Gully Erosion – Part 2

ASSESSMENT OF TREATMENT OPTIONS

‘Soil is a resource best used in-situ, not in transit.’

Photo 1 – Urban gully erosion migrating along a constructed stormwater drain (Qld)

Photo 2 – Rural gully erosion migrating through pastoral land (SA)

1. Introduction

Bank instabilities maybe the most visible aspect of a gully, but the most critical aspect of gully erosion is the stabilisation of the gully bed. Only when the bed instabilities are under control can stabilisation of the gully head and banks occur. In many cases, stabilisation of the gully bed is achieved by natural means, but landholders can play an active role in the early stabilisation of both the bed and banks of a gully.

Technically it maybe possible to stabilise the gully head before the gully bed has achieved stability, but only if it is possible to predict, with some degree of certainty, the ultimate stable profile (i.e. elevation) of the gully bed. In such cases, the stabilisation works need to be designed in a manner compatible with both the existing and predicted future bed levels.

There is usually more than one way to treat gully erosion. The key is finding the treatment option that best suits the local environment and the affected landholders. Various treatment options are discussed within this fact sheet.

2. Treatment options

The stabilisation of an active gully requires an understanding of the various erosion processes that can occur within a gully, plus the ability to recognise the cause of the erosion and identify appropriate treatment measures.

Management options for gully erosion include:

- Letting nature find its own solution — ‘the do nothing approach’.
- Backfilling the gully then stabilising the drainage path in a natural or near-natural condition.
- Partially backfilling the gully through the use of leaky weirs (e.g. rock weirs, brushwood barriers, fencing weirs) and then:
  (i) allow natural battering and stabilisation of the upstream gully to provide a source of sediment backfill;
  (ii) actively batter and stabilise the gully banks to provide an immediate source of earth to partially backfill the gully.
- Stabilising the gully without partial backfilling—this may incorporate components of natural and assisted bed and bank stabilisation.
3. Choosing a treatment option

Understanding the cause of the gully erosion is important because it may help to identify the best treatment option. In some cases it may not be suitable to restore the gully back to its pre-erosion condition, such as when there is a permanent change in the catchment hydrology.

If the wrong treatment option is chosen, then the erosion could simply start over again, even after significant time and money has been spent stabilising the original gully.

Gully erosion can be a stormwater problem, a soil problem, a vegetation problem, or any combination of these three issues. Soil properties, which can vary significantly at different elevations down the soil profile, can be a major factor in the choice of treatment option, as well as how that treatment option is detailed.

If the gully erosion has exposed some highly erodible soils, then stopping the initial cause of the erosion will unlikely stop the ongoing expansion of the gully. In such cases stabilising the gully becomes more of an exercise in soil management than stormwater management.

Most importantly, landholders need to determine the most stable, long-term outcome for the gully—an outcome that is compatible with the needs of the affected landholders and the waterways downstream of the gully.

It would be impossible within this fact sheet to cover all the issues that need to be considered when choosing a treatment option at a given location; however, Table 1 provides some guidance on the key issues.

<table>
<thead>
<tr>
<th>Treatment option</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>The do nothing approach</td>
<td>• Applicable when assets are not at risk from the erosion.</td>
</tr>
<tr>
<td></td>
<td>• This option can result in significant downstream sedimentation problems.</td>
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<tr>
<td></td>
<td>• Generally the slowest option to achieve a stable gully.</td>
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<tr>
<td>Backfilling the gully and forming a stable drainage swale</td>
<td>• Generally only viable for small gullies.</td>
</tr>
<tr>
<td></td>
<td>• This option requires a cheap supply of earth fill.</td>
</tr>
<tr>
<td></td>
<td>• Generally the quickest option to achieve a stable gully.</td>
</tr>
<tr>
<td>Partial backfilling the gully using natural sedimentation processes</td>
<td>• This is usually the cheapest option in the long-term.</td>
</tr>
<tr>
<td></td>
<td>• This option relies on the ongoing supply of sediment from upstream gully erosion. If the upstream gully is stabilised as part of the overall gully rehabilitation, then there maybe insufficient sediment to backfill the constructed weirs.</td>
</tr>
<tr>
<td></td>
<td>• This option is often adopted in circumstance where a gully extends upstream of a given property.</td>
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<tr>
<td>Partial backfilling using local or imported materials</td>
<td>• This option requires heavy machinery.</td>
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<td></td>
<td>• High safety risks are often associated with such earth works.</td>
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<tr>
<td></td>
<td>• Battering the gully banks to provide a source of fill usually accelerates the rehabilitation of the gully banks.</td>
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<tr>
<td>Stabilisation of the gully without partial backfilling of the bed or battering of the banks</td>
<td>• This option can result in a long drawn-out process requiring planting and replanting.</td>
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<tr>
<td></td>
<td>• Significant sediment loss can occur before the gully banks reach a stable form.</td>
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3.1 Natural stabilisation – the do nothing approach

If left to their own devices, most gullies will eventually find their own stable condition; however, the resulting impacts on adjacent landowners and downstream waterways can be devastating.

The ultimate, stable, channel cross-section maybe as wide as a typical local river cross-section (Photo 6) and result in the displacement of many thousands or millions of tonnes of soil.

In many circumstances, the ‘do nothing approach’ can result in the formation of a gully that permanently alters the value of the land, its potential use for both rural or urban purposes, and affect groundwater levels and vegetation for significant distances each side of the gully.

The true cost of the ‘do nothing approach’ is usually passed on as an unseasonable burden to future generations.

Advantages of the ‘do nothing approach’ include:

- the final outcome can be more stable (and natural) than an actively stabilised gully;
- the surrounding environment and wildlife has time to adjust to the changing conditions.

Disadvantages associated with the ‘do nothing approach’ include:

- in most cases, significant quantities of sediment are transported downstream causing ongoing land-use, waterway, and environmental problems;
- permanent changes to local groundwater levels and vegetation adjacent the gully;
- the potential release of significant quantities of soil nutrients, metals and salts.
A case study of natural gully stabilisation

The following photos demonstrate one example of natural gully stabilisation as observed within the Redbanks Reserve near Burra, South Australia. Initially the gully erosion would have been triggered by runoff spilling down the banks of the original watercourse. This erosion eventually forms into lateral bank erosion, which grows to form a series of steep gullies (Photo 8).

![Photo 7 – Area subject to gully erosion](image7)
![Photo 8 – Early stages of gully erosion](image8)

The unstable gully banks experience ongoing lateral bank erosion. This erosion eventually forms flatter, more stable bank slopes (Photo 9). The increased bank stability allows for the re-establishment of bank vegetation; however ongoing bank erosion causes the loss of some of this vegetation, which falls to the gully bed forming brushwood barriers (Photo 10).

![Photo 9 – Lateral bank erosion](image9)
![Photo 10 – Brushwood barrier](image10)

The brushwood barriers help to slow flows and trap sediment (Photo 11), which helps stabilise the gully bed. Eventually all the gullies stabilise with permanent vegetation, and each gully forms a new waterway discharging into the original watercourse (Photo 12).

![Photo 11 – Sedimentation process](image11)
![Photo 12 – Near-stable bank slopes upstream of gully erosion area](image12)
3.2 Backfilling gullies

In most cases it is technically possible to import soil and backfill the gully returning it close to its original condition; however, the costs associated with all but the smallest of gullies are normally beyond the means of most landholders, and it is usually difficult to obtain such quantities of soil.

Photo 13 – Looking upstream towards active gully head (Qld)

Photo 14 – Same gully (left) after the upper reach is backfilled and revegetated

In the past, old gully sites were often fully or partially backfilled as part of local or regional waste disposal programs; however, the natural drainage patterns of the gully can result in ongoing leachate problems from these areas. Consequently this practice has generally ceased.

If the migration of a gully is limited by the existence of a rock outcrop or a road culvert, then any minor gully erosion found upstream of such bed control structures can usually be rehabilitated at a reasonable cost such as shown below in Photo 16.

Photo 15 – Gully erosion looking downstream from a road culvert (SA)

Photo 16 – Same watercourse (left) looking upstream from the road culvert towards the rehabilitated gully (SA)

If a gully is to be backfilled and stabilised, then in most cases it will be necessary to construct a stable drainage channel (Photos 14 & 16) rather than trying to return the land back to the pre-gully ‘sheet’ flow conditions. The land should only be returned to the pre-gully condition if it is known that the events that caused the gully to form in the first place are either no longer active, or have been appropriately managed to avoid any re-occurrence of the gully.

The main factors limiting the backfilling of gullies are the difficulties in sourcing large quantities of soil, and the costs of conducting such earthworks.

Potential pollutants within the backfill material can also become a significant issue, especially if sub-surface flows are expected. Backfill materials that exhibit dispersive properties can lead to tunnel erosion and re-formation of the gully.
3.3 Gully stabilisation involving the partial backfilling of the gully

If the head of the gully is outside the property boundaries of the landholder wishing to conduct the gully stabilisation works, and if the gully head is still active, then it is likely that significant quantities of sediment will continue to pass down the gully. This sediment can be captured within the gully and used to help stabilise the bed and partially backfill the gully.

Porous weirs, also known as ‘leaky weirs’, need to be constructed along the bed of the gully to slow the passage of flow and allow sedimentation to occur. Leaky weirs can be formed from various materials including rock (Photos 17 & 18), fencing materials (Photo 19), logs (Photo 20), gabions (Photo 21), and stiff-grass barriers (Photo 22).
Concrete weirs (Photo 23) and sheet piling (Photo 24) are normally used in association with the importation of earth to partially backfill the gully.

Photo 23 – Partial filling of gully following the installation of concrete weir (SA)  
Photo 24 – Steel sheet piling used to stabilise a watercourse (USA)

Leaky weirs are normally best formed with a slightly curved or V-shaped horizontal profile that points upstream (Photo 18). Such profiling encourages overtopping flows to concentrate towards the centre of the channel, thus reducing the risk of bank erosion adjacent the weir. The exception to this rule is any chute with a fall exceeding 0.5m. Such chutes should have a flat crest perpendicular to the flow (Photos 39, 43 & 44).

One of the differences between stabilising gully erosion and stabilising watercourse erosion is that fish passage requirements generally do not apply to gullies because they usually do not represent aquatic habitats. This allows the use of steep or vertical-faced grade control structures such as shown in Photos 21, 23 and 24.

Both the location and shape of these weirs and grade control structures are critical. The structures must be positioned and designed such that they do not cause adverse flooding conditions within upstream properties, as well as not causing adverse erosion problems immediately downstream of the structure.

If the gully is fully contained within a given property, then the first weir should be designed with a crest approximately equal to the toe of the upstream gully head stabilisation works (Figure 1).

Figure 1 – Introduction of leaky weirs onto the bed of the gully and stabilisation of the gully head
Over time, sediment should collect behind the leaky weirs helping to both raise and stabilise the bed of the gully (Figure 2).

![Figure 2 - Sediment collection behind the leaky weirs](image)

Partial backfilling of a gully, however, will not necessarily stabilise the banks of the gully. To reduce bank erosion and help accelerate the overall stabilisation of the gully, additional leaky weirs may need to be introduced to the gully as shown in Figure 3.

Additional leaky weirs can either be constructed on top of the existing weirs, or constructed mid-point between successive weirs as shown in Figure 3. The latter case requires special care to ensure that the foundation of each new weir is stable (if placed on unconsolidated sediment), and to prevent erosion of the settled sediment immediately downstream of each weir.

![Figure 3 - Installation of additional leaky weirs](image)

Stiff-grass barriers (Photo 22) have the added advantage of being able to extend their growth up through the settled sediment, as well as sending their roots down through previously settled sediment. It is however advisable to limit the ground fall at each stiff-grass barrier to a maximum of 1m, otherwise additional mid point barriers will be required.
Depending on the depth of the gully and the quantity of sediment passing through the system, leaky weirs can continue to be added until the gully backfills to the desired elevation.

**Figure 4 – Further sedimentation behind the new weirs**

It is generally advisable to design a final gully profile that incorporates a vegetated drainage channel capable of handling the expected overland flows (Figure 5).

It is usually not advisable to return a gully totally back to pre-gully ‘sheet’ flow conditions. Even if the gully was backfilled to natural ground level, ongoing settlement of the backfill will likely result in the formation of a recessed drainage swale.

**Figure 5 – Final, stable gully condition**

The process from Figures 1 to 5 can take many decades, if not centuries. In most cases, extensive bank erosion will prevent a gully from ever being returned to its natural condition, unless the gully is actively backfilled with imported soil.
3.4 Gully stabilisation without partial backfilling

In the majority of circumstances, gullies are stabilised without substantial backfilling. The high costs associated with partial backfilling generally can only be justified when dealing with small gullies, say less than 2m deep, or when substantial sediment flows are expected to continue passing down the gully.

There are three critical components to the stabilisation of a gully, those being (Photo 25):

- stabilisation of the gully bed
- stabilisation of the gully head
- stabilisation of the gully banks

Stabilisation of a gully normally needs to begin with the establishment of a stable gully bed. Only after the bed is stable is it normally feasible to stabilise the leading head-cut, and finally the banks of the gully. However, if the gully head is moving rapidly through the landscape, or if the gully head is beginning to threaten important assets, then landowners may choose to establish temporary stabilisation measures at the gully head before turning their attention towards the gully bed.

Stabilising the gully head before the gully bed has achieved stability (Figure 6) increases the risk that future lowering of the bed will undermine the gully head stabilisation measures causing their failure (Figures 7 & 8, Photos 28 to 31). To ensure the long-term stability of any gully stabilisation measures, the designer must be able to predict, with some degree of certainty, the ultimate stable profile (gradient and elevation) of the gully bed (Figure 9).

The first step to determining the gradient and elevation of a stable gully bed is to observe existing ‘stable’ gully beds in the local area, or possibly a section of stable bed located towards the lower end of the gully. Ideally, the stable section of gully should have a soil type and catchment area similar to the active region of the gully.

It can be very difficult to identify a stable gully bed. Well established, mature bed vegetation is a good indicator of stability, but it can also be a false indicator (e.g. Photo 26). This is one aspect of gully management where years of field experience can be a designer’s greatest asset.
Figure 6 – Inappropriate stabilisation of the gully head prior to the gully bed achieving the desired stability

Figure 7 – Ongoing lowering of the gully bed undermines the previously installed gully head stabilisation works

Photo 26 – Unstable gully bed (Qld)  Photo 27 – Stable gully bed (Qld)
A failed rock chute can be expensive to repair, and if not promptly repaired, can lead to the continued upstream migration of the gully head.

Figure 8 – If the gully head stabilisation measures cannot appropriately adjust to the lowering bed levels, then failure of the head works is likely

Photo 28 – Failure of rock chute caused by undercutting (Qld)

Photo 29 – Failure of gabion grade control structure caused by undercutting (Qld)

Photo 30 – Undermining of a culvert outlet caused by ongoing lowering of the downstream channel (NSW)

Photo 31 – Undermining of road culvert caused by the expansion of the downstream gully (SA)
If the migration of a gully head needs to be stopped before the gully bed has found its final stable elevation, then these head works must account for the expected movement of the gully bed. This usually means recessing the toe of the inlet chute well below the existing bed level as shown in Figure 9.

![Figure 9](image)

**Figure 9** – If the gully head needs to be rehabilitated before the bed has stabilised, then these works must account for expected movement of the gully bed

Photo 32 shows the junction between the lower stable region of a gully, and the upper unstable region of the same gully. The head of the gully is shown in Photo 33.

![Photo 32](image)

**Photo 32** – A stable bed is evident within the lower reaches of this gully (Qld)

![Photo 33](image)

**Photo 33** – Same gully (left) showing a gully bed that is significantly steeper than the downstream stable section (Qld)

In many cases, stabilisation of the bed is achieved by natural means; however, landholders can play an active role in the stabilisation of the bed by introducing grade control structures such as check dams, leaky weirs, or hard engineering grade control structures (also known by the engineering term ‘drop structures’). These grade control structures are normally smaller versions of the type of structures used to stabilise the gully head.

The use of leaky weirs and grade control structures is discussed in more detail within Section 3.3 of this fact sheet, and examples of various structures are presented in Photos 17 to 24.

Once the gully bed is stable, or it is possible to predict the final elevation of a stable gully bed, it is then possible to design the stabilisation measures for the gully head (Figure 10). There are numerous ways of stabilising a gully head, each method having its own advantages and disadvantages.
Detailed discussion on the various types of gully head stabilisation measures is provided in Section 4 of this fact sheet.

Following stabilisation of the gully floor and the gully head, attention must then be placed on the stabilisation of the gully banks (Figure 11). Failure to actively stabilise the gully banks can result in a new gully head being formed, which can migrate around the stable gully head and start the erosion process all over again.

Stabilisation of the gully banks usually involves the following tasks:
- stabilising the various lateral stormwater inflow points, usually with some type of chute; and
- vegetating the gully banks after they have achieved a stable batter slope—a stable batter slope can be achieved either by mechanical excavation, or naturally bank erosion.

Once stable inflow chutes are established, flow diversion bunds (Figure 11) may need to be established to direct stormwater runoff away from unstable gully banks to control soil erosion while vegetation is being established on these banks.
4. Stabilisation of the gully head and intermediate head-cuts

Gully head stabilisation measures include traditional hard engineering practices such as shown in Photos 34 to 39, semi-hard engineering structures shown in Photos 40 to 42, and soft engineering structures shown in Photos 43 & 45.

The gully head stabilisation measures presented here can also be used to control well-defined head-cuts that form at intermediate locations along a gully. In fact, within a well-established gully there maybe several structures used to stabilised the gully bed.

When these structures are used at intermediate points along the gully they are more commonly referred to as grade control structures.
Grade control structures that rely on the formation of a hydraulic jump to dissipate energy (such as most rock chutes) require a flat weir crest (Photos 34, 35, 39, 43 & 44). Grade control structures that achieve energy dissipation through the formation of a plunge pool require a curved or V-shaped weir crest that points upstream (Photos 37, 40, 41 & 42).

Ideally, grade stabilisation structures should discharge into a section of channel that is straight for a length of at least six channel depths, but preferably ten channel depths downstream of the chute (Photo 46).
Bank erosion can result if the chute or weir discharges too close to a channel bend (Photo 47).

Photo 46 – Rock weir discharging into a straight channel reach (SA)

Photo 47 – Rock weir located too close to a channel bend (SA)

Most flexible, soft-engineering measures experience a significantly higher risk of failure during the first 1 to 2 years of their operation. Rock chutes reach their highest degree of stability once sediment has filled all voids and vegetation is established over the rocks. Of course, a vegetative cover is not always desirable within natural waterways, but it is generally desirable within gully stabilisation measures.

If the head of the gully contains at least two distinct gully heads (Figure 12), then benefit can be gained by taking one gully head offline while stabilisation measures are be carried out (Figure 13). Once the first rock chute is vegetated and has reached full strength, it is brought back online while the other gully head is taken offline and stabilised (Figure 14).

Figure 12 – Gully with two heads

Figure 13 – First gully head taken offline

Figure 14 – Second gully head taken offline and repaired

Figure 15 – Both gully heads brought online once fully stabilised
5. Stabilisation of the gully banks

The gully banks can be stabilised in their current location using hard and semi-hard engineering measures such as gabion retaining walls (Photo 48), or battered and stabilised with vegetation reinforced with temporary erosion control mats and/or rock (Photos 49 to 53).

Photo 48 – Gabion retaining wall located within a rural river system (NSW)

Photo 49 – Battered and stabilised banks of an urban watercourse with pool-riffle systems introduced to the bed (Qld)

The use of synthetic (plastic reinforced) erosion control mats (Photo 50) is generally not recommended in waterways containing ground-dwelling wildlife that may become entangled within the synthetic mesh. Instead, erosion control mats formed from 100% biodegradable jute or coir products are preferred (Photos 51 to 53).

Photo 50 – Synthetic reinforced erosion control mat

Photo 51 – Jute mesh

Photo 52 – Vegetated rock beaching within an urban watercourse (Qld)

Photo 53 – Vegetation integrated with biodegradable erosion control mats (Qld)
6. Stabilisation of lateral inflow points

Stabilisation of the gully banks usually involves stabilising numerous lateral stormwater inflow points as shown previously in Figure 11. Typically, the best approach is to identify those locations where it is desirable for lateral inflows to enter the gully. At these locations, stable drainage chutes are constructed (Photos 55 to 59).

Once these drainage chutes are stable, flow diversion bunds are established along the top of bank to direct over-bank runoff into these drainage chutes (also shown in Figure 11).

The best long-term results are usually obtained from the use of flexible, soft engineering measures such as vegetation, rock and rock-filled mattresses (Photos 55 to 57). Ideally, both rock and rock mattress lined chutes should be topped with soil and appropriately vegetated.

The failure of drainage chutes is most commonly associated with tunnel erosion problems resulting from underlying dispersive soils (if present), especially for inflexible chute linings.
7. Stabilisation of gullies that pass through dispersive or slaking soils

Dispersive soils are structurally unstable in water, breaking down into their constituent particles of sand, silt and clay. The dispersion process clouds the water with clay particles containing a relatively strong negative electro-static charge. Dispersive soils are normally highly erodible, causing erosion problems such as deep fluting (Photo 60) and tunnel erosion (Photo 61).

Dispersion is caused largely by high levels of exchangeable sodium in the soil (sodic soils), or excessive mechanical disturbance, especially if the soil is wet. Some aggregates readily disperse when immersed in water, while others require mechanical disturbance (e.g. cultivation) before the dispersion process become noticeable.

Not all of the clay particles within a dispersive soil will disperse in all circumstances. Illite clays can become dispersive if disturbed when wet, while montmorillonite clays (present in high shrink–swell soils) have a greater tendency to disperse in all circumstances.

Soils are considered ‘sodic’ and therefore likely to be dispersive if the exchangeable sodium percentage (ESP) exceeds 6%. Soils with an ESP of 6 to 15% are considered moderately dispersive and are likely to be susceptible to tunnel erosion. Soils with an ESP greater than 15% are considered highly susceptible to both tunnel erosion and surface sealing.

The presence of dispersive soils can significantly increase the risk of failure of gully rehabilitation measures. Landowners are strongly recommended to seek advice from soil experts, such as those working within the soil sciences.

Dispersive soils cannot be managed by simply covering the soils with filter cloth or an erosion control blanket. Unfortunately, when working with these soils, even the best-engineered projects can experience problems if adverse weather conditions are experienced within the first few years following rehabilitation.
Various simple, non-scientific soil tests can be conducted on the site to identify if dispersive soils maybe present. The simplest tests are the Jar Settling Test and the Aggregate Immersion Test.

The jar settling test involves placing a crushed soil sample in a clear jar containing distilled (de-ionised) water. The sealed contents are shaken vigorously to further break-up the soil sample. The jar is then left undisturbed for up to 5 days. If the suspended soil settles leaving the water clear, then there is a low risk that the soil is dispersive (Photo 64).

If the settled soil sample leaves the water ‘slightly’ cloudy after 5 days, then the soil maybe dispersive. If the water remains significantly cloudy after 5 days (Photo 65), then there is a high risk that the soil is dispersive.

Another, more widely recognised on-site soil test is the aggregate immersion test. This test involves filling a dish or jar with distilled water to a depth sufficient to cover the soil samples. Hard clumps of soil (about 5mm square) are then placed in the water. The sample is then left undisturbed for an hour.

The clumps of soil will completely collapse if the soil is slaking or dispersive.

For non-dispersive soils, the water remains clear though particles may slightly collapse. For dispersive soils, cloudiness surrounds most or all particles (extending vertically). For highly dispersive soils, discoloration extends vertically throughout most or all of the water (Photo 66).

For slaking soils the water will remain clear, but the soil clumps will completely collapse and spread horizontally (Photo 67).

If either test indicates the potential for a dispersive or slaking soil, then a 0.5kg sample of the soil should be sent away for official scientific testing (e.g. Exchangeable sodium percentage).
In most circumstances, the best treatment for dispersive soils is to ensure the soil is buried under a layer of non-dispersible soil before the final surface treatment (e.g. grass seeding, turfing, rock, rock mattresses, or concrete) is applied (Figures 16 to 19). Dispersive soil should **not** be directly seeded, or directly covered with erosion control blankets.

The minimum thickness of the non-dispersible soil layer is generally between 100 and 300mm depending on the likely erosion risks. A minimum cover of 100mm is generally recommended on gentle bank slopes, 200mm on steep, low-risk slopes, and 300mm on high-risk gully slopes.

If sufficient quantities of non-dispersive soil are not readily available, then a stockpile of non-dispersive soil maybe made from the in-situ dispersive soil through the application of sufficient quantities of gypsum (or similar source of calcium) mixed evenly through the soil. Appropriate soil adjustments should always be determined from professional soil testing and interpretation.

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**Figure 16** – Revegetation of gully banks containing dispersive soils

**Figure 17** – Rock beaching of gully banks containing dispersive soils

**Figure 18** – Gabion stabilisation of gully banks containing dispersive soils

**Figure 19** – Placement of hard linings over dispersive soils
8. Stabilisation of gullies passing through acid sulfate soils

Acid sulfate soil (ASS): a soil containing significant amounts of iron sulfide (usually pyrite, FeS₂) or sulfidic material, which generates sulfuric acid when exposed to oxygen. In their undisturbed state these soils can have a pH 4 or higher, and are often neutral or slightly alkaline.

Acid sulfate soils occur naturally over extensive low-lying coastal areas, predominantly below an elevation of 5m Australian Height Datum (AHD).

Photo 68 – Minor erosion within an excavated drainage channel passing through acid sulfate soils (SA)

Photo 69 – Culvert damage resulting from the exposure of acid sulfate soils (SA)

Gully erosion normally involves the creation or expansion of drainage channels. This erosion can result in the direct exposure of an acid sulfate soil, or the exposure of a potential acid sulfate soil (located well away from the gully) to oxygen as a result of lowering groundwater levels.

The exposure of acid sulfate soils can not only lower the pH of the local soil (to a pH of 4 or less), but can also release acidic waters into the gully and downstream receiving waters. The rate at which this acidification occurs depends on a number of factors, but primarily on the porosity of the soil. In clayey soils, prompt gully rehabilitation can help minimise the potential adverse effects of acid sulfate soils; however, in sandy soils the adverse effects maybe too rapid.

Prior to the rehabilitation of gullies within estuarine floodplains and coastal lowlands (< 5m AHD), the soils should be tested for their acid sulfate potential.

Most States provide guidelines on the management of acid sulfate soils. Preferred management strategies typically involve the following options:

- minimisation of further expansion of the gully;
- neutralisation of exposed acid sulfate soils;
- strategic re-burial of potential acid sulfate soils.

Wherever practical, gullies should be backfilled such that the potential acid sulfate soils are at least 0.5m below the gully invert. This usually involves the battering of the gully banks with heavy machinery, then using this earth to partially backfill the gully. Appropriately spaced rock weirs are installed prior to backfilling to help stabilised the newly formed gully bed.

Neutralising agents may need to be incorporated into the surface treatment of the gully to aid the neutralisation of acidic stormwater runoff, and to neutralise acidic water entering from acidified groundwater inflows. Such actions require expert planned and application. This is particularly important for gullies that discharge into waters where pH-sensitive wildlife maybe present such as in naturally acidic coastal wetlands.

Agents not recommended for the modification of acid sulfate soils include:

- Cement: calcium silicates and calcium aluminates—due to cost.
- Quicklime [CaO]: finely ground, burnt limestone—due to caustic nature.
- Hydrated lime (slaked lime) [Ca(OH)₂]: formed from quicklime that has reacted with water—due to extreme caustic nature.
9. Stabilisation of gullies passing through saline soils

Saline soil: a soil that contains sufficient soluble salts to adversely affect plant growth and/or land use.

Electrical conductivity is the parameter used to determine the level of soluble salts in a soil and hence the soil salinity. Saline soils have an electrical conductivity (EC) greater than 1.5dS/m in a 1:5 soil:water extract, or 4dS/m within a saturated extract.

A build-up of salts within soil can interfere with the uptake of water and nutrients by plants. If left untreated for long periods, then the rehabilitation of salt-affected gullies and the adjacent lands can be very slow, expensive, and often not effective. The management of saline soils requires expert advice.

Gully revegetation often benefits from heavy mulching and large applications (300 to 800kg/ha) of nitrogen and phosphorus rich fertiliser such as diammonium phosphate.

Heavy mulching should be applied to the gully banks and over-bank areas adjacent the gully. Mulch placed on the gully banks may need to be anchored with jute mesh (or similar) to prevent the mulch from being washed away. The purpose of the mulch is to help capture and retain rainwater allowing sufficient time for the water to infiltrate the soil instead of just washing off as stormwater runoff. This is especially important in regions of low annual rainfall.

Gully rehabilitation should include the retention of existing trees along the edge of the gully, fencing off affected areas to prevent grazing, and the planting of salt-tolerant, deep-rooted plants. In cases where the soil structure has broken down, gypsum can be applied. The calcium in gypsum reduces the effects of the sodium on the soil structure.

In saline soil areas, the primary aim is to leach the salts away from the soil surface, sending it back down into the soil profile. This can be achieved by:

- lowering watertable levels (i.e. stabilising the gully without significant backfilling);
- increasing the amount of water that infiltrates into the soil by applying mulch and gypsum;
- introducing deep-rooted, water-demanding plants along the edge of the gully to control salinity levels on the surface of the gully, thus improve gully revegetation outcomes.

In general, the aim of gully rehabilitation should not be to wash the salts downstream where they can adversely affect downstream properties and waterways. This is especially important for gullies that discharge into inland waterways. The management of salt affected lands is however a complex issue, that occasionally may involve the adoption of unconventional solutions, for example the surface drainage of salts from coastal lands has been used in some management plans as the first stage of a complex, long-term rehabilitation plan.

In severe cases, salt tolerant plant species may need to be established on earth mounds up to 500mm high. These mounds should be prepared several months (or at least one wet season) before planting to allow salts to be flushed from the immediate area. Heavy mulching around each plant will help reduce evaporation and the subsequent accumulation of salts within the soil.
10. Revegetating gullies

Once stabilised, the gully should be revegetated as soon as practicable. The gully bed and banks should be actively planted rather than just waiting for natural regeneration; of course the extent and type of vegetation will vary from region to region. It is noted that gullies in arid and semi-arid regions will be less reliant on vegetation for their overall stability.

Revegetation is one of the most effective, long-term stabilisation techniques for both creeks and gullies. Desirable attributes of gully vegetation include species of local provenance that provide shading, habitat and shelter (for wildlife). It is also important that all plants are correctly located within the gully cross-section according to their type of root system and trunk structure. Table 2 provides a general overview of the use of various plant groups.

It is important to note that the root system of different plant groups perform different tasks. As a general rule, tree roots do not bind the soil together to stop it washing away. Tree roots are the anchoring bars that reinforce steep and high earth banks. If exposed, most tree roots are easily washed free of soil (Photos 72 & 73), but there are exceptions!

During plant establishment it may also be necessary to protect disturbed surfaces from short-term erosion with the aid of Erosion Control Blankets, Mats or Mesh. Erosion control blankets and mats reinforced with synthetic netting are not recommended for use along waterways containing ground-dwelling wildlife (this is likely to include most natural waterways). Rock protection of the bank toe (Photo 52) may also be required to provide stabilisation during the plant establishment phase.

Some gullies will experience ongoing sedimentation problems throughout the revegetation phase, which can impact upon the establishment of bed vegetation. Steep gully banks may experience significant shading, which can either assist or hinder the revegetation process depending on the local climate.
### Table 2 – Vegetation types and erosion control characteristics

<table>
<thead>
<tr>
<th>Type</th>
<th>Scour control</th>
<th>Bank stability</th>
<th>Location of plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquatic plants</td>
<td>Provide good stability to the low-flow channel and water’s edge.</td>
<td>Can assist bank stability by protecting the toe of the bank. Some plants (e.g. reeds) can become inflexible as plant density increases. This can aggravate bank erosion. Bank erosion can be controlled through rock placement.</td>
<td>Aquatic plants naturally appear only within the channel bed. If their impact on upstream flooding must be controlled, then heavy shading of any reed beds can reduce their density and thus their impact on flood levels.</td>
</tr>
<tr>
<td>Ground covers</td>
<td>The most effective plant for the control of ‘scour’. To be effective, ground cover plants should be flexible and continuous. Isolated, clumped plants may aggravate soil erosion. Plants with a matted or fibrous (hairy) root system are most effective in sandy soils.</td>
<td>These plants are usually ineffective in the control of bank slumping, bank undercutting, and head-cut erosion. They can be very effective in the stabilisation of channel banks during the early stages of revegetation. For example, the establishment of a temporary grass cover can help control erosion in active gullies while the slower growing permanent plant species are being established.</td>
<td>Ground covers are generally located at all bank elevations and in over-bank areas. Planting densities usually increase within the lower bank area. Isolated ground covers can help stabilise leaf litter under tree stands. Some clumping plants, such as Lomandra, are best placed in locations where they will be fully submerged during regular flood events (e.g. in the lower bank area).</td>
</tr>
<tr>
<td>Shrubs</td>
<td>Shrubs can provide effective scour control if their interlocking branches prevent high velocity water from coming into direct contact with the soil. Localised soil scour can occur around the edge of isolated plants.</td>
<td>Shrubs can contribute to overall bank strength if the depth of their root system exceeds the height of the bank. Shrubs are unlikely to prevent bank undercutting unless the shrubs are located in the lower regions of the bank.</td>
<td>Shrubs are generally best located in the upper bank and over-bank areas. Shrubs are very important on the outside bank of channel bends. Extreme care must be taken when planting shrubs within critical flood control areas.</td>
</tr>
<tr>
<td>Trees</td>
<td>Trees usually provide little protection against bed and bank scour; however, significant stands of trees can reduce channel flow velocities, thus reducing erosion, but they will also increasing flooding. Some trees have root systems that survive when exposed to air. Such plants are usually located close to the channel bank.</td>
<td>Trees are the most effective plants for stabilising banks, but not necessarily stabilising the gully head. Tree roots provide bank reinforcement to control bank slumping and bank undercutting. To be most effective, tree roots should be encouraged to extend below bed level.</td>
<td>Trees are best located within the top-of-bank and over-bank areas. Tree species can vary significantly over the first 5m from top-of-bank. Well-spaced, single-trunk trees with branches above flood height are best in critical flood control areas. Grouped trees should be avoided in critical flood control areas.</td>
</tr>
</tbody>
</table>