Rehabilitation

Waterway and Channel Rehabilitation Guidelines

Ipswich City Council
Final V3
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Purpose of Guidelines

This section of the guideline provides some background into why this guideline was developed and how to best use it to enhance ecological functioning of constructed waterways and channels within Ipswich.

How to use the Guidelines
Guidelines Framework
AECOM was commissioned by Ipswich City Council (ICC) to develop a waterway and channel rehabilitation guideline. This document provides information on the retention or reinstatement of ecological functioning of waterways and channels, from design through to construction and maintenance. These solutions will increase habitat and water quality values associated with these waterways and channels as well as the aesthetic appeal and amenity of these public assets. Design solutions presented in the guidelines also aim to reduce maintenance requirements for these Council assets.

This guideline identifies key maintenance and waterway health issues and concerns within the city of Ipswich and provides drawings and supporting information to outline how these issues should be addressed for different waterway management situations, ranging from constructed swale systems to natural channels in developing catchments.

**How to use the guideline**

The guideline has been developed for use by Council staff to plan and deliver waterway and channel works which will successfully achieve cost-effective waterway enhancement outcomes and reduce future maintenance requirements. The guideline will also be an important reference for developers and designers involved in channel design to ensure that designs meet Council’s requirements, minimise maintenance and maximise waterway health outcomes.

The focus of the guideline is primarily on urban waterways, but many of the principles outlined in this guideline could be adapted and applied to rural waterways.

There are a number of existing guidelines which are currently used by Council that provide detailed technical guidance on the design and treatments for different channels. This guideline does not replicate or replace these existing guidelines, rather it has been designed to act as a bridging document providing practical guidance to inform remediation, rehabilitation and restoration works for waterways within the city of Ipswich (see Guideline Framework).

Council also has a Waterway Health Strategy which was developed to assist with the management and enhancement of natural waterways within the City of Ipswich. It prescribes a change in current management practices to address waterway health improvement as an integral component of Total Water Cycle Management.

**Guideline Framework**

<table>
<thead>
<tr>
<th>Overarching Strategy</th>
<th>ICC Waterway Health Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterway Issue</td>
<td></td>
</tr>
<tr>
<td>Swale design</td>
<td>Erosion remediation</td>
</tr>
<tr>
<td>Riparian vegetation rehabilitation</td>
<td>Restoration of natural channel values</td>
</tr>
<tr>
<td>Bridging Guideline</td>
<td>ICC Waterway and Channel Rehabilitation Guidelines (this document)</td>
</tr>
<tr>
<td>Existing Reference Guidelines</td>
<td></td>
</tr>
<tr>
<td>SEQ HWP Technical Design Guidelines</td>
<td>BCC Erosion Treatments for Urban Creek Guidelines</td>
</tr>
<tr>
<td>/ Design process for swales and other WSUD systems</td>
<td>/ Identification of erosion issues / Different erosion remediation techniques</td>
</tr>
</tbody>
</table>
Waterway Characteristics

This section of the guideline introduces users to the typical characteristics of Ipswich waterways and channels.

Local Area
Waterway Management
Waterway Types
Waterway Characteristics

Local Area
The City of Ipswich lies within the 2,030 km² Bremer River Catchment which encompasses a diverse range of land uses including agriculture, mining, industry, commerce, natural areas and urban development. The Bremer River Catchment contains six major waterways, being the Bremer River, Bundamba Creek, Purga Creek, Reynolds Creek, Warrill Creek and Western Creek. The Bremer River Catchment also forms part of the Brisbane River Catchment, which is the largest river system in South East Queensland (ICC, 2010).

Much of the catchment is considered degraded due to overclearing of vegetation and inappropriate cropping and grazing practices. This land degradation coupled with the presence of erosive soils throughout the catchment means that erosion and sedimentation are serious issues in the Bremer River Catchment (ICC, 2010).

Ipswich is one of the fastest growing sub-regions of South-East Queensland. It is expected that the current population of 135,000 residents will almost double in the next 10 years (ICC, 2005). This increase in population will result in increased urbanisation, which has the potential to negatively impact waterways through increased flow volumes and velocities.

Ipswich has a history of flooding, with some small creeks in urban areas known to rise quickly during heavy rainfalls and also due to backwater flooding from the Brisbane and Bremer Rivers when they are in major flood (BOM, 2010).

Overall, most waterways have been significantly modified or altered from the pre-European state, with only a few waterways still maintaining aspects of the natural features, biodiversity and ecosystem functions representative of a waterway in a healthy natural state (ICC 2009).

Waterway Management
Waterway management initiatives should aim to meet suitable and achievable waterway conditions based on the current condition of the waterway and catchment. It is therefore important to classify the waterway type and to identify existing characteristics before determining waterway management initiatives.

Catchment development will increase catchment flows and as such, will modify the waterway condition. Identifying the stage of channel adjustment will influence the type of improvement works which will be required. For example, if the channel is in the process of adjusting to catchment urbanisation, works should be undertaken to increase channel capacity to ensure that increased catchment flows can be safely conveyed within the channel or designed over channel areas, decreasing erosion pressure within the waterway. Alternatively, if the catchment is fully developed and the channel adjustment has occurred, the channel just needs to be stabilised and rehabilitated.

Waterways in Ipswich can be classified according to their level of modification: from constructed open channels in developed catchments through to minimally impacted natural channels in developing catchments. All of these waterways remain a valuable asset, providing a number of environmental, landscape and social values (see Table 1).

Where waterway enhancement works are proposed the level of improvement and associated works should reflect the potential to reinstate the pre-developed waterway values. Rutherfurd et al. (2000) used the terminologies of waterway restoration, rehabilitation and remediation to distinguish between different recovery pathways and end points:

Restoration – Return the waterway to the pre-development waterway characteristics

Rehabilitation – Potential exists to re-create many waterway values but it may not be possible to fully restore the waterway to its original ecosystem condition due to catchment modifications.

Remediation – Due to the extent of catchment modification returning waterway health to the pre-developed condition is unlikely. It requires establishing a changed but nevertheless healthy waterway representing an ecosystem state that accommodates changes in the catchment conditions.

This guideline has been developed to focus on constructed drainage systems and waterways which will require either remediation (such as open channels in developed catchments) or rehabilitation (natural channels in developing catchments). Details around the more extensive works required for these remediation and rehabilitation efforts are provided in the Natural Channel Design Guidelines (BCC, 2000).

Plate 1: Drainage channel within Ipswich parkland (image: AECOM)
Table 1: Summary of waterway and channel types and values
(each of these are documented in more detail in Section 3: Waterway Management Scenarios)

<table>
<thead>
<tr>
<th>Waterway Type</th>
<th>General Description</th>
<th>Ecosystem Function and Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>High maintenance swale system</td>
<td>Typically a shallow constructed open drainage channel located in road verges, central road medians or housing developments. Typically grass or vegetated with a regular cross section, designed to receive intermittent storm flows.</td>
<td>Moderate water quality function improvement (sediment trapping and nutrient transformations), low to moderate habitat values</td>
</tr>
<tr>
<td>Weedy open channel in grassed parkland</td>
<td>Small and shallow channel within a parkland which has regular base flows. Storm flows regularly exceed channel capacity and flow through parkland.</td>
<td>Moderate water quality function improvement (sediment trapping and nutrient transformations), low to moderate habitat values</td>
</tr>
<tr>
<td>Natural channel with headcut erosion - upper urban catchment</td>
<td>Natural waterway in urban catchment with deepening channel, typically with steep, unstable banks.</td>
<td>Limited ecosystem functioning in this section of the waterway (active erosion and sediment transport)</td>
</tr>
<tr>
<td>Natural channel with headcut erosion - upper rural catchment</td>
<td>Natural waterway in rural catchment with deepening channel, typically with steep, unstable banks.</td>
<td>Limited ecosystem function in this section of the waterway (active erosion and sediment transport)</td>
</tr>
<tr>
<td>Piped flows entering natural channel</td>
<td>Piped outfall entering waterway directly or via a swale system, causing localised erosion within the channel</td>
<td>Reduced ecosystem function in this section of the waterway (active erosion)</td>
</tr>
<tr>
<td>Channelised overland flow entering natural channel</td>
<td>Natural channel with sedimentation occurring on outer boundary of riparian zone (typically in rural catchments)</td>
<td>Moderate channel ecosystem function, however lateral in-flows are bypassing the riparian zone thus limiting transformation processes, such as, sediment trapping and nitrification and denitrification.</td>
</tr>
<tr>
<td>Natural channel in developing catchment</td>
<td>Natural channel with significant areas of remnant riparian vegetation within a developing catchment</td>
<td>Ecosystem function is being impacted by increased catchment flows causing bank erosion</td>
</tr>
<tr>
<td>Landscape and Social Values</td>
<td>Affect on Downstream Ecosystem Function</td>
<td>Remediation / Rehabilitation Potential</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Generally weedy and unaesthetic, generating complaints from local residents</td>
<td>Limited moderation of peak discharges, limited pollutant load reduction.</td>
<td>Potential to create a vegetated swale (with or without trees) providing some improvements to ecological, landscape and social values</td>
</tr>
<tr>
<td>Weedy and unaesthetic, generating complaints from park users and local residents</td>
<td>Limited moderation of peak discharges, limited pollutant load reduction.</td>
<td>Potential to create a broader riparian zone with a floodplain function providing moderate improvements to ecological function as well as landscape and social values</td>
</tr>
<tr>
<td>Steep and unstable banks typically accompany head cut erosion which impact on amenity and public safety</td>
<td>Bed and bank erosion result in sediments being transported downstream</td>
<td>Potential to establish grade control structures to prevent further erosion and stabilise bed and banks, improving ecological, social and landscape values</td>
</tr>
<tr>
<td>Steep and unstable banks typically accompany head cut erosion, mainly on private property, impacting any riparian vegetation and stock safety</td>
<td>Bed and bank erosion result in sediments being transported downstream</td>
<td>Potential to establish grade control structures and use other bank stabilisation techniques (such as stock fencing) to improve ecological, social and landscape values</td>
</tr>
<tr>
<td>Eroded banks and weedy swale systems impact landscape and amenity and public safety values</td>
<td>Localised erosion may result in downstream deposition</td>
<td>Use of a sediment pond or flow dissipation device will slow flows before they enter the channel, improving ecological, social and landscape values</td>
</tr>
<tr>
<td>Eroded riparian edge impacts landscape values (mainly on private property)</td>
<td>Channelised flows result in increased velocities at the confluence with the downstream waterway</td>
<td>Potential to create a series of discontinuous shallow swales to trap sediments and distribute flows through the riparian shallow swales to trap sediments and distribute flows through the riparian zone to improve ecological and landscape values.</td>
</tr>
<tr>
<td>Steep, eroded banks and a widening channel impact on neighbouring properties and public safety</td>
<td>Eroded sediments are transported downstream. Downstream areas are also impacted by increased catchment flows.</td>
<td>Potential to stabilise banks and provide increased channel cross sections to adapt to new catchment conditions.</td>
</tr>
</tbody>
</table>
### Table 1 Cont.: Summary of waterway and channel types and values (each of these are documented in more detail in Section 3: Waterway Management Scenarios)

<table>
<thead>
<tr>
<th>Waterway Type</th>
<th>General Description</th>
<th>Ecosystem Function and Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel bank erosion at culvert headwalls due to overland flows</td>
<td>Catchment overland flowpaths typically enter waterway at the same location as the piped network. If not designed for, these flows can cause erosion behind stormwater infrastructure along waterway banks, exposing pipes and compromising headwall stability.</td>
<td>Ecosystem function is being impacted by sediment transport associated with isolated bank erosion.</td>
</tr>
<tr>
<td>Channel bank erosion due to overland sheetflow - parkland area</td>
<td>Overland sheetflow can enter waterways on broad fronts. In intense rainfall events, such flows can be considerable even from turfed parkland catchments. Waterway banks without sufficient riparian groundcover are susceptible to erosion under these conditions.</td>
<td>Reduced ecosystem function in this section of the waterway due to broad scale active erosion of banks, reduction in riparian zone ecosystem services and associated sediment transport.</td>
</tr>
<tr>
<td>Channel with steep banks and / or undercutting</td>
<td>Widening of a waterway as a result of bank erosion due to undercutting at the toe of the bank. This situation is nearly always the result of either headward erosion creating steep unvegetated banks and exposing erodable / dispersive soils or constructed or enlarged channels being created with steep batters</td>
<td>Limited riparian in-stream ecosystem functioning in this section of the waterway (active erosion and sediment transport)</td>
</tr>
<tr>
<td>Landscape and Social Values</td>
<td>Affect on Downstream Ecosystem Function</td>
<td>Remediation / Rehabilitation Potential</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Exposed pipes and unstable headwalls can impact public safety as well as amenity</td>
<td>Bank erosion results in sediments being transported downstream</td>
<td>Potential to protect pipe infrastructure with rock in combination with management of catchment overland flows, improving ecological, social and landscape values</td>
</tr>
<tr>
<td>Unstable banks along parks can create a high public safety risk as well as reduce parkland amenity</td>
<td>Bank erosion results in sediments being transported downstream</td>
<td>Appropriate maintenance of riparian groundcover, ensuring herbicides are not used in this environment. Potential to direct catchment overland flows to discharge via a swale to a formalise rock chute within a revegetated bank, improving ecological, social and landscape values</td>
</tr>
<tr>
<td>Unstable banks can impact on amenity and public safety</td>
<td>Bank erosion results in sediments being transported downstream</td>
<td>Potential to establish grade control structures to raise bed level and establish bank stabilisation techniques to improve ecological, social and landscape values</td>
</tr>
</tbody>
</table>
Waterway Management Situations

The purpose of this section of the Guideline is to provide relevant information to enable users to undertake works to improve the existing waterway values of each different waterway type.

- High Maintenance Swale System
- Weedy and Unaesthetic Open Channel in Grassed Parkland
- Natural Channel with Headcut Erosion - Upper Urban Catchment
- Natural Channel with Headcut Erosion - Upper Rural Catchment
- Piped Flows Entering Natural Channel
- Channelised Overland Flow Entering Natural Channel
- Natural Channel in Developing Catchment
- Channel Bank Erosion at Culvert Headwalls due to Overland Flows
- Channel Bank Erosion due to Overland Sheet Flow - Parkland Area
- Channel with Steep Banks and / or Undercutting
Waterway Management Situations

This section of the Guideline provides templates for the possible remediation / rehabilitation of seven different waterway types which are typically encountered in Ipswich. To achieve the primary waterway objectives described above, it is important to undertake the following steps:

1. identify problem / issue
2. identify waterway type
3. understand natural processes underlying the problem / issue
4. redesign waterway addressing the degrading processes and to work to enhance natural processes

Site investigations of typical waterway types within Ipswich have been used to identify typical issues associated with each waterway type, and to gain an understanding of the processes underlying these problems. Information is provided for each waterway management situation to help the user identify the type of waterway they are dealing with (as represented in the ‘existing waterway condition’ image). Preferred design responses have been developed for each waterway type (as represented in the ‘future waterway condition’ image). Notes on the required design, construction, establishment and maintenance elements required to achieve these design responses are provided. Additional details for each of these elements is provided in Section 4 of this Guideline.

To achieve the vision of improved water quality and increased biodiversity for waterways, the focus of the design responses in this Guideline is for the use of soft rather than hard engineering structures where possible. This is due to a number of benefits that soft engineering solutions can provide including:

- self adjustment and movement of structures to respond to changes in the waterway (e.g. rock chutes and riffles)
- infiltration to support passive irrigation of riparian zone vegetation and encouraging denitrification and other soil nutrient cycling processes.
- reduced flow velocities
- natural habitat creation

Before undertaking rehabilitation / remediation works it is important that the following information is gathered for the site:

- Catchment condition - what stage of development is the catchment currently in?
- Soil type - are there dispersive, erosive or expansive soils present?
- Flow regimes - is flow management a management objective?
- Flooding - are there existing flooding issues?

This information will assist decisions around the type, extent and staging of works to be undertaken.

For example, if the catchment is fully urbanised and the channel adjustment has already occurred, the channel just needs to be stabilised and rehabilitated. On the other hand, if the catchment is currently being developed, channel adjustment may have only just begun. This situation may require a combination of works including flow retardation (particularly for the channel forming frequent flows 1.5 - 2 year ARI flows), armouring of the channel or works to increase channel capacity all of which may be staged in response to development rates.

While urbanisation has an impact on both event and base flows, some waterway ecosystems will be highly sensitive to the increased peak flows. In these areas increasing channel capacity will not be an appropriate design response and stormwater capture within the catchment will be required to manage frequent flows.

Additional information is provided in Section 4: Design, Construction and Establishment to assist users to deliver waterway design templates provided in this section.

Plate 2: Use of rock chutes to improve waterway condition - Lilac Street waterway restoration (Image: AECOM)
High Maintenance Swale System

Typical Characteristics
/ Constructed drainage channel designed to convey flows equivalent to the minor drainage system within urban development
/ May be located in road verges, central road medians, housing developments or parklands
/ Typically used at the upstream end of constructed drainage lines
/ Can be designed as a grassed swale, rock lined swale or vegetated swale depending on slope and climate

This waterway situation is created when a grassed swale is poorly designed making maintenance difficult.

Typical Issues
/ Flat swales (<2% grade) often don’t drain creating wet or boggy inverts which cause maintenance difficulties.
/ Steep swales (>5% grade) may be prone to erosion due to high velocities.
/ Grassed swales can be difficult to maintain in wet-dry summer rainfall climates (can die-off in the dry season or become over-grown in the wet season).
/ Rock lined swales can be prone to weed invasion.
/ A lack of shade trees encourages weed growth in channel and on batters.
/ Can become weedy and unaesthetic, generating complaints from local residents.
/ Falls within park maintenance responsibility but often unable to employ typical terrestrial maintenance techniques such as mowing and strip herbicide applications.
/ Maintenance can be difficult if the swale has steep banks.

Design Response
/ Vegetated swales (with or without trees) are the preferred swale format for summer rainfall climate. This design response enables an ‘as-required’ bush-land regeneration maintenance approach rather than a regular parkland maintenance approach.
/ For vegetated swales care needs to be taken in the selection of roughness factors for the sizing of swale cross-sections to ensure appropriate conveyance.
/ Grassed swales may best be avoided in summer rainfall climates unless the design (access and dimensions) is such that the invert can be mown with a side or arm mounted slasher.
/ If the intent is to keep the swale turfed (either short term or long term), flat swales (<2% grade) need underdrainage to allow sufficient drainage to enable mowing.
/ Clear maintenance boundaries need to be created between drainage and waterway corridors and adjacent parkland areas. This can be achieved with formal edging designs (vegetated edge, plinths, boards, mowing edge, etc.) and/or a tree canopy to create a clear maintenance boundary between mown open space areas and riparian vegetation.
/ The establishment of riparian cover on swale batters will also shade out weeds in channel.
/ Stepped cross-sections can also be employed to create more defined maintenance boundaries. This also increases the conveyance area to compensate for increased roughness.
/ Steep swales with erosion potential requires surface and batter protection (e.g. rock armouring and vegetation) and may also require the construction of grade control structures to decrease the grade of the bed to reduce flow velocities.

Key Rehabilitation / Remediation Works
Typical works required to achieve a functional and low maintenance swale may include:
/ Grade control
/ Battering back banks
/ Bank stabilisation
/ Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

Maintenance
Maintenance requirements to ensure the successful establishment of these works could involve:
/ Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
/ Regular inspection of the swale to identify areas of increased sediment deposition or scour of the swale invert or rill erosion on swale batters
/ Removal, and where necessary replacement, of any bank protection material (e.g.: Jute Mat) that has been displaced
Existing Waterway Condition
Weedy, open swale in public area; no shade cover on batters; difficult to maintain channel due to wet / boggy invert.

Improved Waterway Condition
Low flow channel with vegetated batters; shade trees on batters to control weed growth; defined maintenance boundary created between the mown area / and the riparian vegetation.

Flow conveyance can be maintained by increasing the cross sectional area of the vegetated swale by battering back the banks.
Waterway Management Situations

Weedy Open Channel in Grassed Parkland

Typical Characteristics
/ Small and shallow channel with regular base flows
/ Flows regularly exceed the channel and move through mown open space / parkland area
/ May have concrete low flow channel

Typical Issues
/ Open channel often with wet or boggy invert creating maintenance difficulties.
/ No shade trees allowing weed growth in channel and on batters.
/ Weedy and unaesthetic, generating complaints from park users and local residents.
/ Falls within park maintenance area but parkland maintenance techniques are unsuitable for drainage systems and waterways.
/ Over bank flows engaging parkland.
/ Bed and bank erosion.
/ Creation of wheel ruts from slashers, particularly when slashing during wet or boggy conditions, provides areas for mosquito breeding, and compaction of soils.
/ Differential resistance to flow across flow paths can result in erosion at the interface between resistant/rough surfaces and treatments and smoother and less resistant surfaces and treatments (examples include low flow concrete channel and the riparian vegetation and between the riparian vegetation and grassed parkland).

Design Response
/ If over-bank flows in the parkland, the flow paths should be considered, this includes: increasing drainage line capacity by inclusion of a broader riparian zone with a floodplain function, provision of additional or alternative overland flow paths, re-design/relocate park features and facilities to tolerate occasional flooding.
/ Creation of a distinct riparian zone maintained using low frequency bushland techniques.
/ Creation of riparian cover to shade out weeds in channel.
/ Plant out a designated area with riparian vegetation (such as 1 year flood extent) to create a clear maintenance boundary between parks and natural areas.
/ Where bed or bank erosion is evident it may be necessary to re-design the channel and re-enforce the bed and banks with appropriately sized rock stabilised with vegetation.
/ Erosion at the interface of treatment surfaces across the flow path requires some interface treatment that recognises the stability and roughness differences. For example where concrete channel meets riparian zone vegetation a segment of vegetated structural soil intervenes to help stabilise the transition vegetation. Similarly where riparian zone vegetation meets parkland grass, the cut on parkland grass adjacent to the riparian zone needs to be longer and rougher to resist the potential increased velocities during infrequent events.
/ Surface protection due to design velocity or redesign to reduce velocities.

Key Rehabilitation / Remediation Works
Typical works required to achieve an aesthetic and functional open channel in a grassed parkland may include:
/ Battering back banks
/ Bank stabilisation
/ Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

Maintenance
Maintenance requirements to ensure the successful establishment of these works could involve:
/ Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
/ Inspection of channel banks to identify any erosion / scour zones
/ Removal, and where necessary replacement, of any bank protection material (e.g.: Jute Mat) that has been displaced.

This waterway situation is created by a lack of defined interface between the parkland and channel. This results in a lack of management boundary.
**Existing Waterway Condition**
Weedy, open channel within grassed parkland area; no riparian cover; difficult to maintain waterway as part of parkland.

- Wet channel making mown maintenance impossible
- Weedy edges as a result of no riparian cover

**Improved Waterway Condition**
Low flow channel with vegetated riparian zone floodplain area within grassed parkland area; riparian shade trees control weed growth; defined maintenance boundary created between the mown park and the natural asset.

- Wet channel maintained by natural asset maintenance
- Increased drainage capacity is provided with the inclusion of a broader riparian zone with a floodplain function
- Shade trees planted in riparian zone to control weed growth
- Sedges and rushes planted to help control weed growth

Flooding risk is reduced by increasing the cross sectional area of the channel by battering back banks to create a defined riparian floodplain area. This allows trees to be planted in this area without increasing flooding.
Natural Channel with Headcut Erosion - upper urban catchment

Typical Characteristics
/ Natural waterway with deepening channel
/ May have steep banks
/ May be in a developing urban area

Typical Issues
/ Deepening channel caused by an advancing erosion head in the upstream direction. This can cause steep, unstable banks.
/ The leading edge of the headcut erosion can take the form of a small waterfall or steep section in the creek bed.
/ The cause of the erosion may be due to a number of factors including development of the surrounding catchment or direct human modifications to the waterway caused by the creation of road culverts etc.
/ Soil vulnerability in frequent flow events.
/ Upstream control / mitigation of flows.
/ Undercutting and destabilisation of banks (unstable toe of bank).

Design Response
/ Construction of grade control structures to prevent bed deepening from progressing further upstream and establishment of a more stable channel slope within the reach where headcuts have already passed through by slowing flows and allowing material to drop out into the channel, reducing the potential for bed deepening.
/ Bank stabilisation may also be required if banks are very steep and unstable. In most situations where bed erosion has been active, bank stabilisation works such as laying back the batters and rock armouring will be required to achieve a stable environment.
/ Riparian revegetation will be required in association with any bank stabilisation work. Riparian revegetation needs to be carefully matched to bank stabilisation works. Vegetation palettes need to be adjusted for the use of rock or geotextile materials as the bank stabilisation approach.
/ As for simple open channels, the interface of conditions and treatments across the flow-path is important in the stability of natural waterway channels. The boundary conditions around any rock stabilisation structure needs to be carefully designed and vegetated to ensure stability.

Key Rehabilitation / Remediation Works
Typical works required to achieve a stable waterway may include:
/ Grade control
/ Bank stabilisation
/ Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

Maintenance
Maintenance requirements to ensure the successful establishment of these works will involve:
/ Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
/ Inspection of channel banks to identify any erosion / scour zones
/ Inspection of chutes to check for dislodgement of rock protection or the presence of weeds
/ Removal, and where necessary replacement, of any bank protection material (e.g.: Jute Mat) that has been displaced
Existing Waterway Condition
Deepening channel caused by erosion head moving upstream leaving steep, unstable banks.

Improved Waterway Condition
Grade control structures preventing progression of erosion moving further upstream as well as increasing bed level and stabilising banks downstream.

Grade control structures are designed to slow velocities in the waterway which could result in localised flooding. The cross section of the waterway could be increased by battering back banks to reduce this risk.
Natural Channel with Headcut Erosion - upper rural catchment

Typical Characteristics
/ Natural waterway with deepening channel
/ May have steep banks
/ Located in a rural catchment

Typical Issues
/ Deepening channel caused by an advancing erosion head in the upstream direction. This can cause steep, unstable banks.
/ The leading edge of the headcut erosion can take the form of a small waterfall or steep section in the creek bed.
/ The cause of the erosion may be due to a number of factors including clearing of the catchment, loss of riparian vegetation, stock access, or installation of road culverts.

Design Response
/ Construction of grade control structures to prevent bed deepening from progressing further upstream and to establish a more stable channel slope within the reach where head-cut has already passed through by slowing flows and allowing bed material to deposit in the channel, reducing the potential for further bed deepening.
/ Bank stabilisation may also be required if banks are very steep and unstable. In most situations where bed erosion has been active, bank stabilisation works such as laying back the batters and rock armouring will be required to achieve a stable environment for bank revegetation.

/ Riparian revegetation will be required in association with any bank stabilisation work. Riparian revegetation needs to be carefully matched to bank stabilisation works. Vegetation palettes need to be adjusted depending on the use of rock or geotextile materials as the bank stabilisation approach.

/ Depending on the size of the channel and severity of the bank erosion, once the bed has been stabilised, an alternative bank stabilisation approach may be to fence the waterway and re-vegetate the banks without any significant bank works. This approach can be suitable where: the channel is small and bank damage is limited, remnant riparian vegetation exists and can be enhanced and built-on, there is no immediate down-stream waterway that needs immediate protection.

/ As for simple open channels, the interface of conditions and treatments across the flow-path is important in the stability of natural waterway channels. The boundary conditions around any rock stabilisation structure needs to be carefully designed and vegetated to ensure stability.

Key Rehabilitation / Remediation Works
Typical works required to achieve a stable waterway may include:
/ Grade control
/ Bank stabilisation
/ Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

Maintenance
Maintenance requirements to ensure the successful establishment of these works will involve:
/ Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
/ Inspection of channel banks to identify any erosion / scour zones
/ Inspection of chutes to check for dislodgement of rock protection or the presence of weeds
/ Removal, and where necessary replacement, of any bank protection material (e.g.: Jute Mat) that has been displaced
Existing Waterway Condition
Deepening channel caused by erosion head moving upstream leaving steep, unstable banks.

Improved Waterway Condition
Grade control structures preventing progression of erosion moving further upstream as well as increasing bed level and stabilising banks downstream.

Grade control structures are designed to slow velocities in the waterway which could result in localised flooding. The cross section of the waterway could be increased by battering back banks to reduce this risk.
Piped Flows Entering Natural Channel

Typical Characteristics

/ Pipe outfall may be discharging directly into waterway
/ Pipe outfall may also be discharging to waterway via a swale system, typically in a linear mown parkland area.

Typical Issues

/ Piped outfalls to waterways can result in localised erosion to both bed and banks.
/ Piped outfalls to waterways can also result in the deposition of gravel and sediment.
/ Where piped outfalls occur at the start of a natural channel erosion impacts may dissipate with distance downstream where depositional impacts will become evident.
/ Where piped outfalls enter a waterway laterally, high velocity inflows may result in both local bed and bank impacts and also initiation of head-ward erosion which could propagate up-stream. Depositional impacts may also become evident down-stream.
/ Where piped flows enter the waterway from the top of steep banks, high velocity flows may result in significant localised bank and bed erosion. This vertical drop may be due to bed erosion within the channel.
/ Swale systems conveying piped flows are often rock lined, which can become weedy once sediments settle out in the swale system generating complaints from park users and local residents.

Design Response

/ Creation of flow dissipater device between piped flows and waterway. This may be a sediment pond or rock transitional area.
/ The retrofit of a sediment basin will help to capture sediments as well as the detain and slow flows before they enter the channel.
/ The rock transitional area should be designed to spread flows and to control any grade changes between the pipe and the channel. This structure could be a riffle system or a rock chute depending on the grade change.
/ Where piped flows enter the waterway from the top of a steep bank, a rock chute may be required to address the bank erosion. An alternative solution is to construct a pit and discharge the flows into the base of the waterway. For either of these designs to be successful, the cause of the vertical drop needs to be addresses (e.g. address headcut erosion).
/ Where piped discharges are conveyed to the waterway by a swale system, the swale should be protected from high flows and sediment loads by either a pond or a rock transitional/deposition zone, vegetated with riparian species, including trees, to inhibit weed invasion.

Key Rehabilitation / Remediation Works

Typical works required to achieve a stable waterway may include:

/ Grade control / riffle systems
/ Bank stabilisation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

To find more information about the design of a sediment basin, please refer to the SEQ WSUD Technical Design Guidelines (HWP 2006).

Maintenance

Maintenance requirements to ensure the successful establishment of these works will involve:

/ Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
/ Inspection of channel banks to identify any erosion / scour zones
/ Inspection for dislodgement of rock protection or the presence of weeds or accumulated sediment
Existing Waterway Condition - Example #1
Erosion present at pipe outlets due to high velocity flows entering the waterway

Improved Waterway Condition - Example #1
Piped flows are dispersed, reducing velocities and the receiving environment is protected from scour.

Slowing the velocity of water at the pipe outfall could increase risk of localised flooding. The flow dissipater device or sediment pond should be sized to ensure that flooding risk is reduced.
Existing Waterway Condition - Example #2
Erosion present at pipe outlets due to high velocity flows entering the waterway.

Improved Waterway Condition - Example #2
Receiving environment is protected from scour.

High velocity piped flows cause localised erosion within the waterway.

Rock protection minimises erosion within the waterway.
Existing Waterway Condition - Example #3
Erosion present at elevated pipe outlets due to high velocity flows entering the waterway

Improved Waterway Condition - Example #3
Piped flows are delivered from the base of the bank into a stable receiving environment
Waterway Management Situations

Channelised Overland Flow Entering Natural Channel - rural catchment

**Typical Characteristics**

/ Natural channel with vegetated riparian zone
/ Typically located in a rural catchment with cropping or grazing landuse
/ Build-up of sediment on the outer boundary of the riparian zone due to deposition of sediments from sheet and rill erosion of rural paddocks / catchments with limited groundcover

**Typical Issues**

/ Regularly disturbed soil surface in the contributing rural catchment.
/ Overland flows paths from the rural catchment slow when they meet the vegetated riparian zone, causing sediments to drop out along its edge.
/ This build up of sediment causes flows to be directed parallel to the waterway, bypassing the riparian zone.
/ These channelised flows have increased velocity, causing erosion along the flowpath created on the edge of the riparian zone and also on the banks when the flows eventually enter the waterway.

**Design Response**

/ Encourage protection/revegetation of on-farm overland flow paths.
/ Create a linear sediment trap in the form of a series of discontinuous shallow swales to trap sediments and distribute flows.
/ Stabilise depressions and banks where overland flows have been channelised and caused erosion.
/ Revegetation of the banks will be required as part of bank stabilisation works.

**Key Rehabilitation / Remediation Works**

Typical works required to achieve a functional and low maintenance swale may include:

/ Bank stabilisation
/ Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

**Maintenance**

Typical works required to achieve a stable waterway may include:

/ Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
/ Regular inspection of the shallow swales to identify areas of increased sediment deposition or scour of the swale invert or rill erosion on swale batters

*This waterway situation is created by sediment dropping out of overland flows when they meet the vegetated riparian zone*
Existing Waterway Condition - Cross Section Examples
Natural channel with vegetated riparian zone, overland flow from disturbed catchments drop out sediment when they meet the riparian edge which causes flows to channelise and bypass the vegetation.

Improved Waterway Condition
Linear sediment traps (in the form of a series of discontinuous shallow swales) trap sediments and distribute flows through the riparian zone.

Creation of the swale systems does not impact on flooding, allowing flows to evenly distribute through the riparian zone.
Existing Waterway Condition - Plan and Cross Section

Natural channel with vegetated riparian zone, overland flow from disturbed catchments drop out sediment when they meet the riparian edge which causes flows to channelise and bypass the vegetation.

- Build-up of sediment on edge of vegetated riparian zone
- Flow become channelised, causing erosion along the flowpath created on the edge of the riparian zone
- Overland flow

Diagram showing the transition from overland flow to a channelised flow path along the edge of the riparian zone, with sediment accumulation along the edge.
Improved Waterway Condition - Plan and Cross Section

Linear sediment traps (in the form of a series of discontinuous shallow swales) trap sediments and distribute flows through the riparian zone.

Series of discontinuous shallow swales trap sediments and distribute flows

Waterway channel

Shallow swales connecting catchment flows to waterway channel through the vegetated riparian zone. Such swales would need to be meandered through the riparian zone to protect trees and maintain riparian zone stability.

Vegetated swale helps to trap sediments and distribute flows through the riparian zone

Flows distributed through riparian zone in a series of shallow swales

Overland flow
Waterway Management Situations

Natural Channel in Developing Catchment

Typical Characteristics
/ Natural channel with upstream developing catchment
/ Significant areas of remnant riparian vegetation
/ The natural condition of the channel may be an ephemeral system which during the dry, only has permanent water in pools

Typical Issues
/ Rapidly increasing flows because of catchment development.
/ Steep eroded banks, particularly on outside bends.
/ Widened channel caused by increased flows.
/ Sand slugs in channel due to channel adjustment and upstream erosion.
/ Past catchment development, when not addressed adequately at the time, has the risk of creating on-going issues for waterways and adjacent properties.

Design Response
/ Stabilise steep banks on outer side on meanders.
/ Lay-back the inner banks of the meanders to increase channel capacity to better cope with increased catchment flows.
/ Create strategically placed deposition zones to enable easy removal of sand slugs (this activity will only be required for the period of channel adjustment).
/ Ensure there is significant riparian cover to shade out weeds in channel, stabilise banks and to create a clear maintenance boundary between mown parks and natural areas.

Key Rehabilitation / Remediation Works
Typical works required to achieve a stable waterway may include:
/ Bank stabilisation
/ Battening back banks
/ Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

Maintenance
Maintenance requirements to ensure the successful establishment of these works will involve:
/ Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
/ Inspection for dislodgement of rock protection or the presence of weeds
/ Inspection of channel banks to identify any erosion / scour zones

This waterway situation is created by an increase in catchment flows entering natural waterways.
**Existing Waterway Condition**
Widened channel with eroded banks due to increased catchment flows

**Improved Waterway Condition**
Wide channel with stabilised banks.

Flooding risk is reduced by increasing the cross sectional area of the channel by battering back banks on the inside of the channel meanders. This allows trees to be planted in this area without increasing flooding.
Channel Bank Erosion at Culvert Headwalls due to Overland Flow

**Typical Characteristics**
- Natural channel with piped upstream urban catchment
- Stormwater pipes discharge directly into waterway, typically within urban parkland areas
- Overland flow pathway follows piped drainage network

**Typical Issues**
- When the stormwater pipe networks are exceeded, overland flows enter the waterway at the same location as the stormwater pipes.
- Overland flows can cause erosion around the stormwater infrastructure, exposing pipes and compromising headwall stability.

**Design Response**
- Rock placement is required around the pipe and the headwall to stabilise this infrastructure.
- The headwall can be redesigned to act as a weir, spreading overland flows prior to entering the waterway.
- The design of overland flow discharge points needs to be considered as a part of the minor drainage system design. This may require the rock on either side of the headwall to be filled with some concrete.

**Key Rehabilitation / Remediation Works**
Typical works required to achieve a stable waterway may include:
- Bank stabilisation / reinforcement
- Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

**Maintenance**
Maintenance requirements to ensure the successful establishment of these works will involve:
- Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
- Inspection of reinforcement works for stability of structures or the presence of weeds

This waterway situation is created by overland flows entering waterway in the same location as the piped stormwater network
Existing Waterway Condition
Overland flow causing erosion and exposure of stormwater infrastructure

Improved Waterway Condition
Stabilised banks and stormwater infrastructure

Flooding should not be impacted as long as the overland flow paths are not significantly altered as part of the design response
Waterway Management Situations

Channel Bank Erosion due to Overland Sheetflow - Parkland Area

**Typical Characteristics**
- Channel with an adjacent parkland area
- Pathways typically located near top of waterway bank
- Bank maintenance resulting in limited riparian groundcover
- Dispersive soils may also be present

**Typical Issues**
- Under high intensity rainfall events local riparian catchments will result in sheet overland flow, even in turfed parkland environments.
- Some natural concentration of sheetflow will usually occur close to the waterway as a result of natural topography or collection and redirection by paved pathways.
- Where riparian groundcover vegetation has been disturbed by weed management activities, such as herbicide applications, overland flows cause erosion on the exposed banks where they enter the waterway, typically undermining the pathway infrastructure.

**Design Response**
- The overland flows should be addressed as a priority as they are the main cause of the erosion. This can be achieved by designing and constructing specific drainage lines to control the flows (these can be in the form of vegetated swales).
- These drainage lines should be designed to discharge at controlled inflow points along the waterway edge. These inflow points could be protected and managed with the design and construction of rock chutes.
- Existing erosion should be dealt with by placing rock (300mm diameter) and backfilling with soil into the eroded area.
- The riparian zone should also be revegetated to protect the soils for future erosion. The vegetation used in the revegetation should be chosen to ensure adequate ground cover and shade, but should allow for clear view lines to the waterway.

**Key Rehabilitation / Remediation Works**
Typical works required to achieve stable waterway banks may include:
- Grade control / rock chutes
- Bank stabilisation
- Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

**Maintenance**
Maintenance requirements to ensure the successful establishment of these works will involve:
- Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
- Inspection of channel banks to identify any erosion / scour zones
- Inspection of chutes to check for dislodgement of rock protection or the presence of weeds
- Removal, and where necessary replacement, of any bank protection material (e.g.: Jute Mat) that has been displaced.
**Existing Waterway Condition**

Erosion of exposed banks due to channelised overland flows

**Improved Waterway Condition**

Overland flows managed with vegetated swales and rock chutes

*Flooding risk can be managed by ensuring channel capacity is not impacted by riparian revegetation*
Channel with Steep Banks and / or Undercutting

Typical Characteristics
/ Channel with steep banks and a deep incised bed level
/ This condition may be the result of headward erosion as a result of downstream activities or as a result of increase flow and stream power as a result of increased catchment runoff
/ The bank may also experience undercutting and widening as a result of the bed erosion creating steep unvegetated banks and exposing erodible / dispersive soils
/ Parklands or built infrastructure may be located adjacent the waterway

Typical Issues
/ Steep banks can often be unstable, presenting a risk to the public as well as any adjacent private or public assets.
/ Difficult to gain access to construct improvement works or maintain channel.

Design Response
/ The design needs to respond to the existing conditions of the waterway.
/ If active erosion is still occurring in the bed and banks, works need to be undertaken to control the erosion and stabilise and fill the steep, deep eroded channel.
/ Initial works need to focus on bed stabilisation. Bank stabilisation can only occur once the bed is stable.

/ Protection/stabilisation of dispersive soils (refer page 40)
/ Channel stabilisation can be achieved with the use of rock chutes. However, this may not address the safety issues associated with a deeply incised channel.
/ To improve safety, the channel bed may need to be lifted and the banks battered back.
/ If there is sedimentation occurring in the area due to the erosion of upstream sediments, the rock chutes can be designed to capture sediments behind the chutes, raising the channel bed level.
/ If there is limited sedimentation occurring (stable developed upstream catchment) the channel may need to be backfilled with a series of rock wedges as the stable catchment is not likely to produce enough sediment to back fill the channel behind a traditional rock chute in a reasonable time.
/ In this case, rock placement is used to lift the bed level. This rock could be relatively small (D50 ~ 300mm) and simply strategically tipped into the channel to form a series of wedges behind grade control chutes.
/ Lifting the bed level allows the batters to be strategically flattened where existing vegetation permits without requiring major works.

Key Rehabilitation / Remediation Works
Typical works required to achieve a stable waterway may include:
/ Grade control (rock chutes + rock placement)
/ Battering back banks
/ Bank stabilisation
/ Riparian revegetation

Please refer to Section 4: Construction and Establishment for more information for each of these and for other elements which may be required due to specific site characteristics.

Maintenance
Maintenance requirements to ensure the successful establishment of these works will involve:
/ Monitoring, watering and weeding of revegetated areas (as recommended in the ICC Riparian Corridor Revegetation Guideline)
/ Inspection of channel banks to identify any erosion / scour zones
/ Inspection of chutes and rock placement to check for dislodgement of rock protection or the presence of weeds.
Existing Waterway Condition
Deep channel with eroded banks due to past bed erosion.

Improved Waterway Condition
Shallow channel with stabilised banks.

Raising the bed level of the waterway decreases the conveyance capacity of the waterway. Battering back the banks will help to maintain the cross sectional area of the channel.
**Design, Construction and Establishment**

This section of the Guideline provides additional information to assist users to undertake remediation / rehabilitation works to achieve outcomes proposed in Section 3: Waterway Management Situations.

- Project Management
- Design Considerations
- Design Details
- Construction and Establishment
- Maintenance
Project Management
Before undertaking any rehabilitation or remediation works, it is important that the project manager has a clear understanding of the waterway / channel issues which requires addressing. To gain an appreciation of the issue, why it has occurred and how to best address it, the project manager will need to consider a number of different elements such as site context and waterway values. These are discussed in more detailed in ‘Design Considerations’ below.

It is also important that the project manager is familiar with the design opportunities available to best address the waterway / channel issue. These opportunities are presented in Section 3: Waterway Management Situations. They must also be familiar with the design requirements and materials that are needed to achieve these design solutions. This information is provided in ‘Design Details’ on page 24.

Design Considerations
This section provides additional site specific information which is important to consider when designing the rehabilitation or remediation of waterways and channel works. This information should be used to modify design responses outlined in Section 3: Waterway Management Situations to address local conditions.

Initial data collection
To ensure that the waterway works will operate as planned, it is important that the design, construction and establishment period of works are well managed.

Initial data collection, site visit or assessments are required in order to gather the following specific information for the site:

- Catchment details
- Soil type
- Channel gradient
- Channel form (e.g. pools + riffles)
- Flow regimes

This information will help you modify the design solution for each waterway management situation (as presented in Section 3: Waterway Management Situations) to ensure the design response adequately addresses site specific characteristics (as summarised in Table 2).

It is especially important that soils assessments are undertaken at the start of any works and soil type and erosivity will play a critical role in the design and construction of waterway works.

### Table 2: Site specific issues and associated design response required

<table>
<thead>
<tr>
<th>Site characteristics / observations</th>
<th>Design, construction and establishment response</th>
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<tbody>
<tr>
<td>Weedy channel</td>
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<tr>
<td>Steep channel with erosion / scour present</td>
<td>Grade control structures may be required</td>
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<tr>
<td>Dispersive or sodic soils</td>
<td>Surface treatments and choice of vegetation</td>
</tr>
<tr>
<td>Flat channel grade with wet or boggy invetrs</td>
<td>Subsurface drainage (if wanting to maintain the channel as a mown turf)</td>
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<tr>
<td>Developing catchment</td>
<td>Increase channel capacity by battering back banks</td>
</tr>
<tr>
<td>Steep and / or unstable banks</td>
<td>Battering back banks and / or bank protection</td>
</tr>
<tr>
<td>Localised flooding issues</td>
<td>Increase channel capacity by battering back banks and / or provision of shade to decrease roughness associated with weeds</td>
</tr>
</tbody>
</table>

Maintaining / enhancing waterway values
As previously discussed, waterways provide a number of values. The purpose of this guideline is to ensure that these values are maintained or enhanced as a part of waterway management works within Ipswich.

Identifying key existing waterway features is important before undertaking any waterway management works as these should be retained as part of the design, construction and establishment process. These include:

- identifying the stage of channel adjustment relative to catchment development (i.e. is the channel just starting to adjust to catchment urbanisation or has adjustment occurred and the channel just needs to be stabilised and rehabilitated)
- identifying existing vegetation that should be retained
- identifying channel forms (such as pool and riffles and natural controls such as rock bars, etc) which should be retained
There may be a number of waterway values and features that could be enhanced as part of waterway management works. These should also be identified early in the design, construction and establishment process to ensure the scope of works allows for these improvements. This may include:

- enhanced habitat values by vegetating waterway edges and providing pool / riffle systems along the waterway
- enhanced water quality with the use of shade trees, stabilising channel bed and providing stable, vegetated banks
- enhanced recreational/social values by improving waterway aesthetics by controlling weeds with appropriate width riparian zones, shade trees, appropriate management of edges and improving water quality

**Design details**

This section provides additional information on how to successfully design waterway rehabilitation and remediation works to respond to common waterway conditions in Ipswich. This information should be used in conjunction with existing Guidelines to achieve the design responses outlined in Section 3: Waterway Management Situations.

**Riparian revegetation**

To ensure that riparian revegetation establishes successfully, there are a number of key design elements that need to be considered. These include:

- bank orientation
- inundation tolerance / bank position
- use of topsoil
- type of vegetation
- plant structure and channel conveyance

More information is provided on each of these factors below.

**Bank Orientation**

Plant establishment in the riparian zone is closely related to the orientation of the waterway. Vegetation on the south side of an east-west section of waterway can be exposed to the sun for most of the day while the northern side could be more sheltered depending on the topography north of the site. This difference in exposure to the sun means that special attention needs to be provided for the plant selection on these 2 banks, ensuring that more heat tolerant species are specified for the southern bank. Trees on the south side will not cast shade on the water. Along a north-south section of waterway trees on both banks will be exposed to sunlight for half of the day, so no difference in species selection is required for the 2 banks.
Use of Topsoil

All plants require suitable top-soil for successful establishment and good growth. In revegetation exercises where topsoil has been lost, such as in many bank erosion situations, it will be necessary to introduce a suitable soil. Where soils need to be introduced to channel banks and batters it will be necessary to provide an anchoring system for the soil. The simplest anchoring and stabilisation system is rock lining where the spaces between the rock can be filled with soil. Planting can occur into the soil filled voids between the rocks. The soil doesn’t necessarily have to be particularly high quality but needs to be:

/ able to support plant growth,
/ free of weeds
/ non-dispersive.

In areas of saline or sodic soils it will be crucial to have adequate topsoil cover for successful revegetation.

Geotextile materials can also be used to protect topsoil while areas are being re-vegetated. While the use of geotextiles can be very successful at protecting topsoils from erosion, careful consideration of plant selection, planting density and longevity of the geotextile is required to obtain a good long-term result.

For example without appropriate maintenance and selection of matting, geotextiles can inhibit the spread of rhizomatous or suckering species. The successful use of geotextiles with spreading species needs selection of short field life materials and regular adjustment of planting holes as the plants establish and start to spread.

Type of vegetation

Before revegetating your site, it is important to gain an understanding of the local indigenous species that are either present or are known to have existed in the local area. The design of waterway and riparian vegetation needs to balance the pragmatic requirements of creating a stable waterway channel while respecting the relative Regional Ecosystem for the site in question. In general revegetation species should be drawn from a relevant Regional Ecosystem mapped community. For example Regional Ecosystem 12.3.3c: Floodplain (other than floodplain wetlands) is described as: “Melaleuca irbyana low open-forest or thicket. Emergent trees may be present e.g. Eucalyptus moluccana, E. crebra, E. tereticornis and Corymbia citriodora. Casuarina glauca or Acacia harpophylla occasionally present. Occurs on Quaternary alluvial plains”. This community could form the basis for the riparian zone - upper bank community and general riparian corridor. The understorey for this area could consist of Lomandra spp., whereas the lower bank could support Carex appressa or Poa spp. and the channel Schoenoplectus validus.

It is also important that fast growing native species that provide quick coverage for weed suppression and protection of the bank are chosen. The ICC Riparian Corridor Revegetation Guideline provides a list of fast growing plants that are commonly available from local and regional stockists.
Plant structure and channel conveyance

In areas where flooding is a concern it is important to consider the plant structure of any species specified for the channel or floodplain and how the channel and riparian vegetation may influence the conveyance capacity of the waterway. Appendix C of the Natural Channel Design Guidelines (BCC, 2000) outlines a range of recommended Manning’s N values for a range of waterway types and vegetation conditions. It is important to recognise that the roughness of in-stream and riparian vegetation will change over time as the community establishes, develops and matures. Roughness is likely to increase as revegetation establishes and may start to decline over time as the riparian community matures and trees start to control the density and size of ground cover.

Crime Prevention Through Environmental Design (CPTED)

When revegetating the waterway riparian zone, it is important to consider the use of the surrounding area. If the waterway falls within a public open space area, plant selection should ensure that public safety is not adversely affected by the revegetation works. This can be done by choosing groundcovers which do not grow taller than 0.6m and shade trees which can have their lower branches easily pruned.

Other Key References:
- Natural Channel Design Guidelines (BCC, 2000)
  - Section 4: Revegetation
  - Appendix C: Mannings Roughness
- Riparian Corridor Revegetation Guideline (ICC) - details on plant selection, weed control and planting guide

Battering banks

Battering back banks involves the excavation of the bank to decrease its steepness. Battering back banks can provide a number of waterway benefits including increasing channel capacity, stabilising steep banks and can create clear maintenance boundaries. Undertaking bank works can expose soils within the waterway channel and should be undertaken with an appropriate design and construction and establishment plan to minimise risk of bank erosion.

Cross-sectional design

There are a number of different design options when battering back banks. These include:
- creation of low flow channel within a symmetrical broader channel with floodplain
- creation of symmetrical broad channel
- creation of broad channel with meanders and differing slopes

Figure 3: Cross sections of different batter design options

Cross-sectional design is intimately associated with plan-form (see ‘meanders’ discussion below). Cross-sectional design needs to consider the direction of bends and meanders and adjust cross-sectional geometry to limit flow velocities on outside bends. The consideration of cross-sectional variation should attempt to ensure that as flows increase the cross-sectional area increases and the flow path straightens (refer Figure 4).

Figure 4: Plan section of meandering waterway channel showing the straightening of the flow path as flows increase.
Batter slopes
Batter slope design may alter depending on design objectives and site constraints. Site constraints include limited space available due to neighbouring private or public assets and bank condition / soil type. For example sandy soils should not have bank slopes greater than 1:4 while sandy-loam soil with groundcover vegetation may have a 1:3 batter (BCC, 2000).

Batter slopes greater than 1:5 provide safe public access to the waterway. This may be a design consideration if community engagement and access to the waterway is a desired objective for the waterway works. These slopes also allow for mowing which may be required if the banks are turfed.

Typically batters should not be steeper than 1:3. Constrained sites such limited available area and retaining existing trees may require steeper slopes. Any batters steeper than 1:3 will require bank stabilisation works, particular vegetation designs and consideration of cross-sectional compensation on the opposite bank.

Meanders
If a channel is to be rehabilitated, it is often desirable to introduce some channel meanders to improve aesthetics, habitat and channel diversity and also increase the effective channel length. Increasing channel length is one of the most effective ways of reducing the bankfull flow velocity (BCC, 2000).

The Natural Channel Design Guidelines (BCC, 2000) suggests that the meander radius is generally greater than three times the normal channel width. If a sharper meander radius is required then it may be necessary to rock-line the outer bank of the meander.

Construction of meanders may involve ‘flip-flopping’ of batter slopes to create this visual affect (Figure 4). This will require bank stabilisation on the steep outside batter and may result in cutting back into the existing bank on the inside bank to create a flatter batter.

Channel capacity
Battering back existing steep slopes will increase the channel capacity. To ensure that the channel capacity is appropriate, initial data collection should identify the existing and proposed landuse in the contributing catchment. If development is being undertaken or is planned, the channel capacity should be increased to ensure that increased catchment flows can be safely conveyed within the channel or designed over channel areas.

Other Key References:
Natural Channel Design Guidelines (BCC, 2000)
- Section 3: Design Procedures - Steps 6 and 7
Erosion Treatments for Urban Creek Guidelines (BCC, 2004)
- Section A4 - Erosion Treatment Technique #T11

Bank stabilisation
There are a number of options available to stabilise banks, each with their own benefits, risk and preferred application with regards to waterway management. These are shown in Table 3.

Table 3: Bank stabilisation materials summary

<table>
<thead>
<tr>
<th>Stabilisation material</th>
<th>Description</th>
<th>Risk of use</th>
<th>Preferred waterway management application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock and structural soil (with vegetation)</td>
<td>Layers of rocks (average diameter 250mm) backfilled with soil which can then be planted out (rock size will partly depend on the channel slope and flow velocities)</td>
<td>Any rock stabilisation techniques are only appropriate if the bed is stable. Bed instability will always create a risk for bank works</td>
<td>Steep slopes stabilisation (refer Figure 5 and Erosion Treatment Technique #T6 (BCC, 2004) for more information)</td>
</tr>
<tr>
<td>Jute matting</td>
<td>Biodegradable matting which can be cut and planted into</td>
<td>Can restrict plant growth. Needs to be carefully installed to ensure success. Needs to be maintained to ensure good plant growth and establishment.</td>
<td>Use when exposed soils are at high risk of eroding during channel works</td>
</tr>
<tr>
<td>Sterile rye grass</td>
<td>Grass seeds which establish quickly, stabilising exposed soils and can then be planted into</td>
<td>Need time to establish before banks are stabilised</td>
<td>Hydroseeding</td>
</tr>
<tr>
<td>Mulch</td>
<td>Many materials can be used as mulch, such as sugar cane and wood chips</td>
<td>Most mulch materials float easily and therefore are washed away easily when used in waterways</td>
<td>Mulch should only be used on batters if netting is used to control mulch. Mulch is best applied at the top of the bank as part of riparian revegetation works</td>
</tr>
<tr>
<td>Coir logs</td>
<td>Coir netting filled with densely packed coir (coconut) fibre</td>
<td>Should not be used in isolation of other stabilisation measures</td>
<td>Applied to toe of batter to provide short term protection as batter vegetation establishes</td>
</tr>
</tbody>
</table>

Other Key References:
Erosion Treatments for Urban Creek Guidelines (BCC, 2004)
- Section A4 - Erosion Treatment Technique #T6
Natural Channel Design Guidelines (BCC, 2000)
- Appendix A: Channel Features
Grade control structures

There are a number of techniques available to control erosion along the bed of a waterway. A summary of these techniques is provided in Table 4. More information on the construction of these techniques is documented in the Erosion Treatments for Urban Creek Guidelines (BCC, 2004).

Table 4: Grade control structures summary

<table>
<thead>
<tr>
<th>Grade Control Structures</th>
<th>Description</th>
<th>Risk of use</th>
<th>Detailed construction information*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock / log bed control</td>
<td>Involves using logs or rocks to create a retaining wall across the bed of the stream (acting as a weir-type structure)</td>
<td>- Logs will eventually rot - Can be seen as a fish movement barrier</td>
<td>Erosion treatment techniques #T1 and #T2 (refer Figure 6)</td>
</tr>
<tr>
<td>Rock chutes*</td>
<td>Rock used to form a rock chute which transfers stream from a higher to lower elevation without erosion</td>
<td>- Risk of failure related to appropriate selection of rock size</td>
<td>Erosion treatment technique #T3.</td>
</tr>
<tr>
<td>Boulder Plunge Pools</td>
<td>Large boulders used, placed in the creek bed and banks to control movement of erosion upstream.</td>
<td>- Can be seen as a fish movement barrier - Materials may not be readily available</td>
<td>Erosion treatment technique #T4</td>
</tr>
</tbody>
</table>

*This information can be found in Erosion Treatments for Urban Creek Guidelines (BCC, 2004)

**Under most circumstances an appropriately designed chute is often the preferred solution because of the long-term stability performance and revegetation potential and possibilities for fish passage and waterway connectivity.

It is important to integrate revegetation works with physical control structures. Without the soil protection ability of vegetation most physical works will fail. Vegetation provides a self repairing and adjusting system to augment the initial stability created by physical works.

Managing dispersive and sodic soils

Understanding soil types and conditions is crucial for successful waterway management works. This is especially important in Ipswich due to extent of dispersive soils across the city.

Dispersive and sodic soils need careful management to ensure stable waterway conditions are achieved. Where dispersive or sodic soils are exposed, erosion risk is high. Exposed subsoils need to be covered with topsoil prior to revegetation or bank stability works (Figure 7). Any capping soil used should be classified as an engineering clay. Topsoil will need to be held in place with rock or geotextile materials until vegetation is established. In areas with sodic or saline subsoils the salinity tolerance of revegetation species needs to be considered.
Construction and establishment

Waterway works can be problematic as they are undertaken in areas which flow regularly, resulting in risk of scour and erosion during construction and establishment. During this high risk stage of works, erosion and sediment control is a priority.

The timing of the works can help to reduce risk associated with construction within waterways. Typically, bulk earthworks should be undertaken in the dryer winter months.

The staging and sequencing of works can also reduce risk. Works should be staged from upstream to downstream locations, minimising the area of exposed ‘transportable’ sediment at any stage. Works can also be broken down into interim vs future works, reducing the timeframe and also the costs associated with each stage of works. Interim works can be undertaken immediately and within existing budgets to simplify existing maintenance of waterways. This work can involve weeding and mulching weedy riparian areas and also trying to control weeds in the channel. Future works can then be undertaken to create the ‘Improved Water Condition’ when timing (dry winter months) and budgets allow. When staging is necessary it is important to have a final rehabilitation plan to ensure the staged works will eventually sum to the desired outcome.

Figure 8: Risk trajectory of waterway works from construction to on-going maintenance

To reduce risk of failure during establishment, there are a number of activities which should be undertaken.

/ Any rock structures should be monitored and reset if required.
/ Regular watering is required for all vegetation to ensure successful establishment. Watering should be undertaken on an “as needed basis” depending on climatic conditions (typically weekly for 4 weeks, fortnightly for 4-12 weeks and monthly watering for 3-6 months)
/ Additional irrigation may be required for vegetation on exposed banks
/ If jute matting is used, checks should be undertaken to ensure that it is not restricting plant growth. This may require additional cuts to be made in the matting. Checks should also be undertaken to ensure the jute matting does not become dislodged, which could result in the smothering of plants and / or erosion.
/ Weed management is essential until plants are fully established and can suppress weed growth with their density and foliage cover.

Maintenance

Waterway rehabilitation/remediation solutions proposed in this guideline are designed to enhance the natural values of waterways within Ipswich City Council. Typically this will involve revegetation of the riparian zone. To ensure the success of these designs, maintenance needs to take in the following considerations:

/ Timing of maintenance activities
/ Responsibilities
/ Maintenance requirements

Timing

Maintenance of waterway rehabilitation works will require an initial investment to be made to ensure the vegetation is established as designed, resulting in a more robust natural vegetation community. Once this landscape is established, the maintenance effort required to maintain the area will diminish, trending to a level of effort much less than is currently exercised for an equivalent open space area. This concept of diminishing maintenance burden is theoretically illustrated in Figure 9.

Figure 9: Maintenance effort associated with regular park maintenance and waterway rehabilitation works

This concept recognises that during the plant establishment period of waterway rehabilitation works (approximately 2 years), intensive maintenance will be required to control weeds, and to identify and replace unsuccessful plantings. After the establishment phase, the maintenance burden will taper off over the following four to five years as the vegetation community continues to mature. Beyond this time, maintenance requirements will continue to decrease as the vegetation community matures. It is envisaged that after 5-7 years the area should be incorporated into the regular natural asset maintenance program. Regular monitoring should be conducted to ensure that any new weed infestation is controlled and litter is removed.
Responsibility
Many channels and waterways are located within public open space areas. The waterway restoration solutions proposed in this guideline involve the establishment of riparian vegetation and in-stream works. Typical park maintenance such as mowing and strip herbicide applications is not appropriate for these areas. As such, the maintenance of these natural assets should be undertaken by the appropriate group within Council. This may result in a change of maintenance responsibilities within these parkland areas from predominately park maintenance to a mix of natural area and park maintenance (shown in Figure 10).

Design Requirements
Design solutions proposed in this guideline recommend clear maintenance boundaries to be created to delineate between the drainage and waterway corridors and adjacent parkland areas. This can be achieved with formal edging designs (plinths, boards, mowing edge, etc.) and/or a tree canopy to create a clear maintenance boundary between mown and natural bush maintenance areas. Stepped cross-sections can also be employed to create more defined maintenance boundaries.

The boundary will delineate the areas which require regular park maintenance and natural asset maintenance (refer Figure 10). The requirements for both of these areas differ as highlighted below.

Regular park maintenance may involve:
- Litter collection
- Mowing
- Repair / replacement of structures such as decking, seats and bollards and paths

The intensity of this maintenance will remain relatively constant over time.

Natural asset maintenance will require initial investment to ensure works establish as designed. Maintenance requirements during this establishment phase will involve:
- Watering
- Weed removal
- Replacement of unsuccessful plantings
- Checks for erosion

Once the works are established, the maintenance of the area will reduce significantly and will require on-going monitoring to ensure that any new weed infestation, litter and erosion is controlled.

A case study on the maintenance costs of vegetated systems by the Cooperative Research Centre for Catchment Hydrology found that the cost of maintaining vegetated swales dropped from $9.00/m²/year to $1.50/m²/year (Lloyd et al. 2002).
References

Brisbane City Council (BCC) (2004), Erosion Treatments for Urban Creek Guidelines, version 3

Brisbane City Council (BCC) (2000), Natural Channel Design Guidelines


Ipswich City Council (ICC), Riparian Corridor Revegetation Guideline

Ipswich City Council (ICC) (2009), Waterway Health Strategy


