Information Sheet

1. CONSERVATION

1.2 Gully stabilisation and repairs

Introduction

A gully can be defined as a steep-sided eroding watercourse which is subject to periodic flash floods. Once a gully has started to form, a concerted effort must be made to halt the chain reaction which causes it to develop further.

The steep topography and the erodible soils found in many of the sugarcane growing areas, make gully formation a common problem. In South Africa, as a result of gully formation, large amounts of sediment are deposited in dams, streams and rivers.

A gully has a detrimental effect on the surrounding land. Besides the loss of valuable soil, the watertable is lowered and the soil dries out, causing vegetation to die and increasing runoff and erosion. At a later stage, lateral gullies begin to extend from the main one and once these form, the situation is extremely difficult to rectify. Control is then difficult and expensive. Prevention is therefore far better than cure.

Causes of gully erosion

A watercourse is ordinarily in balance, i.e. the size of the channel and the shape and gradient are determined by the flow it has to carry. If this state of equilibrium is upset, the channel becomes enlarged, and a gully begins to form.

The disturbance of the balance of a watercourse may result from an increase in the amount of runoff, or a decrease in the ability of the channel to carry the runoff even if the volume of runoff remains fairly constant. Gully erosion is therefore likely to result from:

- increased runoff from unprotected, arable or over- grazed land
- areas where the natural vegetation has been removed followed by poor standards of management or undesirable crop management practices
- badly designed conservation layouts.

A decrease in the ability of the channel to carry runoff water can be caused by:

- streambed and streambank cultivation
- badly designed and inadequately protected waterways
- removal of the natural vegetation, such as trees, in the channel
- silting-up of the channel.

Gully formation

As a result of disturbance of the balance or equilibrium in a water course, a channel forms where water is concentrated in the water course. The narrow cross-section of this channel results in increased velocities and scouring, and the depth and size of the channel is then increased. As this happens, differences in ground level occur at the head of the channel and

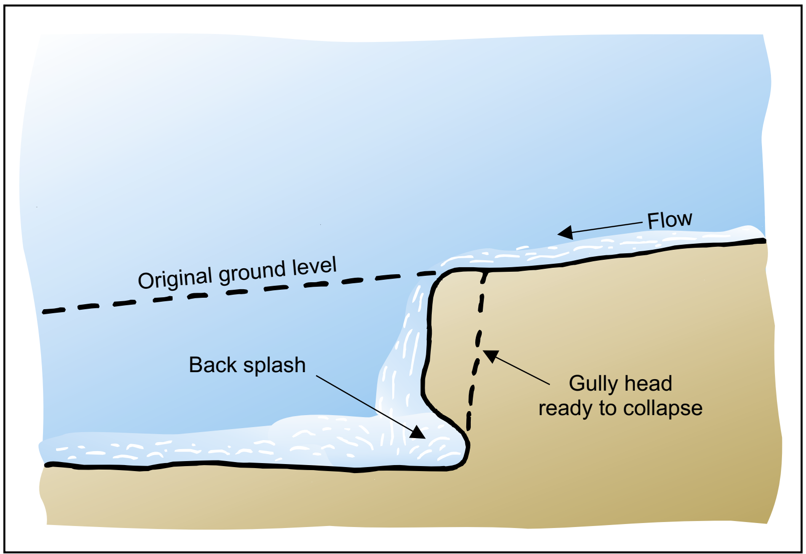

Figure 1. Example of gully head erosion.

erosion is accelerated. The result is that, as the head of the gully works back upstream, the height of the overfall increases. This overfall is the most actively eroding part of the gully. The waterfall action both scours the soil where it lands and also splashes and swirls against the face of the waterfall. The bottom of the face is eroded away leaving the top overhanging.

This eventually collapses leaving a vertical face, thus starting the cycle again (Figure 1).

Continuing runoff causes the gully to deepen and widen. As the gully extends up the catchment, lateral gullies branch out from incoming drainage lines, while sedimentation occurs in the lower part of it and at the outlet. Several gullies may therefore form in areas with long slopes and deep soils.

Reclamation and stabilisation

Reclamation and stabilisation are two different ways in which gully erosion can be approached. Reclamation is the action taken to reinstate soil levels to pre-erosion conditions, whereas stabilisation refers to action taken to arrest the erosion at a given stage and prevent further damage from taking place. Reclamation should be carried out wherever possible.

Principles of reclamation:

- recognise, eliminate or otherwise control the causes of erosion
- reinstate original ground levels
- establish effective vegetative cover in the watercourse.

Principles of stabilisation

- recognise, eliminate or otherwise control the cause of erosion
- stabilise the gully head
- stabilise the side and bed slopes of the gully
- establish effective vegetative cover in the lower waterway where the stabilised channel returns water to the natural watercourse.

Reclamation and stabilisation with vegetation

Vegetation slows down the velocity of the water by increasing the hydraulic resistance of the channel. If the velocity is sufficiently reduced then some of the sediment being carried by the water will be deposited. This can result in a situation where the vegetation will grow vigorously in the deposited soil, becoming denser and in turn trapping increasing amounts of silt, until the whole gully is filled up with silt.

Table 1. Some trees suitable for control of gully erosion and streambank stabilisation.

Botanical name	Common name	Position in stream channel	Frost resistance
Ficus sur	Cape fig	VR	
Ficus sycomorus	Sycamore fig	VR, PG	
Ficus natalensis	Natal fig	VR, PG	
Acacia karroo	Sweet thorn	P, VR	Excellent
Bridelia micrantha	Coast gold leaf / Mitseeri	P, VR	
Buddleja salvifolia	Sagewood	P, VR	Excellent
Celtis africana	White stinkwood	P	Very good
Clerodendrum glabrum	Tinderwood	P	Good
Combretum erythrophyllum	River bushwillow	VR	Excellent
Croton sylvaticus	Forest croton	P	
Faidherbia albida	Ana tree	VR	
Halleria lucida	Tree fuschia	P, VR	Very good
Harpephyllum caffrum	Wild plum	P, VR	Good
Ilex mitis	African holly	VR	Excellent
Macaranga capensis	Wild poplar	VR	
Maesa lanceolata	False assegai	P	Good
Myrica pilulifera	Broad-leaved waxberry	P, VR	Excellent
Phoenix reclinata	Wild date palm	VR	Good
Rauvolfia caffra	Quinine tree	VR	Good
Rhus chirindensis	Red currant	P	Very good
Syzygium cordatum	Waterberry / Umdoni	VR	Good
Trema orientalis	Pigeonwood	P	
Voacanga thouarsii	Wild frangipani	VR, PG	

PG - Trees with spreading roots that can grow in wet channels
VR - Vigorous rooting trees suitable for bank stabilisation
P - Poineer or precursor trees that are fast growing, can tolerate full sun when young and create partial shade for other trees and seedlings to follow

Source: Wetland Fix Part 4, Indigenous Plants Suitable For Streambank Stabilization and Channel Plug Development, compiled by Jon Wyatt Rennies Wetland Campaign

The difficultly in establishing vegetation in gullies is that the environment is usually inhospitable. The gully bed, banks and sides are often virtually sterile and plants are extremely difficult to establish. Suitable planting sites must therefore be prepared and plants selected. Plants of a spreading, creeping nature generally provide better cover than those with an upright habit.

Trees also play an important role in gully control by binding the soil with their roots and protecting the surface with a mulch of litter. Trees that tend to throw up suckers and form new trees wherever their roots are exposed by erosion, those with fibrous root systems, and those which cover the soil with a thick mat of leaves are ideal for gullies (Tables 1 and 2).

To establish grasses, bags of fertile soil are laid into shallow trenches dug in the bed of the gully so that they are about level with the bed. Small cuts are made in the bag and the grass seedlings are planted through the cuts.

Trees should be established in polythene bags and then planted out into carefully selected and prepared holes (the polythene bag is then removed). The trees should not be less than 600 mm in height, to avoid being eaten by small buck or mistaken for weeds by labourers. By the time the tree has outgrown its reservoir of fertile soil, it should be strong enough to survive the harsher conditions.

If the banks or sides of gullies have to be shaped then it is preferable to plant grass over these disturbed areas. Once the grass has become established, pioneer tree species can be planted to provide the first step in developing a natural succession of other indigenous trees.

Reclamation and stabilisation with structures

In many cases gully control by means of vegetation alone is not sufficient. Vegetation is often washed away or the soil depth is insufficient to support growth. In these cases there is a need to use structures as well.

The purpose of the structures is to reduce the flow rate of the water so that a silt-load will be deposited in the gully, eventually to the height of the structure itself.

There are many different types of structure available for combating gully erosion. Some are more durable than others. Temporary structures are also used to help hasten siltation. These are placed between permanent structures which are

Table 2. Some grasses suitable for erosion control in KwaZulu-Natal (Extracted from 'Common Veld and Pasture Grasses of Natal').

Name of species		Soils					Bioclimatic groups				
Botanical	Common	Wet	Compacted	Shallow	Fertile	Sandy	Coast Lowlands	Coast Hinterland	Mistbelt	Riverine (Tugela)	Lowland to upland (Zululand)
Hemarthria altissima	Red swampgrass	•					•	•	•	•	•
Microchloa caffra	Pinchushion grass		•	•				•	•	•	•
Setaria sphacelata var. torta	Creeping setaria						•	•	•		•
Stenotaphrum secundatum	Coastal buffalo grass	•				•	•	•		•	
Bothriochloa insculpta	Pinhole grass									•	•
Aristida congesta	Tassel bristlegrass		•	•							•
Eragrostis racemosa	Narrow-heart lovegrass		•				•	•	•	•	•
Imperata cylindrical	Cottonwood grass	•					•	•	•	•	•
Eragrostis curvula	Weeping lovegrass				•		•	•	•	•	•
Rhynchelytrum repens	Natal redtop		•	•			•	•	•	•	•
Pennisetum clandestinum	Kikuyu	•			•		•	•	•		

positioned at key points, such as at road and terrace crossings.

NOTE: The structure as shown is designed to reinstate ground levels exactly. If a depressed waterway is preferred, the structure can be lowered and the earth bunds will not be necessary

The type of structure required will depend on the severity of the erosion and conditions such as the gully depth, width, nature of the bed (i.e. sand, clay or rock), and the area of the catchment. The purpose of the structure should determine which type to use because different structures will be required for reclamation and stabilisation.

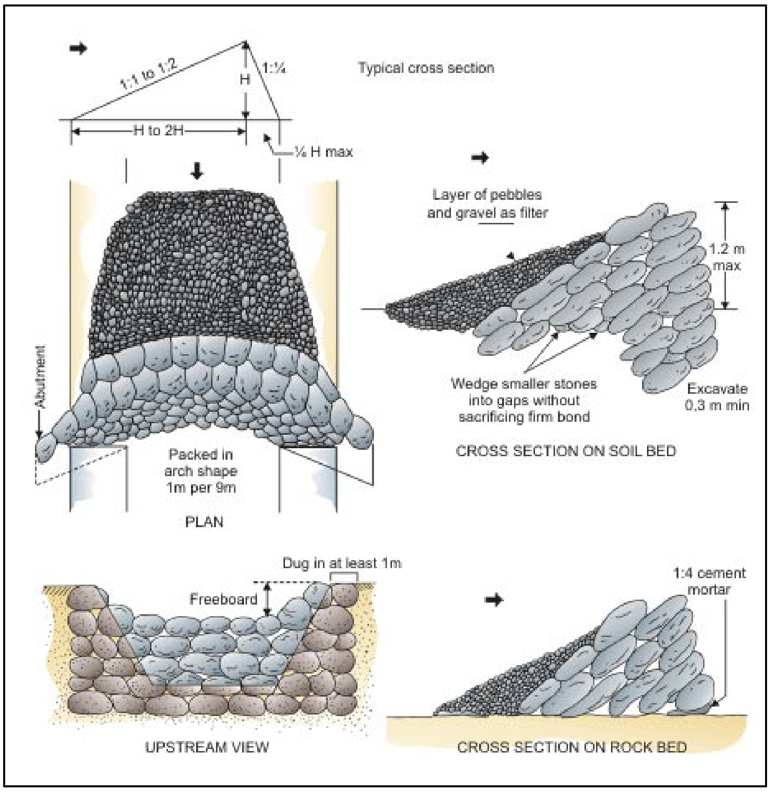

Figure 2. Stone packed structure.

Structures for stabilisation

Pole weirs, pole and brush weirs, and pole and wire checks are needed for catchments ranging from 5 to 20 ha. These structures can only be used where the gully bed is soil. Where the gully bed is rock, temporary stone packs for small catchments should be used, but the wall should not be higher than 0,4 m (Figure 2).

Where severe scouring or gullying occurs, pole, pole and brush, and pole and wire mesh checks are necessary for small catchments (Figure 3), provided the gully bed is soil.

Structure for reclamation

Semi-permanent or permanent structures are required for reclamation of gullies as these structures must remain in position for a long time. This is because it takes many years for the situation to be completely rectified. The type of structures required in the event of severe erosion are packed stone or stone in wire mesh checks or gabions, for small catchments if the gully bed is soil (Figure 4).

Permanent gabion weirs (Figure 5), masonry or concrete weirs and earth dams, should be used on solid rock beds for catchments greater than 5 ha in extent.

Structures for gully head control

The gully head is the most actively eroding part of the gully and requires attention. The type of structures required are Reno mattress chutes (Figure 6), gabions, sandbags (Figure 7), stone pitching, drop inlets and conveyor belting chutes.

The most successful structures for gully head control and check weirs are gabion weirs and Reno mattress chutes.

Gabion weirs: These consist of wire baskets filled with stone. The wire baskets are placed one on top of another and wired together. A trench is dug across the gully bed. A section of filter fabric the width of the gully and of sufficient length to wrap back over the finished weir height, is laid through the trench and upstream from it.

Rock-filled gabion baskets are placed on top of this filter fabric in the trench and built up until a weir is formed. The cloth is then folded back over the upstream face of the weir and covered with soil and rocks. There is a depression in the centre of the top of the weir to allow water to flow over it without cutting round the sides. (Figure 5).

Reno mattress chutes: These consist of long flat wire baskets filled with stones and placed side by side. These structures are usually placed at the gully head of where waterfall action is expected. The channel is shaped to the correct dimensions, a filter fabric laid, and the mattress placed on top of this. When the structure is complete the mattress should not protrude above ground level (Figure 6).

The main advantage of these structures is their flexibility which allows them to adjust, without any loss of strength, to the settlement which results from the scouring of the foundations. If galvanised wire is used their lifespan is greatly increased.

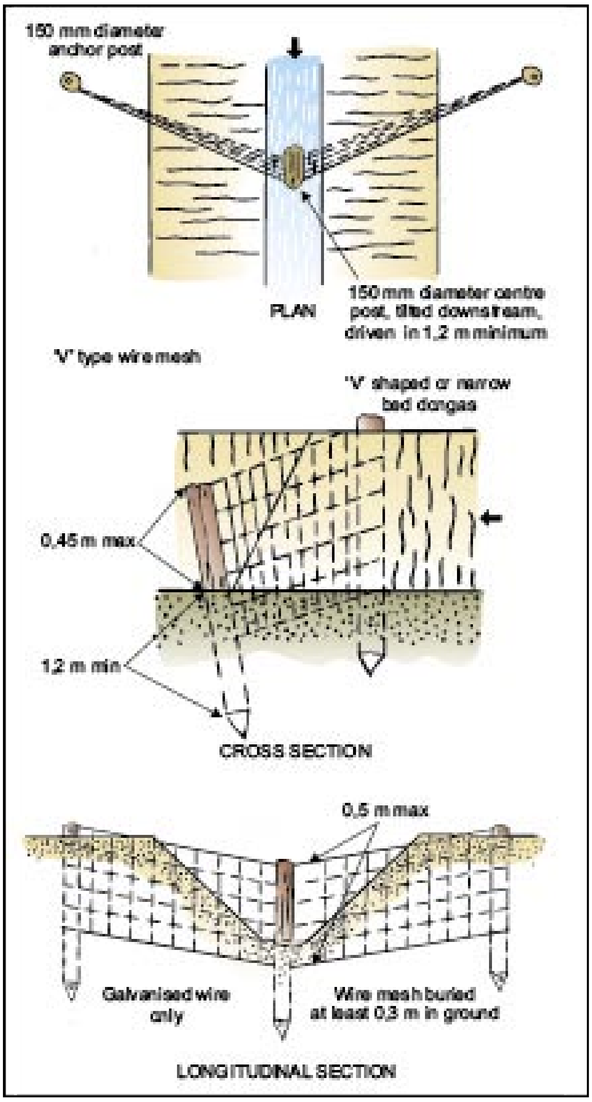

Figure 3. Pole and wire mesh check

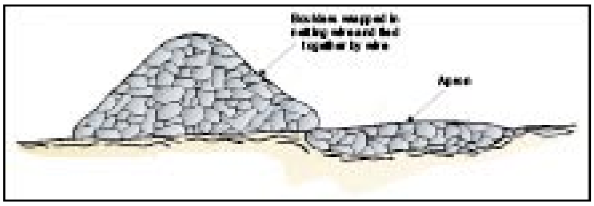

Figure 4. Stone in wire mesh.

Siting of the structures

Research has shown that a sediment trapped by a barrier or check across a gully forms a surface which slopes upwards in an upstream direction. Furthermore, the steepness of the sediment slope is inversely proportional to the size of catchment (as for a natural intact watercourse). It has been determined that the maximum sediment slope which can be achieved without the introduction of vegetation can be calculated by the following formula:

$$\text{Slope }\% = \frac{1{,}17\%}{A^{0{,}4}}$$

here A = area of catchment in km^2

This enables the designer to calculate the most efficient spacing of successive structures (Figure 8).

To make it more practical (although not as economical) for the farmer, the structure should be sited so as to ensure that its basin will initially flood and ultimately silt up as much of the gully bed as possible. The spacing of structures should ensure that the crest of the lower structure is level at least with the base of the one immediately above it.

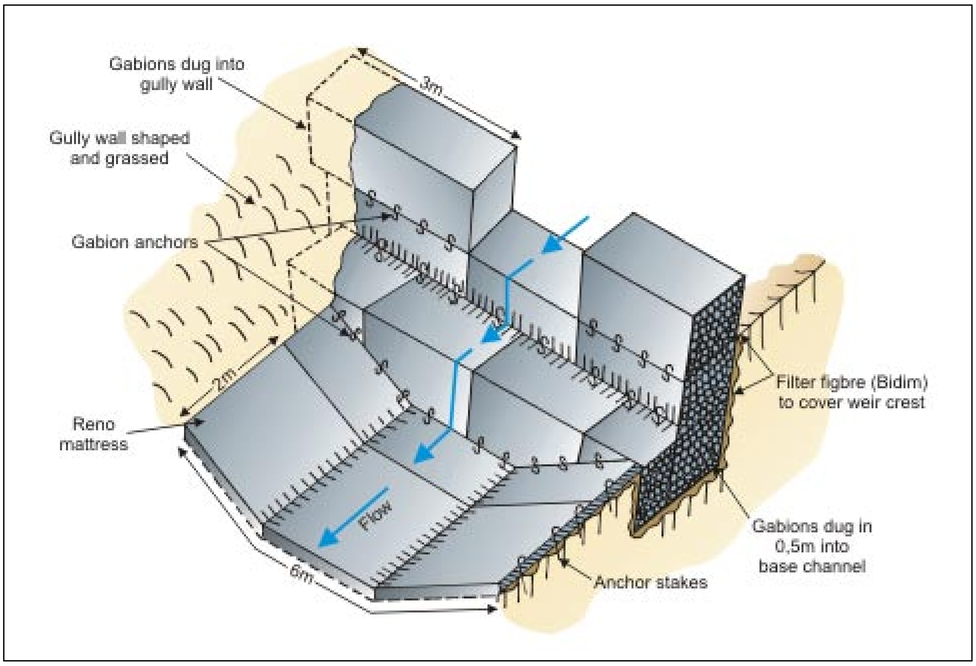

Figure 5. Gabion weir.

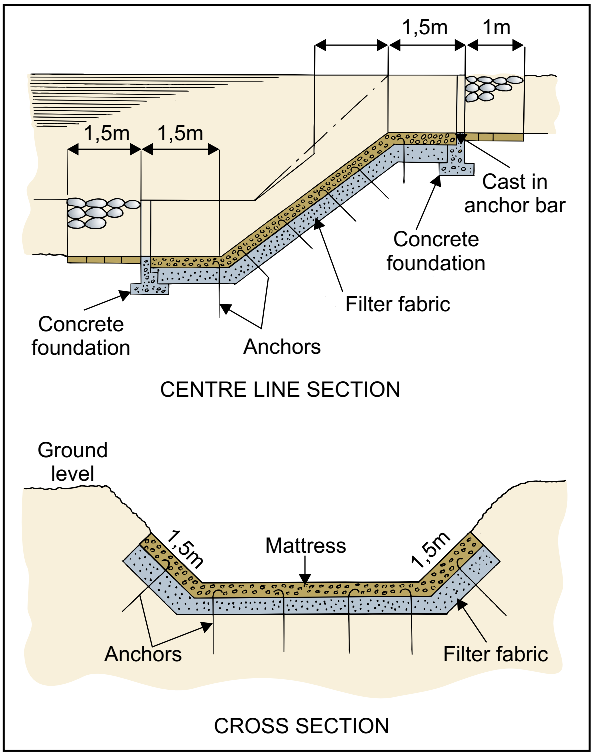

Figure 6. Reno mattress chutes.

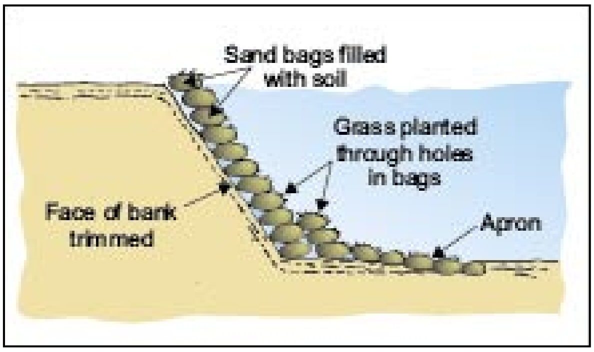

Figure 7. Sandbags at gully head.

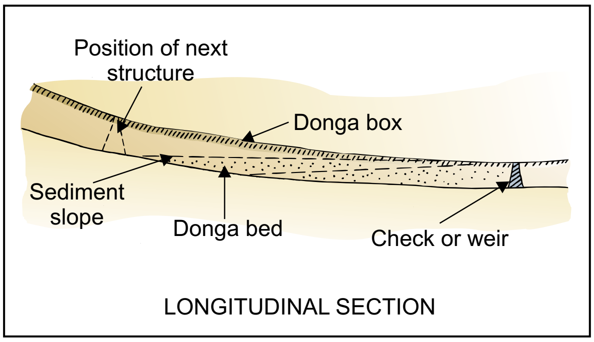

Figure 8. Sketch illustrating sediment slope.

Design of the overflow section of structures

The overflow section of a structure should be big enough to take the biggest probable flood. If it is too small, the floodwater will pass over the whole width of the structure and erode the banks on either side of it.

Reclamation structures: The dimensions of the overflow section must be the same as that required of the final waterway.

Large catchments and control structures: A minimum freeboard of 1 m should be used, except in structures where the spillway is fully protected. In this case the freeboard can be increased to 1,5 m and the overflow sections of these structures maybe narrower than the channel above and below them but the transitions must be adequately protected. The dimensions of the overflow sections are dependent on a number of factors. The rate of flow down the watercourse has been determined and the overflow section designed to accommodate it. The rate of flow will in turn depend on the condition of the catchment, i.e. soil type, ground cover and % slope.

The design of this overflow section requires the use of various graphs and tables, and should therefore be done by a specialist.

To prevent lateral seepage round the ends of the wall, structures must be carefully keyed into the banks. The key should extend into the bank on either side for a distance equal to the height of the wall. After the wall has been built the surrounding space must be carefully refilled with tightly packed impervious material.

The water falling over the structure strikes the ground with much force. Adequate protection must be provided to prevent scouring at the foot of the wall. Tightly packed stones or a Reno mattress chute would be ideal.

An important aspect of gully reclamation and stabilisation is the attitude of the grower towards both the repair and prevention of gullies. The grower should always have consciously in mind that:

- bare ground will always erode
- unprotected drops into waterways will always develop into gullies
- small gullies will inevitably become large gullies
- the cost of repairing a gully will increase at an accelerating rate
- prevention is better than cure.