely to be successful, reconstruction of native vegetation will be required. This would apply where weed cover is greater than 70% of a site, native seed banks are poor, species diversity is very low and vegetation community structure is poor to non-existent.

Consistent with the definition of reconstruction, this option involves a wholesale reinstatement of the original vegetation community. The aim of reconstruction will be to recreate the system that would occur naturally onsite by planting a range of species such as native grasses, reeds, and shrubs on the lower parts of the bank and shrubs and small trees higher up the bank to recreate a more natural vegetation structure (Figure 12.3). Local native plant species, i.e. plants that are indigenous or commonly found, occurring naturally within the Wingecarribee region (including trees, shrubs, herbs and grasses) are to be used.

This type of reconstruction could be seen as a progressive goal on suitable riparian land. The initial fencing and planting of a grass buffer strip could be seen as the first stage of improving water quality buffers.

Restoration in this context would involve primary weeding using techniques such as cutting and painting or drilling and injecting woody weeds, spraying of herbicides and scraping and painting canopy weeds such as vines. Beyond this primary weeding phase, secondary weeding will be required, possibly in combination with mulching or brush matting of exposed soils.

Planting of appropriate native species is required to recreate the site's original vegetation community with respect to species and composition. Follow up weed control and then maintenance weed control over a two to three year period is assumed to be required.

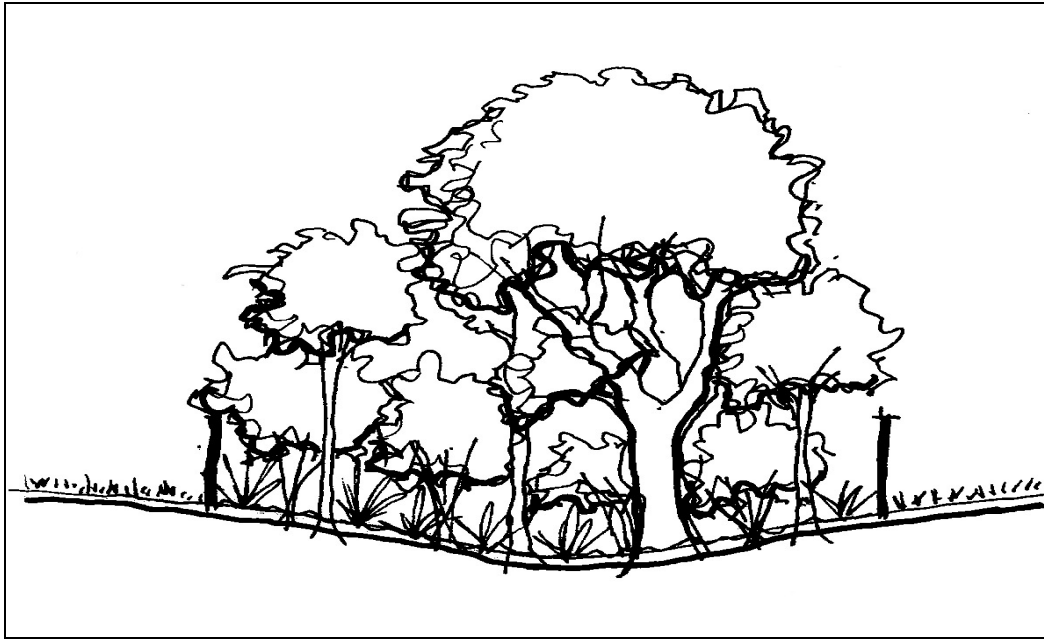


Figure 12-3. Conceptual image of structural reconstruction (Australian Wetlands, 2008).





Figure 12-4. Conceptual image of riparian water quality buffer indicating existing degraded condition (above) and revegetated riparian water quality buffer (below). (Australian Wetlands, 2008).

12.2.6 Designed Landscape

A designed landscape response is likely to occur in more residential areas where visual aesthetic plays a more important role due high use and / or proximity to existing community assets such as parks, walkways, play grounds etc. These areas have an existing landscape character and any riparian works need to be sympathetic of this. Rather than trying to recreate a full riparian community the designed landscape should take cues from the surrounding landscape and enhance existing plantings, views and amenity.

Plants used in the designed landscape response are to be native species used in a way that complements existing plantings. Ground covers are to be planted in dense, mass plantings providing swathes of foliage and colour. Shrubs should be limited in number to maintain views to the creek and be planted in groups. Shrubs should also be chosen for their flower and placed accordingly. Canopy trees are important to provide connectivity along the creek line in the absence of a fully stratified vegetation community and to shade the creek line itself. Trees should be located so that at maturity the canopies touch but also so that the canopies do not interfere with existing, significant plantings along the Cherry Tree Walk.

13. Actions

13.1 Priority Actions

The following Priority Actions are not site specific but are required when viewing the site in its entirety from a Water Quality, Sedimentation and Biodiversity perspective. These actions are not to be viewed in isolation and should be read in conjunction with previously completed and adopted management plans where applicable. Refer to Section 4.2 Local Strategies and Plans for a list of relevant strategies and plans. The priority actions have been developed with the use of the RAMS site assessment to generate priority actions and visual identification of issues not specifically identified in the RAMS assessment. The following Chapter and Design drawings offer site specific plans to address more specific actions to be adopted along the creek line.

The results of investigations detailed within the plan, combined with the strategies culminate in an action table below.

Actions have been assigned priority based on the severity of the threat the action addresses and the cost of implementing the action. Performance targets within the table have, to the greatest extent possible, been made specific and measurable as well as the recommended course of action to pursue this target detailed. Cost estimates are derived from established commercial rates.

1. Immediate/High. These actions should be implemented within the first year.
2. Medium. These actions should be implemented within five years.
3. Long Term. These actions should be considered as achievable within ten+ years.

TABLE 13-1: PRIORITY ACTIONS

Action/ Recommendation	Priority	Recommended Outcome	Costs
Water Quality			
Audit existing Stormwater Quality Improvement Devices (SQIDS) within the sub-catchment to make recommendations for their repair, upgrade, maintenance or decommission.	Medium	Audit completed to enable and update of Council's stormwater asset inventory by mid 2012.	\$20,000-\$30,000
As part of an audit identify water quality hotspots and conduct feasibility investigations for retrofitting existing devices and commissioning new devices.	Immediate/ High	Investigation to be undertaken by mid 2012.	Included above.
Complete detailed designs of high priority SQIDS consistent with best practice WSUD.	Medium	Briefs are prepared for detailed design work which can be completed either internally or by contractors by mid 2012.	\$15,000-\$35,000 per device
Investigate opportunities for source control of stormwater run-off and pollution associated with industrial areas west of Mittagong Rd	Medium/High	Commence negotiations with key land-holders around point-source stormwater management and harvesting in mid 2012.	\$5,000-\$10,000 per site
Evaluate existing stormwater outlets to determine if GPTs and/ or Bioretention Filters are required.	Medium/High	Complete preliminary investigation by mid-2012.	\$25,000-\$45,000
Investigate opportunities to create inline treatment devices such as wetlands, vegetated swales and bio-retention swales in existing open	Medium/High	Complete preliminary investigation by mid to late 2012	\$35,000

Action/ Recommendation	Priority	Recommended Outcome	Costs
drainage network			
Investigate opportunities for streetscape retrofit of SQUIDs Strategies might include stormwater harvesting, trash racks and biopods. Engage with landholders to try and establish public/private partnerships	Medium	Complete preliminary investigation by early 2013	\$15,000
Commission a feasibility study on the flood mitigation, water quality wetlands and improved Biodiversity potential in the open space area upstream of Stanley Park and to the south of the constructed channel.	High	Commission a preliminary feasibility study by mid-2012.	\$35,000
Environmental Management			
Undertake detailed survey to inform future detailed design of degraded banks for the sections of creek between Merrigang and Victoria Street and for 100m downstream of the Mittagong Road culvert.	Immediate/ High	Complete survey by early 2012	\$15,000
Undertake survey and/or confirmation of property boundaries to determine extents of RE1 zoned lands adjacent to the creek line and private property.	High	Complete survey by early 2012	\$15,000
Co-ordinate Council GIS and Cadastre information with respect to creek flow path	High	Complete survey by early 2012	
Removal of all Willows along the subject site particularly Old South Road through to Bowral St via Stanley Park, and downstream of Willow Road	Immediate/ High	Removal of existing trees and the continued monitoring of occurrences to ensure ongoing control and removal	\$25,000
Enforcement and Compliance			
Enforce the protection of riparian vegetation in all new developments.	High	Review policies relating to riparian buffer zones by mid	N/A

Action/ Recommendation	Priority	Recommended Outcome	Costs
Develop and implement site specific plans for the extension of riparian buffer widths in association with the development process.		2012.	
Best management practices in stormwater management to be included in all new developments.	High	Condition the demonstrated performance of stormwater management measures as part of the defect liability period.	N/A
Build capacity within Council planning and compliance staff to review the design and construction of WSUD devices.	High	Develop and increase expertise of around WSUD within Council staff through attendance at relevant training courses. Have at least two WSUD specialists within Council by end of 2012.	\$700 per training course (approx.)
Education			
Establish demonstration sites throughout the catchment providing examples of best practice riparian management	Medium	Identify in consultation with relevant stakeholder suitable demonstration sites. Establish demonstration sites by late 2012.	N/A
Continue to provide weed management information to the community, targeting weed identification, removal techniques, alternative replacement with native species, impacts of dumping garden waste in bushland etc.	High	Review and update weed education initiatives by mid 2012.	\$3,000
Raise awareness and understanding of aquatic weeds and appropriate control.	High	Review and update weed education initiatives by mid 2012.	\$3,000
Work with land holders to create buffer along creeks and drainage lines for habitat create and improvement of water quality.	High	Fund or continue to fund work with landholders.	As required and as funding becomes available

13.2 Site Specific Actions

The following actions are site specific and should be read in conjunction with detailed drawing set 1-11032-1-14 (Appendix A and B).

Section 1 Old South Road – Mittagong Road

Site 1:

Old South Road – Bowral Street – Intersection with Constructed Channel. Drawing 3-11062-3

TREATMENT

- Remove all Willows from near and around creek line;
- Remove old unused bridge;
- Establish boundaries of 10m wide Pioneer Planting zone and 10m wide grass buffer zone each side of creek line;
- Establish fencing to outside edge of grass buffer to keep stock out of buffer zone and creek line;
- Establish bank protection using LWD, rocks or branch bundles around in stream obstacles (existing trees) to prevent bank scour;
- Remove woody weeds from creek line and use as branch bundles;
- Establish pioneer plant species along entire reach
- Stabilise and regrade banks to 2H:1V as required

Site 2:

Bowral Street – via Stanley Park and Constructed channel. Drawing 3-11062-4

TREATMENT

- Remove all Willows from near and around creek line;
- Remove excavated stream material from the top of bank to reconnect the stream with the surrounding landscape'
- Establish boundaries of 10m wide Pioneer Planting zone and 10m wide grass buffer zone each side of creek line;
- Undertake riparian reconstruction works;
- Establish fencing to outside edge of grass buffer to keep stock out of buffer zone and creek line;
- Establish bank protection using LWD, rocks or branch bundles around in stream obstacles (existing trees) to prevent bank scour;
- Remove woody weeds from creek line and use as branch bundles;
- Establish pioneer plant species along entire reach
- Stabilise and regrade banks to 2H:1V as required
- Plant tree canopy species along constructed channel to shade channel
- Undertake bank stabilisation works
- Undertake riparian reconstruction on Council and Private lands
- Undertake supplementary planting
- Continue and undertake weed control

Site 3:

Bowral Street – Shepherd Street. Drawing 3-11062-6

TREATMENT

- Undertake investigation of stormwater outlet near Bowral St;

- Establish boundaries of 5m min. Designed Landscape treatment to true left bank;
- Undertake weed removal and supplementary planting on true right – private lands;
- Remove woody weeds from creek line;
- Undertake supplementary planting ;
- Continue and undertake weed control;
- Place boulders in creek, as required where sediment slugs have formed.

Site 4:

Shepherd Street – Merrigang Street – Rose Street. Drawing 3-11062-6

TREATMENT

- Establish boundaries of 5m min. Designed Landscape treatment to both embankments;
- Establish/ extend riparian planting into park land on the true left of the creek
- Remove woody weeds from creek line;
- Undertake supplementary planting ;
- Continue and undertake weed control;
- Place boulders in creek, as required where sediment slugs have formed.
- Undertake investigation/ survey to allow detailed design of the creek line from Merrigang St through to Rose St. This area exhibits large exposed, vertical banks, erosion in close proximity to the Cherry Tree Walk and is adjacent to contaminated lands

Site 5:

Rose Street – Victoria Street. Drawing 3-11062-8

TREATMENT

- Establish boundaries of 5m min. Designed Landscape treatment to true right adjacent to Cherry Tree Walk;
- Establish full riparian reconstruction to the true left of the creek
- Remove woody weeds from creek line;
- Undertake supplementary planting ;
- Continue and undertake weed control;
- Place boulders in creek, as required where sediment slugs have formed;
- Create in-stream rock ribs in existing sediment benches to facilitate sediment movement

Victoria Street – Mittagong Road. Drawing 3-11062-8

TREATMENT

- Undertake investigation/ survey to allow detailed design of the creek line from **Victoria Street** as shown. This area exhibits large exposed, vertical banks, erosion in close proximity to the Cherry Tree Walk and is adjacent to significant specimen trees;
- Establish boundaries of 5m min. Designed Landscape treatment to both embankments;
- Remove woody weeds from creek line;
- Undertake supplementary planting ;
- Continue and undertake weed control;
- Place boulders in creek, as required where sediment slugs have formed.

Section 2 Mittagong Road – Sewage Treatment Works

Site 1:

Northern Tributary. Drawing 3-11062-9

TREATMENT

- Remove all Willows from near and around creek line;
- Establish boundaries of 10m wide Pioneer Planting zone and 10m wide grass buffer zone each side of creek line;
- Establish fencing to outside edge of grass buffer to keep stock out of buffer zone and creek line;
- Establish bank protection using LWD, rocks or branch bundles around in stream obstacles (existing trees) to prevent bank scour;
- Remove woody weeds from creek line and use as branch bundles;
- Undertake supplementary planting ;
- Stabilise and regrade banks to 2H:1V as required.

Site 2:

Centennial Road – Mount Road. Drawing 3-11062-10

TREATMENT

- Remove all Willows from near and around creek line;
- Selectively remove woody weeds;
- Establish boundaries of 10m wide Pioneer Planting zone and 10m wide grass buffer zone each side of creek line;
- Establish fencing to outside edge of grass buffer to keep stock out of buffer zone and creek line;
- Establish bank protection using LWD, rocks or branch bundles around in stream obstacles (existing trees) to prevent bank scour;
- Remove woody weeds from creek line and use as branch bundles;
- Establish pioneer plant species along entire reach;
- Undertake supplementary planting ;
- Place boulders in creek, as required where sediment slugs have formed;
- Stabilise and regrade banks to 2H:1V as required.

Site 3:

Mount Road – Willow Road. Drawing 3-11062-11

TREATMENT

- Remove all Willows from near and around creek line;
- Remove bunding to top of bank;
- Establish boundaries of 10m wide grass buffer zone;
- Undertake riparian reconstruction works;
- Establish fencing to outside edge of grass buffer to keep stock out of buffer zone and creek line;
- Establish bank protection using LWD, rocks or branch bundles around in stream obstacles (existing trees) to prevent bank scour;
- Remove woody weeds from creek line and use as branch bundles;
- Establish pioneer plant species along entire reach;
- Stabilise and regrade banks to 2H:1V as required;
- Undertake supplementary planting

- Continue and undertake weed control

Site 4:

Willow Road – Oxley Hill Road. Drawing 3-11062-12

TREATMENT

- Remove all Willows from near and around creek line;
- Selectively remove woody weeds;
- Establish boundaries of 10m wide Pioneer Planting zone and 10m wide grass buffer zone each side of creek line;
- Establish fencing to outside edge of grass buffer to keep stock out of buffer zone and creek line;
- Establish bank protection using LWD, rocks or branch bundles around in stream obstacles (existing trees) to prevent bank scour;
- Remove woody weeds from creek line and use as branch bundles;
- Establish pioneer plant species along entire reach;
- Undertake supplementary planting ;
- Place boulders in creek, as required where sediment slugs have formed;
- Stabilise and regrade banks to 2H:1V as required.

Site 5:

Oxley Hill Road – Sewage Treatment Plant. Drawing 3-11062-13-14

TREATMENT

- Remove all Willows from near and around creek line;
- Selectively remove woody weeds;
- Establish boundaries of 10m wide Pioneer Planting zone and 10m wide grass buffer zone each side of creek line;
- Establish fencing to outside edge of grass buffer to keep stock out of buffer zone and creek line;
- Establish bank protection using LWD, rocks or branch bundles around in stream obstacles (existing trees) to prevent bank scour;
- Remove woody weeds from creek line and use as branch bundles;
- Establish pioneer plant species along entire reach;
- Undertake supplementary planting ;
- Place boulders in creek, as required where sediment slugs have formed;
- Stabilise and regrade banks to 2H:1V as required.

14. Concept Design

This section contains a description of the proposed works and is intended to identify an appropriate detailed concept design via which revegetation, rehabilitation, sedimentation and bank erosion can be rectified. This section should be read in conjunction with the design drawing set by AWC with reference Revision A, 3-11062-1 to 3-11062-13 available at Appendix A.

14.1 Design Development

Consistent with the project brief issued by Council, this rehabilitation project aims to protect, restore and enhance riparian vegetation and habitat. Specific objectives for the work are:

- *To re-instate and stabilise the bank toe using a combination of large woody debris and rock*
- *To re-vegetate the lower, mid and upper bank with suitable native species*
- *To manage stormwater run-off in a manner that avoids erosive action to the riparian zone*

- *To improve the riparian buffer*
- *To improve the fish habitat values associated with the site*
- *To protect cultural heritage values*

These objectives informed the design development and resulted in a site sensitive bio-engineering response which uses to the greatest extent practical, local and/or renewable materials.

Key degrading impacts of weeds, erosion and sedimentation are addressed as part of the design. Fencing will limit stock access, vegetated buffer strips or swales proposed at various locations will control stormwater run-off and a combination of large woody debris, coir logs and rock will prevent bank erosion. Revegetation with appropriate native species will compliment these actions.

Final placement of structures and materials should be approved by the Designer, Project Ecologist or other suitably qualified practitioner.

14.2 Materials

To the greatest extent practical, the riparian works are to incorporate local and/or renewable construction materials. Key elements include:

- Large woody debris (LWD) for bank stabilisation and prevention erosion. This timber will be sourced from site and locally.
- Coir logs – are a biodegradable coconut fibre product which can be installed by hand and will be used in the same manner as LWD.
- Locally sourced rock will be used within drainage swales and within toe structures.
- Locally sourced native plant stock.

No steel or cement is to be used within the bank stabilisation works.

14.3 Creek Restoration Strategies

- Where possible dredging of the creek should be avoided unless to undertake stream restoration works.
- Improve bank toe stability with suitable selected indigenous riparian vegetation.
- Consolidated bank toes at specified locations with ecologically designed post and branch bundles or Coir Log. These structures will prevent bank collapse and significantly improve the overall geomorphic habitat structure of the creek. These structures will also enhance sediment transport and encourage sediment redistribution along bank toes.
- Create scour pools in the creek by strategically placing ecologically designed rock ribs and boulders. This will also enhance sediment transport through the reach. The proposed structures in low to moderate flows will also help to:
 - oxygenate the water;
 - reduce water stagnation; and
 - increase stream velocities.
- Provide extensive shade to the creek with suitable selected indigenous riparian vegetation. This will help to reduce and regulate water temperature in the creek. This will also significantly increase dissolved oxygen levels in summer months, improving water quality.

14.4 Creek Line Restoration Plan

- Separate creek line restoration plans have been developed for each creek section. These plans have been developed in order to address identified threats and implement creek restoration goals and strategies. A plan of each creek section (drawing) providing a view and the location of prescribed stream restoration treatments is also provided.

14.5 Bank Treatment

- All embankments are to be regraded to a slope of 2H:1V, juted and planted. In general the banks are stable with most of the required rehabilitation required occurring at the toe of the bank or in-stream. Not all of the site banks require regrading. Previous works in the area have provided stable embankments that require weeding and planting only.

- **Large Wood Debris (LWD/ Root Wads)**

Treatment Objectives

- To prevent bed sedimentation.
- To provide reinforcement to bank toe, bed and prevent scouring.
- To prevent sediment deposition significantly improving flood flow conveyance.
- To provide habitat for riparian vegetation and fauna.

Location of Treatments

- Treatments are located on the outside of bends along the site and opposite the outlet of contributory channels in rural settings

Construction Notes

- The primary consideration of the LWD is to reduce scouring and to prevent erosion migrating up the channel, not to stop it entirely.
- LWD or bundles of logs are aligned parallel to the stream bank. The spacing of LWD, ensure adjacent logs overlap. Ensure root of each log is upstream of trunk/ stem.
- LWD are made by placing into a trench excavated into the existing unconsolidated bank material. LWD - 300mm-500mm dia. are to be trenched/ pressed into the bank using the excavator and are to finish at the same height of the bank and are not to extend into the stream any further than the existing, unconsolidated material so as not to reduce the existing cross sectional area.
- Logs or bundles of logs are to be native, hardwood species.

- **Rock Revetment**

Treatment Objectives

- To prevent bed sedimentation.
- To provide reinforcement to bank toe, bed and prevent scouring.
- To prevent sediment deposition significantly improving flood flow conveyance.
- To provide habitat for riparian vegetation and fauna.

Location of Treatments

- Treatments are located on the outside of bends along the site and opposite the outlet of contributory channels where space is constrained by neighbouring property/ infrastructure/ paths etc

Construction Notes

- The primary consideration of rocks is to reduce scouring and to prevent erosion migrating up the channel, not to stop it entirely.
- Rocks are aligned parallel to the stream bank.
- Rocks are to be placed into a trench excavated into the existing unconsolidated bank material. 650mm dia. min. are to be trenched/ pressed into the bank using the excavator and are to finish at the same height of the bank and are not to extend into the stream any further than the existing, unconsolidated material so as not to reduce the existing cross sectional area.
- Large, angular, hard, boulders should be used that are not prone to shearing or fracturing.
- Rocks should be angular with the flattest side of the rock laid onto the streambed to prevent rocks from rolling or gliding away.

- **Post and Branch Bundles/ Brush Boxes or Coir Log**

Treatment Objectives

- To prevent bed sedimentation.
- To provide reinforcement to bank toe, bed and prevent scouring.
- To prevent sediment deposition significantly improving flood flow conveyance.
- To provide habitat for riparian vegetation and fauna.

Location of Treatments

- Treatments are located on the outside of bends along the site and opposite the outlet of contributory channels in rural settings for post and branch bundles or for Coir logs where space is limited or there are access issues or where detailed bank restoration is required.

Construction Notes

- 2m x 50mm x 50mm ground treated timber posts are to be driven into the creek bed at 1m intervals for the length of the treatment indicated in the plans. Posts are to be no more than 500mm from the edge of the existing bank.
- Only native species should be used providing there are no seed pods or flowers on the branches. Branches are to be 2-4m in length with a maximum diameter of 75mm and placed with butt ends orientated downstream. Stagger ends so that tips are evenly distributed along the length of the treatment.
- Compress branches and tie off to posts using high tensile 3mm wire. Drive posts further into creek bed to tighten wires and compress.
- Back fill with excavated site soils and compact heavily to prevent excessive erosion
- Coir logs are to be installed as per manufacturer's specifications
- Backfill behind coir logs and bundles with existing site material and plant with riparian species. Coir logs can have plants planted directly into them.

14.6 In-Stream Treatment

- **Boulders**
- Treatment Objectives
- Boulders create hydraulic diversity. As flow accelerates around boulders, scour pools are created and downstream bars are formed. This process facilitates the transport of sediment through the creek section, preventing net sediment deposition.
- Boulders create cover and substrate for macro-invertebrates and other aquatic fauna.
- The turbulence induced by the boulders aerates the water and will improve water quality.
- Boulders create only minor increases in channel roughness during bankfull flow conditions (Rutherford et al. 2000). Hence, they are not likely to have any impact on flood flow conveyance.
- Location of Treatment
- Boulders are placed as a series of several boulders randomly placed in clumps.
- Clumps of boulders have been placed specifically in the creek section, at approximately the desired location of riffles or where sediment slugs presently exist.
- Clumps of boulders are located in creek sections where stream banks are stable.
- Boulders should be placed away from stream bank edges as they can cause localised bank scour.
- Boulders can be randomly placed.
- Boulders should project slightly above the water surface at normal flow, creating habitat for fauna (birds, turtles, etc.).
- Boulders should have a minimum diameter of 650mm. Large boulders do not need to be trenched in to the creek bed.

- The primary consideration when installing boulders should be to ensure they add as much hydraulic disturbance as possible to encourage scour and bar formation for improved stream habitat and geomorphic stability.
 - Large angular boulders should be orientated to create the greatest hydraulic disturbance. Granite or basalt quarried rocks are the best rock source, because their sharp edges enhance turbulence. Hard rock should be used that is not prone to shearing or fracturing.
 - Boulders should be angular with the flattest side of the rock laid onto the streambed to prevent rocks from rolling or gliding away.
 - Boulders should be positioned to maximise disturbance by orientating their longest dimension at right angles to the flow, and by placing the largest rocks near the centre of the stream with the fastest flow.
- **Rock Ribs or Large Logs**
 - Rock Ribs/ Large logs/ bundles of logs are aligned perpendicular to the stream bank. The spacing of rock ribs is to be ten (10) metres from adjacent ribs
 - Rock ribs/ large logs/ bundles of logs are made by placing either, into a trench excavated into the existing unconsolidated bank material. Large boulders, 300mm-500mm dia. or logs 300mm-500mm dia. are to be trenched/ pressed into the bank using the excavator and are to finish at the same height of the bank and are not to extend into the stream any further than the existing, unconsolidated material so as not to reduce the existing cross sectional area.
 - Logs or bundles of logs are to be native, hardwood species. Ribs are to be a minimum 1m wide up to a maximum width of 2m.
 - Large, angular, hard, boulders should be used that are not prone to shearing or fracturing.
 - Rocks should be angular with the flattest side of the rock laid onto the streambed to prevent rocks from rolling or gliding away.

14.7 Mitigation

Site sensitive construction methods will be required to ensure any construction related impacts are avoided or mitigated. Prior to any work commencing a Construction Environmental Management Plan (CEMP) and work method statement should be prepared by the Council appointed Contractor and approved by the project superintendent.

Samples of all proposed construction materials should be submitted to the superintendent for approval prior to delivery to site. All materials and stockpiles should be placed and protected to ensure no risk to the public or the environment.

Prior to work commencing, the extent of works, nominated access points and the exact positioning of structures and design elements should be set out for inspection and approval to ensure all site constraints are considered and understood. The work zone and no access zones should be clearly defined. Trees that require pruning or removal must be authorised by the superintendent.

15. References

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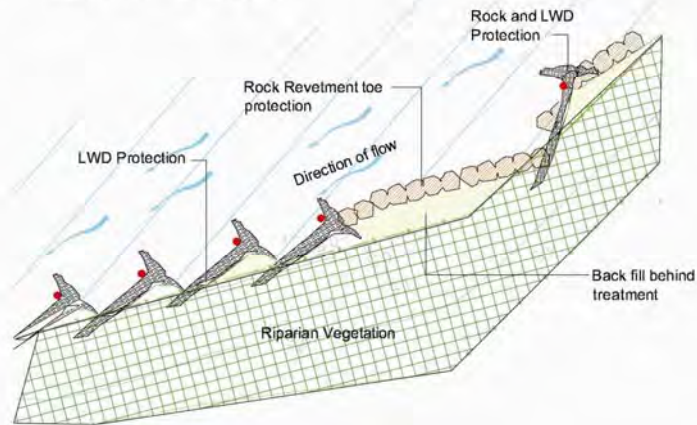
Tabacchi et al. (1998). **Development, Maintenance and Role of Riparian Vegetation**.

Washington, J., P. Beier, D. Majka, S. Newell, E. Garding, (2002) **Best Management Practices for Wildlife Corridors**.

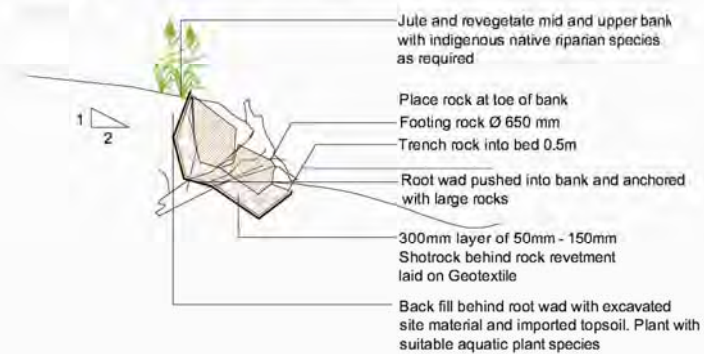
Appendix A – Drawing Set

Appendix B - Details

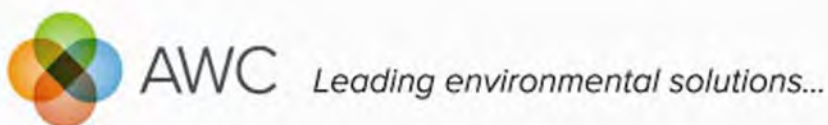
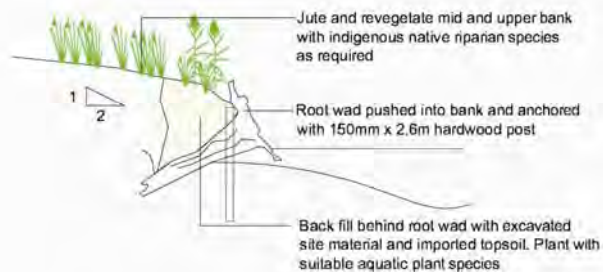
Toe Protection Plan (NTS)



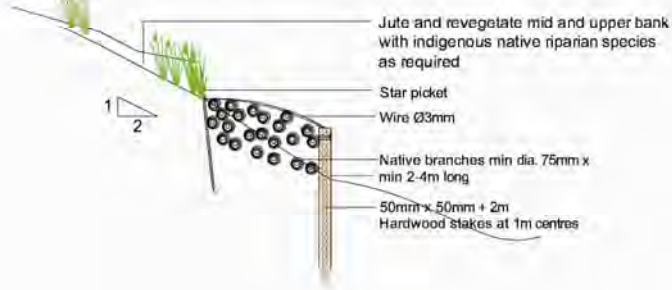
Rock and LWD (Root Wad) Toe Protection (NTS)



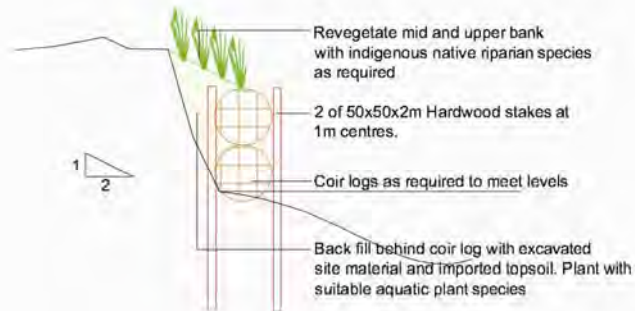
LWD (Root Wad) Toe Protection (NTS)



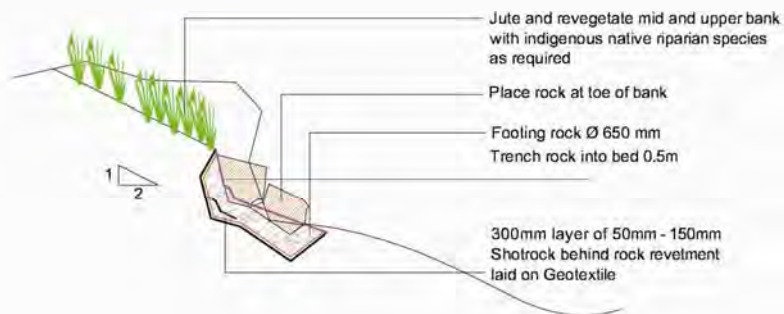
Branch Bundle Toe Protection (NTS)



Coir Log Bank Protection (NTS)



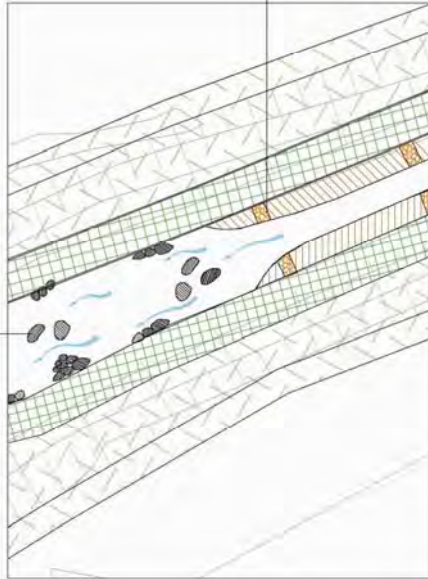
Rock Revetment Toe Protection (NTS)



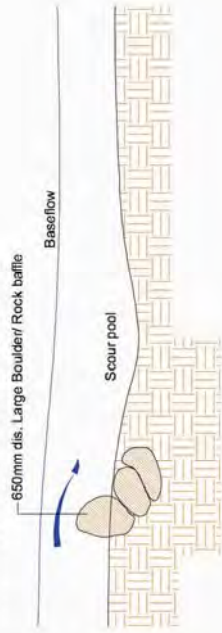
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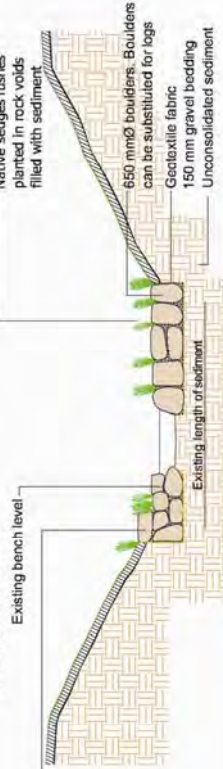
Instream Boulders/ Rock Baffles Rock/Log Ribs
Plan (NTS)



Instream Boulders/ Rock Baffles (NTS)



Rock/log Ribs (NTS)



A rock rib is formed excavating approximately one metre by one metre trench across the bench, lining with filter cloth, then backfilling with rocks. The ribs are to be revegetated.



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