Gully erosion

Gully erosion is a highly visible form of soil erosion (Figure 1) that affects soil productivity and restricts access to and use of land. Soil eroded from a gully can also damage infrastructure, burying fence lines, silting up waterways, clogging road culverts, and filling dams and reservoirs.

Suspended sediments generated by an eroding gully can harm water quality. Nutrients and pesticides are attached to these fine colloidal clay particles and they can remain in suspension for a long time, clogging groundwater aquifers, polluting watercourses and threatening aquatic flora and fauna.

Controlling gully erosion can be difficult and costly. It may be justified on better quality soils where there is a reasonable chance of success or in strategic locations such as where a road or building is threatened by an advancing gully. However, rehabilitating gullies over large areas where soils are poor is not cost effective and may be impractical. For this reason prevention is by far the best way to control gullies.

Figure 1 – A four metre deep gully advancing into grazing land (photo: B Carey)

How gullies develop

Gullies are steep-sided watercourses that flow only during heavy or extended rainfall. Gully erosion is caused when run-off concentrates and flows fast enough to detach and transport soil particles. As runoff plunges over the gully head it picks up energy and may form a waterfall. Splashback at the base of this waterfall erodes the subsoil at the gully head and causes the gully to eat its way up the slope.

Gullies may develop in watercourses or other places where run-off concentrates. In cultivated paddocks or pastures, advanced rill erosion can develop into gully erosion if it is ignored and no protective measures are taken. Even a small rill starting in a cattle pad can eventually develop into a large gully.

Gullies generally have the capacity to accommodate far more run-off than they are likely to carry under normal circumstances. A watercourse is usually in a state of balance where its size, shape and gradient are matched to the flows it carries. If this balance is disturbed, for example by a larger than normal flow, a gully may start to form.

Gullies may also become wider due to slumping of the sides. This occurs most commonly on the outside curve of meanders. Scouring of the toe-slope of the bank weakens the gully side and leads to soil falling away under gravity. Soil deposited in the bed as a result of this process is then washed away in subsequent flows.

When gullies are still active the sides are usually vertical. However, the sides generally become more sloping once the gully starts to stabilise. This process may occur naturally but can also be sped up by gully treatment measures.

Secondary gullies or branches can be created by runoff entering a gully from the sides. This can result in what is known as a 'badlands' effect. The gully floor may cut down further as these secondary gullies advance up the channel. When this occurs, sediment deposition below the gully head will result in a "steps and stairs" pattern in the bed.

While high flows from intense rainfall are the biggest cause of gully erosion, the prolonged low flows resulting from an extended wet period can also contribute to problems. Constant low flows through a drainage line can saturate the soil in the trickle zone which structurally weakens it and makes it very susceptible to erosion. The constant wet conditions created by trickle flows may also retard the growth of vegetation and reduce its ability to resist erosion.

The depth of a gully is often limited by the depth of soil to the underlying rock. On much erosion prone land in Queensland soils are quite shallow and gullies are usually less than 2 metres deep. However on deep alluvial and colluvial soils gullies may reach depths of 10 to 15 metres.

Dispersible sub-soils

Areas with dispersible subsoils are especially vulnerable to gully erosion, especially when the top soil is disturbed. Dispersible subsoils are very common throughout Queensland. The topsoil in these areas is characteristically shallow, light textured, and relatively stable, with an abrupt change to a highly erodible clay subsoil that has a high exchangeable sodium percentage. When saturated by seepage flows or subject to splash back, dispersible subsoils will slump, leaving the topsoil unsupported. The topsoil then collapses and the process is repeated (Figure 2).

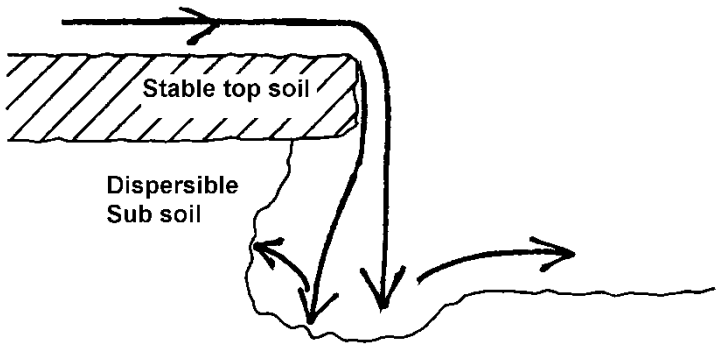

Figure 2 – the process of gully formation in a dispersible sub soil

Sub-surface flow in dispersible soils can saturate gully sides, causing the walls to slump and the gully to expand. Under these circumstances the gully head can continue to advance with little or no surface flow. This process is comparable to the way a hole dug to the depth of the water table in the sand at the beach expands as the sides slump away.

A simple way to test for soil dispersibility is to place a small clod of dry subsoil in a jar of water. The soil is dispersible if the clod disintegrates and the water becomes cloudy. For more information on dispersibility refer to Science Notes W15 (Water series) Dispersive soils − Guide for use in farm dam construction.

Tunnelling

Tunnelling can increase the rate of headward and lateral expansion of gullies in dispersible soils. When dispersible subsoils are exposed, the amount of water flowing into cracks in the soil increases. This causes water to seep more rapidly into the soil and the cracks to enlarge. Cracks enlarged through this process can develop into tunnels. These tunnels which carry a suspension of soil and water eventually collapse causing the gully head to progress rapidly.

Cracking clay soils

Cracking clay soils, such as those found on the Darling Downs and the Central Highlands are less prone to erosion than the dispersible clay soils described above. However gullies can still develop in these soils.

Cracking clay soils characteristically develop cracks as they dry out. In very dry weather, cracks of up to 2 metres deep and 100 mm wide may develop. This may cause large slabs of soil to fall into the gully leaving vertical (or near vertical) sides. The cracks are interconnected laterally and when storm rainfall occurs, water penetrates the soil through the cracks and moves downslope. Eventually the soil will swell and the cracks close up, however this will not happen quickly enough to prevent large volumes of water from accumulating in cracks in the subsoil. If the water finds an outlet, the hydraulic head this creates may result in subsurface flow and cause tunnelling.

Saline areas

Saline areas are very susceptible to gullying. Salt in soil inhibits the growth of protective vegetation and increases dispersibility of some soils. On the positive side, the presence of an eroding gully may help to drain the area which could help reduce the impacts of the salinity by lowering the water table. For this reason, when controlling gullies in a situation such as this it may be most appropriate to aim to stabilise the gully but not to fill it in.

Triggers of gully development

Gullies may be triggered by:

- exposure of susceptible soils to raindrop action and runoff by cultivation, grazing, fires or salinity
- increased runoff due to changed land cover such as tree clearing in a catchment or construction of new residential areas
- concentration of runoff due to furrows, contour banks, waterways, dam bywashes, stock pads, fences, tracks or roads
- poor design, construction or maintenance of waterways or diversion of a drainage line to an area of high risk to erosion, for example, a steep creek bank or highly erodible soils in cropping areas
- low flows or seepage over a long period
- 'down-cutting' in a creek causing gullies to advance up the drainage lines flowing into it

Preventing gully erosion

Prevention is definitely better than cure. Repairing a gully once it has developed is expensive, requiring a long-term investment, and is frequently unsuccessful. To prevent gullies from starting it is very important to undertake regular monitoring. It is important that indicators of gullying are detected early on and action taken quickly before a gully develops into a problem. Some common measures to prevent the development of gullies include:

Plan and develop agricultural properties so that:

- catchments are managed to ensure runoff is not increased
- the capability of land is assessed and it's use does not exceed it's capability
- roads, fences and laneways are located and constructed so that they do not divert and concentrate runoff.

Manage grazing land so that:

- stock are excluded from land that is vulnerable to gully erosion
- watering points, stockyards, shade areas and gates are located away from gully-prone areas
- contour banks (if present) are properly maintained or levelled or gaps created to safely disperse runoff. Contour banks are normally not necessary on well managed pasture land. Poorly maintained banks in such situations may lead to rilling and gullying.
- grazing pressure is managed to ensure adequate cover is maintained throughout.

Manage cropping land so that:

- stubble is retained and contour banks and waterways constructed and maintained to control erosion on sloping cultivated land
- waterways are constructed to the correct specifications and are stabilised and maintained
- contour banks discharge into waterways at safe locations
- practices that concentrate flood flows are avoided, in particular on cultivated floodplains.

Develop urban areas so that:

- heavily trafficked areas such as school grounds do not become bare and compacted
- land that is steep or in drainage lines is not developed
- soil disturbance is minimised, topsoil stockpiled and respread, and affected areas revegetated quickly
- flood detention systems are constructed below areas that will generate runoff.

Controlling gully erosion

Vegetation is the best long term tool for controlling gully erosion. Engineered structures may be required in conjunction with revegetation to stabilise a gully head or to deposit silt and promote vegetation on the gully floor. However, whilst structures will progressively deteriorate, becoming less effective over time, vegetation can be self-sustaining or even improve over the years.

Engineered gully control structures may be made of concrete, masonry, wood or other building material. Structures need to be carefully designed and well maintained as they are inherently at risk of failure and may be undermined or bypassed. Designing and constructing such structures requires specialised skills and may be expensive.

When deciding what action to take to control a gully the following factors should be considered:

- The ***cause*** of the gully. There is little point in investing heavily in a structure to control a gully without doing anything to address the root cause of the problem.

- The ***impact*** of the gully. Success in controlling a gully generally requires a large investment of time and money. If the consequences of taking no action to control the gully are not high this time and these resources may be more effectively utilised to address other matters?
- The size of the gully ***catchment***. The larger the catchment the more complex the problem.
- The type of ***soil*** in which the gully occurs. Vegetation will establish more easily and grow more rapidly in fertile soils. Erosion problems are more likely to occur in poor soils.
- The ***components*** of the gully. Is the gully head, the floor, or the sides eroding most actively? Does the gully have branches? What is the height of the gully head?
- The ***potential to divert*** runoff away from the gully. Is there an option to divert run-off flowing into the eroding gully to a safe disposal area?

The key to success with most gully stabilisation is choosing the right time of the year to do the work. Autumn is generally the best time for most of Queensland as there is less chance of high volumes of runoff at this time. Autumn also offers the best prospect of sufficient soil moisture and warmth to successfully establish and grow vegetation.

Using vegetation

Vegetation in a gully slows the flow of water, protecting against further scouring and minimising the risk of erosion. Once vegetation becomes established it can change conditions in the gully to be conducive to further growth. This is because as the flow in the gully is slowed by the initial vegetation, sediment is deposited forming an ideal environment for more vegetation to establish. However, gullies can be a harsh environment in which to establish vegetation in the first place. They dry out very rapidly and the substrate is usually infertile subsoil.

Vegetation that grows vigorously with a spreading, creeping habit is preferred for gully control. This is because plants with these characteristics will do a better job of stabilising the soil. When choosing species preference should be given to local native plants, especially in areas where exotic species are undesirable such as natural vegetation or areas near waterways from which weeds may readily spread. However, in agricultural areas there is usually a range of exotic grasses and other species already well established that are suitable and/or have been used with success for controlling erosion. It is always advisable to seek the opinion of local experts as to whether a plant you are thinking of using has potential to become a weed.

It is recommended that gullies that are being treated are fenced. Stock are attracted to gullies, especially if they include shade trees. This can expose the area to excessive grazing pressure which can damage vegetation, compact the soil and expose it to erosion. If water is available, it should be used to irrigate the vegetation which will assist it to establish. An initial application of a mixed fertiliser can also assist vegetation cover to establish quickly.

Trees are desirable in the areas surrounding gullies but are not likely to successfully stabilise an actively eroding gully head. If trees are grown in gullies they should be well-spaced and have an open canopy to allow protective understorey vegetation to grow and protect the soil surface. Where subsurface flows are contributing to gully erosion, trees in the area above the gully head may help to dry out the soil deeper into the profile and provide structural support to prevent subsoils from slumping.

Gully reshaping and filling

The practicality of using earthworks to restore a gully depends largely on its size and hence the amount of fill needed to restore it to the desired shape. When using earthworks to treat a gully, topsoil should be stockpiled

to be later respread over exposed areas to assist vegetation to rapidly establish. Steep gully sides can then be reshaped. Annual crops such as millet (summer), oats or barley (winter) can be used to provide a quick cover. It may be an advantage, if possible, to temporarily divert water away from the gully while new vegetation is establishing.

Where gullies occur in cultivation paddocks they can be filled at the same time as contour banks are being constructed to manage the runoff that is contributing to the gullying. When doing this, particular care will be required to ensure that the banks have sufficient capacity where they cross old gully lines as this is a common site for contour bank failure.

Controlling gully heads

Gully head erosion can be controlled with:

- **Diversion banks**: these divert run-off from the gully head to a stable outlet. Unfortunately, such outlets can be difficult to find and if insufficient care is taken instability may simply be transferred from one area to another.
- **Chutes**: these are formed by battering gully heads to a stable slope. The role of a chute is to convey run-off safely to a lower level. Chutes are lined with erosion-resistant materials such as stoloniferous grasses, reinforced turf, erosion control mats, rock, rock mattresses, concrete, rubber or PVC sheeting.
- **Drop structures**: these allow runoff to drop vertically to a lower level, where the energy is dissipated before flowing down the watercourse. Drop structures can be made of formed concrete, concrete blocks, gabions, timber or steel plate. Gabions and rock mattresses have an advantage of being flexible and permeable.
- **Gully dams**: these are situated so that they 'drown' the gully head when the spillway is operating. Run-off is then returned to the watercourse at a safer location or directed onto a grassed area via a diversion bank. To successfully stabilise gullies the dam bywash and outlet must be stable. This can be difficult to achieve in erosion prone soils.

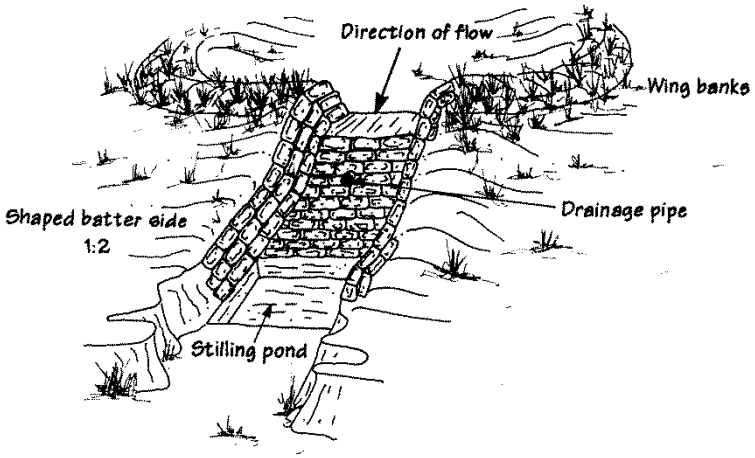

Figure 3 – Chute for controlling an eroding gully head

Stabilising the gully floor

Long-term success in stabilising a gully requires that a good vegetative cover be established on the gully floor. This vegetation prevents further gullying and allows the gully floor to gradually fill with silt, reducing the height of fall over the gully head.

A series of small weirs made from wire netting, logs or concrete can trap sediment in the gully floor and encourage the growth of vegetation. The same effect can be achieved with vegetation by establishing species with erect growth forms such as vetiver grass (*Chrysopogon zizanioides*) and lomandra (*Lomandra longifolia*). Branches of dead shrubs or trees can also make a useful contribution to stabilising a gully floor, retarding runoff flows and encouraging further sedimentation. These will also restrict access by grazing animals. However, old car bodies (which are often used for this purpose) are not recommended for gully stabilisation. They divert flows against the sides of the gully and increase the erosion.

Further information

This and other science notes are available from the Queensland Government website www.qld.gov.au – search 'science notes' or for further information about this science notes series phone **13 QGOV** (13 74 68) – Ask for science notes – Land series. Other science notes related to this topic include:

- L13 Erosion control in cropping lands
- L34 Monto vetiver grass for soil and water conservation
- L91 Erosion control in grazing lands.

For further information on soil erosion visit http://www.qld.gov.au/soils or email soils@qld.gov.au.