

Revegetating Grassy Gullies



Catchments
& Creeks

Version 1, 2026

Revegetating Grassy Gullies

Version 1, August 2026

Written and illustrated by: Grant Witheridge, *Catchments and Creeks*, Queensland, Australia.

Images prepared using Adobe Photoshop and Illustrator.

Permission is granted for readers to:

- store the complete document on a database, but not isolated parts of the document;
- print all or part of the document, and distribute such printed material to a third party;
- distribute the complete document in electronic form to a third party, but not isolated parts of the document.

All diagrams are supplied courtesy of Catchments & Creeks and remain the ownership of Catchments & Creeks. No diagram or photograph may be reproduced within another publication without the prior written permission of the Director of Catchments & Creeks.

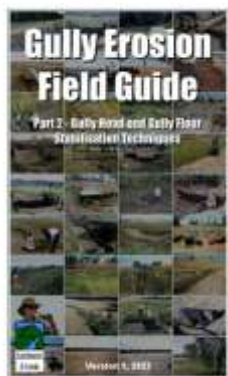
This document should be referenced as:

Witheridge, G.M. 2026, *Revegetating Grassy Gullies*. Catchments & Creeks, Bargara, Queensland.

© Catchments & Creeks, 2026

Cover image: The revegetation of a grassy gully in southern New South Wales (19/12/2013).

Principal reference documents:



Gully Erosion Field Guide, 2022

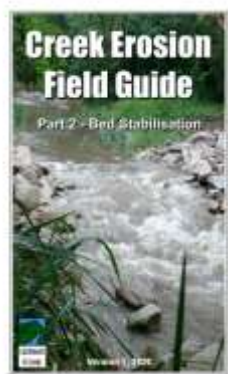
Gully Erosion Field Guide – Part 2, Gully Head and Gully Floor Stabilisation Techniques

Catchments & Creeks Pty Ltd, 2022, Barga Queensland.

129 page PDF document

Version 1, February 2022

Part 2 of this three-part document presents design information on gully head and gully bed stabilisation.



Creek Erosion Field Guide, 2022

Creek Erosion Field Guide Part 2 – Bed Stabilisation

Catchments & Creeks Pty Ltd, 2021, Barga Queensland.

123 page PDF document

Version 2, February 2022

Part 2 discusses the planning of creek erosion treatments, fish-friendly bed treatment, common properties of rock, the hydraulics of grade control structures, fish-friendly and non fish-friendly bed stabilisation techniques.



Use of Rock in Waterway Eng, 2000

Use of Rock in Waterway Engineering

Catchments & Creeks Pty Ltd, 2014, Brisbane Queensland.

72 page PDF document

Version 3, 2020

This document provides a pictorial guide to the sizing and placement of rock within waterways.



Construction Site Revegetation, 2025

An Engineering Guide to Site Revegetation

Catchments & Creeks, 2025, Barga Queensland.

97 page PDF document

Version 1, June 2025

This document provides a review of construction site revegetation techniques.

Contents	Page
Purpose of field guide	5
About the author	5
Introduction	5
Terminology	6
Examples of grassy gullies	7
Possible reasons for revegetating a grassy gully	9
Long-term changes to the gully landscape	10
The risk of causing an erosion problem	11
1. Gully Erosion and Land Stability Issues	
Introduction	13
Potential erosion issues	14
Nature's way of controlling gully erosion in steep valleys	15
The likely triggers of gully erosion in newly vegetated valleys	16
Cause 2: Trees subjected to high-velocity flow	17
Cause 3: Dispersive soils	18
Field testing for dispersive properties (Aggregate Immersion Test)	19
Cause 4: Potential issues associated with fencing a revegetation project	20
2. Changes in Catchment Hydrology	
Introduction	22
Factors affecting the infiltration of stormwater into soils	23
The movement of water through a soil profile – NO PLANTS	24
The movement of water through a soil profile – WITH PLANTS	26
Looking for ways to improve stormwater infiltration into soils	28
The effects of soft grass and stiff grass ground covers	29
3. Revegetation Programs	
Introduction	31
Planting in areas of expected high flow velocity	32
Planting within a floodway – Long stem planting	33
The use of recessed check dams to control future gully erosion	34
Alternative valley floor stabilisation measures	35
Native grasses	37
The use of mulch in riparian areas	39
4. The Use of Mulch to Improve Soil Conditions	
Introduction	41
Using mulch to soften compacted soil	42
Using mulch to improve the structure of 'plastic' soils	43
The techniques we can use to anchor loose mulch	44
5. Glossary of terms	45
Other Catchments and Creeks field guides that may be of interest	47

Purpose of field guide

This field guide has been prepared to:

- provide guidance on the revegetation of the upper regions of grassy valleys and gully heads that have, in the distant past, been cleared of their natural bushland
- provide landowners with a warning about the potential erosion problems that may arise from such revegetation projects (even though the risk of such erosion may be low)
- provide landowners with options for preventative measures.

The photos presented within this document are intended to represent the current topic of discussion. These photos are presented for the purpose of depicting either a preferred or discouraged outcome (as the case may be). In some cases, the photos may not represent current best practice, but are simply the best photos available to the author at the time.

The caption and/or associated discussion should **not** imply that the site shown within the photograph represents either good or bad land management practice. The circumstances, site conditions and history of each site are not known by the author. This means that there may be a valid site-specific reason why the landowner/designer chose the treatment option depicted in the photo.

About the author

Grant Witheridge is a [retired](#) civil engineer with both Bachelor and Masters degrees from the University of NSW (UNSW). He has over 40 years experience in the fields of hydraulics, creek engineering and erosion & sediment control, during which time he has worked for a variety of federal, state and local governments, as well as private organisations.

Grant commenced his career at the UNSW Water Research Laboratory (1981) constructing and operating physical flood models of river floodplains. He later worked for Brisbane City Council on creek engineering and stormwater management issues. He ended his career working through his own company, Catchments & Creeks Pty Ltd.

Introduction

In the distant past, landowners were encouraged to clear their land of natural bushland in order to maximise the farming and grazing potential of the land. Such land clearing was considered to be adding to the productive 'value' of the State. These days, however, many landowners are being encouraged to revegetate parts of their land in order to gain the benefits that such revegetation can bring, and add (again) to the 'value' of their land.

In farming, there will always be the 'right way' and the 'wrong way' to perform any given task. In many cases the [wrong way](#) produces better short-term outcomes, while the [right way](#) produces fewer long-term problems. Unfortunately, the right way often costs a little more (or a lot), it usually takes a bit more planning (or a lot), and it normally requires a bit of advice from neighbours that have recently completed a similar task.

The [revegetation of grassy gullies](#) is no different, and can be achieved in both a [wrong way](#) and a [right way](#). But there are real problems that your experienced neighbour, or your friendly Landcare officer, may never have experienced. These are the long-term problems associated with the eventual formation of gully erosion under the canopy of this new vegetation.

The important point to note is that just because you are returning the valley back to its 'original' vegetated condition, does not mean the valley will return to its original stability. If mistakes are made, then the revegetation program can trigger gully erosion that can cause serious long-term damage to the valley.

These are not problems that every landowner will experience. Hopefully, very few people will experience such problems, but every landowner should be alert to these potential problems.

The author [fully supports](#) the revegetation of grassy gullies; however, the author just wants the outcome to always become a benefit to the landowner, and not a future burden.

Finally, the author acknowledges that there is a **lot more** to the process of revegetating a grassy gully than is discussed within this field guide. This document represents just a water engineer's contribution to the discussion—its does not present the 'full picture'.

Terminology



Field day



A vegetated overland flow path



A farmer's 'waterway'



Grassy gully

Introduction

- The use of appropriate **terminology** in a publication can be difficult when the readers cover a wide array of people.
- What some people call a valley, others may call a gully, or an escarpment.
- What city people call an overland flow path; some rural communities call a waterway.
- In this document I will try to adopt 'rural' terminology, but please forgive me if I misuse some terms.

Overland flow path

- In engineering, an **overland flow path** is a region of concentrated surface flow that is insufficient in flow capacity to be called a 'watercourse'.
- An overland flow path typically does not have well-defined channel banks, but it can be created by a junction of two opposing land slopes, which act as 'banks'.
- Engineers would classify a **grassy gully** as an overland flow path.

Waterways

- A dictionary would typically define a 'waterway' as a navigable watercourse.
- However, in some rural communities, the term: 'waterway', is often used to describe a shallow drainage line that crosses either pasture or cropping land.
- Consequently, the **grassy gullies** that engineers may call an '*overland flow path*', and the general public may call a '*valley*', while some rural communities refer to as a '*waterway*'.

Grassy gully

- Within this document, the term; **grassy gully** will be used to describe:
 - the upper region of drainage line
 - the top of a grassy valley that has been cleared of natural vegetation
 - the upper region of a watercourse, where the flow path does not have well-defined banks.
- The term: **gully** shall refer to a drainage line that is experiencing significantly incised (deep-cut) soil erosion.

Examples of grassy gullies



Photo supplied by Catchments & Creeks Pty Ltd

Grassy gully (Qld)



Photo supplied by Catchments & Creeks Pty Ltd

Grassy gully (Qld)

Examples of grassy gullies



Photo supplied by Catchments & Creeks Pty Ltd

Recently revegetated gully (NSW)



Photo supplied by Catchments & Creeks Pty Ltd

Recently revegetated gully (WA)

Possible reasons for revegetating a grassy gully



Field day (Qld)

Introduction

- The possible **reasons** for the revegetation of a grassy gully include:
 - benefits to the landowner
 - benefits to the landowner's stock
 - benefits to local wildlife
 - reduced risk of gully erosion
 - benefits to downstream properties
 - participation in a regional program (e.g. Mountains to Mangroves).



Shaded gully (Qld)

Potential benefits to the landowner

- The potential **benefits** to the landowner include:
 - reduced risk of uncontrolled gully erosion (if done right)
 - reduced risk of land slips
 - increased stormwater infiltration and groundwater replenishment
 - increased shading for stock.



Wildlife (NSW)

Potential benefits to wildlife and land stability

- The potential benefits to the local wildlife include:
 - improved wildlife habitat, shelter and movement corridor
 - provision of an alternative escape route from bushfire and flood events
 - additional source of food.



Downstream properties (Qld)

Impacts on downstream properties

- The potential **benefits** to downstream properties include:
 - reduced risk of flooding when gully rehabilitation is applied on a wider scale
 - increased stormwater infiltration and groundwater replenishment.
- Potential **adverse effects** on downstream properties include:
 - increased risk of salinity issues in certain cases (but rare).

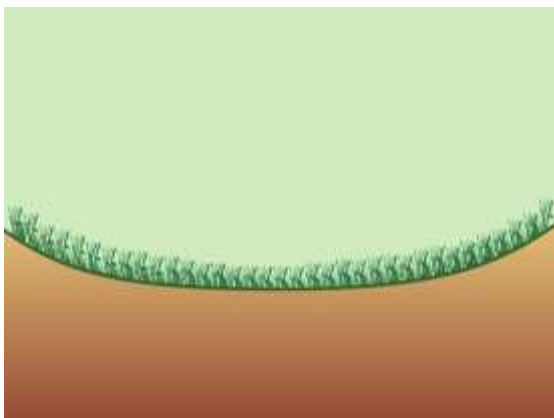
Long-term changes to the gully landscape



Original 'natural' valley condition

Natural conditions of the landscape

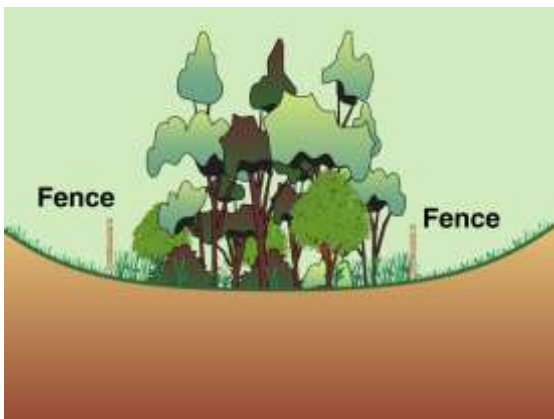
- It is assumed that prior to European settlement, the valley was fully vegetated, and that this land condition was relatively stable without the risk of gully erosion.



Existing grassy gully

Historical land clearing

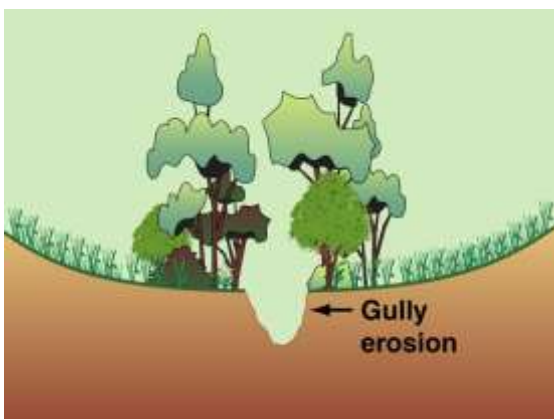
- It is also assumed that sometime within the past 200 years the land was largely cleared of woody vegetation to increase the pasture potential of the land.



Proposed revegetation of gully

Opportunity to revegetate the gully

- The opportunity now exists for the existing grassy gully to be revegetated, and to return it to something like its 'natural' condition.
- These sites may be 'fenced' (left), or unfenced (below) depending on whether the aim is to avoid stock having access to the site during the early growth phase.



Potential erosion risk

Potential erosion risks

- The questions are:
 - Is there the risk that the proposed gully revegetation will trigger future gully erosion?
 - Is it possible to identify those gullies where this erosion risk actually exists?
 - Are there measures that can be taken to reduce these erosion risks?
- The latter point is addressed in [Chapter 3](#).

The risk of causing an erosion problem



Site inspection (Qld)



Rill erosion (Qld)



Localised soil erosion (Qld)



Gully erosion within a dispersive soil (Qld)

Introduction

- The potential problems that can arise after a grassy gully is revegetated include:
 - formation of gully erosion (long-term problem)
 - erosion along fence lines
 - aggravation of salinity issues.
- The risks of gully erosion being caused by the revegetation of a grassy gully are usually low, but the risks are real.

Minor erosion

- Potential minor erosion problems can include:
 - rill erosion along fence lines
 - isolated soil scour caused by turbulent water flow.
- There is a medium risk of this form of erosion occurring as shading increases under the shrub and tree canopy.

Significant erosion

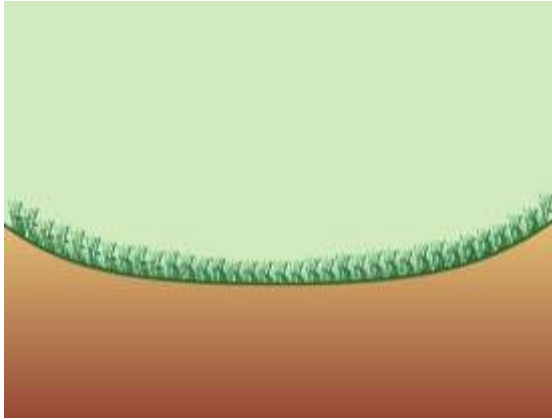
- Significant erosion problems can include:
 - deep soil scour caused by turbulent water flow
 - the formation of a low-flow channel along the invert of the valley.
- The risk of this form of erosion is generally medium to high.

Severe gully erosion

- If the underlying subsoil is **dispersive**, then:
 - the risk of gully erosion forming along the revegetated gully is high
 - if gully erosion occurs, then this erosion can very quickly grow to a depth that could make the erosion difficult to rectify.
- Soil testing should be performed before any revegetation if dispersive soils are known to exist in the region.

1. Gully Erosion and Land Stability Issues

Introduction



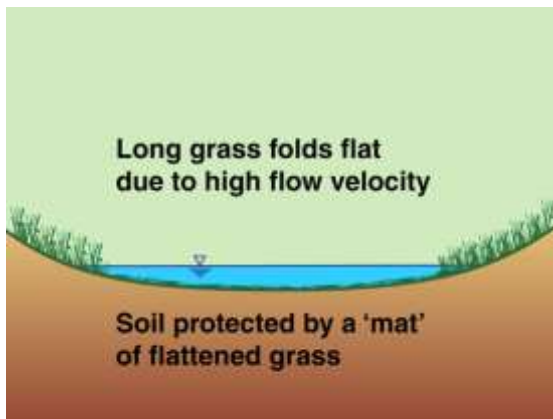
Existing grassy gully

Introduction

- The existing site conditions are assumed to consist of a grassy valley floor with minimal surface erosion issues.
- If there is evidence of minor soil erosion along the valley floor, then this erosion should be appropriately stabilised prior to commencing the revegetation program.
- Such erosion control measures can be incorporated into the long-term bed stabilisation measures recommended within this chapter.



Grassy valley (Qld)



Existing surface flow conditions

Existing storm flow conditions

- It is assumed that storm runoff currently passes down the valley by folding the grass flat, which allows the grass to form an erosion-resistant grassy 'mat'.

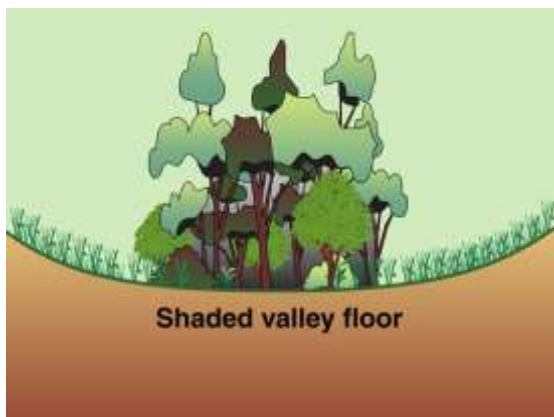


Surface flow over grass (NSW)



Surface flow over long grass (Qld)

Potential erosion issues



Heavily shaded valley floor

The width of the revegetation zone

- The proposed revegetation zone should be pegged out.
- The width of this revegetation zone at any location will likely depend on a number of variables, including available funding, and the landowner's wishes.
- From a [hydraulic perspective](#), the ideal width of the revegetation zone should extend beyond the expected width of any surface runoff.



Early stages of gully revegetation (NSW)



Shaded valley floor limited grass growth

Expected loss of essential ground cover vegetation

- Revegetating a steep gully is not the same as establishing a new garden bed—the aim is not to remove all the existing grasses.
- Rather than physically removing the grass, which is considered by many to be just another weed, the aim is for much of the grass to be shaded-out as the canopy develops.
- Also consider the use of native grasses.



Erosion around the base of a tree (Qld)

The potential formation of localised soil erosion

- Any gully revegetation program should anticipate that localised soil scour will occur as newly-planted trees begin to mature.
- The risk of this type of erosion can be minimised through the adoption of companion planting.
- Companion planting involves the placement of shade tolerant ground covers downstream of trees.

Nature's way of controlling gully erosion in steep valleys



Exposed bedrock (SA)



Exposed bedrock (Qld)



'Bridging' tree roots (Qld)



Natural mulch 'damming' (Qld)

Introduction

- So, what is different about a newly vegetated valley that makes it susceptible to gully erosion, when the same pre-European valley was not?
- The answer can be found in the maturity of the bushland, which includes:
 - a fully-established interlocking root system, and
 - 'bridging' twigs and mulch (see below).
- Also, some valleys have the protection of the underlying bedrock (left).

Condition 1: Exposed bedrock

- The erosion risk could have been reduced through the exposure of bedrock, or rocky outcrops.
- The rocky material does not prevent the initial erosion, but it can prevent the erosion expanding into a form of deep gully erosion.
- **What this means to a current landowner:** Inspection pits can be dug to determine if bedrock is close to the surface, which would mean the risk of future gully erosion is low.

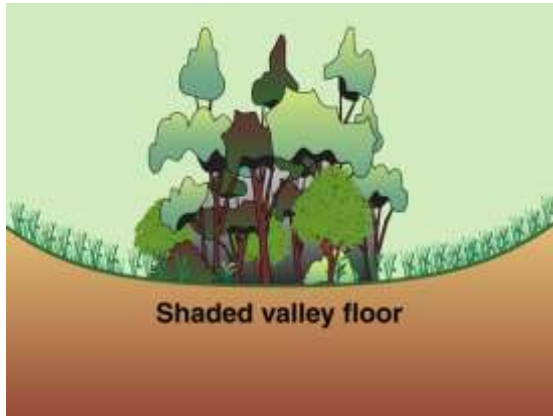
Condition 2: Bridging tree roots

- In well-established bushland; trees, shrubs and ground covers all work together to control soil erosion.
- If such interaction between plants did not exist, then the soil and/or plants would have been removed long ago.
- New revegetation programs can replace the native vegetation, including the correct balance between upper, middle and lower storey plants, but an effective interlocking root system will take years to develop.

Condition 3: Loose mulch forming flow-spreading weirs

- When mature bushland generates an effective canopy, the shading can cause a loss of lower-storey ground covers, which can leave the soil unprotected.
- However, within well-established bushland, fallen twigs and branches can form natural **leaky weirs** that 'bridge' between trees and shrubs, and help to hold loose mulch on the surface of the soil, which helps to slow runoff velocities, and reduce the risk of erosion.

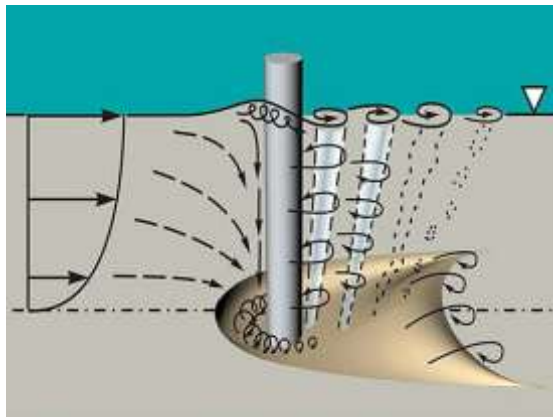
The likely **triggers** of gully erosion in newly vegetated valleys



Shaded valley floor



Loss of ground cover plants in shade



Induced eddies and turbulence



Gully erosion within a dispersive soil

Introduction

- There are three main triggers of gully erosion within a newly revegetated valley, those being:
 - the effects of shading
 - the effects of flow turbulence
 - the potential to expose dispersive subsoils.
- In some cases, flow turbulence can cause more harm than high-velocity flows.

Cause 1: The shading of ground cover vegetation

- Prior to the revegetation program, the valley, or gully, was protected with a healthy covering of long grass.
- This grass may at times look brown and unhealthy, but in grass-terms, it was just sleeping—it still had the ability to protect the soil from stormwater runoff.
- However, revegetating the valley would eventually cause of thinning of this grass and its protection.

Cause 2: Flow turbulence induced by tree trunks

- When winds blow around a building, they generate eddies, which can be observed as dust and litter rotates in circles.
- When water flows around a tree trunk, or a fence post, it can also generate eddies.
- These eddies try to rotate soil particles in small circles, which over time, can form scour holes immediately downstream of the trunk or fence post.

Cause 3: The exposure of a dispersive subsoil

- Dispersive subsoils exist all over Australia.
- If these subsoils are exposed to erosion, they can quickly generate deep gullies.
- However, these unstable soils have existed in a 'stable' form within our landscape for millions of years.
- They were stable because they were protected by a non-dispersive topsoil.
- 'Working' the land can remove the topsoil and increase the risk of gully erosion.

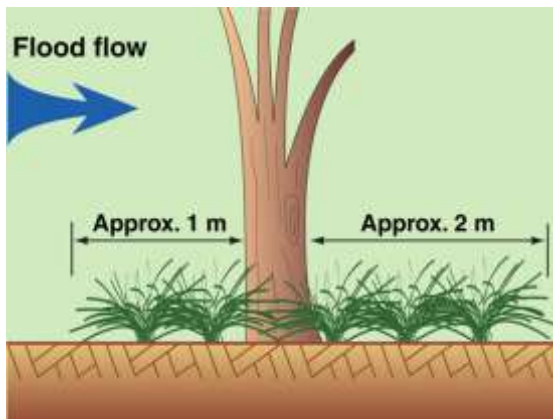
Cause 2: Trees subjected to high-velocity flow



Flood-induced soil scour



Erosion downstream of a floodplain tree



Companion planting around a tree



Companion planting

Introduction

- This is an example of the soil scour that can occur on the downstream side of an isolated tree.

Erosion potential

- Isolated trees do not survive well when they are located within areas of high flow velocity (say greater than 1.5 m/s).
- As storm runoff passes around a tree trunk it can generate an eddy, which can drill a scour hole immediately downstream of the tree.
- This action is one of the ways that flood events can remove trees that are growing in the 'wrong place'.

The protection of trees located with floodways

- The erosion problem described above, which can damage isolated trees that are located in regions of high flow velocity, such as a floodway, can be managed by companion planting:
 - planting native stiff grasses around the base of the tree, such as *Lomandra*
 - planting understorey plants around the base of the tree.



Companion planting

Cause 3: Dispersive soils

Dispersive soils

- Dispersive soils are highly unstable when wet, resulting in severe, deep rilling (known as *fluting*), tunnel erosion, and/or gully erosion.
- Soils with a hard setting surface, and a high sodium content (sodic soils or Sodosols), are very prone to erosion.
- Dispersive sub-soils are a problem because they can quickly turn any cut drain into gully erosion.



Effects of raindrop splash (Qld)



Dispersive soil creek erosion (NSW)



Invert rill erosion (Qld)



Dispersive soil bank erosion (Qld)



Creek bank erosion (Qld)



Gully erosion (SA)



Gully erosion (NSW)

Field testing for dispersive properties (Aggregate Immersion Test)



Slightly dispersive soil



Non-dispersive, non-slaking soil



Dispersive soil



Slaking soil

Aggregate Immersion Test

- The **Aggregate Immersion Test** can be used as an 'indicator' of dispersive soils.
- This test involves filling a dish with distilled water (generally available at petrol stations and supermarkets) to a depth sufficient to cover the soil samples.
- Several dry, hard clumps of soil are **gently** placed in the water.
- The water is then observed for colour changes (**after** all the air has escaped).

Non-dispersive soil

- If the water remains clear and the boundary of the soil clumps remains clearly defined, then the soil is likely to be non-dispersive.
- If the original soil clumps were loose or heavily disturbed, then these clumps will likely separate into smaller pieces when initially placed into the water—this does **not** indicate that the soil is dispersive.
- Air escaping from the soil can also cause the clumps to fall apart.

Dispersive soils

- If the water discolours both horizontally and vertically around the soil clumps, then the soil could be dispersive.
- Highly dispersive clumps of soil will collapse in less than 10 minutes.
- **Caution:** using tap, tank, or groundwater, can sometimes mask the dispersive reaction due to minerals and/or chemicals in the water—hence the reason for the distilled water.

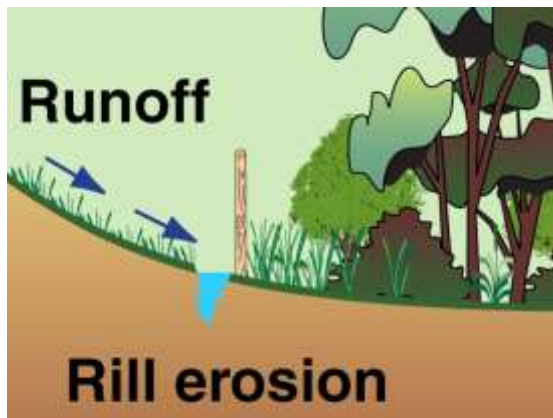
Slaking soils

- Slaking soils are soils that readily collapse in water, but do not necessarily cloud the water.
- If the water remains clear, and the clumps completely collapse and **spread horizontally**, then the soil could be a slaking soil.
- Slaking soils commonly occur within landscapes that contain granite rock.
- These soils can be highly erodible, especially if disturbed by digging.

Cause 4: Potential issues associated with fencing a revegetation project



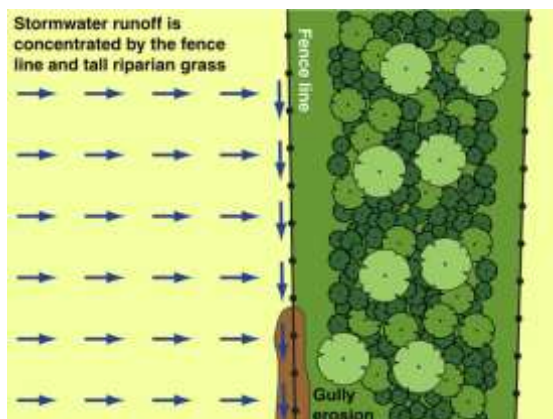
Fencing of riparian zone (SA)



Fencing of riparian zone (Qld)



Gully erosion along a fence line (Qld)



Gully erosion along the fence line

Introduction

- During the early growth phase, landowners may choose to control livestock movement and overgrazing.
- However, such actions are not without the risk of causing problems, including:
 - the undesirable redirection of stormwater runoff along fence lines
 - gully erosion along fence lines
 - increased cost of fence replacement following wild fires.

The redirection of stormwater runoff

- When riparian zones are fenced, it is typical for the density of the grasses on the creek side of the fence to be thicker than on the paddock side of the fence.
- This change in hydraulic roughness can cause stormwater runoff to be redirected along the fence, which causes the storm water to now move as 'concentrated flow'.
- **Note:** It is not the fence that causes the flow diversion; instead, it is the change in grass density (or resistance to flow).

Gully erosion along fence lines

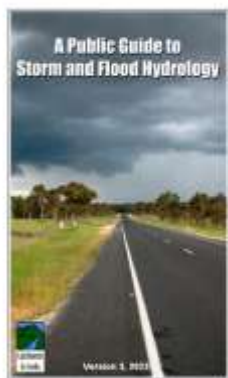
- If high-velocity, concentrated flows travel along a fence line, then soil erosion can occur around the base of each post:
 - which can cause a localised loss of grass cover
 - which can expose the soil resulting in the formation of a gully
 - which, if it exposes a dispersive subsoil, can quickly form a major gully erosion problem that will be expensive and difficult to repair (photo left).

Zigzagging fence lines

- If a property has a history of stormwater runoff being diverted along its fence lines, then the fencing of riparian zones should aim to:
 - zigzag the fence such that regular low points are formed along the fence that will force the stormwater to be released from the fence line at as many 'safe' locations as is possible, and
 - ensure that stormwater is only released at locations where lateral bank erosion is unlikely to occur.

2. Changes in Catchment Hydrology

Introduction



Storm and Flood Hydrology, 2023

Introduction

- A deeper explanation of catchment hydrology is presented in the **Catchments and Creeks** publication: [A Public Guide to Storm and Flood Hydrology](#).
- A critical factor in storm hydrology is the **response time** of the drainage catchment; that is, the time it takes for storm runoff to travel from the top of the catchment, to a location of interest along the waterway.
- Peak flood flows (Q) can be reduced if this response time (t_c) is increased.



Photo supplied by Catchments & Creeks Pty Ltd

Land clearing

The effects of early land clearing on catchment hydrology

- Even though the upper parts of a drainage catchment are usually steep, the velocity of surface runoff is often slower in these upper catchment areas because the water depth is usually shallower.
- Having bushland at the top of a drainage catchment helps to slow storm runoff, and helps to reduce flooding.
- Clearing bushland from these upper slopes usually causes an increase in downstream flooding.



Catchment hydrology

The effects of increasing the response time of a drainage catchment

- The process of revegetating the upper regions of drainage catchments, particularly, the grassy gullies that exist at the tops of hills, has several ecological and environmental benefits; but, for the landowner, these benefits extend to:
 - a reduction in peak storm runoff
 - a reduction in the erosion potential downstream of the revegetation, and
 - an increase in groundwater flows.



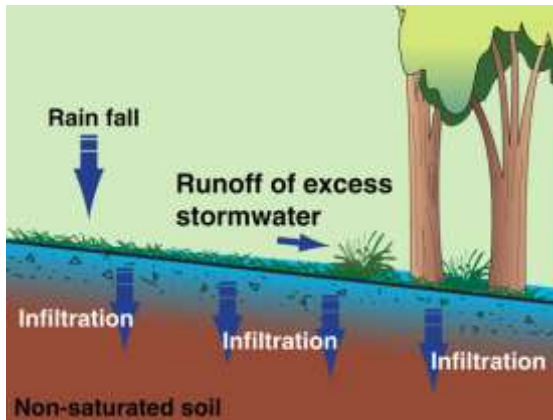
Photo supplied by Catchments & Creeks Pty Ltd

Natural bush mulch

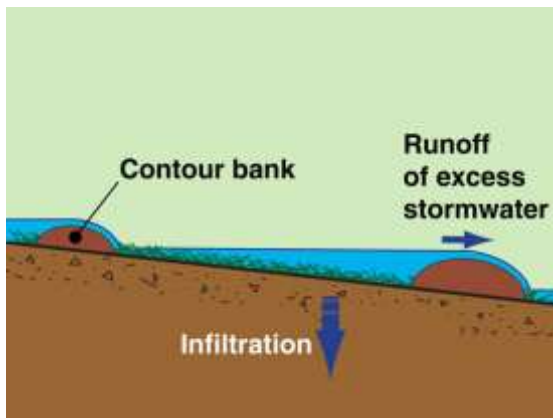
The benefits gained by holding mulch and leaf litter on the floor of revegetated land

- An additional benefit gained through the revegetation of grassy gullies is the retention of twigs, mulch and leaf litter across the floor of the bushland.
- This material helps to slow the velocity of storm runoff, and allows for an increase in the volume of rainwater that is able to enter the soil as groundwater.
- Of course, burning bushland has the opposite effect.

Factors affecting the infiltration of stormwater into soils



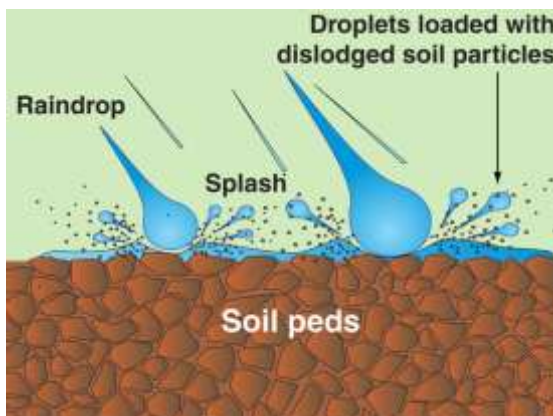
Stormwater runoff



Use of contour banks (long-section)



Non-clumping ground cover vegetation



Raindrop impact erosion

Introduction

- Some people have defined stormwater runoff as the surface flow of stormwater from a saturated or impervious surface.
- The problem with such a definition is that it fails to recognise that stormwater runoff can also occur over non-saturated soil.
- Once the rainfall exceeds the infiltration rate of the soil, any excess stormwater will spill away from the soil.

Effects of 'duration'

- The total infiltration of water into the soil is a product of:
 - rate of infiltration ($\text{m}^3/\text{s}/\text{m}^2$) or ($\text{L}/\text{s}/\text{m}^2$)
 - surface area (m^2)
 - **duration** (s).
- You can increase the **duration** that the stormwater is held on the soil by:
 - roughening the soil surface
 - planting non-clumping ground cover
 - pooling the water with contour banks.

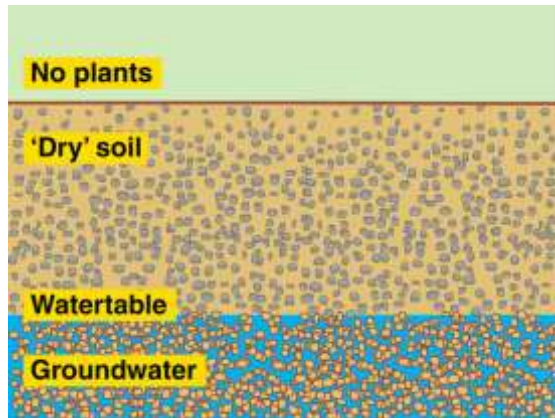
Effects of 'water depth'

- The infiltration rate of water into the soil is influenced by:
 - the soil permeability (not porosity)
 - the planting ground cover
 - the **depth** stormwater.
- You can increase the **depth** of the stormwater by:
 - roughening the soil surface
 - planting non-clumping ground cover
 - pooling the water with contour banks.

Effects of 'raindrop impact'

- Raindrop impact erosion can:
 - separate clay particles from soil crumbs and peds (aggregates)
 - explode clay particles into the air (that may cause a brown stain on the side of buildings)
 - cause these clay particles to fill all the cracks and pores in the soil surface, thus preventing, or at least slowing, the infiltration of stormwater.

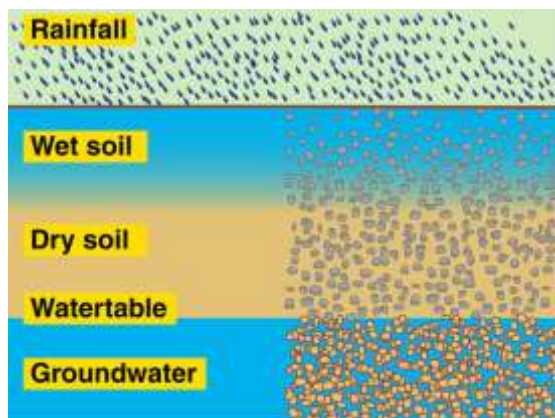
The movement of water through a soil profile – **NO PLANTS**



Dry soil with no plant cover

Consideration of water movement within a soil profile without vegetation cover

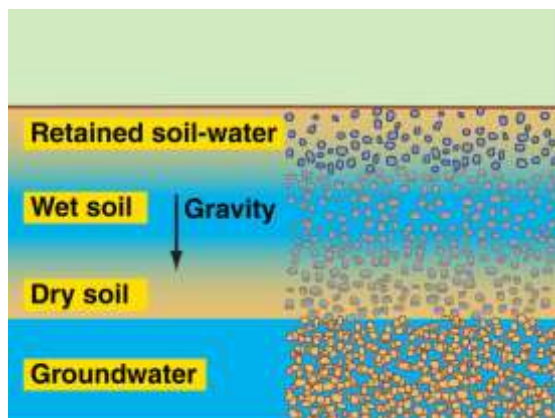
- Consider a soil with the following soil profile:
 - the **upper soil**, possible consisting of the A-horizon and B-horizon soil
 - the **middle soil**, which is likely to be below the root depth of most plants
 - the **lower soil** region that is likely to contain groundwater, which could be fresh, but is more likely to be slightly brackish.



Light rainfall

Light rainfall

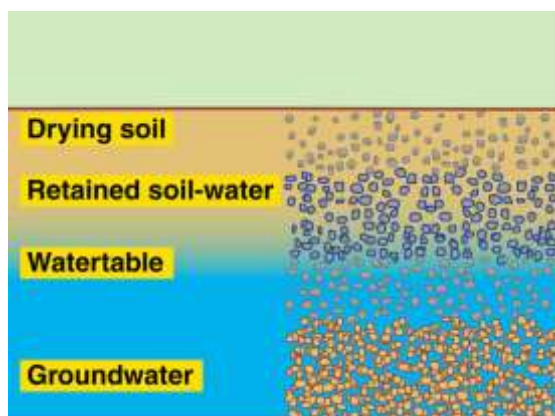
- Light rainfall can wet the upper soil region.
- The soil still has some degree of stability because of the drier middle soil region (i.e. the soil remains relatively stable if a light vehicle drove over the soil).
- Any stormwater that infiltrates the soil will slowly seep through the soil profile due to the effects of gravity.



Rain stops

Rain stops

- Rain stops, and any stormwater that had infiltrated the soil either:
 - evaporates
 - stays attached to the soil particles due to the effects of surface tension (most of this water, but not all, would remain available to plants if they were in place)
 - or otherwise, the water would continue to seep through the soil profile towards the watertable.

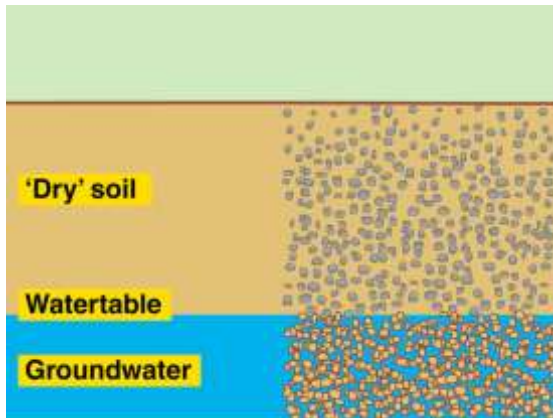


Dry period

Dry period

- Without plant cover, evaporation would be high, and could dry the soil to a depth of several centimetres.
- The middle region of soil may retain some attached soil-water due to surface tension.
- Most of the water would continue to descend until it reaches the watertable (and joins with the groundwater).
- Technically, the 'watertable' temporarily rises to the top of this incoming water, which may, or may not, have absorbed salts on its travels through the soil.

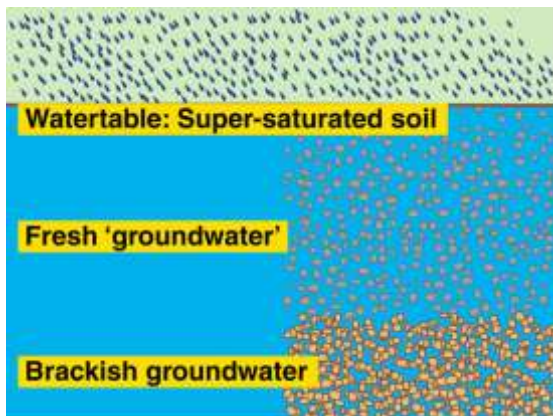
The movement of water through a soil profile – **NO PLANTS**



Extended period of dry weather

Extended period of dry weather

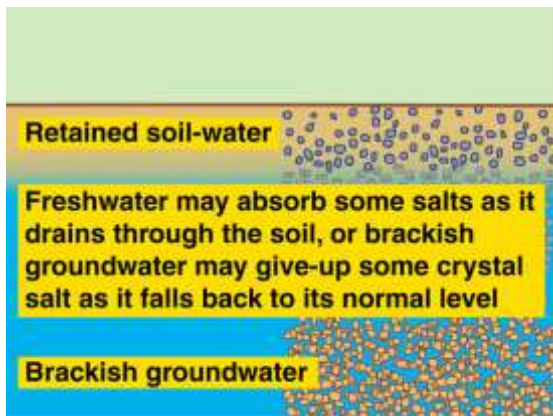
- If the dry weather continues, then the soil profile could eventually return to its fully 'dry' condition.
- However, the soil is not completely dry because there will be some water that remains attached (adsorbed) to the surface of the soil grains.
- The finer the soil grains, the greater the volume of water that can remain trapped in the soil due to the effects of surface tension.



Heavy rainfall

Heavy rainfall

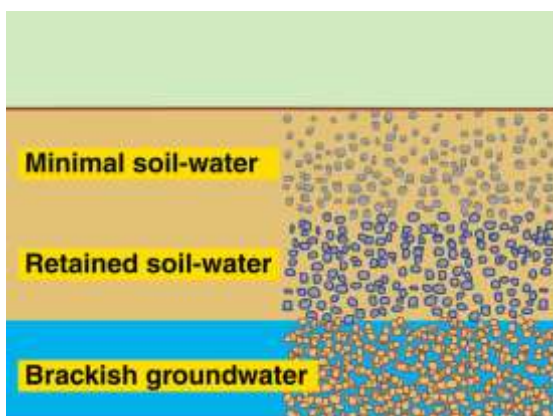
- If the soil profile is subjected to heavy rainfall, then the soil can become saturated from the ground surface, all the way down to the [permanent groundwater](#).
- Technically, this places the position of the [watertable](#) at the soil surface.
- The soil profile is now [super-saturated](#).
- The soil usually loses its structural strength, and becomes [boggy](#).
- The upper region of groundwater is fresh and does not mix with the brackish water.



Rain stops

Rain stops

- The rain stops, and the retained soil-water either:
 - evaporates
 - stays attached to the soil grains, or
 - continues to fall through the soil profile towards the long-term groundwater level.
- The fact that fresher water sits on brackish water does not mean that salts will be lifted up into this upper 'freshwater'; however, some limited mixing can occur.

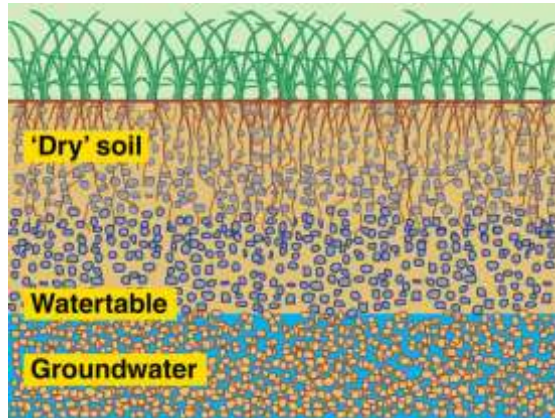


Extended period of dry weather

Extended period of dry weather

- If another period of dry weather follows this heavy rainfall, then the soil profile will likely become:
 - upper dry soil
 - middle layer of soil with some retained soil-water, which cannot evaporate, or fall under gravity
 - lower soil region, which likely contains the permanent watertable and groundwater.

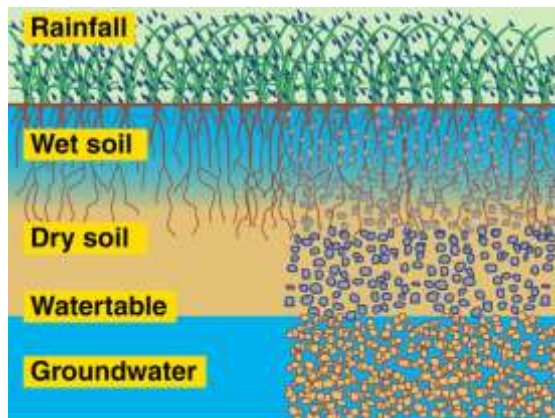
The movement of water through a soil profile – **WITH PLANTS**



Soil profile

Consideration of water movement within a soil profile with vegetation cover

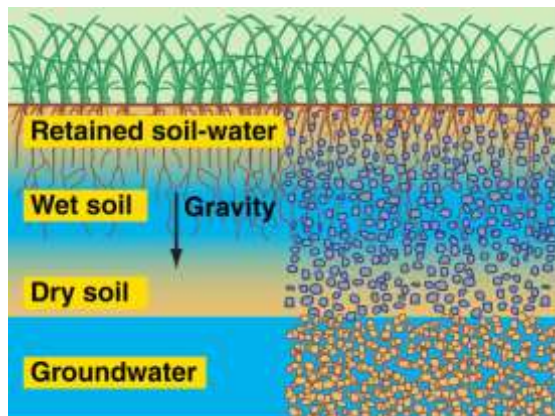
- Consider the same soil profile as before, but with plant cover:
 - the **upper soil**, possible consisting of the A-horizon and B-horizon soils
 - the **middle soil**, which is likely to be below the root depth of most plants
 - the **lower soil** region, which is likely to contain groundwater, that could be fresh, but is in this case is brackish.



Light rainfall

Light rainfall

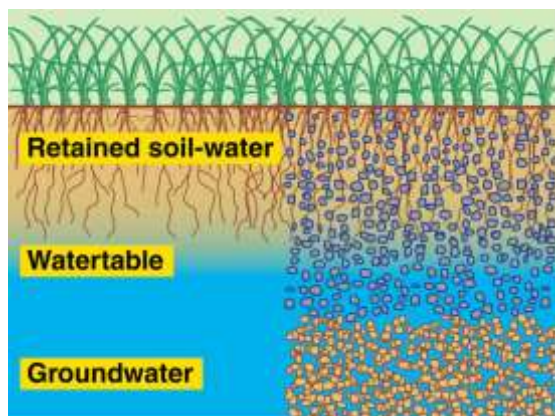
- With **vegetation cover**, the differences are:
 - less soil erosion on the land surface
 - lower rates of evaporation
 - slower runoff velocity, which means stormwater is held on the land for longer periods, which increases the percentage of stormwater that has time to infiltrate the soil.
- The depth of soil wetting depends more on the duration of rainfall, than the intensity of rainfall.



Rain stops

Rain stops

- With **vegetation cover**, the differences are:
 - lower rates of evaporation from the upper soil layer
 - some soil-water from the upper soil layer is taken-up by the plants
 - as air re-enters the upper soil layer, the plants will be able to extract oxygen from the soil during the nights.
- The plant roots are **unlikely** to reach to the depths of the watertable and underlying groundwater; however, this will not be the case at every location.

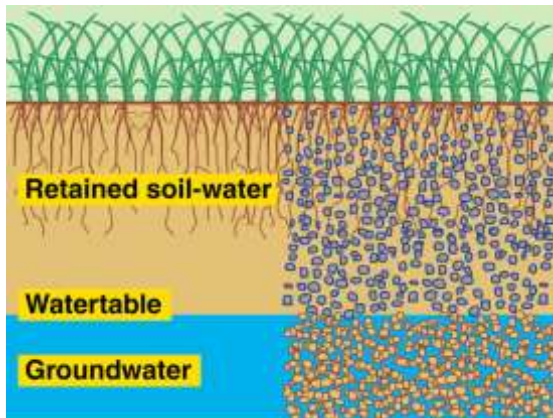


Dry period

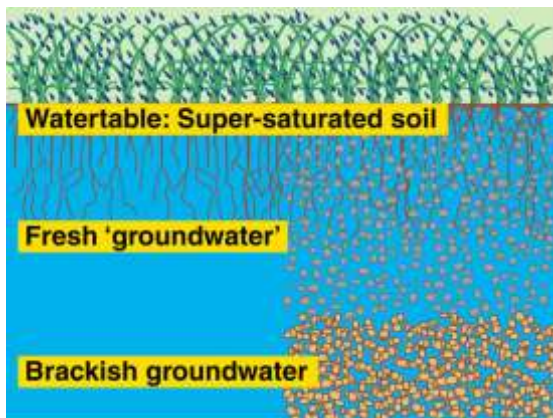
Dry period

- After an extended dry period, if **vegetation cover** still exists, the differences are:
 - lower rates of evaporation from the upper soil layer
 - the plants continue to extract oxygen from the upper soil region during the nights.
- Any stormwater that falls past the root zone will continue to fall towards the groundwater.

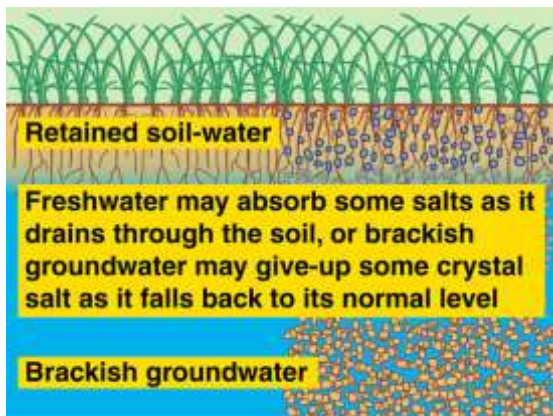
The movement of water through a soil profile – **WITH PLANTS**



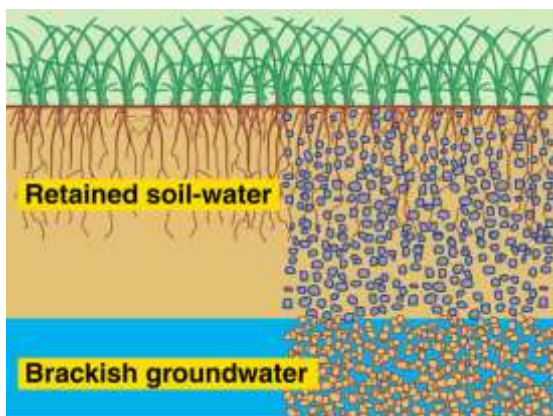
Extended period of dry weather



Heavy rainfall



Rain stops



Extended period of dry weather

Extended period of dry weather

- Plants DO NOT lift the soil-water up to the land surface, except for the water that is fully contained within the plant's roots.
- Plants DO lift metals, minerals and nutrients from the upper and middle soil regions up into the structure of the plant.
- Leaf mulch dropped by plants ultimately results in these materials helping to form new topsoil.
- When the plant dies, if left in place, the minerals and metals will enter the topsoil.

Heavy rainfall

- After heavy rainfall, and with vegetation cover, the differences are:
 - plant roots can provide limited structural strength and stability to the saturated soil, which can reduce the risk of land slips
 - this increased soil strength can assist in dealing with limited pedestrian traffic during this period of soil saturation.
- Some large trees can become unstable if subjected to strong winds.

Rain stops

- Vegetation cover does not really change this phase of soil-water movement.
- Salts are only likely to be lifted up into the middle soil regions in situations where the brackish groundwater is lifted up into these regions, possibly as a result of:
 - extended periods of rainfall increasing the lateral flow of groundwater towards a waterbody
 - extensive land clearing that similarly, increases the lateral flow of groundwater towards a waterbody.

Extended period of dry weather

- After an extended dry period, if vegetation cover still exists, the differences are:
 - lower rates of evaporation from the upper soil layer
 - soil-water continues to be taken-up by the plants from the upper and middle regions
 - the plants continue to extract oxygen from the upper soil region during the nights.

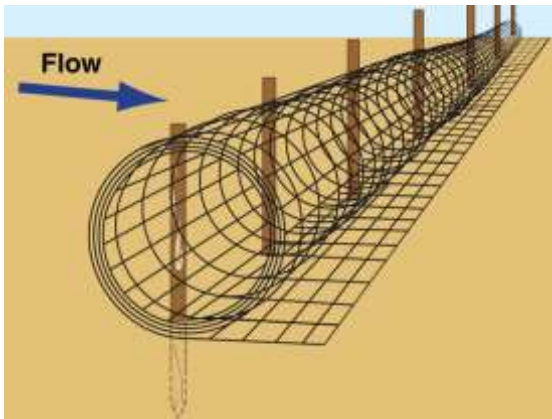
Looking for ways to improve stormwater infiltration into soils



Woody ground cover



Brushwood barriers



Rolled wire mesh barrier



Stakes / Rakes

Introduction

- Where necessary, farmers should take appropriate steps to increase the percentage of stormwater runoff that is able to infiltrate into the soil.
- However, farmers must be aware of the potential impacts their activities can have on their surroundings, which includes the potential for **your** increased infiltration to cause salinity issues on **down-slope** properties.

The infiltration of stormwater into soils

- The critical infiltration factors are:
 - **duration** of flow, which is linked to the depth and velocity of runoff
 - the **depth** of runoff (sheet flow or channelled flow)
 - the **velocity** of runoff, which is linked to the surface roughness
 - the **surface roughness**
 - the volume of stormwater retained on **wetted surfaces** (e.g. mulch) that can latter drip into the soil.

Techniques for increasing stormwater infiltration

- Techniques include:
 - woody ground cover
 - mulching
 - contour banks
 - artificial surface roughness, such as: brushwood barriers, leaky weirs, horseshoe bunds, stakes, rakes, contour wetlands, rolled wire mesh, low-set wind breaks and/or fencing.



Fencing

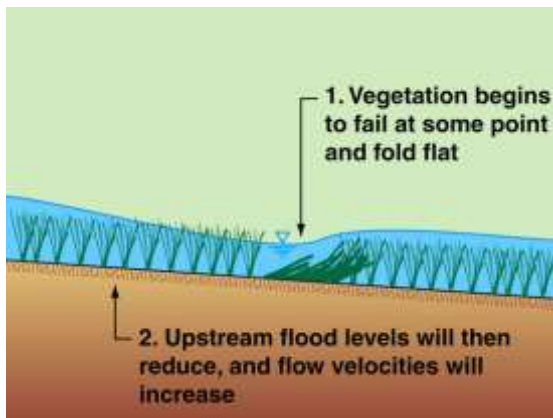
The effects of soft grass and stiff grass ground covers



Crop cover

The problem with non-woody ground covers

- Covering land with vegetation can add surface roughness to the land; **but**, non-woody plants (e.g. grasses) have a tendency to fold flat when subjected to high-velocity flows, or floodwater that exceeds a depth of around 300 mm.
- The collapse of these plants can cause storm runoff to concentrate, which results in very little infiltration of water into the soil.



Grasses flattered by flows



Concentration of flows through grass



Stiff grass (Vetiver grass) (Qld)

Stiff grass barriers

- Stiff grasses, such as Vetiver (tall), or Lomandra (medium height), can form a fence-like barrier, which can be used to slow the movement of overland flow.
- **Great care** must be taken when establishing a stiff grass barrier in order to make sure it achieves the desired effect.
- Planting one or two parallel rows of plants can be effective at 'slowing' flows, while planting a thicker barrier can cause flows to be diverted, or the trapped water to spill like a weir.



Pile field (just one example)

Stakes, rakes and pile fields

- The name of this technique varies from guideline to guideline, and state to state.
- The concept is simply a well-spaced grid of either metal stakes, fence posts, or reinforcing (Reo) bars.
- The spacing of the 'stakes' varies with the local need, but typically the spacing must allow for the movement of all necessary farm vehicles.
- During floods, the stakes capture organic debris, which slows the progression of the floodwater.

3. Revegetation Programs

Introduction



Site revegetation (Qld)



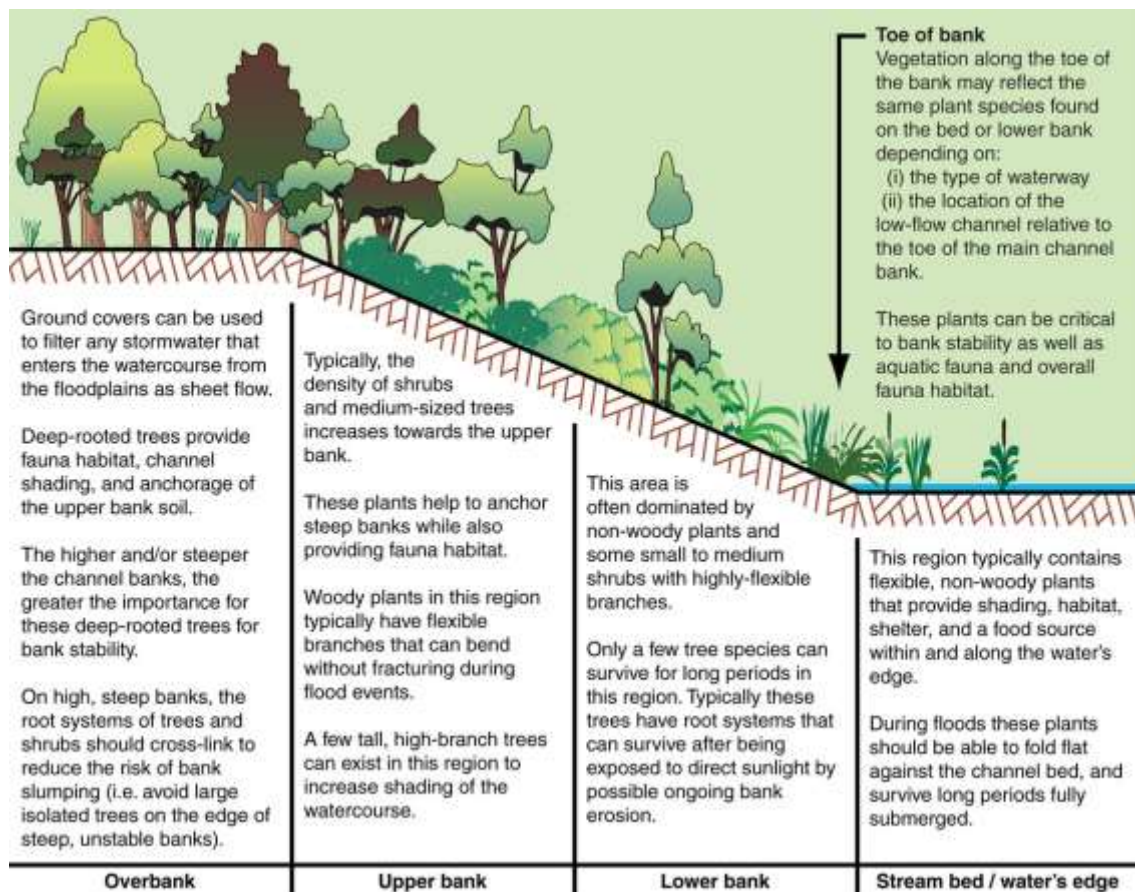
Site revegetation (Qld)

Introduction

- Gully revegetation is not a case of simply delivering a truck-load of native plants to a farm, and then planting them randomly over the designated area.
- Plants play one role in respect to the overall planting scheme, but also a role in how they interact with the plants that surround them.
- Grouping certain ground covers with certain trees can make the overall grouping stronger.

Planting density (general guide)

- An appropriate balance between ground cover, mid-storey and canopy plants is:
 - 50% ground cover species
 - 30% middle storey species
 - 20% upper storey species.
- Plant spacing in non-flood control areas could be:
 - 0.5 to 1 m for ground covers
 - 2 to 4 m for mid-storey plants
 - 4 to 5 m for upper storey plants.

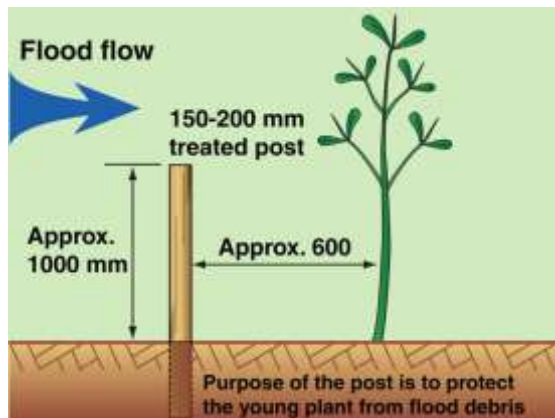


Desirable characteristics of vegetation placed next to a watercourse

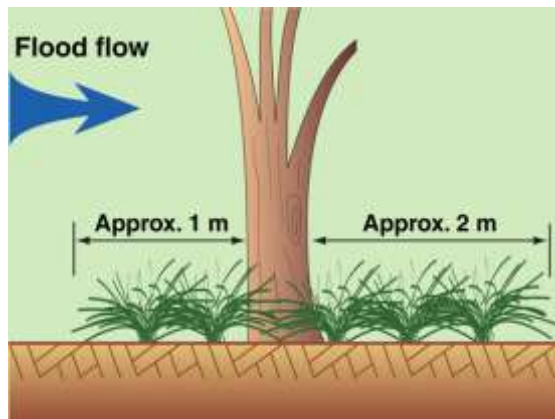
Planting in areas of expected high flow velocity



Flood damage to a sapling



Protecting plants from flood debris



Protection of isolated trees in floodways



Jute mesh (Qld)

Difficulties of planting in floodways

- Newly established vegetation can be damaged by high-velocity flows:
 - plants can be pushed over by high velocity flows
 - plants can be pushed over as a result of storm debris (typically organic matter) wrapping around the plant
 - turbulence around the base of the plant can cause the localised loss of soil (i.e. a scour hole).

Planting in floodways

- Saplings can be protected from high-velocity water by:
 - staking the plant
 - forming a triangular flow screen
 - adopting long-stem planting.
- Saplings can be protected from mulch debris by placing a debris trap (post) upstream of the plant.
- Isolated trees can be protected from soil scour around their base by planting stiff grasses (*Lomandra*) around the tree.

Companion planting

- Companion planting involves placing certain ground covers around the based on certain trees and shrubs.
- For example, if a scour hole is a possible concern downstream of a newly-planted tree, then *Lomandra* or native grasses can be grouped downstream of the tree.

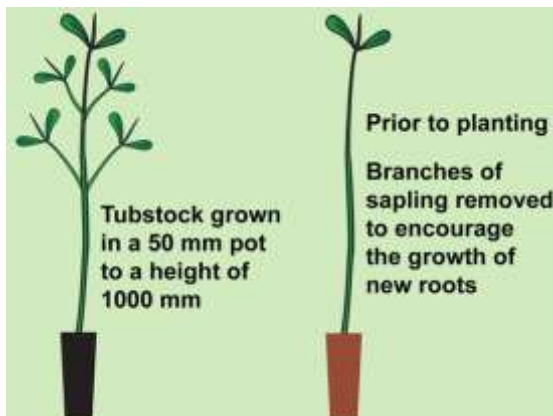
Erosion control mesh

- The term '**blanket**' is typically used to describe rolled erosion control products.
- The term '**mat**' is typically used to describe rolled erosion control products that have a high shear strength.
- A '**mesh**' is a blanket that has an open weave, usually made from jute or coir.
- A mesh can provide temporary protection for plants placed in areas of high flow velocity, but the mesh **must** be well anchored.

Planting within a floodway – Long stem planting



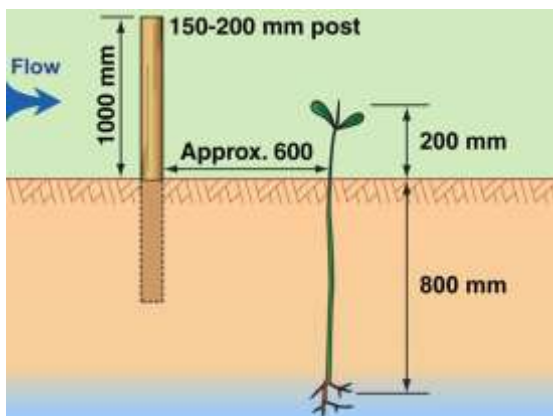
Exposure of roots by severe bank erosion



Establishment of long stem saplings



Pre-planting preparation



Planting of long stem plant

Introduction

- Depending on the plant species and the environmental conditions:
 - an exposed root system may begin to function as part of the tree's trunk system, and
 - a buried section of a sapling's stem may transform into part of the plant's root system (adventitious roots).
- Long stem plants make use of the latter condition, but only for selected species in appropriate situations.

Initial growth stage

- The benefit of long stem planting is the enhanced anchorage of the sapling, which reduces the risk of the young plant being washed from the soil during a flood.
- In order to achieve this enhanced anchorage, the sapling must be planted deep into the soil, which means suitable tubestock need to be prepared:
 - grown in 50 mm pots
 - grown to a height of 1 metre.

Preparation prior to planting

- Branches of the sapling are removed to encourage the growth of roots.

Planting of long stem saplings

- Holes dug to a depth of 800 mm.
- Fertiliser pellet placed at the rootball.
- Placing the rootball deep in the soil allows these roots to be beyond the competition zone of other plants (weeds), and closer to a source of water.
- A stake/post can be placed upstream of the sapling to protect the plant from flood debris (in addition to staking the plant).

The use of recessed check dams to control future gully erosion

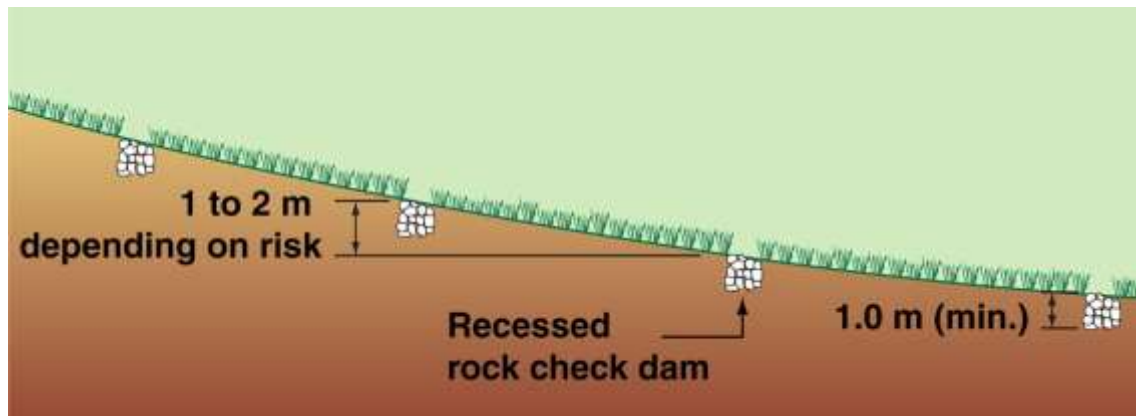


Photo supplied by Catchments & Creeks Pty Ltd

Recessed rock check dam (NT)

Being pro-active to prevent or control future erosion issues

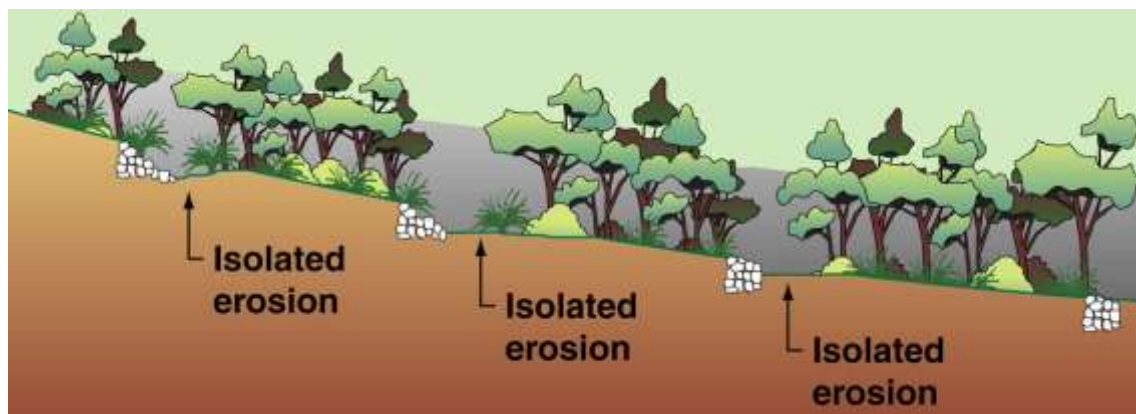
- If a site has been assessed as high risk, or if the landowner wishes to be pro-active in their erosion control, there are some treatment options that can be installed prior to the revegetation program commencing.
- Treatment options include:
 - recessed rock check dams
 - rock pads
 - cut-off walls.



Installation of recessed rock check dams prior to revegetation



Mature vegetation shades the valley floor



Stabilised gully erosion (ideal outcome)

Alternative valley floor stabilisation measures



Vegetated rock placement (NSW)

Rock stabilised valley floor

- Rock can be integrated with the revegetation program to increase the scour resistance of the valley floor.
- The extent of rock placement would depend on the assessed erosion risk.
- Rock can integrate well with sedges and native grasses.
- Rock placement typically consists of two layers of rock.



Rock stabilised valley floor



Poring concrete into cut-off trench

Concrete cut-off trench

- A two metre deep trench can be excavated with a pipe trenching excavator, otherwise use a backhoe.
- Ideally, steel reinforcing mesh should be installed in the trench to increase the structural integrity of the cut-off wall.
- The author has never used this system and has concerns for its use.
- This technique should be used with extreme caution.



Concrete cut-off trenches

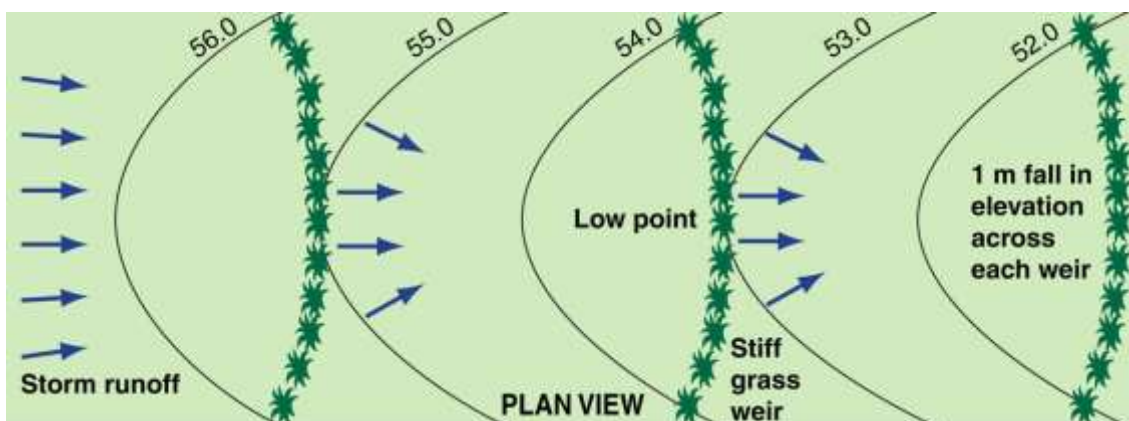
Alternative valley floor stabilisation measures



Stiff grasses after a flood event (Qld)

Stiff grass weirs

- Stiff grass weirs operate like a 'leaky weir' system.
- Their long-term value is questionable because the eventual shading from canopy cover can adversely affect the strength of the grass.
- Typical plant is '*Lomandra*'.
- Vetiver grass should not be used because its growth is too tall.



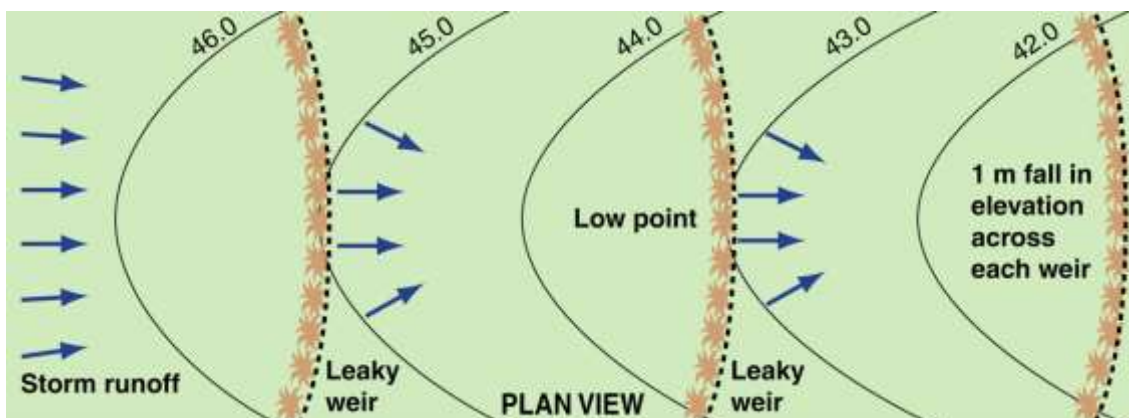
Stiff grass weirs (plan view)



Leaky weir (NSW)

Leaky weirs

- Leaky weirs are commonly used in the control of gully erosion.
- The weirs can be constructed from various locally-available materials, but the most common products are wire mesh and brushwood.
- Both stiff grass weirs and leaky weirs require approximately a 1 m fall in elevation across the crest of the weir to ensure flows always spill over the centre of each weir.



Leaky weirs (plan view)

Native grasses



Barbed Wire grass (Lemon-scented grass)



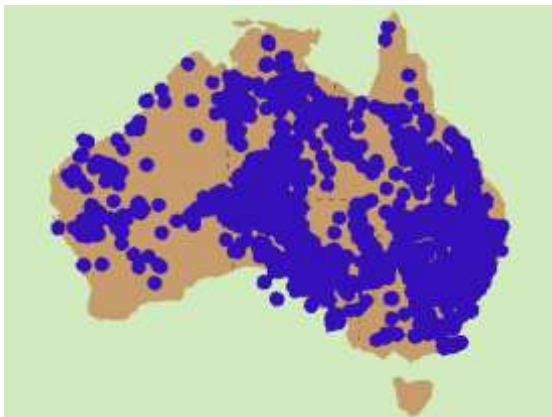
Black Spear (*Heteropogon contortus*)

Location maps for native grasses

- The following maps show the approximate location of recorded sightings of native grasses.
- The maps are not accurate, and were developed from a variety of sources.
- Designers should always seek local advice and locally-prepared location maps.



Chloris grass



Cotton Panic grass (*Digitaria brownii*)



Curly Windmill grass



Kangaroo grass (*Themeda australis*)



Mitchell grass (*Astrebla* spp.)

Native grasses



Native Wheat grass (*Elymus scaber*)



Queensland Blue grass



Redgrass (*Bothriochloa macra*)



Spear grass (*Austrostipa species*)



Tussock grass (*Poa labillardieri*)



Wallaby grass (*Austrodanthonia spp.*)



Weeping grass (Meadow rice grass)



Windmill grass (caution use of this map)

The use of mulch in riparian areas



Loose mulch applied to a creek bank



Geo logs used on a steep creek bank



Straw mulch (Qld)



Bush mulch (NSW)

A potential source of pollution

- Mulch can provide many benefits to valley rehabilitation; however, it can also be considered a form of pollution for waterways (mainly urban waterways).
- Many urban streams experience 'eutrophication' (the enrichment of the waters by nutrients) often leading to excessive algal growth.
- If the mulch is not adequately anchored, then it can contribute to these water quality problems.

Retaining loose mulch on steep banks

- The value of mulch during plant establishment increases in importance as the bank slope increases; however, the difficulties of holding the mulch in place also increase.
- Meshes, logs and geo logs can be used to help retain mulch on steep slopes.

Straw and cane mulch

- Straw and cane mulch should be used with caution adjacent to waterways, unless such mulch can be adequately anchored to prevent it from simply being blown or washed away.

Bush mulch

- Bush mulch has the potential to be more stable than straw mulch, but appropriate care must still be taken to prevent the mulch from being washed from the site.
- Alternatives include:
 - compost blankets
 - rock mulching
 - erosion control blankets (jute meshes).

4. The Use of Mulch to Improve Soil Conditions

Introduction



Hard, compact surface conditions



Mulch treatment of a compacted soil (Qld)



A-frame, wire mesh, leaky weir (Qld)



Eutrophication of waterways

Introduction

- If the soil conditions within the proposed revegetation program are:
 - hard-setting soils, or
 - poorly grassed soilsthen, consideration should be given to adding soil modifiers to the revegetation program.
- Organic matter, in the form of mulch, can be used to improve soil conditions, but the trick is to find ways to hold the mulch on the steep valley/gully slopes.

Using mulch to soften compacted soil

- **Mulch** can be used to help break-up heavily compacted soils.
- The mulch, itself, does not work directly on the soil; instead, the mulch encourages biological activity within the soil (i.e. within soil microbes), which leads to:
 - the break-up of the soil, and
 - the initial formation, or restoration of, 'topsoil' properties within the soil.

(This property is discussed in more detail over the page.)

Use of leaky weirs to temporarily hold mulch on the site

- A series of low-height **leaky weirs** can be used to hold the mulch on the land.
- Ideally, leaky weirs are positioned along the **contour** so that they promote 'uniform flow' conditions (i.e. an even flow across the width of the valley floor).
- These leaky weirs simulate the role of fallen twigs and branches in natural bushland.

The reasons why 'mulch' can be classified as a pollutant

- When used properly, mulch can be a very good soil and farming asset.
- When used without due care, or knowledge of its consequences, mulch can become a waterway pollutant.
- Mulch is organic matter (except for the various rock mulches), which means it can contribute to the eutrophication of water bodies.
- **Eutrophication** means: over-feeding.

Using mulch to soften compacted soil



Compacted clay soil (2003)

Introduction

- Clayey soils that have been subjected to a lot of vehicular or even human traffic, can become very compacted and hard.
- Grasses struggle to establish or even survive in such soils.
- An urban park with very limited grass cover can quickly become an unusable public space.



Placement of treated mulch (2003)

Placement of recycled wastewater sludge

- This park was dressed with treated sludge from the council's wastewater treatment plants.
- The treated sludge is just another type of organic mulch—a very useful product, and most definitely not a 'waste' product.



Grass growth (2005)

Re-established grass cover

- The resulting healthy grass cover has rejuvenated the public's usage of the park.



Grass growth (2018)

Ongoing grass cover

- However, one drawback of the healthy grass cover is an increase in annual cost of grass mowing for the council.
- Note; some of the trees in this park did suffer wind damage during a later severe storm.

Using mulch to improve the structure of 'plastic' soils



Excess working of saturated soils

Introduction

- Soils should not be worked when they are either:
 - too wet, or
 - too dry.
- If a heavy clay soil is trafficked (worked) when it is saturated, then the soil can develop 'plastic' properties.
- This means a clump of the soil can be squeezed through your finger in a manner that produces a long continuous ribbon.



Heavy mulch cover (during a storm)

Feeding the bugs

- At this location, landscape equipment had been moving over the soil for several days while the soil was saturated by rainfall.
- If these high-clay content soils were allowed to dry without treatment, then the soil would be left in a compacted condition that would be near impervious.
- However, this soil was covered with a thick layer of sugarcane mulch (while the rain and equipment disturbance continued).



Integration of mulch into the clayey soil

Farming the farm

- After the rain and all equipment movement had stopped, the remaining mulch was integrated (mixed) into the clayey soil.
- Integrating the mulch into the soil is expected to achieve the following:
 - improved soil structure
 - improved soil drainage (as the organic mulch decomposes, it leaves behind fissures in the soil)
 - increased organic content.



Established grass cover

Weeds can be used to improve the soil

- Within months of the landscaping works being completed, the grass was re-established, and the soil drained as well as it did before the works had commenced.

The techniques we can use to anchor loose mulch



Tub-grinder mulch production

Tub grinding mulch production

- Vegetation can be mulched using either:
 - a cutting action (chipper), or
 - hammer-action (tub grinder).
- **Chipping** the vegetation produces a mulch that can be easily spread with a 'blower', but can also be easily washed away by stormwater runoff.
- **Tub grinding** produces a more stable mulch that is less likely to be displaced by stormwater runoff.



Bitumen spray (NSW)

Bitumen tackifier

- Loose mulch can be anchored with:
 - a light coating of anionic bitumen
 - mechanical crimping
 - jute mesh
 - wire mesh (long-term application).



Organic glues (Qld)

Non-re-wettable glues

- Non-re-wettable glues (tackifiers) can be used to temporarily anchor loose mulch.
- Such glues are used in commercial applications such as hydromulching, bonded fibre matrix, and compost blankets.
- The natural gums from various trees, such as pine trees, can be diluted to form a homemade tackifier.



Crimped straw mulch (USA)

Mechanical crimping the mulch into the soil

- Straw and cane mulches can be mechanically crimped into the soil using farming equipment.

5. Glossary of terms

Aggregate	Any hard material added to cement to make concrete, or to bitumen to make asphalt. Coarse aggregate is usually material retained on a 4.75mm or 2.36mm sieve. Fine aggregate is usually material passing a 4.75mm or 2.36mm sieve.
A-horizon, B-horizon	The A-horizon is the original top layer of mineral soil. The B-horizon is the layer of soil below the A-horizon, which is usually finer in texture, and stronger in colour than the A-horizon.
Companion planting	The grouping of certain plants that work together to achieve a specific outcome.
Compost blanket	An applied layer of fully composted organic mulch.
Cut-off trench	A long, narrow excavated keyway constructed along the centre line of a dam, dyke, levee or embankment and filled with relatively impervious material intended to reduce seepage of water.
Dispersive soil	A soil that is structurally unstable in water, breaking down into its constituent particles (sand, silt and clay) and consequently allowing the dispersive clay fraction to disperse and cloud the water. The dispersion is caused by the high, negative, electro-magnetic charge on the surface of clay particles typically less than 0.005mm in diameter.
Gully	An open, incised erosion channel in the landscape generally greater than 30 cm deep. Active gullies are characterised by moderately to very gently inclined floors and precipitous walls. Gullies are formed by complex processes but a major factor is a concentrated surface water flow, hence they are frequently found in drainage lines. Major flows only occur in gullies during and/or immediately after periods of heavy rainfall.
Grassy gully, grassy valley	The upper region of drainage line, the top of a grassy valley that has been largely cleared of natural vegetation. or the upper region of a watercourse, where the flow path does not have well-defined bed and banks.
Gully erosion	A complex of processes in which soil removal is characterised by large incised channels, usually deeper than 30 cm. The severity of gully erosion may be recorded as minor, moderate, severe or very severe.
Hardsetting soil	The condition of a dry surface soil when a compact, hard and apparently apedal condition prevails. It is a soil which resists the infiltration of water.
Jute	A strong vegetable fibre used for making fabrics, cordage, and similar.
Leaky weir	A porous weir that allows water to pass, but retains the majority of organic matter.
Mountains to Mangroves	An organised campaign to restore the riparian attributes of waterways from their mountain source, to the sea.
Overland flow path	The flow path of overbank flow, including roadways and shallow drainage easements over which stormwater flows in excess of the capacity of the minor drainage system.
Reo	Means: Steel reinforcing bar.
Response time	It is represented by the shortest time necessary for all points on a catchment area to contribute simultaneously to flow past a specified point. It is equivalent to the time required for runoff to flow from the most hydraulically remote part of the catchment to the point of interest, usually the catchment outlet.

Rill erosion	The process of removal of soil by runoff from the land surface whereby numerous small channels, generally up to 30cm deep, are formed.
Rock mulching	A 'mulch' formed from aggregate.
Stiff grass	A grass that normally stands near vertical.
Stiff grass barrier	A filter 'wall', or 'leaky weir', formed from stiff grasses.
Subsoil	Sub-surface soil material comprising the B-horizons of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the topsoil.
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 time following periods of heavy rainfall within its catchment.
Waterway	[1] General: A term commonly interchangeable with the term 'watercourse'. The legal definition may vary from state to state, and region to region. [2] Rural: A stable overland flow path of sufficient capacity to discharge surplus runoff from pasture or cultivation paddocks and to allow it to flow to a lower level without causing erosion. The runoff would normally be concentrated within the waterway by the natural landscape or by soil conservation banks and/or gully control structures.

Other *Catchments and Creeks* field guides that may be of interest



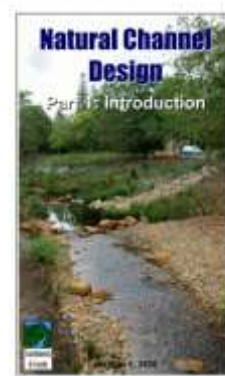
Gully Erosion – Parts 1 to 3



Farm Dams, 2026



Managing Soil Erosion on Pineapple Farms



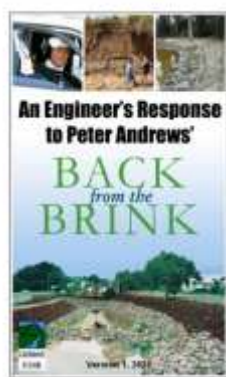
Natural Channel Design – Parts 1 to 3



Creek Erosion Field Guide – Parts 1 to 4



Use of Rock in Waterway Engineering



Engineer's Response to P.Andrews' book



Rational Method Hydrology

