Watercourse Erosion – Part 1

EROSION TYPES AND THEIR CAUSES

Watercourse: A channel with defined bed and banks, including any gullies and culverts associated with the channel, down which surface water flows on a permanent or semi-permanent basis or at least, under natural conditions, for a substantial period of time following heavy rainfall within its catchment.

Types of watercourse erosion

By definition a watercourse is a ‘drainage channel’, but drainage is just one of its functions, it is also a habitat (a home), a wildlife corridor, a refuge, and a nature reserve. Depending on its location, it may also be a human movement corridor, recreation area, retreat from the urban landscape, research and education area, and a buffer zone separating adjacent land uses.

Waterways must be allowed to function in harmony with their catchments and surrounding land uses. More importantly, stormwater runoff from a modified catchment must remain in balance with the ‘values’ attributed to the waterway.

If the balance is altered, then the most common outcome is erosion of the watercourse. Watercourse erosion can include erosion within the channel and adjacent floodplains. However, not all watercourse erosion is ‘bad’, and not all erosion is the direct result of human activities. Stream migration, for example, is a natural process resulting from natural channel erosion; however, it can also be an unnatural or accelerated process resulting from human activities.

The size of the watercourse channel is dependent on four key elements: water, vegetation, soil and rock (Figure 1). A variation in any one of these elements can cause an in-balance (Figure 2) resulting in expansion, contraction or simply a change in the shape or location of the channel.

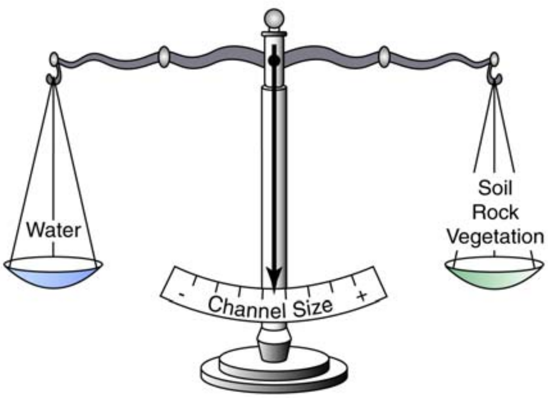

Figure 1 – A watercourse in balance

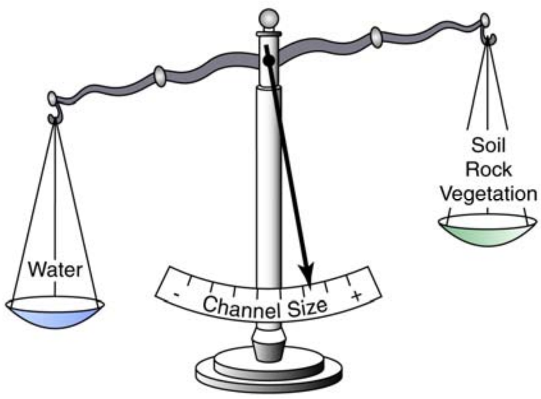

Figure 2 – A watercourse out of balance

Watercourse erosion is the stream’s way of adjusting to changes that have occurred within the drainage catchment. These catchment changes can be short-term, such as the effects of severe floods or a temporary change in plant densities following bushfires; or long-term such as resulting from deforestation, urbanisation, or a change in plant species along a watercourse.

Of course there can be more than one cause of the watercourse erosion. In some cases, the initial cause of the erosion can be significantly different from the forces causing the erosion to continue. For example, a creek bank could begin to erode as a result of sediment deposition on the channel bed. The minor erosion at the toe of the bank may then lead to a total bank failure during the next flood.

In the above example, the primary cause of the channel erosion may at first appear to be the effects of high-velocity flood flows; however, failure to adequately address the sediment deposition problem may result in ongoing erosion problems even after significant time and money has been spent repairing the eroded bank.

All too often landowners and waterway officers treat what they first see, rather than taking the time to see what is really going on within the waterway.

The stabilisation of active channel erosion requires: an understanding of the various types of bed and bank erosion, the ability to recognise the likely causes of such erosion, and the ability to identify appropriate treatment measures. Obtaining this information usually involves seeking expert advice, including advice from relevant State agencies.

(a) Bank scour

Photo 1 – Bank scour (Qld)

Photo 2 – Bank scour around the outside of a channel bend (Qld)

Bank scour is the removal of material from the surface of the creek bank as a direct result of stream flow. The erosion maybe the result of excessive turbulence (Photo 1), or high flow velocity, such as on the outside of a channel bend (Photo 2).

Causes include: high velocity stream flows, poor vegetation cover, excessive reed growth within the bed of the creek, turbulence caused by trapped debris such as fallen trees, or high velocity water discharged from stormwater pipes or culverts.

Vegetative treatment measures primarily rely on the use of flexible ground covers placed within the lower bank and along the water's edge, and low-branch woody species (e.g. shrubs) placed on mid and upper bank areas, and on the outer bank of channel bends. Generally, planting schemes need to ensure that the banks need to be 'hydraulically' rougher than the channel bed.

The use of trees within the channel may increase flow turbulence aggravating the erosion.

(b) Bank slumping

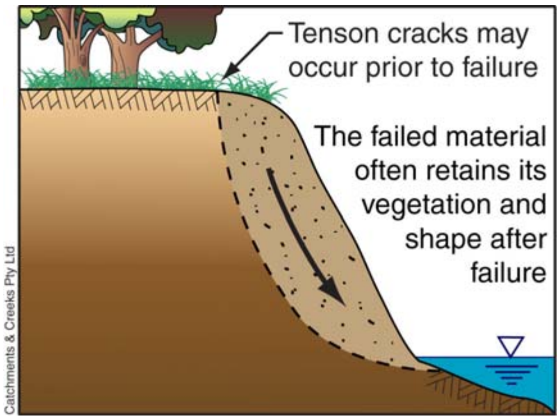

Figure 3 – Bank slumping

Photo 3 – Bank slumping (SA)

Bank slumping is the mass movement of bank material (Figure 3). Geological slip circle failures are included in this category.

Causes include: the removal of trees from the top of the bank, deepening of the channel by erosion or dredging, an unusual or rapid lowering of flood waters following saturation of the banks, or excessive fill material placed on or near the top of bank.

Vegetative treatment measures primarily rely on the use of shrubs on the channel banks, especially on the outer bank of channel bends; and deep-rooted trees placed planted on the upper and over-bank areas, especially on steep and/or high banks.

(c) Bank undercutting

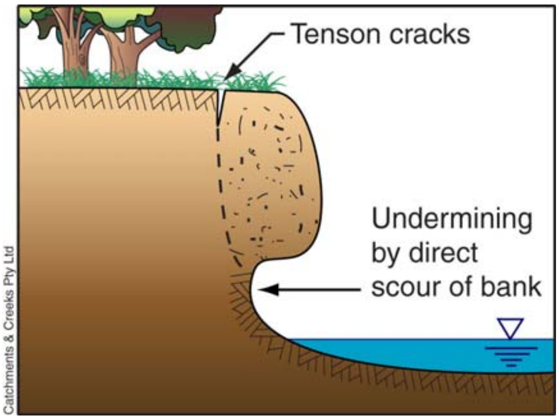

Figure 4 – Bank undercutting

Photo 4 – Bank undercutting (Qld)

Bank undercutting is the removal of material from the lower portion of a channel bank by 'bank scour'. This erosion results in the creation of an overhanging bank that usually fails in a more violent motion than occurs in 'bank slumping'. In effect, bank undercutting is a combination of bank scour within the lower bank, which ultimately causes upper bank slumping. The two actions may not occur simultaneously.

Causes include: a migrating low-flow channel, frequent high-velocity in-bank flows, exposure of a weak soil layer within the lower bank, changing catchment hydrology (e.g. urbanisation), or the removal of essential lower bank vegetation.

Vegetative treatment measures primarily rely on the stabilisation of the lower bank with rock and tall, flexible, ground covers. Shrubs are normally located on mid and upper bank, and on the outer bank of channel bends. Trees are primarily located on the upper bank and over-bank areas, especially on steep and/or high channel banks.

The lower bank area often requires additional scour protection (e.g. rock and/or groynes) during the plant establishment phase.

(d) Bed scour

Photo 5 – Bed scour (Qld)

Photo 6 – Head-cut erosion (Qld)

Bed scour is the direct removal of material from the bed of the creek either by high velocity flows (causing uniform scour along the bed, Photo 5), or the formation of a head cut (waterfall) that migrates up the creek (Photo 6).

Causes include: clearing of vegetation from the channel resulting in increased flow velocities (e.g. weed removal or de-snagging), changes in catchment hydrology (e.g. urbanisation and land clearing), or the exposure of weak (e.g. dispersive) soils within the channel bed.

Bed stabilisation with grasses and other flexible, non-clumping, ground covers maybe suitable on ephemeral streambeds, otherwise the bed may need to be stabilised with rock. In gullies, the erosion often exposes poor quality soils that will require appropriate chemical adjustment prior to revegetation.

(e) Lateral bank erosion

Photo 7 – Lateral bank erosion (Qld)

Photo 8 – Lateral bank erosion (SA)

Lateral bank erosion is the erosion of the creek bank resulting from the entry of lateral inflows (usually stormwater) into the creek. The erosion usually takes the form of an upstream progressing erosion head (head-cut) that propagates laterally from the main channel forming a new gully (Photo 8).

Causes include: excavation of the downstream channel bed, a change in catchment hydrology, or a change in the quantity or direction of overland flows entering a waterway channel.

Treatment normally involves engineered measures such as rock chutes, pool–riffle systems, and grade control structures. In gullies, stiff grasses such as Vetiver grass, can be used to slowly stabilise and partially back-fill the gully with sediment—this can help to reduce the rate of progression of the head-cut.

(f) Fretting

Photo 9 – Wave induced erosion (Qld)

Photo 10 – Fretting erosion (Qld)

Fretting is the direct removal of erosion prone material from the bank of a creek by wave action (Photo 9). This erosion results in the undercutting (Photo 10) and possible failure of the bank.

Causes include: wind-generated wave action, waves generated by boat traffic, or the removal of essential vegetation such as mangroves.

The bank can be stabilised through the formation of a sandy 'beach' in front of the eroded bank or the formation of a retaining wall (generally undesirable). The beach acts as an effective energy dissipater for the waves. Alternatively, the bank can be stabilised with rock, either with or without vegetation.

It is usually better to incorporate treatment measures that help to dissipate the wave energy, rather than hard engineering measures, such as retaining walls, that simply reflect the wave energy to another location. Rock protection measures should maintain an open void structure to help adsorb the wave energy; however, it should be noted that the placement of rock along the toe of the bank can adversely affect the habitat value of the water's edge.

Table 1 - Erosion type identification chart

Erosion Type ➔ / ➔ Indicators	Bank scour	Bank slumping	Bank undercutting	Bed scour or head-cut	Fretting	Lateral bank erosion
Fluting (multiple, deep, narrow, rills formed down the bank)	✓					
Bank erosion generally limited to heavily shaded areas	✓		✓			
Lateral movement of the channel bank	✓	✓	✓		?	
Collapsed bank material retains original shape and vegetation		✓				
Tension cracks in overbank area running parallel to bank		✓	✓			
Collapsed bank material has largely washed away			✓			
Undercutting along the toe of the channel bank			✓		✓	
A well-defined waterfall (often mobile) formed in the bed				✓		
Bell-shaped scour hole formed in the bed				✓		
Exposed foundations of structures (e.g. bridge piers).				✓		
Bank erosion limited to narrow area around the water's edge					✓	
Eroded gully propagating laterally from the creek bank						✓
➔ Possible Causes						
Several in-bank stream flows or a long-duration in-bank flow	✓		✓	✓		
Significant over-bank flood event	✓	✓	✓	✓		✓
Flood event with rapid draw-down (e.g. shutting of dam gates)		✓				
High velocity flow on the outside of a channel bend	✓	?	✓			
Significant deforestation within the catchment	✓	✓	✓	✓		✓
Urbanisation of the catchment	✓	✓	✓	✓		✓
Increased runoff entering the channel from over-bank areas						✓
Excessive or inappropriate in-bank vegetation		✓	✓			
Trees removed from top of bank and over-bank areas		✓				?
Lack of in-bank vegetation (e.g. after weeding or fire)	✓	✓	✓		✓	✓
Channelisation or de-snagging within the downstream channel	✓		✓	✓		
Channel revegetation has increased shading of channel bank	✓		✓			
In-stream obstructions such as fallen trees, or debris	✓		✓	✓		
Exposure of a weak soil layer within the channel bank	✓		✓		✓	
Dispersive (sodic) subsoils exposed on the channel banks	✓		✓			✓
Dispersive (sodic) subsoils exposed on the channel bed				✓		
Unstable flow entry conditions into a waterway culvert				✓		
Unnatural concentration of flows by a new waterway culvert				✓		?
Introduction or change in boat traffic along the waterway					✓	

What to look for when observing watercourse erosion

Some of the common indicators and warning signs are discussed below.

(i) Look for the formation of an unnatural waterfall in the bed of the creek. In small creeks and drainage channels these waterfalls often take the form of a 'bell-shaped' scour hole. This form of erosion usually identifies head-cut erosion and is a clear indication of an unstable channel bed. The cause can be either a change in catchment hydrology, or a change in the downstream channel conditions, such as caused by the clearing of in-bank vegetation, lowering of downstream flood levels, or the construction of a downstream culvert with an unstable drop inlet.

(ii) Long-term bed erosion can often be observed by noting the increasing exposure of hard engineering structures such as bridge piers, culvert foundations, or stormwater outlets. This could indicate either an unstable channel bed or channel migration. The presence of channel migration can be confirmed by reviewing of historical aerial photographs.

(iii) Lateral movement of the low-flow channel within the bed of the main channel can initiate the effects of excessive sedimentation, excessive growth of aquatic vegetation, or simply natural erosion processes.

(iv) The lateral movement of a channel bank, usually on the outside of a bend, is an obvious sign of bank erosion, usually resulting from direct bank scour and/or bank undercutting. Historical aerial photos or construction plans prepared for instream structures may indicate the extent and rate of the bank movement.

(v) A significant change in the colour or strength of the bank material near the erosion site may indicate a significant change in soil properties. This can be a major problem that requires immediate investigation and treatment.

(vi) The degree of weathering or exposure of tree roots can be a good indicator of the rate of erosion and the suitability of a given tree species for placement near active bank erosion.

(vii) Dispersive soils are highly erodible. Such soils are usually evident by deep, narrow rutting (fluting) in the banks caused by lateral inflows. The only feasible means of protecting these soils from erosion is to cover them with erosion-resistant topsoil and then revegetate and/or stabilise with rock. Dispersive soils **must** be covered with a layer of non-dispersive soil before the placement of any erosion control measures.

(viii) If the bank erosion is occurring over a significant length of the bank, rather than within isolated sections, then the erosion is likely to be the result of bank scour or bank undercutting rather than bank slumping.

(ix) Evidence of old channel meanders (often easy to observe in aerial photographs) may indicate that the creek had been straightened during past flood mitigation works, or as a result of natural processes. This channel straightening may have increased the flood gradient, thus increasing stream velocities and the potential for creek erosion.

(x) Evidence of isolated pools or depressions within a wide floodplain can indicate that the creek is highly mobile (i.e. the creek's location often changes significantly during flood events). This is usually a natural erosion process that is difficult to control, but it may also be the result of turbulence generated around fallen trees and trapped flood debris.

(xi) Tension cracks along the top of the bank (or within the bank) may indicate bank undercutting or partial bank slumping. Unlike cracks caused by drying soil, tension cracks will normally concentrate along a common plane parallel to the channel bank.

The most common cause of tension cracks is bank undercutting. The cause can be the removal of essential over-bank tree cover, erosion on the outside of a channel bend, or the effects of several high-velocity in-bank stream flows.

Bank slumping is likely to be the result of excessive tree removal from the upper bank and over-bank areas. Often these cracks begin to appear several years after removal of the trees due to the time required for the old root system to begin to fail.

(xii) A near-vertical or partially undercut earth bank usually indicates that erosion is occurring along the toe of the bank (bank undercutting). If the erosion is near vertical at the top of the bank but concave at the base, then this could be the result of bank slumping.

(xiii) If an isolated section of the bank has already collapsed, then the type of erosion (undercutting/slumping) may be determined by the form of the collapsed material. If the bank material remains at the base of the bank in one or more obvious sections, possibly with vegetation still growing in the soil, then the erosion is likely to be the result of bank slumping. If the collapsed material has fractured into several small clumps, or has washed away altogether, then the erosion is likely to be the result of bank undercutting.

(xiv) If one bank is significantly higher than the other, then check if bank scouring is occurring on the higher bank at, or slightly above, the level of the lower bank. In such cases, erosion treatment measures may only need to concentrate in the lower area of the high bank. Once this lower bank region is stable, the upper bank will normally be stable.

(xv) Slip-circle bank failures can often be detected by observing one or more of the following indicators:

- damage to property fencing caused by shifting soil;
- obvious slip scars;
- terraced formations;
- clumps of trees that have died for no apparent reason;
- tree trunks that have developed a bend following displacement of the soil;
- cracking in nearby structures (footpath/bikeways) adjacent to the creek bank.

(xvi) An eroded gully propagating laterally from the bank of a creek (i.e. lateral erosion) usually indicates that there has been a change in stormwater runoff (volume or concentration) flowing overland toward the waterway. The most common cause is de-forestation of the catchment or the effects of urbanisation.

(xvii) Severe erosion downstream of a causeway usually indicates that there is a significant fall in water level across the causeway during flood events. Channel works downstream of the causeway (such as channel widening or vegetation clearing) can also lower flood levels aggravating channel erosion immediately downstream of the causeway.

(xviii) Severe bed erosion downstream of a culvert may indicate high exit velocities, but could also indicate a downstream problem. This erosion is best managed by introducing roughness to the channel bed, usually in the form of a rock scour pad. Scour protection measures that are hydraulically smooth, such as concrete or rock mattresses, can simply transfer the flow energy further downstream.

(xix) Severe bank erosion downstream of a culvert is likely to indicate either a poorly aligned culvert, or the generation of large eddies either side of the culvert during flood events.

(xx) Erosion at the water's edge may indicate the effects of wave action caused by boats. Erosion that has resulted from high-velocity flows is more likely to be observed in deeper water areas or on the outside of a channel bend.

Understand the cause before designing the cure

Some of the common causes of creek and gully erosion are listed below.

(i) Clearing of vegetation from the contributing catchment can significantly alter the catchment hydrology. This can result in changes to the frequency, volume and duration of creek flows causing channel expansion.

(ii) Urbanisation of the contributing catchment can significantly change the hydrology unless the principles of Water Sensitive Urban Design (WSUD) are embraced throughout the catchment. Traditionally, urbanisation has caused the greatest change to the smaller, more frequent channel flows, which are the flows that cause most of the channel erosion.

(iii) A significant change in the hydraulic capacity of a watercourse (e.g. by weeding, snag removal, channel expansion) can result in upstream channel erosion.

(iv) The removal of vegetation from the bed or banks of a creek can result in localised erosion. It should be noted that weeds can provide effective erosion control benefits. Therefore, if weeds are to be removed from a channel, then this should be done during periods of low flow; otherwise, erosion control blankets may need to be placed over the exposed soil.

(v) The clearing of vegetation from a floodplain located on the inside of a large creek meander can initiate erosion on the floodplain resulting from high velocity floodwaters flowing short-cutting across the floodplain. This may ultimately cause the relocation of the main channel.

(vi) Shading of a creek can cause the loss of essential ground cover vegetation resulting in bed and bank erosion. It is important to consider the adverse effects of bank shading when planning creek rehabilitation works. Of course, this does not mean that the shading of creeks is a problem, it just means that the effects must be appropriately managed.

(vii) In arid and semi-arid areas, shading can be highly beneficial to bed and bank vegetation by helping to create a micro-climate within the channel, and helping to maintain soil moisture levels.

(viii) Unusually thick concentrations of bed vegetation can initiate bank erosion (usually on the northern, shaded bank). Bed vegetation can be altered by a reduction in the shading of the channel, the deposition of nutrient-rich sediments, or changes in channel maintenance (e.g. weeding activities).

(ix) One of the most common causes of creek erosion is the existence of bends or meanders in the creek's alignment. Such erosion can be both natural and accelerated (human induced). A bend in the channel causes high velocity water to push, or roll, towards the outer bank resulting in bank erosion such as bank scour or undercutting.

(x) Bank failures can result from excessive weight being placed on or near the channel bank, such as excavated bed material being dumped on the top of the channel bank. This form of bank failure usually follows periods of heavy rain when the soil becomes saturated. A saturated soil weighs significantly more than a dry soil, and this added weight is often enough to initiate bank slumping.

(xi) Bank slumping usually results from water saturation of the upper bank soil. This water can originate from groundwater seepage, or the after effects of flooding. In some circumstances, normal tidal movements can result in bank slumping following the removal of essential bank vegetation (often there is a significant time delay between the vegetation removal and the bank failure). Bank slumping, however, can also occur without the effects of excessive soil moisture.

(xii) Bank erosion is often caused by the uncontrolled discharge of stormwater down the face of the bank. This form of erosion usually occurs when local stormwater is collected in small grass swales that discharge in an uncontrolled manner down the creek bank.

(xiii) In areas where a creek has recently experienced gully erosion, the resulting changes to local groundwater levels may cause stress to bank vegetation ultimately resulting in failure of the bank.

(xiv) Instream obstructions such as fallen trees, culverts, pipe crossings, and thick reed beds can cause large-scale turbulence resulting in bed and/or bank erosion.

(xv) The placement of 'hydraulically smooth' bank stabilisation measures on the outside of a channel bend (e.g. gabions, concrete, or non-woody vegetation) can cause high flow velocities to be generated adjacent the bank. These high velocities can initiate bed erosion adjacent the treated area, or bank erosion immediately downstream of the treated area. It is for reason that new bank erosion problems are often found immediately downstream of recently installed bank stabilisation works.

(xvi) Culverts can initiate upstream bed erosion if they are inappropriately recessed into the bed of the channel. Inappropriately drop inlet designs can result in the formation of a small waterfall (head-cut) that migrates up the creek.

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