Gully Erosion

OPTIONS FOR PREVENTION AND REHABILITATION

Experiences from the Burnett & Mary River Catchments, Queensland

By John Day & Bob Shepherd

Burnett Mary Regional Group — Practical Solutions for Natural Resource Management
Australian Government
Reef Trust
Reef Alliance — Growing a Great Barrier Reef

ACKNOWLEDGEMENTS

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Special thanks to:	Geoff Titmarsh, Darryl Hill, Barry Stone, George Bourne and the participating landholders of the Burnett, Mary, Fitzroy and Burdekin river catchments
Photos:	John Day, Vikki Evans, Dominique Hinchliffe, Ann McKenzie, Glenda Pickersgill, Peter Wilson, James Henderson, Bob Shepherd, Geoff Titmarsh and past BMRG staff
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THE REEF TRUST PHASE III

Reef Alliance 'Growing a Great Barrier Reef' project is a partnership between agricultural industry, regional NRM bodies and facilitated by the Queensland Farmers' Federation (QFF), with a common goal of securing the future health of the Great Barrier Reef. The Reef Alliance Program is funded by the Australian Government Reef Trust.

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Practical Solutions for Natural Resource Management

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1 INTRODUCTION

Erosion occurs when wind or water forces the movement of soil and rock particles. These natural processes have, over time, shaped the topography of the landscape. The amount of soil or rock displaced at a site depends on the natural vegetation cover on the land, the intensity, duration and frequency of the wind and rain events and the erodibility of the soils and rock at the site. All human activities, including food production with domesticated animals and crops, have the potential to initiate and exacerbate erosion to varying degrees. One of the most visual and destructive forms of erosion is gully erosion.

1.1 WHAT IS GULLY EROSION?

A gully is defined as an erosion path that has a depth exceeding 0.3 metres (m) and has active erosion at the head or along the walls.

Gully erosion is a major environmental challenge and is widespread across landscapes in Queensland. Gullies are considered the worst stage of soil erosion due to the permanent damage they cause to the landscape. Gullies are also acknowledged as a significant contributor of sediment deposited in water reservoirs and into the Great Barrier Reef lagoon.

Most landscapes will eventually generate surface runoff during extended or intense rainfall events. As water concentrates in narrow pathways between grass tussocks or along insect and animal trails, the velocity increases and the erosive force begins to cut deeper and deeper into the soil. If the subsoil is prone to dispersion or slaking, and is exposed to the water turbulence, then it will often dissolve quicker than the surrounding topsoil. The topsoil around the exposed subsoil may still have grass growing in it and be quite stable. Even very small waterfalls cause the water velocity to increase, perpetuating the erosion event (see Figure 1). This process continues with subsequent rainfall events, causing gullies to deepen and widen over time.

Soil formation rates are quite slow and gully erosion can cause dramatic soil loss from a landscape. Gullies are a significant contributor of sediment to water courses and cause major threats to sustainability in cropping, horticulture and grazing production systems if left unchecked.

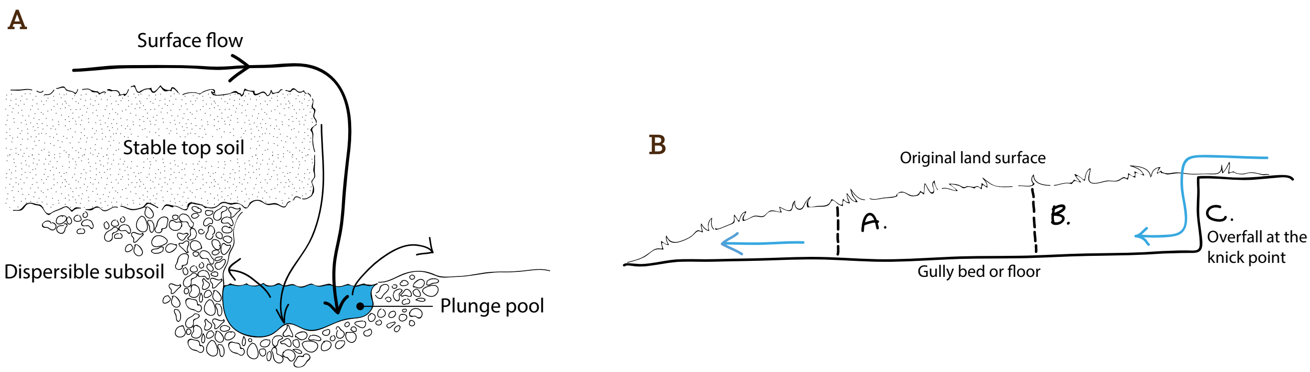


FIGURE 1:
Gully advances – (A) gully head development, (B) changes in height and bedslope as gully advances upslope. (Redrawn from the Queensland Soil Conservation Guidelines, Ch. 13).

1.2 FACTORS THAT INFLUENCE GULLY EROSION

Rainfall intensity, duration, wind and hail, ground cover, vegetation type, soil type, soil condition and land slope all influence the initiation of gully erosion and the rate and extent of damage to a natural landscape. Human activities associated with modern agricultural and urban living also have an impact on soil erosion processes.

Gully formation is closely linked to soil types and is more common where the topsoil is denuded and erosion-prone subsoils are exposed to the erosive power of raindrop splash and flowing water. The most erosion-prone soils are those with dispersive and / or slaking characteristics, which give them a tendency to 'dissolve' and slump very soon after coming in contact with water.

All soils are made up of mineral particles of various sizes (sand, silt and clay), water, organic matter, micro-organisms and gas. All these elements are arranged in various amounts to give the soil a certain texture and chemical composition, both of which affect the way the soil responds to erosive forces.

Very sandy soils allow water to infiltrate down through the profile to deep drainage, resulting in less surface water runoff. Water infiltration is often impeded when the soil has a higher clay content at the surface, particularly if the topsoil clay is unstable in water. If the clay 'seals' the natural pores or openings in the soil, then more surface runoff is likely during heavy rainfall events. However, some clay soils crack deeply and have stable clay structures that allow more water infiltration and it will take longer for runoff to occur, unless the rain is very heavy and even these large cracks are sealed.

Soils with high silt content at the surface often set very hard after being wet and intense rain will generate a large volume of runoff. These soils tend to scald when vegetative cover is lost from the surface. As a general rule, soils with a hard setting surface and a high sodium content in the subsoil, described as sodic soils or Sodosols, are very prone to erosion. These soils will disperse and slake on contact with water. Heavy black and brown clay soils are also prone to slaking and dispersion even though they are often very productive soils.

Soil texture, organic matter and chemical make-up affect the way erosion develops, so it is wise to conduct a soil test on eroding soils to help understand the problem and define the best solution to stabilise the active erosion and prevent further damage occurring. Detailed soil type descriptions can be found on Queensland Government web sites – search 'common soil types in Queensland'.

1.3 GULLY CATCHMENT WATER FLOW ESTIMATIONS

When considering the repair of a gully erosion site, a critical piece of information required is the amount of water that runs through the gully during rainfall events of differing durations and intensities. The size of the catchment, land slope, vegetation type and vegetation cover levels on the catchment and the rate of water infiltration into the soil all directly affect the quantity of water that will flow through the gully.

Calculations can be done to estimate the 'peak flows' from a catchment using the rational method, with charts and descriptions provided in the online publication, *Soil Conservation Guidelines for Queensland* (Chapters 3 and 13, and Appendix 3 Design aids for soil conservation works and measures). The Ramwade flow calculator tool is also available online to help with calculations. It is important to seek the advice of an experienced technical officer to assist with calculating the peak flow for a catchment. Once the estimated flow is determined, an experienced technical officer can assist with the design of suitable structures to rehabilitate and stabilise the site. It is important to ensure the structure will have the capacity to accommodate the peak flow from the catchment.

If it is impossible or uneconomic to access professional technical advice on the peak flow it is possible to make an estimate based on local knowledge of the site. Consider the depth of the largest flows witnessed through the gully. Multiply the depth of the highest flow through the site by the width of the flow to give a cross-section area of the water flow. For example, if the gully flow depth in a higher-than-normal rain event is 0.6 m across a gully width of 5 m, the cross-section of the water flow is 3 m^2 (see Figure 2).

To work out the volume of water flowing through the gully, it is necessary to estimate the flow rate. This can be measured by timing a floating object and measuring the distance travelled in 1 second (or 10 seconds and dividing by 10) to get the velocity in metres per second (m/s). The water in the middle of the stream flows the fastest so it is wise to time an object floating in the middle of the gully. If it is not possible to measure the flow rate, a good rule of thumb to use is that most gullies flow at 1–3 m/s, depending on the steepness of the gully floor and other factors like roughness or vegetation in the gully floor and the size of the flood.

To estimate the volume of water flowing in the sample gully (Figure 2), use an indicative velocity of 1.5 m/s multiplied by the cross-section area of water calculated above (3 m^2), to give a volumetric flow rate of 4.5 m^3/s.

To rehabilitate the site, any structure will need to be designed to safely cope with this volume of water. Water velocity is the most destructive erosive force, so the aim of all gully rehabilitation efforts is to reduce the velocity of the flow. The wider and shallower the water flow, the less the velocity and less erosion. A rule of thumb is to keep the flow depth at around 0.3 m, which will generally keep the velocity at around 1 m/s, within the normal range for most streams.

Several variables, including the vegetation on the gully floor, affect the velocity and flow depth. For example, thick stands of long grass on the gully floor will slow water right down and increase depth, without causing erosion.

To find a design width to safely carry the volume of water (4.5 m^3/s) in the sample gully (Figure 2), at a safer velocity (1 m/s) and at a safe depth (0.3 m), a complex set of factors affect the outcome. The expected width using simple division would be 15 m, however, using calculations described in the *Soil Conservation Guidelines for Queensland* for waterways in cropping and weirs for gully chutes, the recommended structure width for the sample gully is from 17 to 19 m. This extra width is crucial for the stability and longevity of the structure.

This example is provided to give an insight into the complexity of the design process. To determine a suitable width, it is not just a simple exercise of putting in a new depth of flow and multiplying the sum out. As the depth reduces, the velocity reduces, so there are two variables interacting, requiring complex maths or trial and error calculations. An experienced technical officer will assist with the final design using the graphs and spreadsheets that have been developed to improve the accuracy of the outcome and reduce the chance of cost blowouts and structure failure.

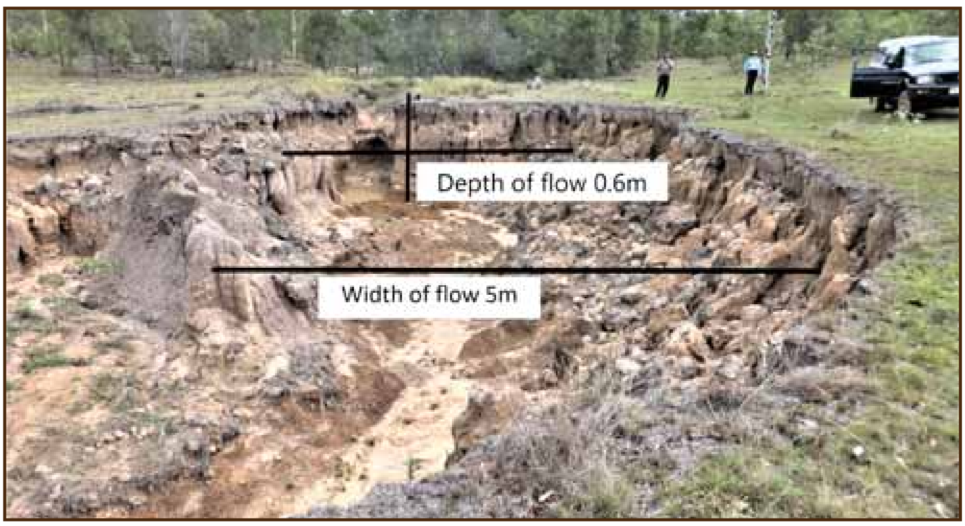


FIGURE 2: *Example gully showing flow width and depth.*

2 PLANNING FOR GULLY EROSION PREVENTION

All property improvements, including fencing, yards, tracks, shade, water facilities and buildings need to be carefully planned to facilitate an efficient and cost-effective business. The aim is to minimise the use of costly resources, such as capital and labour, and minimise stress on management, workers and livestock. Gully prevention is always better than cure. The following are some basic principles and guidelines to reduce erosion when planning the development of the critical property infrastructure.

2.1 PLANNING PROPERTY LAYOUT

ORDER OF DEVELOPMENT

During the first stages of development, boundaries are fixed, and the availability of water is usually the major constraint that determines both the location of fences and paddock size. Over time, with improvements in water supplies, further subdivisions can take place to isolate land types and increase stock segregation and grazing control, which can improve pasture health and achieve more sustainable land use.

Give the first priority to fencing off the most productive areas (such as cultivation and improved pasture areas) so that these areas can be managed more intensely. In grass paddocks, this allows the adjustment of stock numbers to match the available pasture.

The second priority should be to fence off areas at high risk of erosion. This allows light grazing when feed is available and the removal of all stock in times of drought. The aim is to keep as much vegetative ground cover as possible at all times.

Further subdivision may be used to separate:

- *land types*
- *timbered country with lower carrying capacity*
- *areas with potential for agroforestry*
- *high quality native pasture areas*
- *creek frontages and riparian corridors.*

Additional features such as laneways and holding paddocks can also be included in the plan, depending on the stock and land management requirements of the property and business.

SUBDIVISION PLANNING

Subdivision of a property has a multitude of benefits for land and stock management. In the past, access to water governed most fencing layouts. These days graziers can meld together the best principles for locating watering points in relation to land type, paddock layout and infrastructure design to achieve more even grazing pressure and spell paddocks when required.

To begin the planning process, gather all the information that may influence the property infrastructure layout. Satellite imagery of the property is a good way to show the natural features and the location of existing and intended infrastructure.

Mark the main natural features of the property, including:

- *land types*
- *major ridges*
- *water courses and well-defined depressions*
- *areas requiring special treatment e.g. stony, wet, weed infested or eroded areas.*

Next, mark in existing infrastructure, including:

- *buildings and yards*
- *internal and external access roads*
- *existing fencing*
- *watering points, including dams, bores, pipelines, tanks, water holes and sites for future watering points.*

The availability and distribution of water points and the number of paddocks required to allow adequate segregation and grazing management of the herd are important factors in designing the subdivision plan. In planning fencing, the tendency is often to fence according to a geometric pattern that looks good on a flat sheet of paper. This approach can easily lead to serious erosion as a result of badly located fence lines.

When planning fence location, carefully consider the location of cultivation areas, access tracks, fire breaks and stock tracks (pads), all of which can concentrate natural water flow and cause serious erosion. When considered together, a fencing plan can be made that maximises benefits and minimises erosion and other risks. See section 2.3 for detailed recommendations for fence location.

2.2 PROPERTY WATERING FACILITIES

THE IMPORTANCE OF WATERING POINTS

Water is the most important resource on a property. Where water is scarce, or watering points are poorly distributed, pasture utilisation is extremely variable. Fencing and the location of water points are inextricably linked and can be used to direct stock movement and grazing patterns.

The availability of poly pipe and concrete and poly tanks and troughs, plus cost-effective pumping equipment, means that it is now realistic to plan water reticulation systems to suit the optimal fencing layout and not vice versa. While it is not cheap to reticulate water, the upfront costs of water reticulation can be balanced by the long-term benefits of less erosion associated with poorly sited fences and more sustainable pasture utilisation.

THE NATURAL CONSEQUENCES OF WATER POINTS

The natural consequences of stock using watering points are: 1. Excessive grazing of the vegetation in the immediate vicinity and 2. the excessive disturbance of the soil caused by cattle trailing in and out for water, or camping nearby.

Drought conditions accentuate the pressure on the land surrounding permanent watering points, such as bores and dams, which are more exposed to serious damage than the land around seasonal stream water supplies. Consequently, it is expected that the area around a permanent watering point will be sacrificed from pasture production.

The extent of the sacrifice area surrounding a watering point will depend on the susceptibility of the soil to wind or water erosion, the number of cattle using the water point and the degree of protection that terrain and vegetation cover may afford the site. For this reason, it is desirable to site watering points in stable locations.

LOCATION OF WATERING POINTS

Providing sufficient watering points will encourage stock to spread out and better utilise the available pasture, without walking long distances. Reducing the concentration of stock will reduce overgrazing and soil erosion around the watering point.

To avoid the formation of a large sacrifice area, locate watering points such as troughs and dams:

- *on reasonably level sites that are not subject to large flows of run-on water*
- *at least 1–2 km from areas of highly erodible soils such as shallow, texture-contrast soils*

- *ideally on coarse sandy surface soil*
- *1–2 km apart in steep country*
- *3–4 km apart in lower sloping country*
- *in multiple locations within large paddocks*
- *in or amongst belts of trees or scrub*
- *away from drainage areas*
- *so that stock can approach the facility from several different directions.*

If the paddock encloses extensive areas of texture-contrast soils, use seasonal surface waters rather than reticulated water facilities. The use of seasonal surface water only means these highly erodible soils will be rested during prolonged droughts, reducing the risk of erosion when the rain comes and ensuring more rapid pasture recovery so that cattle can utilise the forage after the rains replenish the surface water supplies.

Some texture-contrast soils have subsoil that is suitable for the construction of stock water dams. However, extreme care must be taken during construction as some subsoils are very dispersive and tunnelling may cause dam wall failure. Check the properties of the subsoil before undertaking any earthworks on texture-contrast soils.

Areas of shallow, rocky or hard soils provide good water catchments for dams, as runoff occurs even during light falls of rain. Small dams sited below these areas will therefore fill frequently and provide reliable stock water. As grass responds to light falls of rain in these areas, good feed is often available but can only be utilised if stock water is available.

In low gradient, well-grassed areas with deep soils, surface runoff will only occur after heavy rain or prolonged periods of lighter rain. Dams situated in and below these areas need to be much larger and deeper to provide a reliable water source throughout the year. On these catchments, the collection of runoff will be greatly improved if catch banks or diversion drains are used to bring water from other catchments into the large dam.

ANCILLARIES ASSOCIATED WITH WATERING POINTS

Generally, dams should be fenced and the water pumped to a turkey nest or tank from which it can gravity-feed to one or more troughs. Therefore, it makes sense that the turkey nest or tank is located as high as possible in the landscape. The troughs can be placed at suitable locations, even several within a paddock, and still be gravity-fed.

Excluding stock access to dams avoids animals getting bogged and the loss of capacity that results from stock trampling and siltation. Fencing makes the area safer for weak stock, extends the life of the dam and maintains the water quality for stock. The fenced-out area should include the by-wash and by-wash return slopes so grass cover can be maintained at all times.

Where possible, provide shade clumps close to the dam, but downstream of the bank to prevent large amounts of dung from camps getting washed into the dam, where it would cause pollution and algal blooms.

Do not allow any trees and shrubs to grow on the dam wall, by-wash or by-wash return slope. Shrubs and trees on the by-wash can trap debris and restrict flood flows and tree roots growing in the wall provide conduits for leakage and piping, potentially leading to wall failure. Maintaining grass cover on all dam structures helps prevent water runoff that can lead to erosion of these structures.

If a windmill is used to lift water from the dam to a turkey nest or tank, locate it in an open area with a 400 m radius clear of obstructions such as large trees.

DAM CONSTRUCTION AND MAINTENANCE

This section only provides general recommendations for the construction and maintenance of by-washes and embankments. When planning a new dam it pays to obtain expert advice on dam design and construction.

When clearing a site prior to constructing a dam, it is very important that the by-wash return slope is not cleared or damaged in any way with mechanical equipment. If the slope is treed it can be cleared chemically or with a chainsaw, cutting each tree close to the ground.

Stockpile topsoil removed from under the embankment, by-wash areas and excavation areas for later use.

Design the by-wash width and flow capacity according to the size of the water catchment that will contribute runoff to the dam. A rough rule of thumb for calculating by-wash width on small dams is:

By-wash width (m) = 2 x the square root of the area of catchment (ha)

An extra few metres can be added to the result of this calculation as a safety measure.

Soil condition during construction is an important consideration, especially if building dams on unstable soils (e.g. dispersible clay subsoils). Dry soil is difficult to compact properly, and overly-moist soil is difficult to work. A water truck may be needed to maintain optimal soil moisture during construction and compaction.

Compact the embankment well throughout construction. A scraper will compact soil much better than a dozer. A sheep's foot roller will help to achieve proper compaction, particularly in conjunction with a dozer.

Dam embankments should have at least 1 m of freeboard above the by-wash. The by-wash must be excavated level to ensure uniform width and low depth, to achieve low velocity flow discharge down the return slope and back into the drainage line.

Trickle flows wreck by-washes. Where trickle flows are unavoidable, use a drop inlet and an outlet pipe with the top of the drop inlet approximately 0.1 m lower than the by-wash level. Where possible, build silt traps above the dam intake to reduce the rate of siltation.

Topsoil is generally replaced to a depth of 0.1–0.15 m over embankments and the by-wash. As soon as possible after construction, plant a spreading type of grass over the exposed earthworks. Suitable grasses include couch, pangola, Bisset creeping blue, angleton or Rhodes grass, rather than a tufted grass species such as buffel grass. Regular slashing of grass in the by-wash and return slope areas will promote a dense ground cover. Fencing to exclude stock, particularly from the by-wash, is highly advisable. Establishing a strong stand of grass on dam structures will save a lot of time and money in maintenance of dam by-washes and walls.

2.3 **PROPERTY FENCING**

FENCE LOCATION PRINCIPLES

Fencing is a significant investment on any property and comprises a large portion of the capital expenses. Despite the size of the spend on fencing, there is often insufficient time spent planning the most effective and efficient placement for new fences to achieve the best overall outcomes for the property and business.

Fencing has the potential to achieve much more than simply enclosing a specified area of land.

In the past, fences were often erected following a geometric pattern. In most cases, differing soil types, pastures, topography or water availability were not taken into account. Now, with more intensive use of resources, land degradation problems can emerge if fencing is not considered within an overall property plan.

Vehicle tracks, stock tracks and fire breaks are usually associated with fence lines and, because water concentrates in these areas, extensive erosion can result if the placement of fence lines is not well planned. For example, cattle tend to make well-defined tracks along fence lines and their hooves make the soil loose, powdery and erosion-prone. A cattle track can soon become a shallow rill or drain, which serves to divert runoff and carry it quickly to drainage lines when it would otherwise flow slowly over the surface. The extent to which cattle tracks become an erosion problem depends on the intensity of stock use, soil type and pasture cover.

Water courses often occur at the junction of different soil types. Consequently, fencing placed adjacent to a water course will often separate soils that require different management and will not interfere with water disposal from cultivation, access tracks, firebreaks and stock tracks. Building fences on both sides of a water course provides the opportunity to manage the riparian area as a distinct land type.

Fence lines should follow natural features such as water courses, ridges, rocky outcrops and timbered areas. Fences can also follow the contour around slopes or at natural slope changes. Fencing along natural boundaries will usually involve more planning than fencing in a geometric pattern, but the advantages of easier access and more efficient use of land will more than compensate for this.

Sometimes, compromises must be made to achieve the major objective and may result in a fence running down slope. If that is the case, it is preferable that the fence run at right angles to the contours, to shorten the distance where erosion may occur and reduce the chance of concentrating overland flow.

In cultivation areas, build fences:

- *along a split in contour bank direction*
- *at the origin ends of contour banks*
- *alongside a waterway (but never in the waterway)*
- *20–30 m above a top diversion bank to allow for maintenance.*

FENCE CONSTRUCTION

Fencing on the contour helps reduce erosion risk but can be difficult with conventional and suspension fencing, which need to be strained tightly with strainer assemblies on every bend. A compromise is to approximate the contour with a number of straight sections of fence.

When fencing along contour banks, permanent fences should be placed about 5 m below the bank. This allows room for construction and maintenance of banks. Permanent fences along the top of contour banks are difficult to strain and impede bank maintenance.

A good alternative is electric fencing. Electric fences are not generally strained as tightly as conventional fences, and hence need less strainer assemblies, enabling them to be positioned along the contour. Electric fences can also be located on top of contour banks as they are easily removed to allow bank maintenance.

FENCE MAINTENANCE

As with all capital improvements, the key to fence longevity is maintenance – not just of the fence, gateways and yards, but also any associated vehicle and stock tracks that run alongside the fences.

In areas where it is inevitable that water will concentrate on tracks close to a fence, it pays to invest in some preventative maintenance to divert pressure off the track, such as:

- *whoa-boys to divert water*
- *fallen logs, bark strips or rock piles placed across the stock tracks to temporarily divert water, and stock, away from the fence.*

LANEWAYS

Laneways are an increasingly common component of new fencing layouts. When located and built correctly they are real labour savers with respect to stock management. Avoid narrow laneways, which are often subject to heavy grazing and are at a high risk of becoming eroded and unproductive. A well-managed laneway that is 50–100 m wide can provide useful stock feed when used as a temporary holding paddock and is less subject to erosion. When laneways are wide, there is less pressure exerted on the fences and so lower-cost fencing options can be safely used.

GATEWAYS

The location of gates can make a considerable difference to the ease of stock movement, and also minimise erosion risk, water accumulation and wet patches. To minimise erosion risk and reduce pasture damage, consider locating multiple gateways along a long fence, siting each gateway on level, or near level, ground on erosion resistant soils such as gravels, well drained loams or rocky areas. Having multiple paddock access points makes it possible to vary the path of stock movements, reducing the erosion risk associated with stock tracks from a single gateway to the water point or the next gate.

Gateways are often located in the corner of a paddock for ease of stock movement. However, locating the gate approximately 100–200 m from the corner avoids the tendency for stock to jam in the corner as they go through the gate. By avoiding this unnecessary pressure in the corner, there is less need for expensive strengthening with rails and the like.

Avoid locating a gate in a drainage line or on erosion prone soil. Locating gateways on higher ground ensures good drainage and avoids water being channelled through the gateway.

STOCKYARDS

Stockyards and small holding paddocks are exposed to heavy stock concentration and can easily become a focal point for erosion and pasture degeneration, if sited incorrectly. As with watering points and gateways, the best sites are stable soils on relatively flat ground. Stockyards must be located in open surroundings to facilitate easy handling of stock in and around the yards. The best site is an open area on firm, loamy soil with a slope up to 1%, with some trees in the holding paddocks and cooling yards for shade.

Loam soil, and particularly sandy loam, is less boggy and less dusty than heavy clay soils, which are prone to soil movement and boggy conditions. A slight slope will provide drainage from the working area and the yard site. Avoid sites near gullies, hollows and obstructions, such as rocky areas, that impede stock movement and could cause erosion.

Consider the direction of prevailing winds to avoid having dust blown from the close working yards to the race area or towards nearby living quarters. Suitably located tree lines can reduce wind and dust problems.

Ideally, yards are centrally located with holding paddocks that provide direct access to as many larger paddocks as possible. Where this is not possible, a laneway system will greatly increase handling efficiency.

2.4 PROPERTY ACCESS TRACKS

THE NEED FOR FARM ROADS AND TRACKS

Ready access to various locations within the property is essential for the efficient running of a property. Property tracks are used when:

- *inspecting waters, fences, crops, pipelines, power lines and stock*
- *fighting fires*

- *controlling animal and plant pests*
- *carting stock or grain to and from yards or silos*
- *accessing buildings and other infrastructure.*

How often a track will be used and its purpose will influence decisions related to the type of construction and the amount of money invested in construction and maintenance. There are basically two types of internal property roads or tracks:

- All weather: *such as from the public road to the homestead and other main buildings, and sometimes to stockyards and silos. These roads are generally gravelled and need to be correctly sited, well-constructed and properly maintained.*
- Dry weather only: *such as general access tracks through the property. The standard of these tracks may vary considerably, with the most-travelled ones generally being of a higher standard.*

PROBLEMS ASSOCIATED WITH ROADS

Access tracks can become severely eroded if they are not located, constructed and maintained correctly. Erosion generally occurs as deep rilling of the track and gullying in the table drains. The erosion occurs as uncontrolled runoff is channelled along wheel ruts for an extended distance over a bare or poorly vegetated soil surface, resulting in large volumes of fast moving water being delivered into table drains. The degree of erosion is largely determined by the soil type and slope, and whether the track has been designed to cope with the volume of water that is likely to accumulate during heavy rainfall events. Tracks in steep areas, where road construction involves considerable soil disturbance and there are long sections of steep grade, are particularly prone to erosion.

Many level, or near level areas, receive large amounts of surface flow from surrounding undulating areas, and shallow flow, hundreds of metres wide, are a normal occurrence with moderate rainfall. Any disturbance to the natural pattern of flow, such as road construction, or even slightly defined wheel tracks that result from regular vehicle use, can divert very large volumes of water away from its natural course. Serious gullying can occur if this excess water is concentrated in an erosion-prone area. Any kind of traffic in areas set aside for water disposal can lead to gullying that is difficult and expensive to repair.

When a vehicle track diverts runoff that would normally flow slowly over the land surface, and carries it rapidly to drainage lines, the country immediately downslope of the track is starved of natural water flow and the pasture growth will suffer.

Problems often exist where firebreaks and access tracks are required to follow property boundaries where the soil type and slope is not compatible with safe track construction. These sites remain as problems and require considerable construction and maintenance effort to avoid the occurrence of serious erosion.

TRACK LOCATION

Access tracks should provide the best and most direct access possible to each part of the property. To achieve this requires prior planning and thought. All the rules that apply to dry weather only tracks, also apply to all weather access tracks – the only difference is the cost.

The best location for a track, whether formed or not, is along or close to the top of the main ridges (if these are reasonably accessible) and down a spur ridge if it is necessary to take the track across a drainage line. By having the track on the ridge, it will accumulate less water and dry out faster after rain. Also, maximum visibility is afforded, which is important when checking on stock and for the general running of the property.

If the main ridges are not reasonably accessible, the next best location for tracks is at the foot of the lower slopes, or along the edge of the flat. Avoid having long straight stretches of track in these situations.

Instead, create a track with a series of broad bends, so water that collects on the track is able to disperse at frequent low points.

If it is necessary for a track to cross a flat, it should follow the contour, to minimise disturbance of the natural water flow.

Where access is required across the slope, the track should zig-zag so that low spots occur in the track, allowing water to drain off. A zig-zag path reduces the volume of runoff and the length of slope along the track so that erosion is reduced.

Quite apart from reducing erosion damage to the country, locating tracks according to the principles outlined above will save maintenance costs, and reduce travel time and vehicle wear-and-tear.

TRACK CONSTRUCTION

With all weather access roads, the capital costs are relatively high. Therefore, it is important that the road is well drained and that the location of the table drains coordinate with existing or proposed soil conservation measures. On long slopes, carefully consider drainage and restrict the length of table drains so they do not accumulate an excessive volume of water. The construction of a series of flat bottomed, near-level spur drains located at suitable intervals along the table drain allows water to spill out to the side and spread over the surrounding land or tip into a contour bank. Sharp, deep and steep spur drains are the cause of most erosion associated with constructed roads.

A dry weather only access track is a low standard, low cost road built with a minimum of clearing and earthworks. Simply stick raking and slashing the path is ideal 'construction'. Crowning and forming of the track is generally not necessary and gravelling is seldom used except for short sections that are prone to specific problems, such as waterlogging. Aim to establish tracks that will require minimal maintenance.

If a formed road must be built, it should be constructed where it will not interfere with natural drainage. There are a number of cases where raised roads constructed across a low slope have interfered with above-slope drainage and below-slope vegetation to the extent that water tables have been raised, bringing salts into the rooting zone of vegetation. Reduced grass cover downslope reduces water infiltration and increased water and wind erosion, often resulting in scalds.

CLEARING TIMBER TO CREATE A NEW TRACK

Avoid uprooting trees on steep, erodible slopes, as tree roots help bind the soil. In addition, large root holes in highly dispersible soils predispose the soil to tunnel erosion.

If large trees are on the proposed track line, make a deviation around them rather than uprooting them. Where it is necessary to cross a water course, it is recommended that any timber that must be removed be cut as close as possible to the ground with a chainsaw so that the root system is left intact and no root holes are left to cause tunnel erosion. Where fallen timber is not too dense, felled trees should be removed from the site or left lying, rather than stacked. Stacking felled timber into windrows can divert and concentrate runoff. If stacking is necessary, place the stacks along the contour.

Do not burn felled timber on steep erodible slopes or on stream banks, as burning will destroy the surrounding protective ground cover.

TRACK EARTHWORKS

The access track should be wide enough to allow a change in the position of wheel tracks. Aim to establish an obstacle-free, grass-covered track that is defined mainly through routine vehicle use over time.

To minimise erosion associated with track construction, keep soil and vegetation disturbance to a minimum. A light blading to remove obstacles, such as stones and logs, is often all that is necessary. Avoid crowning and cutting of access tracks. This reduces the amount of disturbance and also avoids the need for table or spur drains for water removal, as the water flow is not concentrated on the track.

In most cases, grading or blading property tracks is not necessary and should be avoided. Grading and blading leaves windrows that block or concentrate water flow that would otherwise flow across the track. If a grader windrow is unavoidable, place it on the downslope side of the track. At intervals of 20–30 m, knock a hole in the windrow to allow water that accumulates on the road to escape. Flatten any windrows that cross drainage lines.

WHOA-BOYS

Even when tracks have been correctly sited, wheel ruts can collect water, and if the length of slope is sufficient, this water can gain velocity and begin to erode the track. Whoa-boys (low, trafficable cross banks) can be built to intercept runoff on long slopes and divert it safely to the lower side of the track. Whoa-boys that are correctly located and built provide effective, cheap and long-term low maintenance road drainage. Whoa-boys can also be used on eroding cattle tracks and small gullies up to 0.5 m deep to stop the problem worsening.

The earth for the whoa-boy should all come from a level borrow pit surveyed on the lower side of the track (see Figures 3, 4 and 5). Whoa-boy dimensions should be:

- *Batters 4–8 m depending on vehicle type. If semitrailers need to use the track then the whoa-boy bank batters need to be very broad, particularly on steeper track sections.*
- *Height 0.3–0.45 m above the existing road surface, depending on the capacity required and the slope of the track.*
- *Grade 0.05 m fall across the road to ensure water does not pond in the channel.*
- *Outlet onto a level borrow pit beside the track.*

Whoa-boys with dimensions less than those above are rough and slow to drive over. They quickly lose their capacity to drain once compacted through vehicle use.

Site each whoa-boy where there is a suitable outlet point that:

- *is not blocked by stumps or rocks*
- *allows water to spill onto an area of undisturbed vegetation*
- *does not allow water to flow back onto the road.*

Where roads are very wide and there are several eroded tracks, the borrow pit for the whoa-boy can be extended in length to provide more soil for the longer bank and infill (see Figure 5). If an eroded table drain must be filled to build a whoa-boy, the bank at that point must be well compacted with extra earth to allow for slumping and to cope with the concentration of runoff in the table drain.

The erodibility of the soil and the steepness of the track determine the required spacing of whoa-boys (see Table 1). Spacing will vary depending on the characteristics of individual sites. If rill erosion becomes apparent on a track, this signals the need to establish whoa-boys across the track. As a general guide, measure from the top of the slope in the affected section of the track to where the rilling starts and built the whoa-boy some distance up the slope, above the start of the rills. If the slope is long and more whoa-boys are needed, build them no more than the measured distance apart. On steep grades they may need to be spaced 30–60 m, depending on soil type and track conditions.

Effective whoa-boys can be built on roads with gradients of up to 26%. Beyond this gradient they have inadequate capacity and are difficult to negotiate even with a 4WD vehicle. If the track slope is 26%, then the downhill batter of the whoa-boy approaches 48%, which is close to the grade limit for most 4WD vehicles. Consider alternative routes for the proposed track if the slope will exceed 26%, particularly on soils with high erosion hazards.

SURVEYING WHOA-BOYS

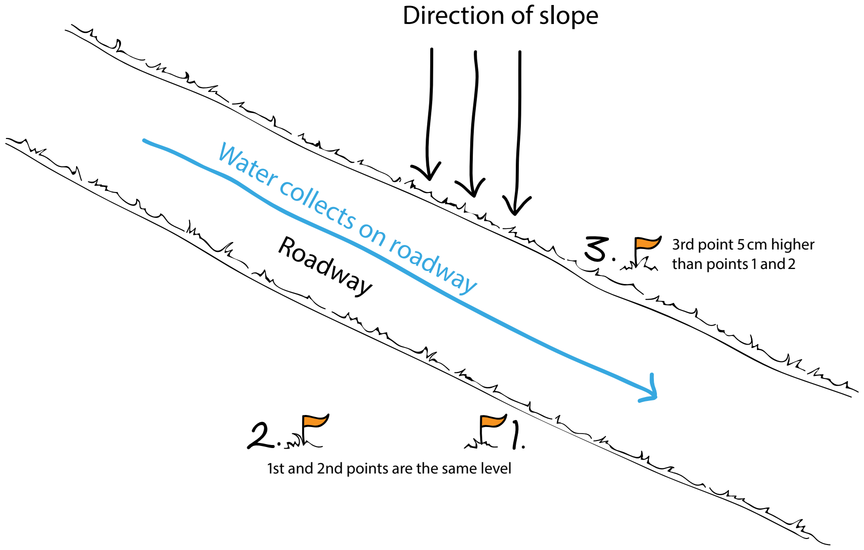


FIGURE 3: *Surveying whoa-boys (based on a design by Darryl Hill).*

CONSTRUCTING WHOA-BOYS

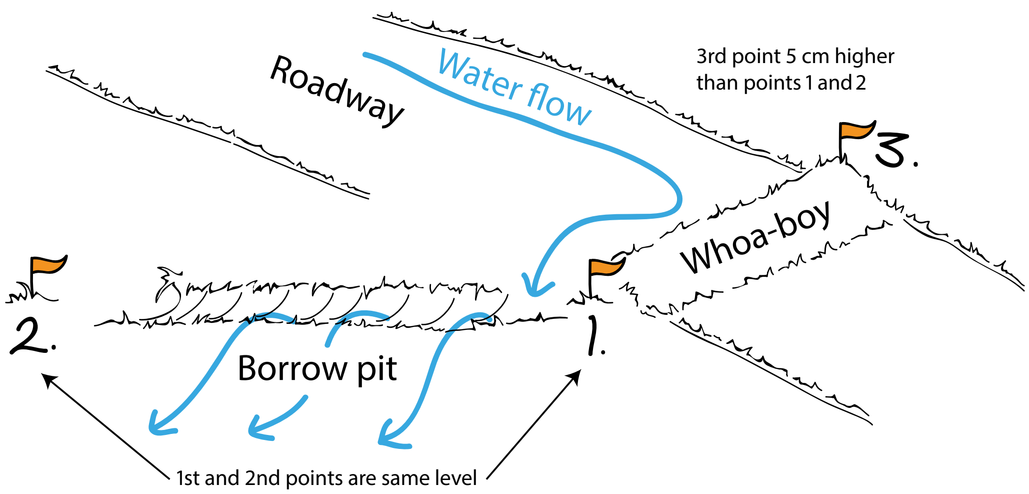


FIGURE 4: *Constructing whoa-boys (based on a design by Darryl Hill).*

WHOA-BOYS ON BADLY ERODED ROADS

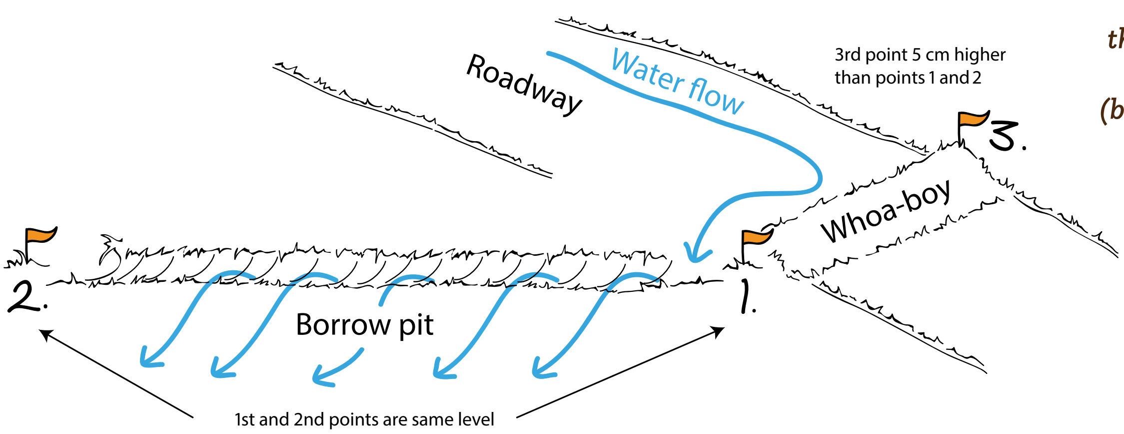


FIGURE 5: *Earth for bank and fill moved from the extended level borrow pit (based on a design by Darryl Hill).*

TABLE 1: *Table indicating how slope and erodibility determine the spacing of whoa-boys.*

SLOPE (%)	DISTANCE BETWEEN WHOA-BOYS (m)	
	HIGHLY ERODIBLE SOILS	MODERATELY ERODIBLE SOILS
0.5 – 1.0	130	250
1.0 – 2.0	90	200
2.0 – 3.0	75	150
3.0 – 4.0	65	125
4.0 – 5.0	60	100
5.0 – 6.0	40	75
6.0 – 10.0	30	50

TRACK CROSS FALL

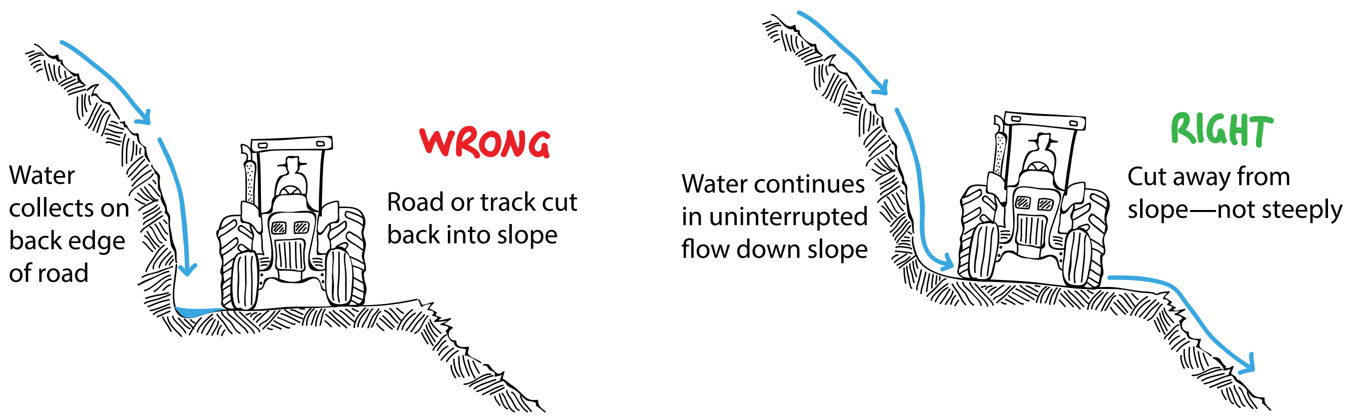
If a formed road is required (e.g. to stockyards), and it must negotiate some sloping land, consider using a construction method called 'cross fall'. The track cross fall method involves creating a slight camber (0.10–0.25 m, depending on soil type) toward the downhill side of the track to direct runoff across the road and over the road batter, avoiding the accumulation of water flowing along the road (see Figure 6). The low profile associated with this standard of road can withstand the dispersed flow of cross fall drainage. To ensure effectiveness of the cross fall, grade off any earth windrow that develops on the downslope side of the road during construction.

To maintain cross fall and ensure that wheel ruts do not concentrate water, whoa-boys are still required on sloping sections of track.

Be aware that adding sufficient camber to the road to provide adequate drainage may create safety problems for vehicles using the road. Seek site-specific professional advice to ensure safe and effective construction.

CUTTING INTO SLOPE

FIGURE 6:
Cutting a track into the slope. (Redrawn from Self-help Landcare for New Farmers – Planning Property Development Series).



CROSSING DEPRESSIONS AND DRAINAGE LINES

Pay particular attention to tracks where they cross gullies or streams. Serious erosion can occur if runoff is allowed to follow the tracks into the gully crossing. Build a whoa-boy 10–20 m back from the edge of the gully to divert water away from the track and wheel ruts.

TRACK MAINTENANCE

Regularly check and maintain the capacity of any whoa-boys.

Proper location of tracks with whoa-boys should largely eliminate the need for grading the surface of the track. As recommended in the earthworks section above, it is best to avoid mechanical formation of vehicle tracks through the property. The use of a scraper or grader on in-property tracks frequently causes severe erosion while providing very doubtful improvements in vehicle access. This form of construction merely provides a convenient channel for water to flow in.

Once such a track is cut, ongoing maintenance is required, potentially exacerbating the problem after every substantial rain. Eventually the track can be 0.15–0.45 m below the natural ground surface, forming a permanent water course and erosion of the track is inevitable.

If a track is important enough, or degraded enough, for mechanical treatment to be proposed, the first consideration should be relocation of the track. If the track must remain in its present position, grade it only where necessary to straighten it or to repair damaged sections. If a grader windrow is unavoidable, place it on the downslope side of the track. At intervals of 20–30 m, knock a hole in the windrow to allow water that accumulates on the road to escape. Flatten any windrows that cross drainage lines and grade off any windrow that develops on the downslope side of the road during construction.

Once a track is cut to more than a centimetre or two below the natural surface, it is necessary to construct wide flat-bottomed, near-level spur drains or whoa-boys to direct water off the track at frequent intervals, to prevent runoff causing erosion.

3 LOW INPUT GULLY REHABILITATION METHODS

Low input gully rehabilitation methods include fencing, mulching, seeding, fertilising, wet season spelling, light stocking rates, rotational grazing, whoa-boys on cattle and farm tracks and using various sizes of timber as silt traps during a stick raking process.

3.1 FENCING, SEEDING, FERTILISING AND MULCHING

Fencing, seeding and fertilising, with or without mulching, can be used to encourage revegetation and natural healing of an eroded site. This type of rehabilitation is effective on all gully types. However, complete rehabilitation and stabilisation is only likely to be achieved in relatively shallow gullies (e.g. 0.5 m deep or less) that do not have steep gully walls or deep gully heads, and are located in small catchments.

Very dispersive soils are difficult to rehabilitate in this way due to the subsoil providing unfavourable conditions for plant establishment. On sodic soils, consult an agronomist and do soil tests to determine if gypsum application may assist with stabilising the soil and encouraging grass establishment. Other types of soil amendments such as manure or compost can potentially aid grass establishment.

3.2 ROTATIONAL GRAZING AND SPELLING

Wet season spelling, light stocking rates and or using rotational grazing can be viable options to rehabilitate small-scale erosion sites within relatively small catchments. A key feature associated with this practice is establishing numerous water points to ensure even grazing pressure across a paddock and reducing grazing pressure on fragile land-types.

Aim to maintain at least 60% of the grass bulk and 100% ground cover at all times for this grazing strategy to effectively improve the soil health and prevent, or rehabilitate, erosion.

3.3 WHOA-BOYS ON CATTLE PADS AND FARM TRACKS

Even when farm tracks have been correctly sited, wheel ruts can collect water and cause erosion if the length of track slope is sufficient. In these cases, whoa-boys (low, trafficable cross banks) are built to intercept runoff and divert it safely to the downslope side of the track. Correctly located and built whoa-boys provide effective, cheap, long-term, and low maintenance road drainage. For details, see Whoa-boys section in 2.1.2 Property access tracks.

Correct construction and placement of who-boys on all property tracks, fire breaks, fence lines and small gully systems can significantly reduce total soil loss and increase productivity through better water infiltration and retention on the landscape.

3.4 OPPORTUNISTIC USE OF STICK RAKED TIMBER

This option is only low cost when used in conjunction with a planned stick raking land treatment.

If a paddock is being stick raked as part of a strategic timber management operation, it is an ideal time to check all erosion sites in the proposed treatment area and make the best use of the stick raked timber to improve infiltration, slow water flows and provide silt traps in actively eroding gully floors.

Stick rake lines can be arranged in a checker board pattern (see Figure 7) on the contour across any slope to slow and spread water to improve infiltration, reduce runoff and protect perennial grass seedbanks from stock, without obstructing vehicle and stock movement through the paddock.

Another option is to arrange the stick rake lines on the contour with breaks for access on the ridge lines (see Photo 1). The stick rake lines can effectively block the gully or drainage line heads and divert and spread water away from the drainage lines toward the ridges, particularly if a slight fall is placed on the lines to lead water away from the depressions (see Figure 8).

Take care with the location of breaks in the stick rake lines to ensure that their placement will not encourage cattle to traverse through fragile sections of the paddock, creating tracks that could become new erosion sites. There may also be situations where continuous rake lines could be used specifically to exclude stock access to the fragile rehabilitation area.

Arranging stick raked brush and small regrowth in an active gully so that the branches face upstream can provide a silt trap that encourages revegetation while also providing protection from grazing pressure (see Photo 2). Stick raking a mix of large and small timber into lines to act as diversion banks that slow overland flow and divert water away from an active or a repaired gully head can be useful to provide the environment for revegetation and rehabilitation (see Photos 3 to 5).

Stick raking large logs and trees to fill gullies is likely to generate turbulent water flow, dramatically accelerating erosion around the logs during large flows. Large logs and trees also increase the risk of denuding and scalding the gully if a fire escapes onto the site.

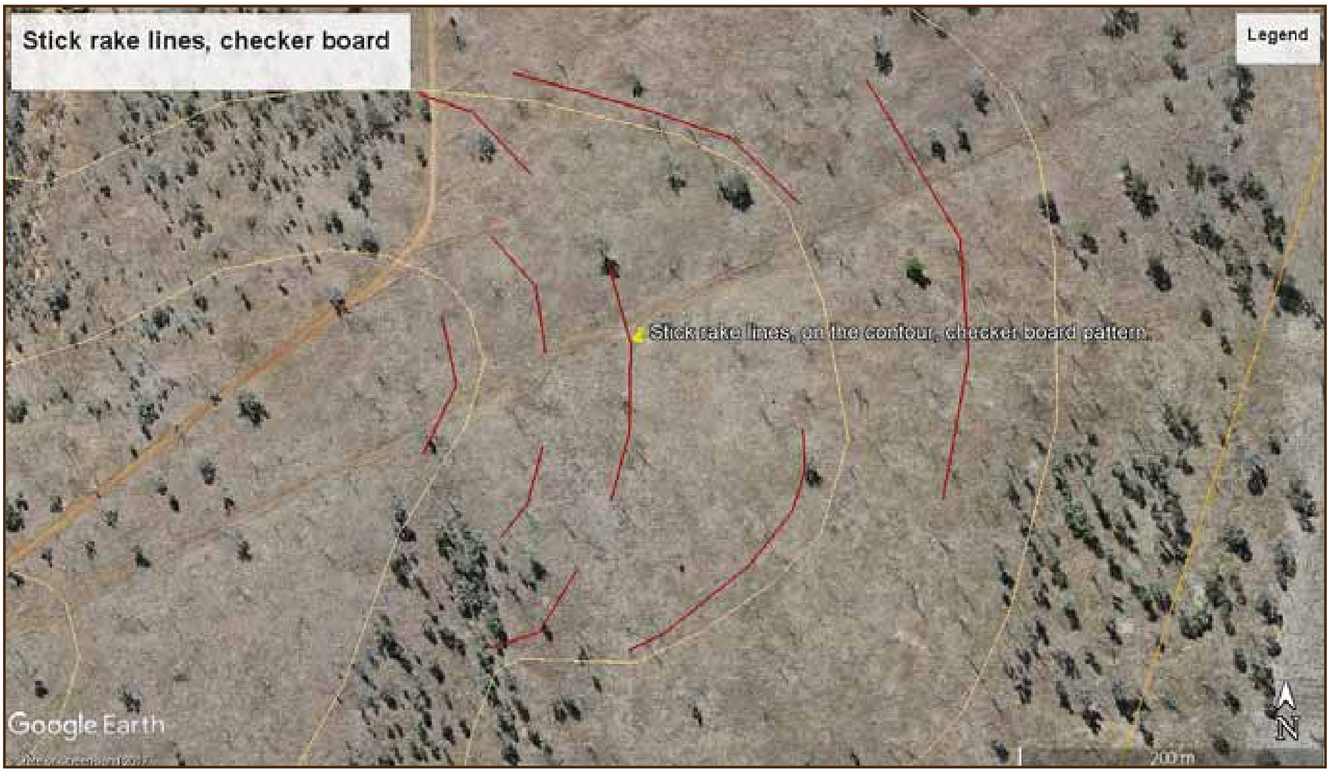


FIGURE 7 / ABOVE:
Stick rake lines arranged in a checker-board pattern, on the contour.

PHOTO 1 / LEFT:
Stick rake lines on the contour, with breaks for access on the ridge lines.

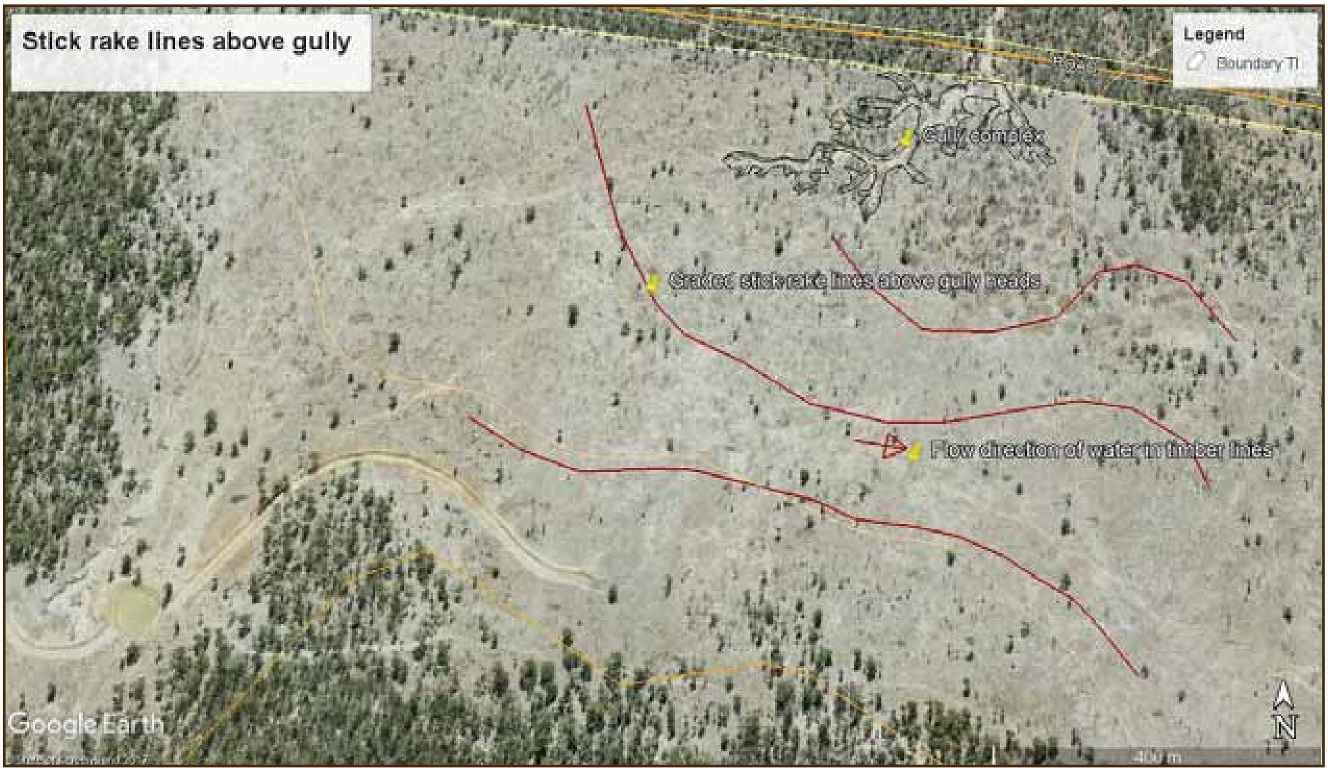


FIGURE 8 / ABOVE:

Stick rake lines to divert and spread water away from the gully heads towards the ridges.

PHOTO 2 / LEFT:

Stick raked timber in an active gully, providing a silt trap to encourage revegetation and protect the new growth from stock.

PHOTO 3:
Deep gully erosion on a small catchment.

PHOTO 4:
Gully battered and stick rake lines used to divert water away from gully head.

PHOTO 5:
Two years later, the gully is grassed up after good rain.

4 MEDIUM INPUT GULLY REHABILITATION METHODS

This suite of erosion control methods generally involves some form of construction with earthmoving machinery, without the use of other materials such as rock, steel or wire fabrications. The options include diversion banks with filling or battering, dam construction, deep ripping and pondage banks. These are deemed 'medium input' as a single operator using earthmoving equipment can implement all methods. Planning and marking out may need the input of specialist assistance, but the construction is conventional and easily done by competent operators.

For effective regeneration and full stabilisation of these sites fencing, mulching, seeding and fertilising should be included as standard practice.

4.1 DIVERSION BANK THEN FILL OR BATTER THE GULLY

BUILD THE DIVERSION BANK

Diversion banks can be used to divert water away from a gully or erosion site, allowing the site to revegetate without ongoing interference from high flow water. To begin, design the bank to carry the expected water flows and then ensure there is a suitable site for disposal of the diverted water. Consult a suitably experienced technical adviser to assist with the site selection, design and survey of diversion banks. Chapter 8 of the *Soil Conservation Guidelines for Queensland* provides details on all aspects of diversion bank design and survey.

Site diversion banks so they will deliver the diverted water to a broad, flat discharge area with very good grass cover. If this is not possible, spreader banks can be used to safely dissipate discharge water flowing off the end of the diversion bank (see Figure 9).

Survey the diversion bank to obtain the correct gradient in the channel. The careful removal, stockpiling and reinstatement of topsoil over the finished construction is a high priority, giving the site the best chance for quick and complete revegetation with grass cover (see Photos 6–12). A bulldozer and grader working together is the best method for constructing a diversion bank. The grader strips and stockpiles the topsoil from the channel area and replaces the topsoil over the channel after the dozer has built the bank to the required height.

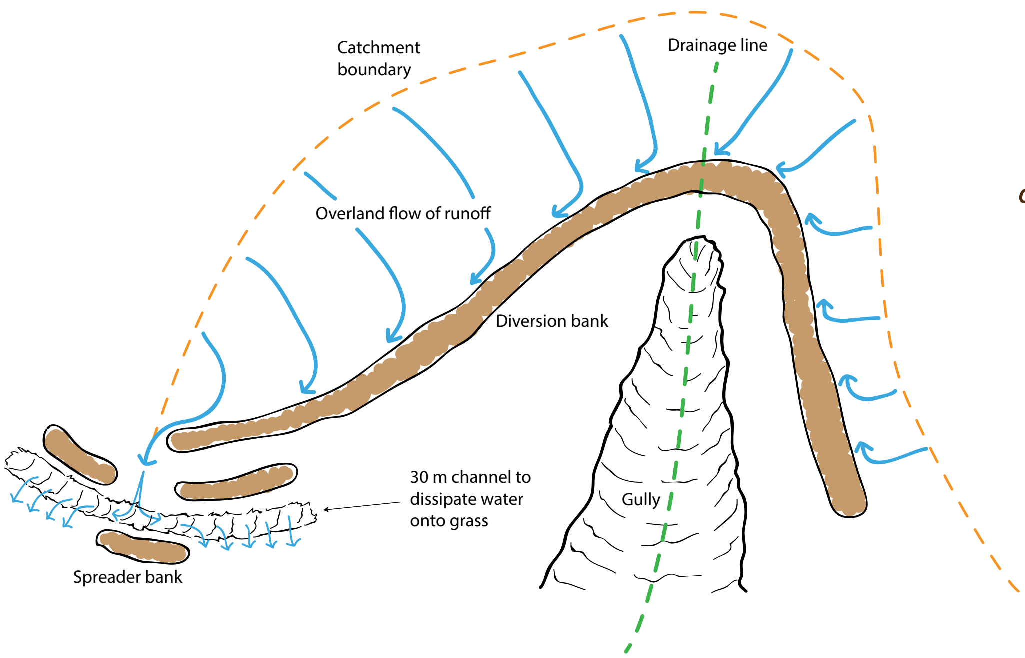


FIGURE 9: ***A spreader bank allowing water to safely flow from the end of a diversion bank. (Adapted from Chapter 13 Soil Conservation Guidelines for Queensland).***

FILL OR BATTER THE GULLY

When the topsoil is removed and the subsoil exposed, a deep ripper and dozer is used to either completely fill the gully or reshape the gully walls using a batter of at least 3:1 (horizontal : vertical). If the gully is relatively small and there is little to no established vegetation, then filling may be the preferred option.

If the site has a wide gully with a well grassed stable floor, then battering the gully walls and leaving the gully floor undisturbed with grass cover intact is a better option as this will reduce the construction cost and reduce the erosion hazard for the gully floor.

For both options it is essential that the disturbed area is completely covered with topsoil then mulched, seeded and fertilised. If possible stock should be excluded using permanent fencing or at least excluded from the paddock until the grass is well-established.

Photos 6 to 12 show the processes involved in gully head diversion and fill and diversion and batter techniques. *(Photos 6-12 by Bob Shepherd)*

PHOTO 6:
Sweep topsoil away from the gully and stockpile.

PHOTO 7:
Stockpile topsoil in a horseshoe shape around the gully sides and gully head.

PHOTO 8:
Deep rip the subsoil.

PHOTO 9:
Push subsoil into gully and reshape with low profile batters. Construct the diversion bank around the gully head.

PHOTO 10:
Replace the topsoil by pushing at 90 degrees to the gully.

PHOTO 11:
Final trim on the topsoil. Note that the dozer tracks are at 90 degrees to the contour at all times, including the batters on both sides, to help trap soil and water.

PHOTO 12:
Finished diversion and gully-fill site. Mulching, seeding and fencing to follow. Freshly constructed diversion bank is visible in the background.

4.2 DAM CONSTRUCTION

Dams are an effective gully control option if their construction will also provide a useful addition to the water infrastructure for the property. The key consideration for this option is the availability of stable by-wash areas for the dam, preferably on both ends of the wall.

See Section 6.2 – Dam construction and maintenance for details.

Use the catchment size to determine the peak flow through the site. This is required to calculate a suitable by-wash width. If peak flow cannot be calculated easily, use the rule of thumb:

By-wash width (m) = 2 x the square root of the area of catchment (ha).
Then add an extra few metres for safety.

Check that there is sufficient quantity of suitable clay available at the site to ensure the dam will hold water. Dispersive and slaking clays are very common in gullied situations so seek out earthmoving contractors with the necessary experience and technical know-how to construct dams on these soils. Watering, rolling and using a scraper during construction will help ensure the dam wall is properly compacted.

If the construction of a dam is deemed practical and safe, place the dam wall across the gully so the head is reshaped during the construction process and then inundated when the dam fills with water (see Figure 10).

When construction is complete, fence the dam wall and by-wash area to exclude stock and install a tank and trough to provide stock access to water at a site that is not likely to erode, preferably downstream from the dam to reduce pumping costs (see Figure 11).

FIGURE 10: *Diagram showing the plan for construction of a gully dam.*

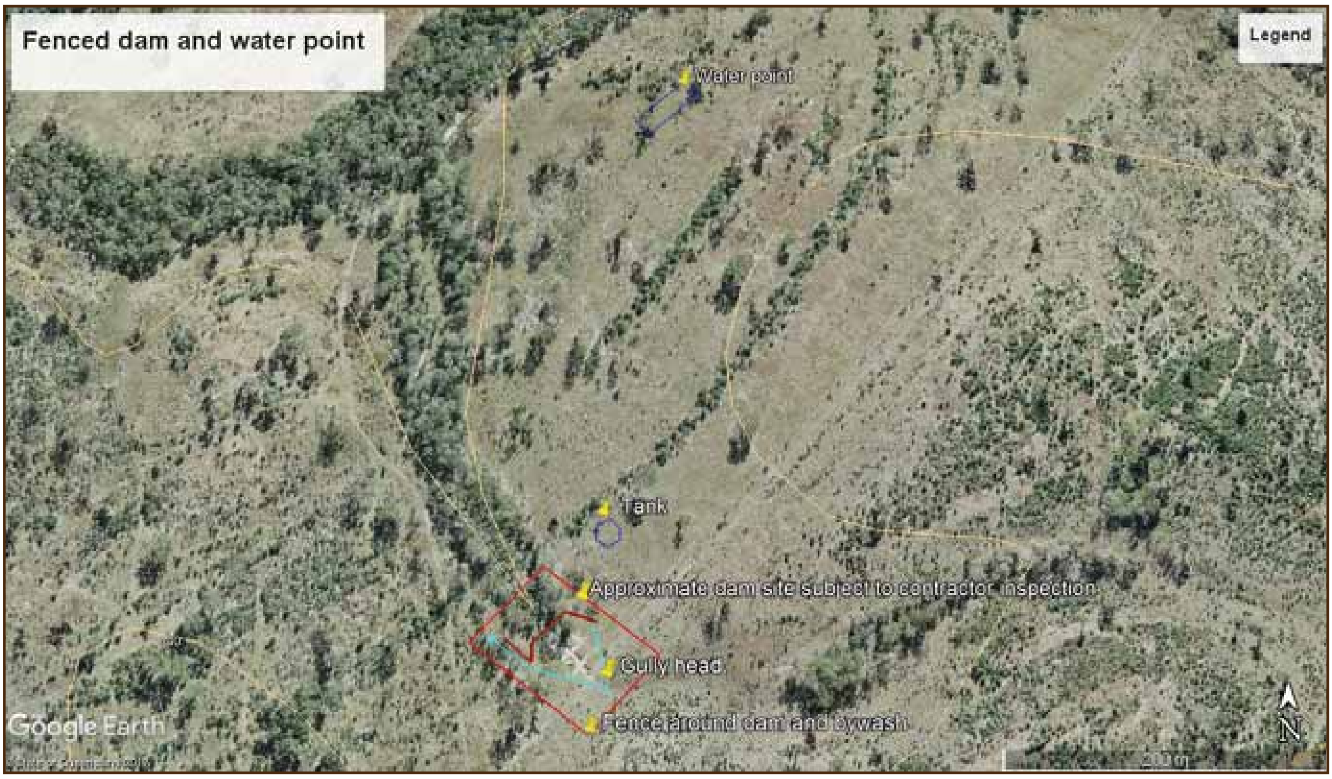


FIGURE 11: ***Diagram showing the plan to fence the dam and install a tank and trough system downstream for stock.***

4.3 PONDAGE BANKS

Pondage banks can be treated the same as a dam, provided design aspects are considered. Pondage banks are most effective as a dual-purpose production and erosion control option if the land slope is very low (1% or less). Pondage is not suitable for long-term water storage as the main purpose is to create a shallow pond to allow water-loving grasses to proliferate. Most pondage systems will dry up by the end of winter each year. Pondage banks can trap silt and slow the rate of runoff across the landscape. Like a dam, a correctly placed pondage bank will inundate the gully head and serve as a silt trap. Pondage banks can also hold water on the catchment longer, allowing more infiltration on scalded or degraded land. This improved infiltration can stimulate revegetation on areas that may have been bare for a long time.

When correctly placed, pondage banks can be a very productive way to solve an erosion problem on many soil types and situations. When designing pondage banks, give careful consideration to the by-wash, ensure the levels are accurate and that there is adequate freeboard to stop over-topping in intense rainfall events.

If pondage banks are being considered, it is very important to get an experienced technical officer or contractor to assist with the design and survey of the works. The banks can be high and long, making them a big investment and requiring careful planning and costing.

See Photos 13–15 for examples. See also, Photo 17 showing deep ripping above pondage banks on a scalded ridge.

PHOTO 13: *Checkerboard pondage and deep ripping on scalded hill slopes. Two years after completion, this area is very productive.*

PHOTO 14: *Pondage banks on steeper land (up to 5%).*

PHOTO 15: *Full pondage bank on steeper land (5% slope).*

4.4 DEEP RIPPING

Deep ripping is a somewhat controversial treatment, but it is often used in conjunction with other erosion control measures such as diversion banks or fencing and seeding. Ripping consumes considerable machine hours but is a technique that can be implemented by a sole operator. Ripping can significantly reduce runoff as it allows vastly improved infiltration and ponding of rainfall water across the landscape. During very long and or intense rainfall events such as cyclones, supercell storms or rain depressions, there is potential for increased erosion after ripping, particularly if the area is sparsely vegetated.

The Yeoman and similar-styled ripper tine and boot configuration is recommended as these rippers provide seemingly optimum disturbance throughout the soil profile. These implements include a strong thin tine (shank) that causes little disturbance on the surface, with a boot for disturbance at depth (see Photo 16).

ON THE CONTOUR FOR WATER INFILTRATION AND RETENTION

It is recommended that ripping is done on the contour. For the best outcome, level contour lines need to be surveyed over the treatment area at about 60 m intervals (closer if the slopes are steeper than 5%). The spacing between tines for deep ripping should be at least 0.5 m, and wider in more fragile soil types. If using the tines on a dozer then 0.8–1 m is preferable as dozer tines create much more disturbance than the thin Yeoman-type tine.

The ripping operation is done upslope from the eroded area, or on any scalded areas (see Photo 17). It is prudent to not deep rip within 20 m of any active gully heads or edges to reduce the risk of tunnels or rills forming that would exacerbate the existing problem.

The depth of ripping can vary depending on the situation. Generally, ripping to a depth of up to 0.4 m is useful to improve infiltration. The scenario where deep ripping has the greatest potential to be of benefit is where sheet erosion has caused a scalded bare area but the subsoil has not yet been exposed. Successful rehabilitation of the scald will generally involve the construction of a diversion bank above the site, deep ripping to improve infiltration, seeding and fertilising and finally fencing to exclude stock. Ripping can be used below a diversion bank outlet on flat land (around 1%) to spread water and improve infiltration (see Photo 18).

On soils that have a dispersive or slaking subsoil (i.e. soils that melt or slump quickly in water), use shallow ripping in the topsoil only or use very widely-spaced tines to reduce the potential for problems with tunnel erosion.

PHOTO 16:
Yeoman contour ripping in buffel grass pasture.

PHOTO 17:
Dozer ripping above pondage banks on a scalded ridge.

PHOTO 18:
Contour dozer ripping on a black soil flat (less than 1% slope) at the end of a diversion bank to slow and spread water in a Bisset creeping blue grass pasture.

TO TREAT TUNNEL EROSION

The standard treatment for tunnel erosion outbreaks is to contour deep rip the tunnels then compact the area to collapse the tunnels. If this leaves any depressions, level them from the sides or bring in topsoil or gravel to fill the hollows.

During ripping and compacting, apply gypsum at a rate of at least 2.5 t/ha to improve the soil structure, improve infiltration and encourage strong revegetation. To correctly assess gypsum needs, conduct a soil test and consult an agronomist to determine the correct application rate. Rates of 5 t/ha or more are not uncommon.

Once the treatments are complete the area should be fenced, seeded and fertilised to promote optimum establishment of ground cover. Maintaining 100% ground cover year round will reduce the recurrence of tunnel formation.

Two examples of successful treatment of tunnel erosion are provided for sites at Monto (Photos 19–22) and Eidsvold (Photos 23–25).

Example 1 – Deep ripping to treat tunnel erosion at Monto.

PHOTO 19: *Tunnel erosion on a waterway site, before deep ripping.*

PHOTO 20: *Tunnel erosion site after deep ripping.*

PHOTO 21:
The same site after good rain.

PHOTO 22:
Rehabilitated site one year after completion. Breaks in the contour banks that delivered water to the area can be seen approximately every 10 m either side of the waterway.

Example 2 – Deep ripping to treat tunnel erosion at Eidsvold.

PHOTO 23: *Tunnel erosion before deep ripping.*

PHOTO 24: *Tunnel erosion after deep ripping.*

PHOTO 25: *The same site after good rain.*

5 HIGH INPUT GULLY REHABILITATION METHODS

High input gully erosion control methods are used to protect crucial infrastructure or production areas that are likely to be destroyed or rendered unusable if erosion was to occur or worsen at the site. This includes active erosion gullies that continue to produce large quantities of suspended sediment, affecting the water quality in downstream river systems and coastal lagoons. Stopping the soil loss from these gullies is a priority for all catchments that deliver water to the Great Barrier Reef lagoon.

High input gully erosion control methods include silt traps, chutes, drop structures, contour layouts on grazing or pasture land, grassed waterways in contoured cultivation areas and high density stock grazing, seeding and spelling. These methods require significant finance and labour inputs along with personal commitment from the landholder. It is also advisable to engage the services of an experienced technical officer or contractor to assist with the design and oversee implementation of these high input gully rehabilitation methods.

The case studies in Section 7 describe works completed on properties in the Burnett and Mary river catchments between 2013 and 2017. All sites were revisted and assessed in 2018 and found to be stable and effective.

5.1 SILT TRAP WEIRS: WIRE NETTING, HAY BALE, COIR LOGS, STICK AND ROCK

Pervious silt trap weirs can be built from a number of materials including wire netting (or galvanised mesh), hay bales, coir logs, sticks and rock. The key objective is to create a weir with a level crest that is no more than 0.3–0.5 m high at the lowest point of the gully floor. The weir structure extends up the gully walls to prevent outflanking and erosion at the ends of the weir.

The following section provides step-by-step descriptions of how to build each of these structures. Photos 26 to 29 show various pervious silt trap weirs after runoff events.

PHOTO 26: *Wire netting silt trap weir.*

PHOTO 27:
Wire netting silt trap weir.

PHOTO 28:
Wire netting silt trap weir.

PHOTO 29:
Rock silt trap weir in a road table drain.

5.1.1 WIRE NETTING SILT TRAP WEIR

Photos 30–32 illustrate the process of construction for a wire netting (or mesh) silt trap weir.

1. Choose a narrow section of the gully floor with flat bottom and no sharp undulations as the site for the weir.
2. If the bottom of the gully floor is not flat, use hand tools or machinery to create a level base on which to build the weir. If the slope of the gully floor is quite steep, it may be necessary to construct a series of weirs along the gully.
3. Accumulate the materials required for the weir – plain wire (2–3 mm diameter), wire netting (1.2 m wide 1.6 mm gauge netting with 50 mm holes), steel posts (1.65 m), geofabric or rock for the downstream energy dissipater and survey/levelling equipment. Ensure there is sufficient material to suit the width of the weir.
4. If using geofabric as an energy dissipater, roll it out along the line of the weir so that about 0.3 m is on the upstream side of where the posts are to be driven in.
5. On each bank, mark the known height of flows in the gully during high intensity flood events, plus 0.4 m extra freeboard for safety. If the flow height is not known, mark a point that is at least half the depth of the gully walls. Use a string line and level (or laser or dumpy level) to make sure these two points are level. These marks show where the two end posts will be driven into the banks to ensure the weir is not outflanked at the ends during a large flow.
6. Space the steel posts no more than 2 m apart along the full width of the gully floor and up the gully walls to the height marked in the previous step.
7. Partly drive in the posts, through the geofabric if used. If low flows are expected, use a single line of posts angled at about 60 degrees upstream to provide resistance against the flows. If high flows are expected, keep the weir posts upright and add another line of posts angled at about 45 degrees and fixed with wire stays (see step #17).
8. Finish driving in the posts, to a depth of at least 0.45 m or until a hard rock or gravel base is reached, while creating a perfectly level line of post wire holes at the height required for the weir crest. This will usually be 0.3 to 0.5 m high at the lowest point of the gully floor.
9. Thread the plain wire through the holes in the posts to form a fairly level line across the gully floor. Angle the wire up the walls of the gully to ground level at the last steel post, which will be at least half way up the gully wall. Strain the plain wire so it is tight and forms a level, firm crest for the weir.
10. Roll out the wire netting on the upstream side of the posts and cut to length, ensuring there is ample wire netting at each end to extend up the gully walls, past the last post.
11. Tie one edge of the wire netting to the plain wire crest with strong wire ties no more that 0.5 m apart, and at each post. Another option that will provide extra strength is to place the wire netting so that the steel posts protrude through holes in the wire netting close to the edge wire, then tie along the crest with strong wire as described.
12. Once the wire netting is firmly attached to the plain wire and posts, bend the wire netting so it folds down against the posts on the upstream side, with any excess forming a flat connection with the gully floor.
13. Peg the wire netting to the gully floor with strong wire pegs similar to tent pegs no more than 0.5 m apart along the base of the weir. Continue pegging the wire netting to the ground up each of the gully walls.
14. Check the crest again to ensure that it is completely level. If trickle flows are to be directed, incorporate a 0.01 m dip in the exact middle of the weir.
15. Cover the upstream edge of the wire netting with soil to a depth of 0.1 m and spread seed or mulch as required.
16. If geofabric has not been used as an energy dissipater, place rocks on the downstream side of the weir to act as the energy dissipater. If the weir crest is 0.3 m or less, an energy dissipater is not required.
17. If high flows are expected in the gully, the weir can be stayed with more steel pegs and plain wire as shown in Photos 30–32. Angle these posts at about 45 degrees to provide resistance against the flows.
18. Job done. Monitor the weir following the first flow.

PHOTO 30: *Wire netting silt trap weir – top view.*

PHOTO 31: *Wire netting silt trap weir – end view.*

PHOTO 32: *Wire netting silt trap weir – close-up showing netting buried under the grass sod to reduce undermining.*

5.1.2 HAY BALE AND WIRE NETTING SILT TRAP WEIR

Photo 33 and Figure 12 illustrate the process of construction for a hay bale and wire netting silt trap weir.

1. Choose a narrow section of the gully floor with flat bottom and no sharp undulations as the site for the weir.

2. If the bottom of the gully floor is not flat, use hand tools or machinery to create a level base on which to build the weir. If the slope of the gully floor is quite steep, it may be necessary to construct a series of weirs along the gully.

3. Accumulate the materials required for the weir – wire netting (or galvanised mesh), small square hay bales, plain wire (2–3 mm diameter), steel posts (1.65 m). Ensure there is sufficient material to suit the width of the weir, including sufficient wire netting to span the gully twice (see steps 11 and 15).

4. On each bank, mark the known height of flows in the gully during high intensity flood events, plus 0.4 m extra freeboard for safety. If the flow height is not known, mark a point that is at least half the depth of the gully walls. Use a string line and level (or laser or dumpy level) to make sure these two points are level. These marks show where the two end posts will be driven into the banks to ensure the weir is not outflanked at the ends during a large flow.

5. Place the small square hay bales tightly end to end along the line chosen for the weir. Make any adjustments necessary to ensure the top of the bales form a level crest for the weir. The weir height across the gully width should be one bale high and the bales should be placed up the gully walls to at least the known flood height plus 0.4 m, or half the gully wall depth.

6. Space the steel posts across the gully, corresponding with the centre of each bale.

7. Begin to drive the steel posts through the centre of each bale to a depth of about 0.35 m into the gully floor. Ensure that a post wire hole on each post is approximately 0.1 m above the bale. If low flows are expected, use a single line of posts angled at about 60 degrees to provide resistance against the flows. If high flows are expected, keep the weir posts upright and add another line of posts angled at about 45 degrees upstream and fixed with wire stays (see step #19).

8. Drive the end posts into the gully wall and use them to firmly secure the end of the last bale. The last 0.5 m of hay bale on each end of the weir can be let into the gully wall so that the end of the bale is touching the last steel post at approximately ground level (see Figure 12). This will reduce the incidence of erosion around the ends of the weir, known as outflanking. Any soil displaced during construction should be placed on the upstream side to create a batter against the bales to stop water undermining the bales.

9. Pass the plain wire through the holes in the steel posts so that it is 0.1 m above and parallel to the top of the hay bales. Lightly strain the wire.

10. Finish driving in the steel posts until the wire is pressed firmly down onto the hay bales along the full width of the weir. This will hold the bales to the gully floor and reduce the likelihood of undermining. The posts should be driven at least 0.45 m into the gully floor or into base rock when the construction is completed.

11. Roll out the wire netting on the upstream side of the hay bales and cut to length, ensuring there is ample wire netting to extend up the gully walls, past the last post.

12. Tie one edge of the wire netting to the plain wire crest with strong wire ties no more than 0.5 m apart, and at each post. Another option that will provide extra strength is to place the wire netting so that the steel posts protrude through holes in the wire netting close to the edge wire, then tie along the crest with strong wire as described.

13. Once firmly attached to the plain wire and posts, bend the wire netting so it folds down against the bales with any excess laying flat on the gully floor.

HAY BALE AND WIRE NETTING SILT TRAP

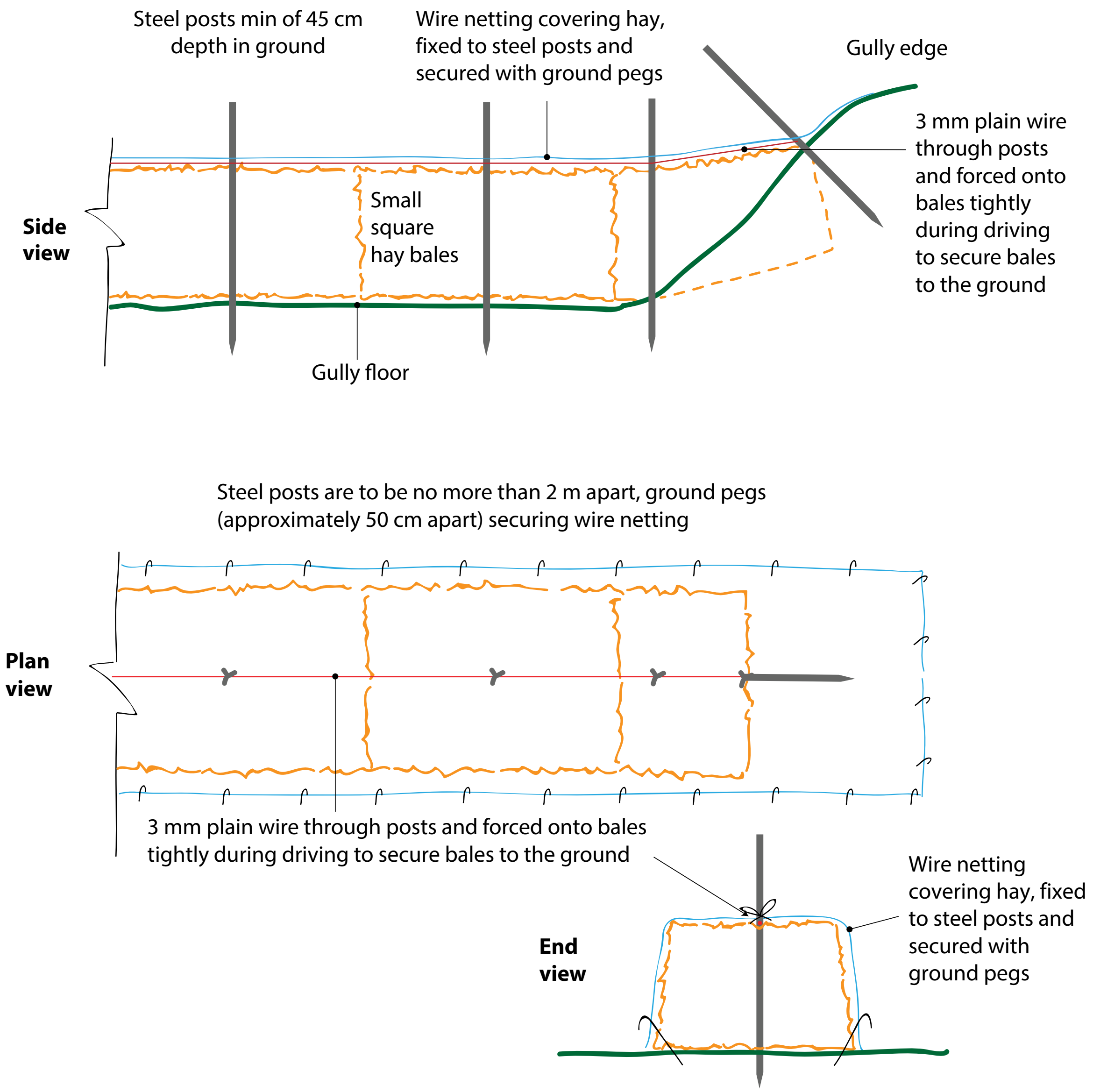


FIGURE 12:
Hay bale and wire netting silt trap weir design.

PHOTO 33:
Hay bale and wire netting weir – completed.

14. Peg the wire netting to the gully floor at the base of the hay bales using strong wire pegs similar to tent pegs no more than 0.6 m apart.
15. Repeat steps 11 to 14 for wire netting placed on the downstream side of the weir. Aim to fully encase the bales with wire netting to prevent dislodgement and livestock or wildlife damage.
16. Peg down the ends of the wire netting where it connects with the gully walls so the wire netting is lying flat on the soil.
17. Check the crest again to ensure that it is completely level. If trickle flows are to be directed, incorporate a 0.01 m dip in the exact middle of the weir.
18. Cover the upstream edge of the wire netting with soil to a depth of 0.1 m, and spread seed or mulch as required.
19. If high flows are expected in the gully, the weir can be stayed with more steel pegs and plain wire as shown in Photos 30–32. Angle these posts at about 45 degrees to provide resistance against the flows.
20. Job done. Monitor the weir following the first flow.

5.1.3 COIR LOG AND WIRE NETTING SILT TRAP WEIR

Photo 34 and Figure 13 illustrate the process of construction for a coir log and wire netting (or galvanised mesh) silt trap weir.

1. Choose a narrow section of the gully floor with flat bottom and no sharp undulations as the site for the weir.
2. If the bottom of the gully floor is not flat, use hand tools or machinery to create a level base on which to build the weir. If the slope of the gully floor is quite steep, it may be necessary to construct a series of weirs along the gully.
3. Accumulate the materials required for the weir – coir logs (3 m x 300 mm), steel posts (1.65 m), plain wire (2–3 mm diameter), wire netting (1.2 m wide). Ensure there is sufficient material to suit the width of the weir.
4. On each bank, mark the known height of flows in the gully during high intensity flood events, plus 0.4 m extra freeboard for safety. If the flow height is not known, mark a point that is at least half the depth of the gully walls. Use a string line and level (or laser or dumpy level) to make sure these two points are level. These marks show where the two end posts will be driven into the banks to ensure the weir is not outflanked at the ends during a large flow.
5. Place the coir logs along the line chosen for the weir, with the ends overlapping by about 0.3 m, if more than one is needed. Make any adjustments necessary to ensure the top of the logs form a level crest for the weir. The weir height across the gully will be the height of one 0.3 m coir log. The logs need to extend up each gully wall to the height marked in step 4.
6. Space the steel posts no more than 1 m apart along the full width of the gully floor and up the gully walls.
7. Where the coir logs overlap, ensure a steel post is placed in the end of the log on the upstream side, and use plain wire to secure the overlapping log ends to each other. Make the line of posts as straight as possible to avoid bends in the weir where the logs overlap. Begin to drive the steel posts through the coir logs to a depth of about 0.35 m into the gully floor. If low flows are expected, use a single line of posts angled at about 60 degrees upstream to provide resistance against the flows. If high flows are expected, keep the weir posts upright and add another line of posts angled at about 45 degrees upstream and fixed with wire stays (see step #17).

COIR LOG AND WIRE NETTING SILT TRAP

FIGURE 13:
Coir log and wire netting silt trap weir design.

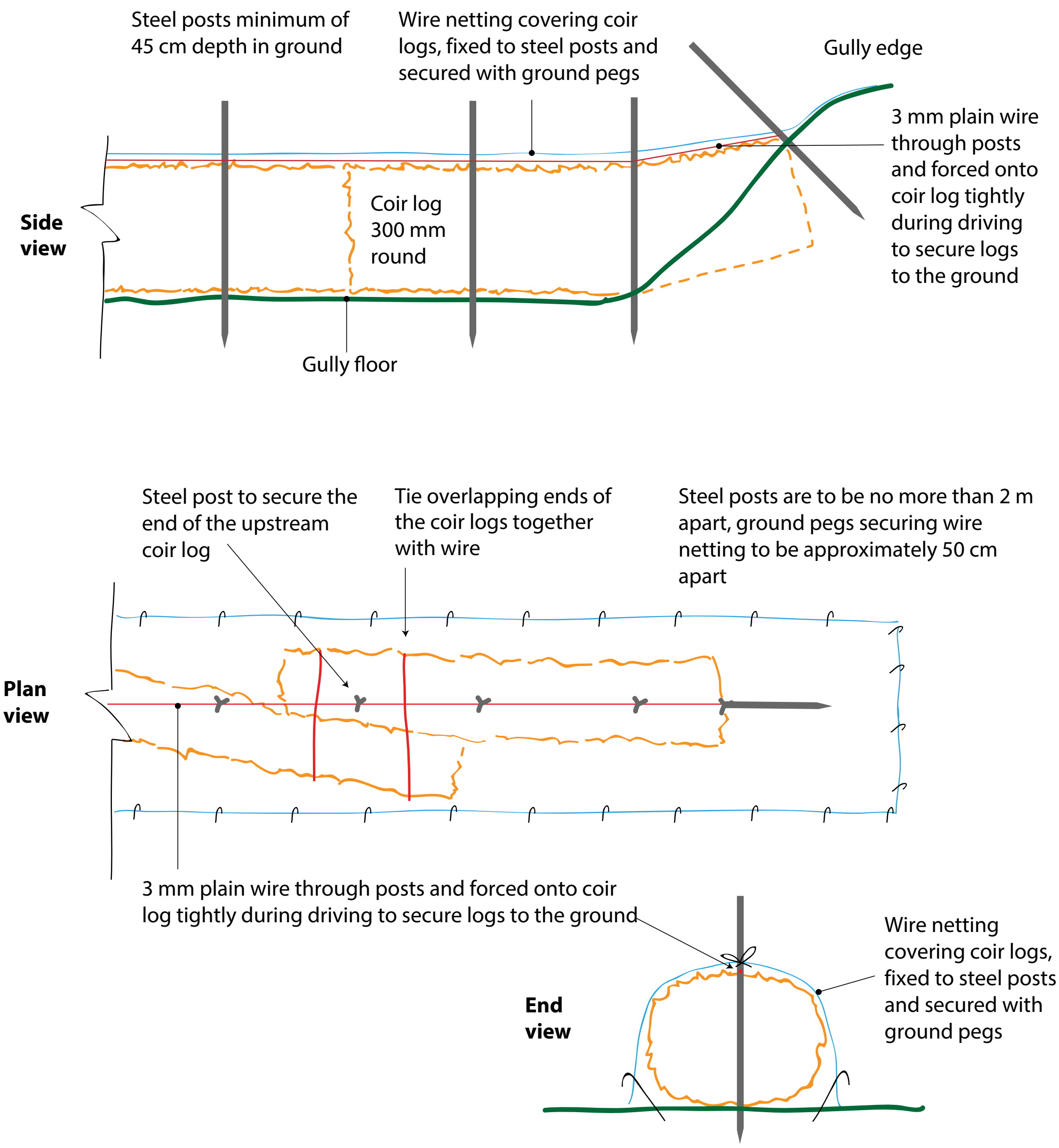


PHOTO 34:
Coir logs used as a silt trap weir in a storm-water drain.

8. Drive the end posts into the gully wall and touching the end of the last coir log. At each end of the weir, the last 0.5 m of coir log can be let into the gully wall so that the end of the log is touching the last steel post at approximately ground level (see Figure 13). Any soil displaced during construction should be placed on the upstream side to create a batter against the logs placed up the banks.
9. Pass the plain wire through the holes in the steel posts so that it is parallel to the top of the coir logs and is at least 0.1 m above the logs. Lightly strain the wire.
10. Finish driving in the steel posts until the wire is pressed firmly down onto the top of the coir logs along the full width of the weir. This will hold the logs to the gully floor and reduce the likelihood of undermining. The posts should be driven at least 0.45 m into the gully floor or into base rock.
11. Roll out the wire netting on the upstream side of the coir logs and cut to length, ensuring that there is ample wire netting at each end to extend up the gully walls, past the last post. Align the mid-line of the wire netting with the plain wire crest and place the wire netting down over the steel posts so that half the width of the wire netting is on the upstream side and half is on the downstream side of the crest. Use strong wire ties to attach the wire netting along the wire crest no more than 0.5 m apart, and at each post.
12. Bend the wire netting so it folds down against the coir logs on both sides, with any excess laying flat on the gully floor.
13. Peg the wire netting to the gully floor at the base of the logs using strong wire pegs similar to tent pegs no more than 0.5 m apart. Aim to fully encase the coir logs with wire netting to prevent dislodgement and livestock or wildlife damage.
14. Peg down the wire netting at each end where it connects with the gully walls so the wire netting is lying flat on the ground.
15. Check the crest again to ensure that it is completely level. If trickle flows are to be directed, incorporate a 0.01 m dip in the exact middle of the weir.
16. Cover the upstream edge of the wire netting with soil to a depth of 0.1 m and spread seed or mulch as required.
17. If high flows are expected in the gully, the weir can be stayed with more steel pegs and plain wire as shown in Photos 30–32. Angle these posts at about 45 degrees upstream to provide resistance against the flows.
18. Job done. Monitor the weir following the first flow.

5.1.4 POROUS STICK OR ROCK CHECK DAMS

This section is a direct transcript from: *Gully Toolbox, A technical guide for the Reef Trust Gully Erosion Control Programme 2015-16,* Scott Wilkinson[1], Aaron Hawdon[1], Peter Hairsine[2], Jenet Austin[1] ([1]CSIRO Land and Water, [2]The Fenner School, Australian National University).

Porous check dams are simple to construct and use materials from near the gully. Consequently, they are cheap to build – enabling many gullies to be treated for a modest budget.

Materials that need to be purchased include: flexible wire mesh with 100 mm square openings, star pickets for anchoring to the base of the gully and some fencing wire.

Materials that can be sourced from the site include: fallen timber (branches and shrubs) and/or rocks. The check dam timber should persist long enough for vegetation to become established and decompose over time.

PHOTO 35:
Porous stick dam.

If rocks are used, the average size of rocks should be 10–20 cm. The rocks should be of mixed sizes with minimal rocks smaller than 5 cm.

Keep the height of each check dam low (<0.6 m), because that is sufficient to trap soil for revegetation. Also, the hydraulic forces increase with height, increasing the chance of failure by scouring under or around the structure. It is far preferable to have many small check-dams in a gully than a few large check-dams that may fail.

The check-dam crest should be higher at the sides of the gully to divert higher flow velocities away from the gully walls and prevent scour around the end of the check-dam. Where gully walls are sloping this can be achieved by continuing the check-dam some way up the gully walls.

Construction of porous check dams with fallen timber is commenced by laying the metal mesh across the base of the gully. Sheets are overlapped and joined with fencing wire. The ends of the mesh are positioned so that the completed structure will be firmly against the gully wall. The fallen timber or rocks are then piled in a sausage-like manner along the mesh. The mesh is then closed over the timber or rocks and secured with fencing wire. Finally, star pickets are driven through the centre of the barrier at approximately 2 m intervals to anchor the check dam to the base of the gully.

Moving the material to the site should be done by hand or with small machines. The use of large machines such as excavators should be avoided or minimised due to soil disturbance leading to more gully erosion and the risk of bringing in weed seeds.

If using rock, or for larger gully catchment areas and runoff volumes (assuming the gully slope is flat enough that check-dams will enable fine sediment deposition), consider keying check-dams into the gully sidewalls and using rock to construct energy dissipating aprons on the gully floor downstream of each check-dam.

In sodic soil, consider reducing the check-dam height and spacing and increasing the porosity to avoid outflanking.

5.2 CHUTES: ROCK AND GEOFABRIC

Rock chutes can effectively stabilise active gully heads. However, they can be quite high cost. If allowing the active gullying to continue is likely to damage infrastructure or valuable resources, then construction of a rock chute may be justified. A properly designed and installed rock chute can provide a complete and permanent solution in such situations. The purpose of a chute is to reduce flow depth and water velocity, and dissipate the energy in the water flowing through the site.

The chute design must cater for at least a 1-in-10 year design flow so that the chute structure and the waterway below the structure are not damaged during the majority of high flow events. Most sites will require professional technical input to ensure the safe and effective design and construction of a rock chute.

Vegetation will readily cover rock chute structures, adding to their strength and permanence. Rock chutes can be constructed using compacted gravel and rock of an appropriate size or using geofabric that is then covered with rock. Texcel and Bidim are geofabrics that have been successfully used in the construction of rock chutes. These products can be ordered in various strengths to suit the size of rock required for use on the chute.

On more stable soils, such as red soils and some brown clays, and when the peak flows are low, the geofabric may not be required, provided a good mix of different sized rock and gravel are used in the construction and the chute is compacted well. If the soil is dispersive in nature, or the flow rate is high, the use of geofabric is recommended. Good grass cover is essential for long-term stability.

Rock chutes, and similar engineered structures, need to be constructed to meet rigorous design specifications that take into account the hydrological features of the gully and the estimated peak flows during rain events of varying intensities.

The structure size and shape is designed to manage a range of likely water flows across the structure. The size of rock required for stability of the chute is a critical feature. Rock secured with strong netting and plain wire can sometimes be used in situations that would otherwise require very large rock.

Photos 36 and 37 show examples of well-designed and constructed rock chutes that have successfully stabilised these two sites. The case studies in Section 7 of this publication provide more detail on gully stabilisation projects involving rock and geofabric chutes.

PHOTO 36: *This photo was taken in the dry season, four years after construction of this 25 m rock and geofabric chute covered with netting. Although salinity at the site has affected grass establishment, the site is very stable.*

PHOTO 37: *A very stable 15 m rock chute on a grazed site four years after construction.*

One methodology for the flow rate calculations and design of a rock chute can be found in Chapter 13 in the *Soil Conservation Guidelines for Queensland (2015)*. The critical components of rock chute design include:

- *Estimate the water volume and water flow velocity entering the chute.*
- *Shape the gully head to suit the specifications of the structure.*
- *Use diversion banks to direct water flow over the chute crest.*
- *Install cut-off trenches at the chute crest and base as designed.*
- *Use geofabric sheeting to cover the soil prior to laying the rock, according to soil type and condition.*
- *Obtain the appropriate mix of rock size to maintain stability during a design flow rate event using a reliable technical source, such as the spreadsheet CHUTE, https://toolkit.ewater.org.au/Tools/CHUTE.*
- *Install energy dissipation measures at the base of the chute to prevent undermining and damage to the gully banks (e.g. rock wall).*
- *Compact rocks into place on the batter if possible.*
- *In high velocity and high flow situations, cover and secure the rock with heavy gauge wire netting tightened with heavy gauge plain wire and steel pegs.*

The basic shapes of rock chutes are shown in Figures 14–16. The crest should be shaped to suit the rehabilitation site. After construction, the site needs to be seeded and fertilised, and fenced, to promote long-term revegetation.

ROCK CHUTE

Figure 14: Rock chute standard shape – side view.

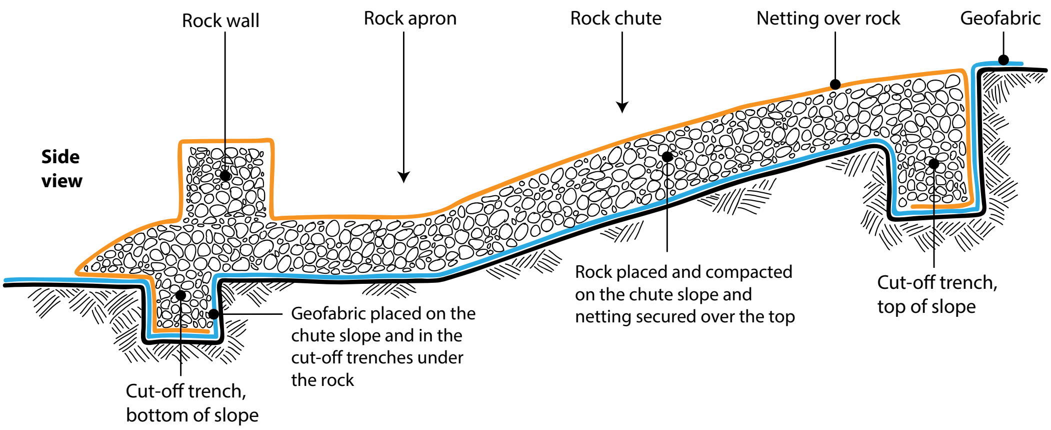


FIGURE 15: *Rock chute standard shape crest.*

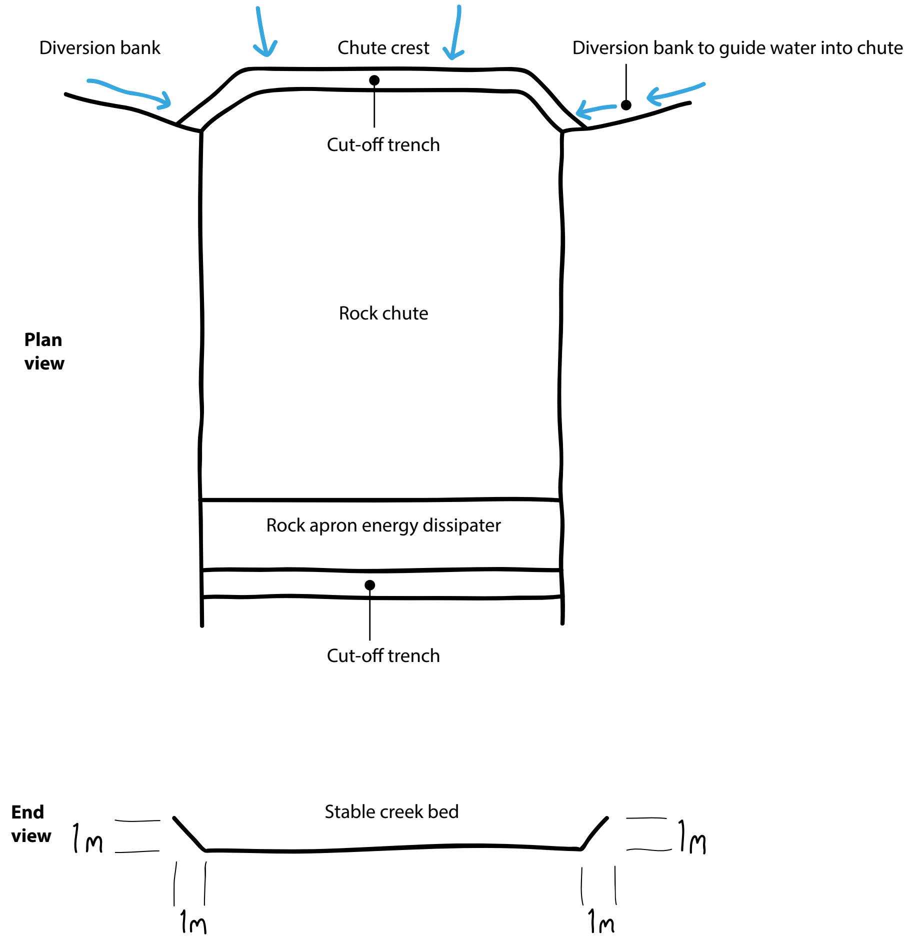
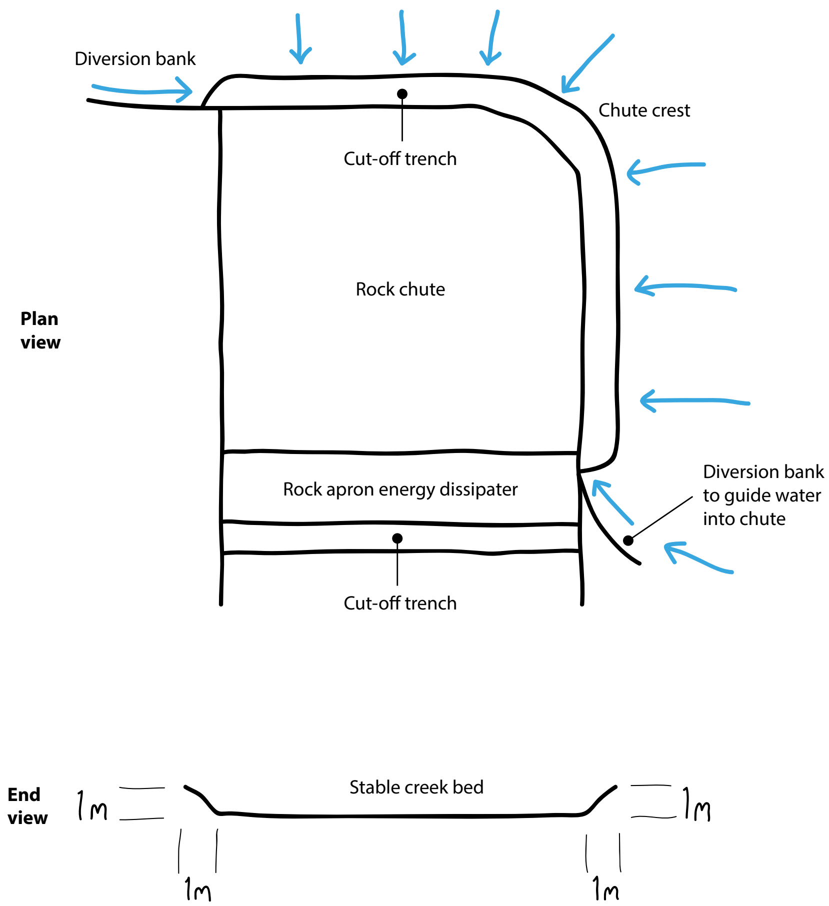


FIGURE 16: *Rock chute one-sided crest.*



5.2.1 PHOTO HISTORY OF A ROCK CHUTE CONSTRUCTION

Photos 38–53 show construction stages of a rock and geofabric chute covered with netting.

PHOTO 38: *Gully head pre-work planning.*

PHOTO 39: *Rock chute site after initial site preparation.*

PHOTO 40: *Rock chute construction begins.*

PHOTO 41:
Shaping the gully head to the specifications of the structure.

PHOTO 42:
Shaping the gully head to the specifications of the structure.

PHOTO 43:
Shaping the gully head to the specifications of the structure.

PHOTO 44:
Installing cut-off trench at the crest.

PHOTO 45:
Installing cut-off trench at the base.

PHOTO 46:
Laying geofabric over the earthworks.

PHOTO 47:
Placing rock into the cut-off trench with netting ends secured in place.

PHOTO 48:
Rocks being laid over the geofabric.

PHOTO 49:
Netting placed over the rocks and secured.

PHOTO 50:
Steel posts and plain wire used to tension netting over the rocks to hold them in place.

PHOTO 51:
Rock chute completed and ready for seeding and fencing.

PHOTO 52:
Gully site post-works and after good rain. The rock is in place and vegetation is starting to grow.

PHOTO 53:
Aerial photo of the site in the dry season, two years after construction.

5.2.2 GEOFABRIC CHUTE

At some sites, simply using the geofabric (e.g. Texcel 400R) alone is sufficient to create a chute to stabilise a gully head. The same design and construction process is followed, except there is no rock or netting required to cover the site. Once the gully is shaped and the cut-off trenches are dug, geofabric can be laid and then secured in the cut-off trenches with the available soil or gravel and rock up to 0.2 m in size.

Compact the trenches well and then fence, seed and fertilise the site to promote revegetation. Over time, soil will cover the geofabric and plants will germinate on the fabric. Although this is a relatively new technique, it shows promise and is likely to be further refined as it is tested in a range of gully rehabilitation situations (see Photos 54–57).

PHOTO 54: *Geofabric chute freshly completed. Plan view.*

PHOTO 55: *Geofabric chute freshly completed. Side view.*

PHOTO 56:
Geofabric alone on a dam by-wash chute, two years after construction.

PHOTO 57:
Geofabric alone on a dam by-wash chute, two years after construction.

5.3 DROP STRUCTURES

Drop structures are used in very few instances and can be fashioned most economically out of geofabric such as 'Grass Roots' and 'Texcel'. The aim of these structures is to create a stable waterfall to stop the advancement of the gully head. Once again, it is important to know the size of the peak flows at the site so that the length of the crest of the drop structure can be designed to reduce flow depth and velocity wherever possible. The design methodologies described earlier are used again here.

Once the width is known, secure the chosen geofabric to the floor of the depression upstream of the gully head, then drape it over the face of the head and into the gully floor below. To ensure the water travels over the geofabric, bury the ends under grass sod in a slight channel or in a narrow cut-off trench. Double-over the ends of the geofabric for added strength with the short section folded under the main piece, and peg down with the pins provided no more than 0.5 m apart under the sod or in the bottom of the cut-off trench. The more pegs, the better.

Netting, steel pegs and plain wire can be used to further secure the geofabric. Wire the fabric to the netting at 0.5 m intervals, and at the joins, to ensure the fabric stays in-place during a runoff event.

A stilling pond or energy dissipater is required to prevent water undermining the face of the gully head. Where possible, cover the bottom of the stilling pond with fabric strips pinned on the gully face and floor with one pin per square meter.

Photos 58–62 show stages of construction through to completion of a geofabric 'structure'. Photo 63 shows another example of a completed geofabric drop structure.

Figure 17 provides a schematic representation of a traditional concrete drop structure design and a field example.

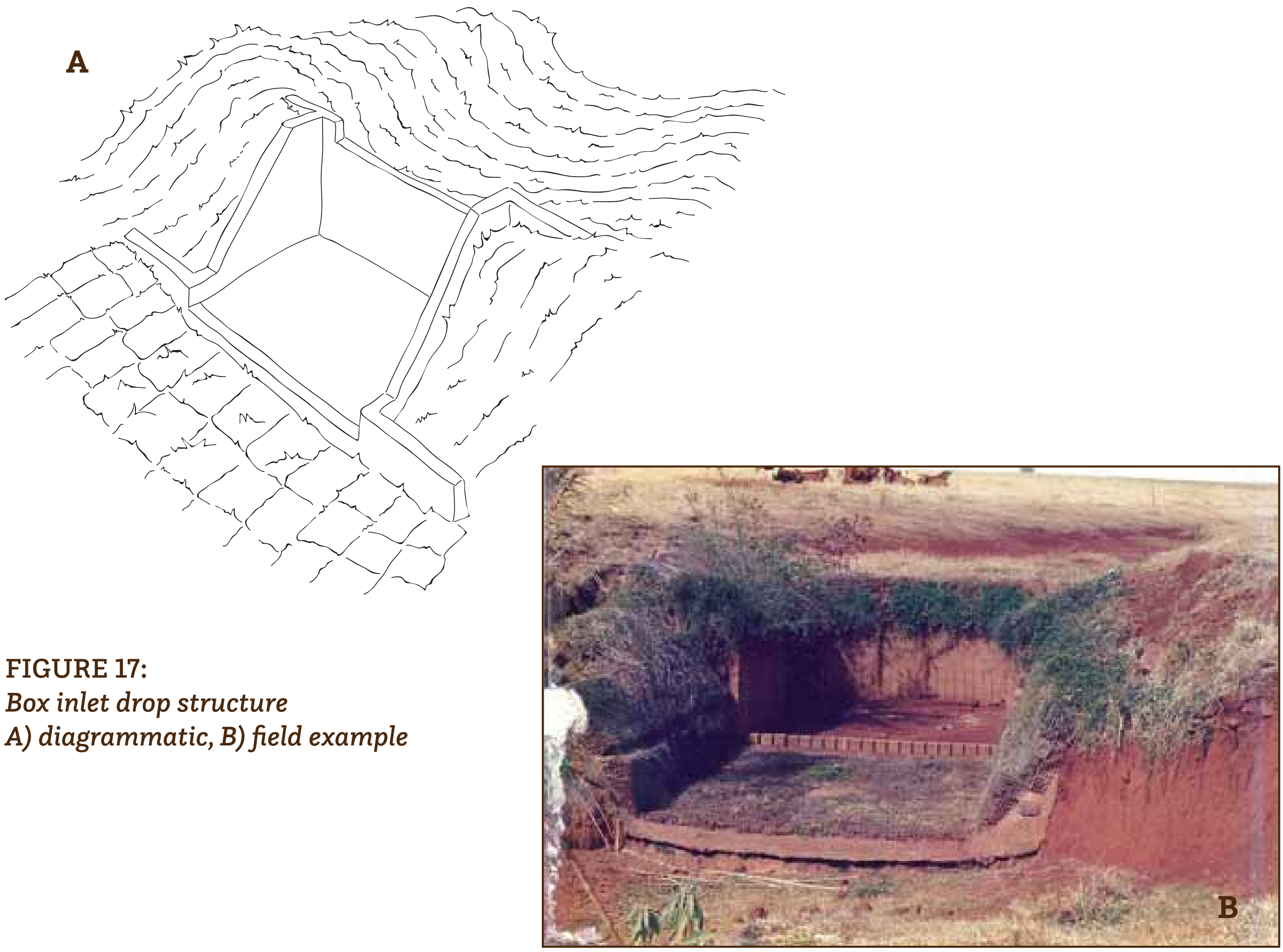


FIGURE 17:
Box inlet drop structure
A) diagrammatic, B) field example

SITE 1
PHOTO 58:
Planning stages of a drop structure.

SITE 1
PHOTO 59:
Construction using Grass Roots geofabric. The upstream edge of the geofabric is secured and buried under grass sods.

SITE 1
PHOTO 60:
Steel posts and wire netting are used to secure the upstream edge of the geofabic.

SITE 1
PHOTO 61:
Almost done. Secure the geofabric to the gully walls and floor.

SITE 1
PHOTO 62:
After two years of rainfall events, good grass cover is evident on and around the structure. The damage to the geofabric that can be seen in this photo was repaired.

SITE 2
PHOTO 63:
Smaller drop structure using geofabric Texcel after a runoff event.

5.4 CONTOUR LAYOUTS ON GRAZING OR PASTURE LAND

The majority of cropping and improved pasture lands in the Burnett and Mary catchments that require contour bank protection have been treated many years ago. On newly developed sites, or if a major change in land use has occurred, contour banks and waterways may need to be constructed to manage water flow through the site. This requires considerable pre-planning before surveying and construction can begin.

Engage an experienced technical officer or contractor to plan paddock layout and access, calculate the water flows and design a safe waterway width to accommodate runoff through the site. They will also survey the banks at the correct grades and spacing to provide adequate protection during most rainfall events. A 1-in-10-year rainfall event is the standard used by soil conservation design methodologies described in the *Soil Conservation Guidelines for Queensland* and has been accepted across all rural industries for many years. Chapters 2 to 9 of the guidelines provide in-depth information on the design of contour layouts.

It is not possible to economically build contour, diversion or pondage banks that are guaranteed not to break. The 1-in-10 year rainfall event provides a practical compromise standard.

It is a costly exercise to build banks to retain and channel water, and their construction will have long-term consequences, so pre-planning and careful budgeting is essential.

Contour banks and near-level pondage banks have been used to improve water infiltration and pasture production on hard-setting soil types in the north Burnett region (see Section 7: Grubb Case study for details of one successful project).

Figure 18 and Photos 64–67 show the planning, construction and completion of a contour layout on pasture land.

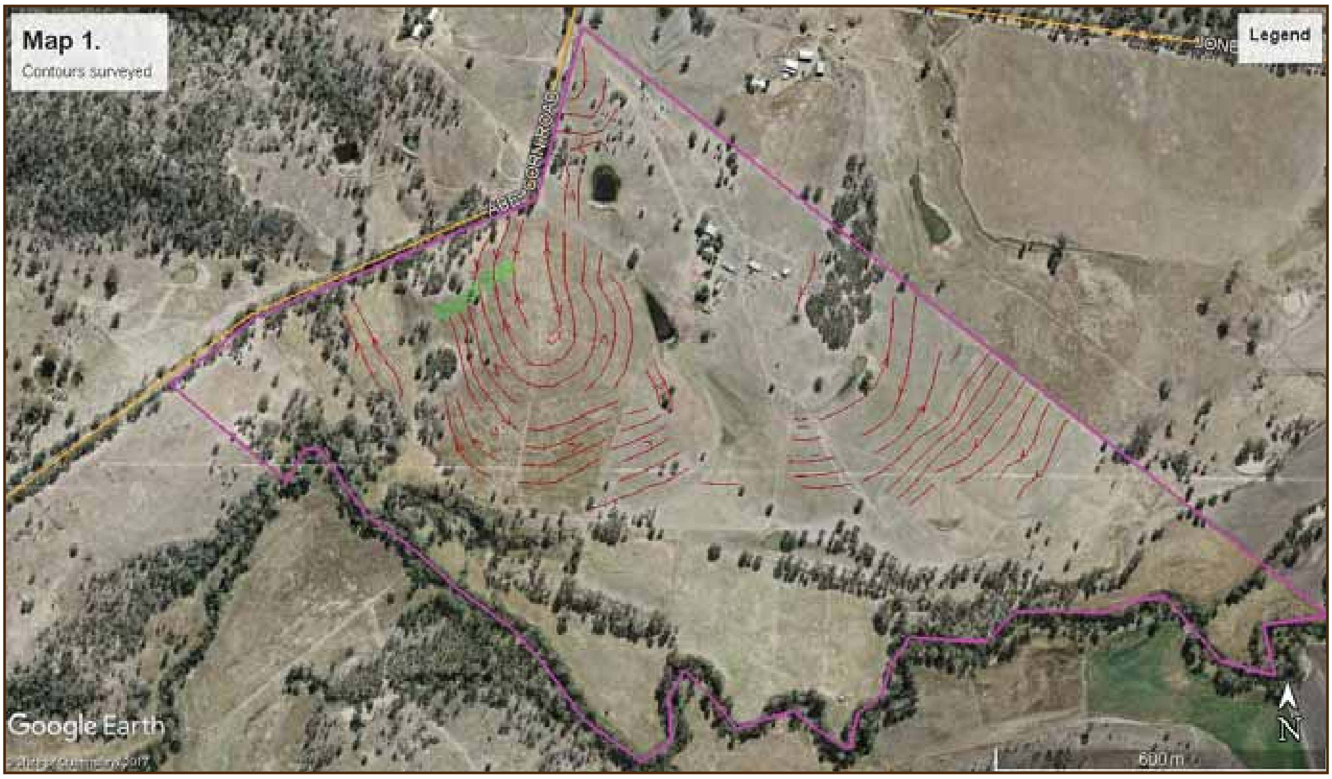


FIGURE 18:
Contour layout for level and near-level banks used to improve water retention and infiltration on a hard-setting soil. Implementation included strategic use of deep ripping above and below some banks.

PHOTO 64:
Pasture land before contour work.

PHOTO 65:
Pasture land during contour construction, deep ripping and gypsum application to improve infiltration.

PHOTO 66:
Pasture land after the contour works and following rain.

PHOTO 67:
Pasture land post-contour works and after rain.

5.5 GRASSED WATERWAYS IN CONTOURED CULTIVATION

Waterways are an integral part of all contour bank systems and, from time to time, they erode during severe rainfall events or as a result of poor maintenance. Once a waterway is eroded it must be repaired during the low rainfall period of the year. If the gully heads are very deep, some form of chute may be required. If the gullies are smaller, up to 0.5 m deep, then reshape the waterway using a laser-guided grader, scraper or more commonly, a tractor-drawn laser-guided levelling scoop.

This equipment is commonly accessible in most farming districts and reliable contractors are usually available. The contractor will level and widen the waterway if necessary and leave the surface suitable for seeding with stoloniferous grasses and cover crops to ensure the quickest possible regeneration of vegetation. In winter this will mean rye grass or oats, possibly with lucerne and clover included in the seed mix.

If the waterway is prone to erosion and over-topping, then it probably needs to be widened. The wider the waterway, the better as wide shallow flows have less erosive power. The diversion and contour banks that deliver water into the waterway will also need upgrading to ensure water does not escape and break the ends of the contour banks.

If there is insufficient winter rainfall to establish good grass cover before the spring storms, then low weirs can be placed across the waterway below each contour bank to spread the water across the waterway so it does not concentrate and re-start the old gullies. Mulch hay with plain wire, netting, shade cloth and stakes were used to construct these weirs (see Photos 68–77) at three different sites. The height of the weirs needs to be quite low, around 0.2 m. This is to reduce the turbulence on the bottom side of the weir.

SITE 1
PHOTO 68:
Low weir constructed across the waterway below a contour bank, using stakes, plain wire and mulch hay. End view.

SITE 1
PHOTO 69:
Low weirs constructed across the waterway below each contour bank, using stakes, plain wire and mulch hay. Side view.

SITE 1
PHOTO 70:
Grassed waterway post-construction of the weirs, after good rain.

SITE 1
PHOTO 71:
Grassed waterway post-construction of the weirs after good rain.

SITE 2
PHOTO 72:
After levelling.

SITE 2
PHOTO 73:
Weirs constructed with shade-cloth and wooden stakes placed below contour outlets.

SITE 2
PHOTO 74:
Weirs holding up silt after rain.

SITE 2
PHOTO 75:
Weirs holding up silt after rain with grass starting to establish.

SITE 3
PHOTO 76:
Cultivation paddock before construction of the contours and new waterway.

SITE 3
PHOTO 77:
Cultivation paddock after construction of the contours and new waterway.

5.6 HIGH DENSITY STOCK GRAZING, SEEDING AND SPELLING

In most active gully situations, it is recommended that livestock be excluded from the site. However, there is an option to use livestock to trample and reshape small erosion gullies (up to 0.5 m deep) with small contributing catchments (less than 2 ha).

To begin, fence the gully area securely with electric or permanent fencing and install gates and wing fences to allow easy stock access. Although any mob of cattle can be used, this strategy is often done in association with training large mobs of weaners and this option is probably the least disruptive to normal property work.

Tail the mob during the day and lock them in the gully paddock overnight. While the stock are confined to the small area the trampling of their hooves knocks the edges off the gully head and walls. The stock also deposit large amounts of manure and urine on the site, which improves the condition and fertility of the soil.

To achieve the required battering of the site, the stock may need to be locked up nightly for up to a month. Once the stock have done sufficient reshaping and fertilising of the site, exclude all stock and seed the whole area. Put stock back in for one more night to bury seed, then exclude stock completely, allowing the site to revegetate after rain. Subsequent grazing of the site is subject to the degree of revegetation. Closely monitor the site to ensure that it remains well-covered with grass at all times.

It involves considerable organisation and man hours to effectively stabilise and revegetate such sites. This approach is not widely used but has been effectively implemented in at least one instance in the Burdekin catchment.

6 MONITORING AND MAINTAINING SOIL CONSERVATION STRUCTURES

Constructing and implementing soil conservation strategies and structures are the first steps in establishing a long-term sustainable erosion management system on any land type and for any enterprise. If the planning, design and construction are to an adequate standard, all works should provide a greater level of protection than having no measures in place. It is important to acknowledge that it is impossible to economically design erosion control works that are guaranteed to never fail. The key to the long-term success of practical strategies for erosion control in rural businesses is having a strict monitoring and maintenance regime.

6.1 BANKS

Banks constructed to divert, pond or channel water are all subject to gradual settlement and slumping. This process occurs more rapidly where the banks are farm-over contour banks in a cropping system. Regardless of the circumstances, there is a simple and easy way to check the capacity of any bank to judge the effectiveness and estimate its water carrying capacity.

Using a string line, line level and ruler, measure the depth of flow capacity in the bank at the outlet end (see Photo 78). Every bank design, regardless of its purpose, usually has a 'constructed' and a 'settled' bank height stipulated for the required bank capacity. This will vary considerably from site to site.

For contour bank layouts, a standard bank height of 1 m (construction height) is used. The variable is the spacing between the banks. On low sloping land the contours are wide apart and are more closely spaced as the slope gets steeper, up to about 10% slope, which is the limit to the viable use of contour banks (see Table 2).

PHOTO 78: *Measuring the depth of flow capacity in the bank using a string line, line level and ruler.*

TABLE 2: ***Recommended contour bank spacing to suit the land slope.***

AVERAGE LAND SLOPE (%)	SINGLE SPACING		DOUBLE SPACING	
	VERTICAL INTERVAL (VI) (METRES)	HORIZONTAL INTERVAL (HI) (METRES)	VERTICAL INTERVAL (VI) (METRES)	HORIZONTAL INTERVAL (HI) (METRES)
1	0.9	90	1.8	180
2	1.2	60	2.4	120
3	1.5	45	3.0	90
4	1.6	40	3.2	80
5	1.8	36	3.6	72
6	1.9	32	3.8	64
7	2.1	30	4.2	60
8	2.4	30	4.8	60
9	2.7	30	5.4	60
10	3.0	30	6.0	60

The standard contour bank height is approximately 1 m at construction, with the expectation that the bank will settle to a height of 0.6–0.8 m, depending on soil type. If the bank height from the bottom of the channel to the top of bank is less than 0.5 m, rebuild the bank to a height of at least 0.6 m to reduce the potential for over-topping and breakage, which would result in serious erosion.

Annual maintenance with a one-way disc plough or square plough can be effective. Another option is the use of a power grader or tractor-drawn grader if regular maintenance is conducted every 4–5 years. If the bank height is very low, dozer top-up may be the most efficient option.

Diversion banks are specifically designed to a height required to manage a certain flow. Maintaining these banks to the design height is crucial and they should be checked after every rainfall event that is above average intensity, and at least every two years.

As diversion banks are designed to have grassed channels, ensure that topsoil from the channel area is stockpiled if major maintenance work is done, then replaced to ensure a grass cover reestablishes.

Like contour banks, whoa-boys need to be topped-up as soon as the capacity and effectiveness is compromised due to silt deposits in the borrow pit and compaction of the mound across the road. Pull silt from the borrow pit onto the road to maintain or increase the height of the whoa-boys. A grader is the most effective machine to maintain whoa-boys, however a competent operator can also achieve a good result using a skid steer, back hoe or small end loader.

6.2 WEIRS, CHUTES AND DAMS

All other structures that have been designed to cope with water runoff are subject to some degree of damage after each rainfall event. Check and maintain these structures after every runoff event, particularly after initial construction when some slumping or erosion is to be expected. Experience has shown that if the small problems are resolved and repaired then long-term stability can be achieved.

The crucial times for maintenance are following the first flow after construction and the first flow after an extended dry period. This is particularly important on cracking clay soils. Once a structure has grassed-up completely and settled, the potential for damage during runoff events reduces. However, it is still possible, so vigilance in monitoring and maintenance is absolutely essential for the desired long-term outcome of permanently stabilised erosion sites.

In summary, managing land in such a way as to prevent soil erosion is an iterative, continuous learning process. There is no structure that can be built and then ignored. Monitoring and maintenance are absolutely imperative.

The key principles to follow when managing all soil erosion sites are: 1. maintain ground cover at 100% with high volumes of grass and 2. reduce the erosive power of water flows using vegetation or well designed structures.

UNDERY

BMRG CASE STUDY

Gully Rehabilitation Saves Dam By-Wash

Burnett Mary REGIONAL GROUP Practical Solutions for Natural Resource Management

Peter and Romaine Undery's property at the Findowie Road district, south Burnett 2014.

BACKGROUND

In 2013 Ex-tropical Cyclone Oswald dumped torrential rain on catchments throughout the Wide Bay Burnett. This event produced run off rates which were estimated to be in excess of a one in one hundred year flood. This event followed on the heels of similar but slightly smaller events in 2010 and 2011.

The South Burnett had been in the grip of an extended dry period prior to these flood years so many catchments were in a state of reduced vegetation cover. The resulting erosion across the region was the worst seen for decades and affected cropping and grazing land alike. Particularly hard hit were contour banks, waterways, dams and dam by-wash areas. Many of these structures had not been maintained adequately for some time due to the extended years of low rain and run off.

THE SITE AND THE CHALLENGES

Peter and Romaine Undery are landholders in the Findowie Road district of the South Burnett who were faced with the prospect of damage to a key stock water dam through an actively eroding by-wash. The catchment supplying the dam has an estimated area of 134 hectares of cleared grazing land with some contoured areas which had been farmed many years ago. Peak flow to the dam was calculated at approximately 7.5 cubic metres per second in a one in fifty year storm event. This is a significant water flow through the system and is much less than would be flowing in a one in one hundred year event such as the recent record 2013 floods. The by-wash of the dam was approximately 7 metres wide and was running at least 1 metre in depth.

Erosion in the by-wash had been gradual up until the extreme events when it increased dramatically leaving a gully head 1.7 metres deep and 7 metres wide marching towards the dam. Alarming progress of the gully necessitated a quick response and Mr Undery sought the advice of the Burnett Mary Regional Group's Soil Conservation Officer to help develop a rehabilitation strategy to stop the advancing erosion near the dam.

THE GOAL AND THE METHODS FOR REHABILITATION

After discussion on the possible options to repair the erosion site the planning team decided on a rock chute design with the added strength of a netting mat construction method.

This method was favoured to ensure that the rock placed on the chute could not be easily moved regardless of the velocity of the flows that could be expected from the catchment. This method was also cost effective due to the proximity of a suitable rock quarry business near the property.

The rock available was a good mix ranging in size from 100mm to 600mm which aligned with the design velocities for the structure. The catchment peak flow for a one in ten and a one in fifty year flood event was calculated. From these peak flows a weir crest length was designed which necessitated a longer crest than the existing by wash width.

The rock chute was designed to deliver the expected flows from ground level above the erosion to the modified, much flatter sloping ground level below the erosion at a depth of approximately 1.7 metres with a slope no less than 3:1. Total chute length is approximately 12 metres (See Diagram 1).

The rock chute crest length was built to the design specification of 15 metres long with a 300mm level rock lip above ground level to encourage silt drop at the top of the chute.

The by-wash was widened and levelled to deliver the water from the dam to the chute crest at low velocity and shallow depth.

The chute crest was constructed in a lopsided horseshoe shape to accommodate the existing gully below the actively eroding section. The bywash bank was retained at a height of approximately 1 metre.

The area below the rock chute has remained basically untouched as a resilient rock surface had been naturally reached. Topsoil and hay mulch was added to the levelled area above the chute and to the banks around the structure. Winter and summer active grass and crop seed was spread on the area prior to mulching to assist in the rapid establishment of vegetative cover.

The construction consisted of the following steps:

- *Top soil removed and stored.*
- *Excavation, shaping and compacting the chute slope and surrounding waterway.*
- *Cut off trenches excavated at top and bottom.*
- *Texel Geofabric placed over the compacted soil on the chute slope and into the cut off trenches.*
- *Netting strips placed in the cut off trenches to attach to the netting over the rock fill.*
- *Mixed rock fill and granite gravel placed to a depth of approximately 400mm on the chute and in the cut off trenches, securing the Texel Geofabric and netting strips.*

- *More netting was secured over the rock and laced together with strong plain wire and tensioned to ensure a complete mat with firm contact to hold the rock in place. Steel pickets were used at the bottom of the structure to aid tensioning of the plain wire and netting.*
- *Top soil was replaced over the area above and around the chute and*
- *Grass seed and mulch spread over the bywash and banks above the structure.*

THE RESULTS

The project developed with inputs from a combination of technical soil conservation experience, local landholder experience and the knowledge and skills of the earth moving contractor and gravel and rock supplier. This combination along with many hours of hard work and planning by Mr Undery and his family has produced a very strong and functional rock chute structure which should secure the safety and integrity of one of the main farm water supply dams into the future.

Perversely the 2014 winter season has been a continuation of dry conditions with the whole shire still drought declared. Construction is finished and grasses have been planted however there is yet to be a useful fall of rain to germinate the grass planting.

The area has been fenced and can be managed to maximise the grass vigour when it emerges. The project will be monitored and regular maintenance will be carried out to ensure the structure performs and provides the ongoing protection for the farm dam.

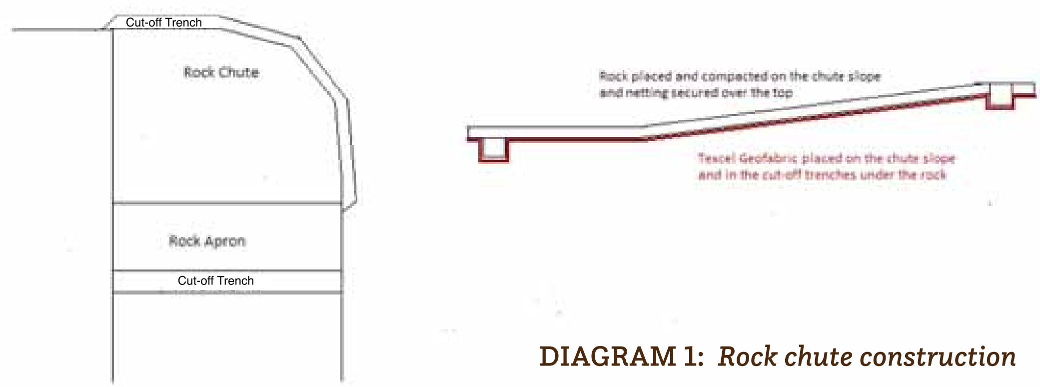


DIAGRAM 1: ***Rock chute construction***

AUTHORS John Day; Peter, Romaine and Sarah Undery. PHOTOS John Day and Sarah Undery.

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The Queensland Government is committed to the productive and responsible use of the State's natural resources and has supported these projects as part of BMRG's Sustainable grazing management and on-ground works: conserving soils in the Burnett Mary Region project.

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ZIEBARTH

BMRG CASE STUDY

Soil Erosion Control and Waterway Gully Rehabilitation

Burnett Mary REGIONAL GROUP
Practical Solutions for Natural Resource Management

Bernard and Janet Ziebarth's Property at Haly Creek 2014.

BACKGROUND

The 2013 Ex-tropical Cyclone Oswald dumped torrential rain on the catchments throughout the Wide Bay Burnett. This event produced run off rates which were estimated to be in excess of a one in one hundred year flood. This event followed on the heels of similar but slightly smaller events in 2010 and 2011.

The South Burnett had been in the grip of an extended dry period prior to these flood years so many catchments were in a state of reduced vegetation cover. The resulting erosion across the region was the worst seen for decades and affected cropping and grazing land alike. Particularly hard hit were contour banks and waterways, many of which had not been maintained adequately due to the extended years of low run off. The damage to these structures was worst at the bank outlets and in the waterways where bare and eroded areas had gradually developed.

THIS CASE STUDY

This case study follows the work of one family in the Haly Creek district of the South Burnett who was faced with the prospect of damage to their 30 mega litre dam through an actively eroding waterway exacerbated by a high water table and saline seepage. The catchment supplying the dam and the waterway has an estimated area of 249 hectares. Much of this catchment is farmed and contoured red soil with average slopes of approximately 3%. The waterway is constructed on the main water course which has been estimated to carry approximately 11 cubic metres of water per second at the peak flow during a one in ten year run off event.

This is a significant water flow through the system and is much less than would be flowing in a one in one hundred year event such as the recent record floods. The waterway is 23 metres wide and Mr Ziebarth estimated there was water 700mm deep flowing through the full width of the waterway in the 2013 flood event.

The erosion in the waterway has been gradual up until the recent extreme events when it increased dramatically and quickly. The wet years also raised a saline water table which has kept the very erosive subsoil layers saturated and primed to slump and wash easily.

During the aftermath of the floods Mr and Mrs Ziebarth sought the advice of the Burnett Mary Regional Group's Soil Conservation officer to help develop a rehabilitation strategy to hopefully stop the advancing erosion in the waterway. The project developed with inputs from a combination of technical soil conservation experience, local landholder experience and the knowledge and skills of the earth moving contractor and gravel and rock supplier. This combination along with many hours of hard work and planning by the Ziebarth family has produced a very strong and functional rock chute structure which should stand the test of time and secure the integrity of the main farm water supply into the future.

METHOD

After discussion on the possible options to repair the erosion site the planning team decided on a rock chute design with the added strength of a netting mat construction method. This method was favoured to ensure that the rock placed on the chute could not be easily moved regardless of the velocity that could naturally occur with the flows expected from the catchment. This method also favoured the cost structure of the work as there is a suitable rock quarry business within relatively close proximity of the property.

The rock available was a good mix ranging from 200mm to 700mm which

aligns with the design velocities for the structure. The catchment peak flow for a one in ten year flood event was designed.

From this peak flow a weir crest length was also designed which reaffirmed the original design of the waterway width. The rock chute was designed to deliver the expected flows from ground level above the erosion to the modified, much flatter ground level below the erosion a depth of approximately 1.5 metres with a slope no less than 3:1. Total chute length is approximately 12 metres (See Diagram 1).

The rock chute crest length was built to the width of the waterway at 23 metres with a 300mm level lip above waterway ground level to encourage silt drop at the top of the chute. The waterway banks were retained at approximately 850mm. The area below the rock chute has been levelled to the full width of the waterway and has been planted with a mix of winter and summer active pasture grasses.

A sub surface Ag drainage pipe was installed from the bottom of the rock chute to a depth of 300mm to drain the saline seepage away from beneath the structure. Mulch was added to the chute area. The slope of the waterway below the chute is very flat now which will reduce the recurrence of erosion.

The construction consisted of the following steps:

- *Top soil removed and stored.*
- *Excavation, shaping and compacting the chute slope and surrounding waterway.*
- *Cut off trenches excavated at top and bottom.*

- *Texel Geofabric placed over the compacted soil on the chute slope and into the cut off trenches.*
- *Netting strips placed in the cut off trenches attached to netting over the rock fill.*
- *Mixed rock fill and granite gravel placed to a depth of approximately 700mm on the chute and in the cut of trenches securing the Texel Geofabric and netting strips.*
- *More netting was secured over the rock and attached with strong plain wire and tensioned to ensure a complete mat with firm contact to hold the rock in place.*
- *Top soil was replaced over the area and*
- *Grass seeded and mulch spread over the waterway and structure.*

RESULTS

Perversely the 2014 winter season has been a continuation of dry conditions with the whole shire still drought declared. Construction is finished and grasses have been planted however there is yet to be a useful fall of rain to germinate the grass planting. The area has been fenced and can be managed to maximise the grass vigour when it emerges. The project will be monitored and regular maintenance will be carried out to ensure the structure performs and provides the ongoing protection for the farm dam and enterprise viability.

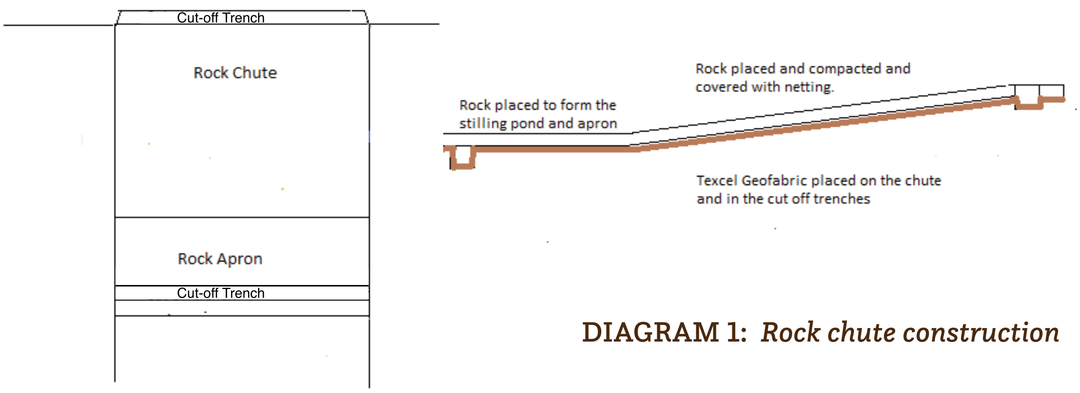

DIAGRAM 1: *Rock chute construction*

AUTHORS John Day, Soil Conservation Officer, BMRG, Bernard and Janet Ziebarth, landholder Haly Creek.

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The Queensland Government is committed to the productive and responsible use of the State's natural resources and has supported these projects as part of BMRG's Sustainable grazing management and on-ground works: conserving soils in the Burnett Mary Region project.

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JONES

BMRG CASE STUDY

Gully Rehabilitation Saves Dam By-Wash

Scott Jones' property, Windera district, South Burnett 2014.

BACKGROUND

The 2013 ex cyclone Oswald dumped torrential rain on the catchments throughout the Wide Bay Burnett.

This event produced run off rates which were estimated to be in excess of a one in one hundred year flood.

This event followed on the heels of similar but slightly smaller events in 2010 and 2011.

The South Burnett had been in the grip of an extended dry period prior to these flood years so many catchments were in a state of reduced vegetation cover. The resulting erosion across the region was the worst seen for decades and affected cropping and grazing land alike. Particularly hard hit were storages and dams. Many burst and the by-wash area on most suffered extensive damage if not total failure.

ABOUT THIS CASE STUDY

Scott Jones is a landholder in the Windera district of the South Burnett. He was faced with the prospect of losing his 50 mega litre irrigation dam through an eroding by-wash. The catchment supplying the dam is significant with an estimated area of 1322 hectares. Much of this catchment is a mountainous area with steep slopes and fast running annual water courses. The dam is constructed on the main water course which has been estimated to carry approximately 69 cubic metres of water per second at the peak flow during a one in one hundred year flood event (design estimates provided by DNRM).

This is an enormous amount of water flowing through the system. Mr Jones had watched his relatively stable by-wash area suffer serious erosion in the 2010 floods. After this event earth works were done to repair the damage. Unfortunately before this could establish a good grass cover the 2011 flood again caused more erosion. He again repaired the damage by rerouting the by-wash to a more gradual slope which had some grass cover. This strategy was very sound under the circumstances and under normal conditions would have resolved the issue. Unfortunately once again the 2013 flood devastated this work before it could become fully settled and consolidated. The reason for the severe erosion was the sheer size of the flood and the resulting mass and velocity of water.

The erosion by this time was starting to encroach on the area adjacent to the dam wall so the long term viability of the whole structure and farm water supply was in danger of failure. Fortunately there was about one hundred and fifty metres of solid ground left to work with.

With the assistance of the Flood Recovery NDRAA funding valued at $25,000 Mr Jones had the opportunity to look at an option for repair which could withstand the forces of future extreme flood events.

Mr Jones sought the advice of the Burnett Mary Regional Group's Soil Conservation Officer to help develop a rehabilitation strategy to limit the erosion. The project developed with inputs from a combination of technical soil conservation experience, local landholder experience and earth moving contractor knowledge and skills.

This combination along with many hours of hard work by Mr Jones has produced a very strong and viable rock Gabion structure which should stand the test of time.

METHOD

After discussion on the possible options to repair the erosion site the planning team decided on a rock chute design with the added strength of the Gabion basket construction method. This method was favoured to ensure that the rock placed on the chute could not be moved regardless of the velocity that

could naturally occur with a wide crested structure. This method also favoured the cost structure of the work as there is a suitable rock source on the property. The rock available is not big enough to place on the chute unsupported however it is big enough to do the job when enclosed in the Gabion baskets.

The catchment peak flow for a one in one hundred year flood event was calculated. From this peak flow a weir crest length was designed. This was then rationalised to the physical surroundings at the site and a rock chute was designed to deliver the expected flows from the level of the dam by-wash to the level of the creek bed which is approximately 3 metres. See (Diagram 1). The rock chute crest length was built to accommodate the length and depth of flow which had been witnessed by the landholder during the 2013 flood.

This structure is 27 metres across the crest and the flow confinement banks are 1.5 metres high. The observed depth of flow through the by-wash in the 2013 flood was approximately 1 meter. The area below the rock chute has been levelled and widened in line with the width of the chute to reduce the velocity and power of the water flow. Rock groins 3 metres wide have been placed at approximately 4 meter intervals down the waterway to the creek bed to dissipate energy, collect silt and spread the water flow.

The construction consisted of the following steps:

- *Levelling and compacting the chute slope and surrounding waterway.*
- *Rock groins placed across the waterway below the chute down to the creek bed*
- *Cut off trench excavated at the top of the chute.*
- *Geofabric placed over the compacted soil on the chute slope and into the cut off trench.*

- *Gabions placed in the cut off trench and filled.*
- *Gabion baskets placed on the chute slope and filled.*
- *Gabion baskets placed at each end of the top of the chute crest and filled and tied into the directing banks.*
- *Rock back filled around the Gabions and on the chute apron.*
- *Topsoil replaced over the site.*
- *Grass seed and mulch spread over the waterway and structure.*

The area from the dam wall to the rock chute crest has also been levelled to the approximate width of the chute crest to ensure the velocity of the flow over the initial dam by-wash area is as low as possible. The crest of the chute is approximately 0.3 metres above the soil by-wash floor which will encourage siltation, some ponding and good grass growth. During construction the top soil was stored and has been spread over the finished site to encourage rapid grass cover.

RESULTS

Perversely the 2013 winter and 2014 spring, summer seasons have been close to the driest on record in the district and although the construction is finished and grasses have been planted there is yet to be a useful fall to maximise the potential of the grass planting.

The grass is however starting to regenerate even under the harsh conditions. The project will be monitored and regular maintenance will be carried out to ensure the structure provides the protection for the farm dam and Mr Jones' livelihood.

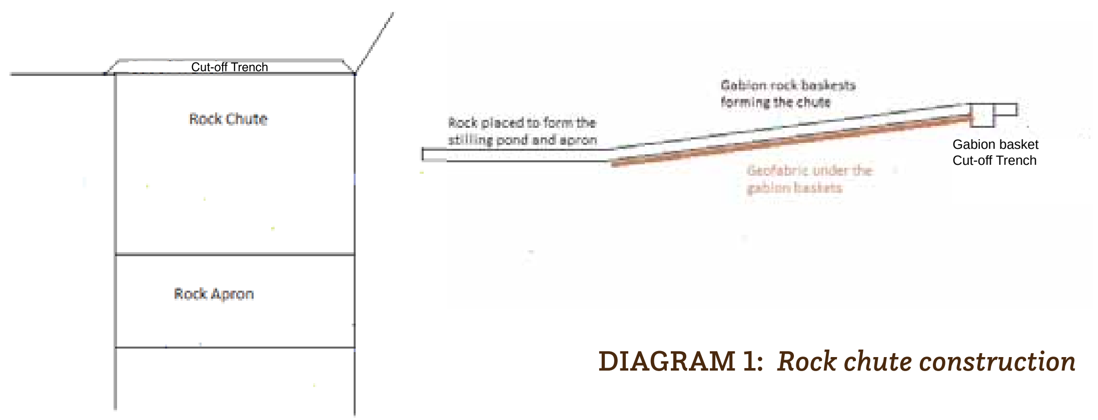

DIAGRAM 1: ***Rock chute construction***

AUTHORS John Day, Soil Conservation Officer, BMRG, and Scott Jones, Landholder, Windera.

Queensland Government

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This project is part of the On-farm Productivity and Riparian Recovery Program; supporting primary producing areas severely impacted by flooding following Ex-tropical Cyclone Oswald 2013 and is funded by the Queensland and Commonwealth Governments through natural disaster relief and recovery arrangements.

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GRUBB

BMRG CASE STUDY

Rehabilitation of Hillslope Erosion Using Near-level Contour Banks

BACKGROUND

The inland Burnett has experienced extreme wet and dry weather events over the last six years. These events have increased the incidence and severity of soil erosion throughout the area.

The sandstone-derived soil types on the western side of Three Moon Creek Valley are particularly susceptible to hillslope and gully erosion. They are of lower fertility than the nearby alluvial plains and prone to low groundcover after dry spells. Historically, many holdings in the area have been dairy farms on smaller blocks subject to intensive management.

The undulating topography of the area, with slopes up to 5%, combined with the hard-setting soils, reduces water infiltration in intense rain events. After the long dry periods, intense rainfall then causes much of the landscape to succumb to hillslope erosion. This project has provided an opportunity for one landholder, Mr Geoff Grubb, to investigate options to stop the insidious erosion of soils on his inland Burnett property.

THE SITE

The undulating poorer soil areas comprise approximately 50ha of Mr Grubb's 116ha property used for intensive beef cattle breeding and finishing.

The soils consist of shallow hard-setting top soils over a dispersive subsoil with sandstone slabs and base rock rising intermittently close to the surface. There is also a small area of slightly heavier soil on the north-eastern boundary adjacent to an alluvial flood plain.

Based on previous experience, the main objective of the project was to hold more water on the hard setting slopes to allow more infiltration and ultimately more grass growth. Mr Grubb approached BMRG's soil conservation officer to devise a method for extending water ponding over the whole block which was suffering from poor infiltration and productivity.

PHOTO 1 & 2: ***The Site / Before Construction***

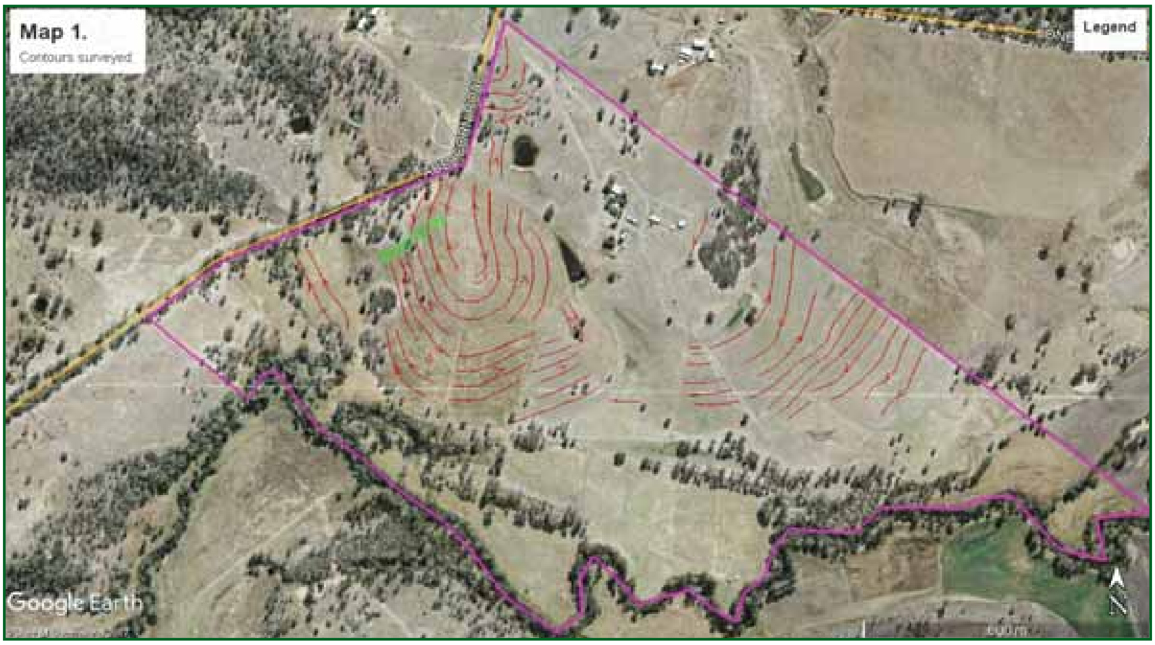

FIGURE 1: ***Map Showing Contour Bank Locations***

METHOD

Mr Grubb, had researched the problem and decided he would like to construct, level pondage banks, to pond water and provide a favourable environment for pasture growth over more of the growing season.

Plans were drawn up to survey and construct a number of level and slightly graded banks. The layout of the banks and water disposal areas were planned to support a fencing program which could further subdivide the area to facilitate a time-control grazing pattern.

Mr Grubb also researched the suitability of shade and fodder trees that could be incorporated into the system to increase shade and provide some provide some browse when needed. The strategy was to plant the trees on the downhill side of the pondage banks which would allow the roots to tap into the deep drainage water around the banks.

The bank layout also trialled a small section of switchback banks and checkerboard banks on the lower slopes. Strategic deep ripping above and below the banks was also trialled in some particularly scalded sections.

In total, 50 individual banks measuring a total of 8150m, were surveyed and constructed over the 50 hectare site. This intensity of banks was necessary due to the relatively steep slopes on much of the site and the limited potential of the constructed bank height. Most of the banks were constructed with a grader but some were developed with a dozer on the steeper sections. The ends of the banks were fine-tuned with a skid steer to further refine their water holding capacity after rain.

The shorter banks (up to 200m depending on land slope) were surveyed level and longer banks with a slight grade. Some of these had small check rills installed post-construction to retain more water. Due to the relatively intense nature of the system and the operation, Mr Grubb was able to fine tune the banks to perform as he wished during the rainfall events that followed the initial construction. The areas that were ripped had gypsum applied to increase infiltration and the whole area which had been disturbed was seeded with legumes and grass species. The project was completed in June 2017.

RESULTS

Since the project was completed, there have been several high rainfall events in the Monto district.

During the month of October 2017, the area received a rainfall total of 289mm, followed by above average rainfall in both December and February. The rain events provided favourable conditions for water ponding and the germination of the planted grasses. All of the treated areas responded

PHOTO 3: ***The Site / During Construction***

PHOTO 4 & 5: ***The Site / Before and After Construction***

PHOTO 6 & 7 : ***The Site / After Construction and Heavy Rain***

with a body of pasture growth which had not previously been seen on those soil types on the property. Newly planted grasses and legumes including Premier Digitaria, Rhodes grass, Creeping Blue grass, Wynn Cassia and Seca Stylo have germinated well. The standout pioneer grasses were the local endemic Signal grass and Urochloa which responded profusely from existing seed in the paddock.

With this impressive grass response and Mr Grubb's plans for a time-control grazing management system, the viability of the operation has been boosted significantly. Mr Grubb is continuing to fine-tune the banks, focusing on areas which are still not adequately responding to rainfall. He is also proceeding to plant fodder and shade trees along the downslope side of strategic banks to further enhance the productivity and animal welfare of the property.

The amount of rain received has ensured that most of the property has responded with lush grass growth.

The value of the system will be fully experienced as winter arrives and the ponded areas retain moisture and continue to grow for much longer durations than the untreated areas.

AUTHORS John Day with Geoff Grubb. PHOTOS John Day.

Queensland Government

Burnett Mary REGIONAL GROUP
Practical Solutions for Natural Resource Management

This activity is funded under the Queensland Government's Regional NRM Investment Program.

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LINDENMAYER

BMRG CASE STUDY

Managing Old Contour Banks to Reduce Erosion in Grazing Lands

Burnett Mary REGIONAL GROUP
Practical Solutions for Natural Resource Management

BACKGROUND

The inland Burnett has experienced extreme wet and dry weather events over the last six years. These events have increased the incidence and severity of soil erosion throughout the area.

During the wet period of the 1970s, widespread cultivation of upland slopes was undertaken in established grazing country in the inland Burnett for planting of sorghum and soya beans. Extensive contour bank layouts were surveyed and constructed during this time. This work saved millions of tonnes of valuable top soil. Since the 1990s, most of these upland areas with contour banks have been returned to permanent pasture and grazing. Over time, the impact of stock movement has caused breaks in the contour banks and erosion in the waterways, particularly after extended dry periods.

Looking to the future, climate experts predict an increasingly erratic and extreme weather outlook with more intense rain events and dry spells. This scenario provides an incentive for landholders with old contour bank systems on their grazing lands to consider options to reduce or remove the associated erosion hazard. This case study highlights the work of landholder, Mr Paul Lindenmayer, of "Craiglea" in the inland Burnett.

Mr Lindenmayer was confronted with a badly eroding waterway, degrading contour banks prone to breakage and subsequent soil loss.

THE SITE

The 25ha catchment is contoured ex-cultivation and pastured mainly with native grasses. The original contour bank system was constructed many years ago and the waterway had been gradually eroding since then. The waterway was an unmodified natural depression grassed with native grasses. Severe droughts from the 1980s to early 2000s, significant flood events from 2010 to 2013 and more recently the 2015 Cyclone Marcia event, pushed the erosion into the severe active stage.

PHOTO 1 & 2: *The Site / Before Construction*

METHOD

Mr Lindenmayer owns a dozer, so it was agreed that the best course of action was to systematically break the contour banks and dam up the outlets at the breaks. This would enable water to pond in the short sections and overflow out both ends into the contour bay below during larger flow events.

The breaks were designed to be staggered so that a direct flow path could not be made from the top of the slope to the bottom from bank to bank. This resulted in a checkerboard pattern of small pondage banks holding and gradually dispersing water across the slope. This strategy vastly improves the water infiltration potential by holding more water on the slope for much longer periods.

A necessary management practice with this approach is keeping high levels of cover on the paddock to make the most of the extra moisture and further reduce any excess runoff.

In the eroded waterway, the gullied sections were blocked with short diversion banks at the gully heads to disperse water away to the grassed slopes on either side. The bare eroding areas of the gully and the pushed banks and gaps were seeded with a mixture of improved pasture species and legumes suitable to the clay soils.

An important factor in this approach is to not cultivate the area ever again - even for pasture renovation or replanting. Using zero tillage strategies could be an option for broad scale legume inclusion or planting improved exotic pasture species. As the soil types in most of these sites are reasonable, judicious management strategies such as time-control grazing and wet season spelling should provide a vigorous and productive natural pasture for relatively low cost, with no potential for soil erosion.

The site planning and construction for this project occurred during March – April 2017 and consisted of the following specific steps:

- *A field plan was prepared and provided for the landholder outlining the distance between breaks in the banks and the relative location compared to the banks above and below.*
- *A dozer was used to push from the bottom side of the banks at an angle against the flow direction of water in the bank to remove a bank section and deposit the dirt into the bank channel, effectively creating a small dam in the bank channel.*
- *The breaks in the banks were made every 30 to 50 metres so that they do not line up directly up or down slope with breaks in the banks above and below. (Due to the very low slopes in contour bank channels, the ponded water will tend to drain out of the next gap in the bank rather than breach*

the small dam made on the other end of the bank section.)

- *The bare pushed areas were seeded later with a tractor and spreader.*
- *An existing fence was maintained to manage future stocking rates.*

RESULTS

The amount of water entering the waterway is now reduced to only that which falls directly on the waterway. All the other water from the contours which is not being held up in the small pondage sections is once again being dispersed evenly across the slope.

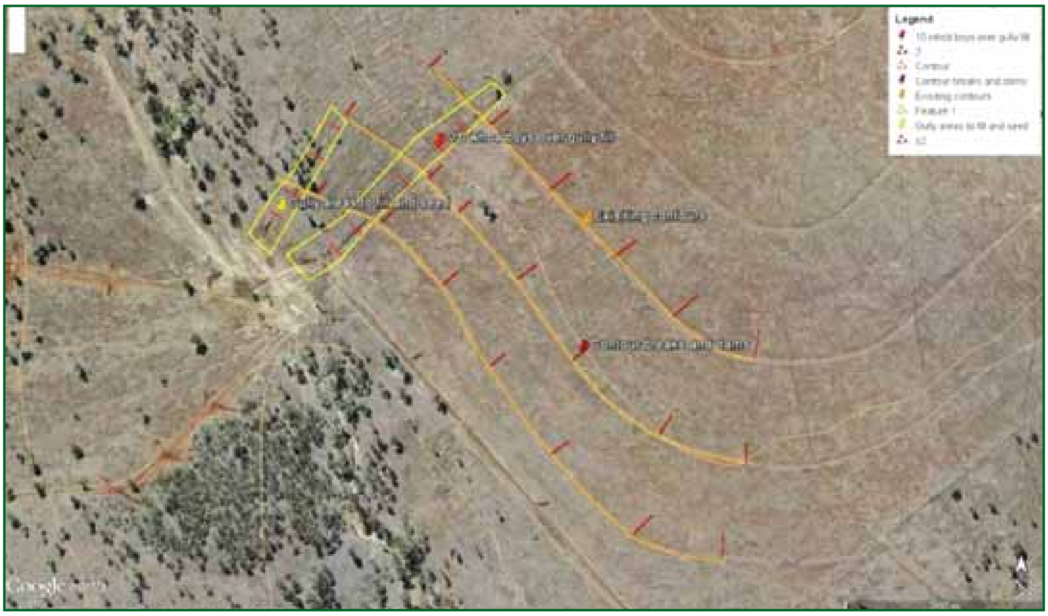

FIGURE 1: *Checker board pattern and banks on gully heads*

FIGURE 2: *Close-up of breaks and expected pondage design*

PHOTO 5 : *The Site / After Construction*

Accumulated water no longer exacerbates the erosion in the waterway allowing natural slumping and re-seeding of vegetation to occur. Since completion of construction work, Cyclone Debbie caused a significant overnight fall of 120mm.

The works held up very well even though there had been no chance for any grass to establish on the push lines. Grass and legume seed had been planted and there has been a very viable germination from that rain which will further stabilise the area prior to the summer storm period.

The project developed with a combination of technical soil conservation experience and the knowledge and skills of the landholder. This combination along with many hours of planning and hard work by Mr Lindenmayer and his family has transformed a problem area into a much-improved production area with no ongoing soil erosion. The project will be monitored and regular maintenance will be carried out to ensure that all structures continue to provide ongoing protection.

AUTHORS: John Day with Paul and Jackie Lindenmayer. PHOTOS John Day.

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APPENDIX

SOIL CONSERVATION GUIDELINES FOR QUEENSLAND (2015)

https://publications.qld.gov.au/dataset/soil-conservation-guidelines

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This is the Foreword, Preface and Contents list for the Soil Conservation Guidelines for Queensland.

FOREWORD

Soil is a precious resource. Soil health and soil management, along with the availability of water, largely determines the level of food production. Healthier soils mean healthier food and more prosperous communities.

Soil is a non-renewable resource. It has taken a very long time for soils to develop—hundreds and thousands of years—and yet that soil can be lost forever as a result of intense rainfall when left unprotected or unsupported by appropriate land management practices. Soil management guidelines have been produced by the Queensland Government since 1965 to provide support to farmers and land managers. This edition of the *Soil Conservation Guidelines for Queensland* is the result of an extensive review, and includes new chapters based on recent research and information from soil managers and experts. These guidelines provide information on soil degradation and practical tools for its prevention from water based erosion. They also provide tools and techniques to remediate degraded areas.

Over many years, and now driven by this government's commitment to conserve the Great Barrier Reef, the Queensland Government has been collecting and analysing crucial information related to soil and its management, including mapping the extent of groundcover and its seasonal changes, mapping of land use, mapping of erodible soils, identifying erosion processes and sources of sediment, and identifying active gullies contributing to soil erosion. The government has also developed decision support tools for farmers to reduce sediment and nutrient runoff, and modelled the effects of farming systems on soil loss.

The Honourable Anthony Lynham MP
Minister for State Development and
Minister for Natural Resources and Mines

The large body of knowledge has been combined with the shared knowledge and contribution of many academics and land management practitioners to produce this new edition of the *Soil Conservation Guidelines for Queensland*.

While the guidelines are based on Queensland experiences and conditions, the information has relevance across Australia. Land managers, Landcare Australia and other community-based groups, regional natural resource management groups and state and local government agencies will find this an invaluable resource informing their land management activities.

The guidelines are also a source of knowledge and practical science for universities and teaching institutions in the training of the next generation of soil conservation practitioners.

We would like to thank all the people who contributed their time and effort in updating the guidelines.

In particular, we acknowledge the principal authors, the late Bruce Carey and Barry Stone, who together brought to the guidelines the wisdom and experience of 90 years of public service to soil conservation.

In conclusion, we strongly recommend the use of the *Soil Conservation Guidelines for Queensland* to all who value and work towards a sustainable approach to land management in Queensland, now and in the future.

The Honourable Leeanne Enoch MP
Minister for Housing and Public Works and
Minister for Science and Innovation

PREFACE

This edition of Soil Conservation Guidelines for Queensland is dedicated to our dear friend and respected colleague Bruce Carey. Motivating and educating people about soil and the need to conserve it was more than a job for Bruce—it was his life-long passion. It was this passion that sustained Bruce over the challenging last few years of his life, and which inspired us and others to help him complete the significant task of rewriting these Guidelines. The result is a wonderful legacy that is certain to be appreciated by those responsible for managing Queensland's soils for generations to come.

The first, entitled the *Queensland Soil Conservation Handbook,* was published in 1966 by the Queensland Department of Agriculture and Stock. The second, entitled *Soil Conservation Measures—A design manual for Queensland*, was published in 2004 by the Queensland Department of Natural Resources and Mines. This, the third, is published by the Department of Science, Information Technology, and Innovation.

With each succeeding edition the information contained has become more extensive and comprehensive reflecting growth in our knowledge of soils and how to conserve them. This edition in particular represents a significant expansion from the previous, with new information about stream and gully erosion and on management of floodplains, infrastructure and horticulture. It is certain to be a very useful resource for soil conservation planners and practitioners across government, regional NRM bodies, Landcare, industries, the private sector and the community.

Early European settlers in Australia had little appreciation of the limitations particular to the soils and landscape they were developing for agriculture. They applied the farming practices with which they were familiar, those that worked in their homelands on the other side of the world, expecting the land to respond as it did there.

Much cropping was undertaken without recognising the importance of retaining vegetation to conserve the soil and protect biodiversity, land subdivision was usually based on the simplest geometric, rectangular layout with little consideration of natural drainage systems, topography and soil types—even mountains were subdivided—and, as if it were needed, additional incentive for wholescale clearing and cultivation was provided by governments requiring that land be developed immediately upon selection.

Soil erosion was the first land degradation problem to become readily apparent in Queensland. Our state's intense and episodic rainfall and the inherent instability of many of our soils mean that Queensland will always be prone to a high risk of erosion.

By 1950, large areas of cropping land in Queensland had become so badly eroded that they had to be withdrawn from cultivation. The government of the day (and those of the following decades) responded with a raft of investments, in particular, research to understand the issues and develop solutions, and extension programs to support farmers and graziers change to more sustainable practices.

Thanks to those efforts, considerable progress has been made. Conservation tillage is now widely practised throughout the cropping lands, steep land is now generally not cultivated or is protected with conservation works such as contour banks and constructed waterways, and graziers are much more diligent about maintaining groundcover. However it is important that we continue to be vigilant. Soil erosion represents a greater risk to Queensland than any other land degradation problem, and the cycles of long periods of reduced erosion under low rainfall and limited runoff which are typically experienced in Queensland can encourage complacency about the risk and lead to neglect of important soil conservation measures.

The process by which public investment in managing natural resources (including soils) is directed and coordinated has become much more decentralized throughout Australia in recent decades. In the past, the government's investment in technical advice and soil conservation planning and design was delivered directly by government agencies. This encouraged a close relationship between landholders and their local government soil conservation extension specialist.

Under the new arrangements, communities through local and catchment-based non-government 0rganisations, play a much greater role in planning and delivering publicly-funded extension advice and on-ground works. Whilst this process of planning through partnerships undoubtedly increases stakeholder engagement and ownership, the need for technical knowledge and proficiency is not reduced. In fact, at a time when experienced people are retiring and regional representation is declining due to the ongoing drive for cost-efficiencies across all sectors of government, the need for a consolidated 'point of truth' such as provided by these guidelines has never been greater.

CHAPTER 1 – INTRODUCTION
This chapter of the *Soil Conservation Guidelines for Queensland* describes the processes of land degradation and their impacts. It then outlines how the history of land management in Queensland has contributed to land degradation problems.

CHAPTER 2 – SOIL CONSERVATION PLANNING
This chapter of the *Soil Conservation Guidelines for Queensland* describes how to write a soil conservation plan for a property, and uses case studies to explore multiple layout options.

CHAPTER 3 – PEAK DISCHARGE ESTIMATION
This chapter of the *Soil Conservation Guidelines for Queensland* describes how to estimate peak discharge for small catchments. This parameter is important to the design of soil conservation structures like contour banks.

CHAPTER 4 – THE EMPIRICAL VERSION OF THE RATIONAL METHOD
This chapter of the *Soil Conservation Guidelines for Queensland* describes how to calculate the peak discharge expected from a soil conservation structure design, such as a contour bank or waterway.

CHAPTER 5 – DARLING DOWNS FLOOD FREQUENCY MODEL
This chapter of the *Soil Conservation Guidelines for Queensland* details the flood frequency estimation model used in the Darling Downs region of South East Queensland.

CHAPTER 6 – CHANNEL DESIGN PRINCIPLES
This chapter of the *Soil Conservation Guidelines for Queensland* discusses ways to design water channels and weirs in such a way that they remain stable for as long as possible. This minimises maintenance costs.

CHAPTER 7 – CONTOUR BANKS
This chapter of the *Soil Conservation Guidelines for Queensland* details how to design, build and maintain contour banks that remain stable and divert water effectively, without interfering with practices such as Controlled Traffic Farming.

CHAPTER 8 – DIVERSION BANKS
This chapter of the *Soil Conservation Guidelines for Queensland* discusses how to design diversion banks, which can be used to protect vulnerable land or infrastructure from surface water flows.

CHAPTER 9 – WATERWAYS
This chapter of the *Soil Conservation Guidelines for Queensland* discusses how to design, construct and maintain soil conservation waterways.

CHAPTER 10 – LAND MANAGEMENT ON FLOOD PLAINS
This chapter of the *Soil Conservation Guidelines for Queensland* provides information about the nature of flooding in rural areas, its impacts and strategies for managing flooding on floodplains to protect soil.

CHAPTER 11 – STREAM STABILITY
This chapter of the *Soil Conservation Guidelines for Queensland* provides introductory information about how to stabilise streams to prevent erosion.

CHAPTER 12 – SOIL CONSERVATION IN HORTICULTURE
This chapter of the *Soil Conservation Guidelines for Queensland* provides general information on how to control erosion in horticultural cropping.

CHAPTER 13 – GULLY EROSION AND ITS CONTROL
This chapter of the *Soil Conservation Guidelines for Queensland* describes the impacts of gully erosion, the factors that contribute to gully development, strategies to prevent gully erosion and options for controlling it.

CHAPTER 14 – PROPERTY INFRASTRUCTURE
This chapter of the *Soil Conservation Guidelines for Queensland* describes how to site, construct and maintain infrastructure such as access roads and tracks, fences, and stockyards to avoid erosion and reduce maintenance requirements.

APPENDICES

This section of the *Soil Conservation Guidelines for Queensland* contains tables and charts that are frequently used in soil conservation design, consolidated in one place for ease of use.

RAMWADE FLOW CALCULATOR TOOL

This is the latest version of the RAMWADE (RAtional Method WAterway DEsign) tool (version 7, April 2016).

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