GULLY MAINTENANCE AND MONITORING TECHNICAL REPORT

Reporting the learnings from the monitoring and maintenance of gully sites remediated through the Landholders Driving Change project.

By Bernie Claussen, NQ Dry Tropics

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NQ Dry Tropics sincerely thanks the landholders of the Bowen, Broken and Bogie (BBB) catchment for their involvement in monitoring and maintaining gully sites over the past three years. We also acknowledge the LDC panel members for their ongoing interest in project outcomes and their thoughtful contributions and advice.

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EXECUTIVE SUMMARY

The Gully Maintenance and Monitoring Project involved monitoring 24 remediated gully sites (19 small-scale and five large-scale) in the Bowen, Broken, Bogie (BBB) catchment during three and a half years (2022- 2025). Maintenance was done at some sites as required. This report communicates observed changes at sites, grazing management, maintenance costs and stability achieved. No major environmental impacts (droughts, floods or fire) affected sites between the time of the initial remediation works in 2019-20 and the end of monitoring in 2024-25. All the five large-scale sites and half of the small-scale remediated gully sites were in highly erodible soils (Sodosols). Another five small-scale sites only had works done in the catchment above the gully.

Remediation of the five large-scale sites involved experts at all stages and all sites were fenced to manage livestock access. Four sites had intensive earthworks to reshape, soil ameliorants applied (gypsum, fertiliser) and pasture seed sown. Structures installed included rock check dams, rock chutes and earthen banks. Of the four intensively treated large-scale sites two had reached a stable state by December 2024 and two were mostly stable. Maintenance was most often undertaken to repair rills and shallow gullies following rain and to stabilise soil around rock chutes. Observations suggest that, at most large-scale sites, the planted legume, *Desmanthus sp*., is increasing and grass species are decreasing. One causal factor may be a decline in fertility since initial works were undertaken because of a lack of nutrient cycling in the proto soil material. Some of the sites may have been negatively impacted by the short-term grazes implemented in the later years.

The 19 small-scale sites were remediated with some expert input, but mostly just in the design phase. Catchment works typically involved ripping, revegetation or banks with spreaders. Eleven of the 14 treated catchments achieved a stable site within four to five years and only 11 per cent of banks required maintenance. At the gullies there was either specific fencing installed around the site or a change in grazing management of the paddock with the gully. Earthworks tended to involve reshaping, fertiliser and seeding, and rock chutes or gully plug dams. Of the 14 treated small-scale gullies only two were considered stable in December 2024 and neither were in Sodosol soils. One gully in Sodosol soil was deemed unstable. The remaining 12 were either 'mostly stable' or 'partly stable'. All sites that were reshaped and seeded required some maintenance, as did all six rock chutes. Data and observations indicate that the management of grazing at small-scale sites is an important influence. At the small-scale sites, when land managers made grazing decisions with a 'high focus on improving land condition', gullies were more likely to progress further towards a stable state. The more typical grazing management ('moderate focus') of resting the site in the wet season and grazing along with the larger paddock for one or more months in the dry season appeared detrimental to many remediated sites.

Remediated gullies, both large and small-scale, in highly erodible soils in the BBB can reach a 'stable' state, as defined in this report, within four to five years. However, there are several caveats:

- There is a low chance of achieving this – only 10 per cent of sites (two of 19) in Sodosols achieved a 'stable' rating and these were both large-scale works.
- Four years is likely the shortest time one could expect to achieve stability, with high quality implementation, timely maintenance and favourable weather.
- The definition of 'stable' used in this report is not comparable to the stability that would be found in healthy landscapes with functional nutrient and water cycles, and no erosion. Sites considered stable in this report are likely to lack resilience.

Sixteen of the remaining 17 treated gullies that were not yet fully stable, were judged to be on the trajectory to achieving stability (mostly stable or partly stable). However, their success hinges on future events; particularly monitoring, maintenance, grazing activity and extreme weather. One large-scale site (Site 5) is a sound demonstration of a low impact approach to facilitating natural regeneration on sites where intensive land reshaping and soil amelioration is deemed not cost-effective. The small-scale gullies in Sodosol soils proved difficult to remediate with bare areas slow to revegetate. In contrast, gullies in Vertosol soil healed more readily. The catchments of Sodosol gullies may stabilise within three years whilst those in the Downs country Vertosol soils may take only two years.

The costs of maintenance for the large-scale sites was relatively low and within a generally acceptable proportion of initial costs (1.7-9.9 per cent). In contrast, the cost of maintenance works at small-scale sites was high, often more than half the cost of the initial works.

Recommendations from this project include:

- Sufficient time is spent in the early stages of planning to understand the erosion processes occurring at a site to ensure the efficacy of remediation works.
- Remediation plans are informed by a site-specific risk assessment/s that provides logic to the approach taken, suggests the duration of monitoring and outlines the likely issues to monitor.
- Suitably qualified people are available to plan, supervise implementation and oversee the monitoring and maintenance of engineered structures and revegetation (e.g. five -10 years).
- Monitoring, maintenance and grazing schedules are worked out collaboratively, involve grazing specialists and are documented.
- The requirements of the landholder with regard to protecting the revegetation, monitoring and maintenance responsibilities are clearly understood, and are formally agreed to by all parties.
- Low impact remediation methods are considered for improved cost-effectiveness or when the risk assessment indicates that it is pertinent to do so.
- The revegetation approach could be improved by planting native pasture species and trait-specific plants, using biological ameliorants, irrigating and mulching.
- Rock chutes installed in gullies with dispersive soils are likely to require on-going maintenance even when they are designed and installed following best practices.

As a consequence the planning stage is likely to take longer and require more collaboration, but is likely to achieve better remediation outcomes and greater cost-effectiveness.

INTRODUCTION

The Gully Maintenance and Monitoring project involved the annual inspection and maintenance of 24 remediated gully sites (19 small-scale and five large-scale) within the Bowen, Broken, Bogie (BBB) catchment during three and a half years (2022- 2025). A small-scale gully is defined as one with a maximum depth of 3m and is typically on hillslopes. A large-scale gully has a maximum depth greater than 3m and is typically a gully complex, lower in the landscape. The project objectives were to:

1. Monitor the gully stability and carry out critical maintenance that will provide confidence in investment and sediment savings.
2. Engage with landholders to improve their understanding of gully maintenance requirements.
3. Generate longer term learnings around time frames and maintenance costs associated with maintaining gullies in a stable condition.

Project activities included:

- evaluating the monitoring methodology and monitoring plan;
- undertaking and reporting on the annual monitoring of all sites;
- managing critical maintenance of sites as required;
- communicating with landholders regarding site condition and maintenance required; and
- producing this document, a technical report to communicate project findings.

This technical report addresses Objective 3; learnings from the project and includes results of the 24 sites; their progress towards stability, the maintenance required, maintenance costs, and overall cost effectiveness. The discussion will focus on observed patterns in the results associated with characteristics such as soil types and treatments that may help inform future gully remediation work.

BACKGROUND

THE INITIAL TREATMENT PROJECT

The 24 remediated gully sites monitored in this project were treated under the Landholders Driving Change (LDC) project (also known as the Burdekin Major Integrated Project) between 2017 and 2021. These gully remediation sites formed part of the 95 LDC practice changes completed with graziers and summarised in Year 4 Performance Report (NQ Dry Tropics, 2022). The projects saved an estimated 10,600 tonnes of fine sediment reaching the Great Barrier Reef (GBR), half of which was attributed to gully remediation treatments.

THIS MONITORING AND MAINTENANCE PROJECT

Towards the end of the project, partners recognised the need for ongoing monitoring and maintenance work to evaluate the most effective methods (and cost-effective methods) for reducing the sediment (and particulate nutrients) generated and delivered from gullies. It was decided that ongoing monitoring could enable the testing of assumptions on how long treatments would last, the required level and frequency of maintenance, and whether reduction in fine sediment exports continued. This project was funded from underspend in this Landholders Driving Change project.

SITE CHARACTERISTICS

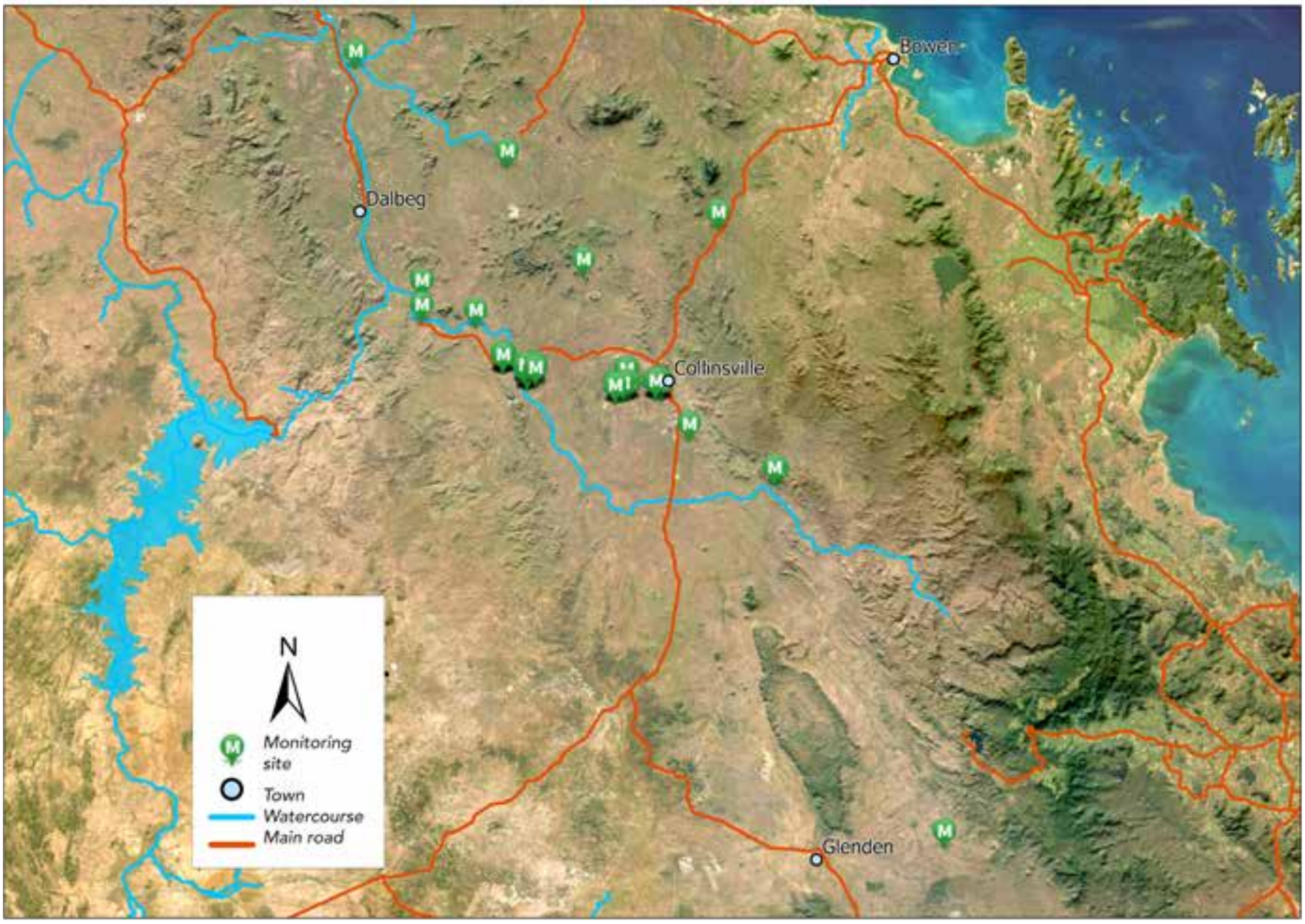


Figure 1. Map indicating the position of the 24 gully sites in the monitoring and maintenance project.

LOCATION

The 24 sites are situated in the catchments of Bowen and Bogie rivers and stretched from the lower Burdekin River in the north to the upper reaches of the Little Bowen River in the south (Figure 1). Most of the sites were along the Bowen River and its tributaries.

This region is considered part of the dry tropics region of Queensland. Average temperatures range from a high of 34 °C in December to a low of 9.5°C in July. The bulk of rainfall occurs in the summer months – December to March. Rainfall during the monitoring period is detailed in the next section.

SOILS AND LAND TYPE

Many of the sites had similar soil, vegetation and landform characteristics. Under the Burdekin region Grazing Land Management land types classification (Queensland Department of Agriculture and Fisheries, 2011) the five large-scale sites were in the 'Loamy alluvial' land type and, according to soil tests, were in Sodosol soil type. Sodosols are one of 15 larger soil groups (Orders) under the Australian Soil Classification system (CSIRO, 2025). Sodosols are typically fragile soils that have structural (e.g. distinct topsoil and subsoils) and chemical (e.g. high sodium) properties that make them prone to erosion.

Twelve of the 19 small-scale sites were mapped as being in the 'Narrow leaved ironbark in deeper soils' land type. Four of these had soils that were classified as Sodosols due to dispersive properties or soil test results (i.e. %CEC for Sodium >6). The remainder had slightly less erodible soils such as Chromosols that slaked but didn't disperse in water. The remaining seven small-scale gullies were in 'Loamy alluvials' (two sites), 'Clayey alluvials' (two sites), 'Downs country' (two sites) and 'Box country' (one site). Most of the soils at these seven sites were Sodosols, Vertosols or Chromosols. Table 2 summarises the soil characteristics for each site.

RAINFALL

Rainfall, and the subsequent runoff it produces, is an important environmental factor affecting the success of remediation works at gully sites. High intensity rainfall events and flooding can damage a site and, at the other extreme, the lack of rainfall (drought) will hamper vegetation growth and, therefore, site recovery.

To assess the impact that rainfall may have had on the remediation of the 24 sites, rainfall data from six nearby Bureau of Meteorology (BOM) gauges was examined. In addition, three of the sites had site specific rainfall data collected by hydrological monitoring stations that CSIRO installed to study the effectiveness of gully remediation on runoff and water quality (Hawdon et al., 2025, p.13). This data has helped inform this report on rainfall during the monitoring period.

Yearly rainfall totals were around average and there were no regional flood events or droughts that impacted the remediated sites between the time they were remediated (2019-2021) and 31 December 2024 (See Appendix 1. Rainfall data). Total yearly rainfall across all sites during the monitoring years (2022-2024) was close to the Bureau of Meteorology's long-term median. Long term median rainfall for the western BOM rainfall stations (Collinsville Post Office, Gatton Vale and Strathmore) ranges from 626 (Gatton Vale) to 706mm annually (Strathmore). During the three years of monitoring all yearly totals from these three gauging stations fell within 573mm (2024) and 825mm (2023) - both extremes were recorded at Gatton Vale. Gatton Vale experienced an early start to the 2023/24 wet season so 2024 was not particularly dry. Long term median rainfall for the Eastern BOM rainfall stations (Mt Pleasant, Strathbogie and Millaroo) range from 648 (Strathbogie) to 736mm (Millaroo). During the three years of monitoring all yearly totals from these three gauging stations are within 703mm and 848mm/year. Yearly rainfall data measured at three gully remediation sites (Mt. Wickham, Glen Bowen and Strathbogie) by CSIRO stations and presented in (Bartley et al., 2025, Pp.32, 36, 39) reflect the BOM data. (Refer to rainfall graphs in Appendix 1).

However, these average conditions are unlikely to tell the full story. Whilst overall, weather at the sites appears to have been mild and favourable for remediation and revegetation; some sites are likely to have been impacted by short high intensity rainfall events. According to BOM IFD data a 60mm 1.5hr fall at Collinsville is a rare event; it has a 2 per cent AEP (annual exceedance probability; 50yr ARI; ~ 1 in 50yr event). In the absence of rainfall intensity records, the highest daily rainfall totals for the six gauging sites were collated; arbitrarily chosen as daily rainfall over 60mm (see Table 1).

Note that the Collinsville Post Office recorded four of these events between January 2020 and December 2024 while the Mt Pleasant Alert, approximately 33km closer to the coast, recorded nine such events. A similar pattern is evident across the region, with fewer high rainfall events west of the coastal ranges (Collinsville, Strathmore, Gatton Vale) compared to within the coastal ranges (Mt Pleasant, Strathbogie and Millaroo). If some of these daily rainfall totals fell within hours on remediated sites such as during a storm they are likely to cause rilling and scouring, and hinder revegetation progress.

In conclusion, while there were no widespread floods or droughts since initial works were carried out at these 24 sites, evidence suggests that there were high intensity rainfall events that damaged remediated sites, particularly in the initial years after works, 2020 and 2021. Such events are typical for tropical areas and so should be expected and planned for.

Table 1. High daily rainfall recordings (>60mm) to indicate rainfall events that are more likely to have damaged the 24 remediated sites through high runoff.

BOM station	Nearby Projects	2020	2020	2021	2021	2021	2021	2022	2022	2022	2022	2023	2023	2024	2024	2024	2024
		Jan	Dec	Jan	Mar	Aug	Nov	Jan	Feb	Oct	Nov	Jan	Dec	Jan	Feb	Nov	Dec
Gatton Vale	18, 19, 20						72				88	79		79			
Collinsville	7, 8, 9, 10, 11, 12, 13, 15, 16		126						100			85					73
Strathmore	1, 2, 3, 4, 5, 6, 21, 23	112		70							63	74		67			
Mt Pleasant Alert	14		97	95				64		60		137	75		69	87	62
Strathbogie Alert	24, 25	80		188		61		63				133					82
Millaroo	22	80		73	80	74		75	73			135		79			60

FIRE IMPACTS

One of the sites was affected by fire during the first five years following remediation works. This was a small-scale site 25 where a small fire burnt the wood that was put in the gully head between 2022 and 2023 monitoring.

SITE CLUSTERS - SCALE, SOIL AND LANDSCAPE POSITION

The 24 sites have been divided into three main groups to enable similar sites to be compared. These three groups are colour coded in Table 2:

1. Large-scale sites (yellow rows - 5 sites),

2. Small-scale sites that treated the gully, and the catchment if necessary (blue rows - 14 sites) and,

3. Small-scale sites that treated the catchment only; the active gully was not treated (green rows - 5 rows).

All five of the large-scale sites have Sodosol soils of alluvial origin and are lower in the landscape. Three sites had catchments contributing runoff into the gully.

Of the 14 small-scale sites that had the gully treated to some degree (Blue in Table 2), 11 were classed as hillslope gullies and the remaining three alluvial gullies. Sodosol, Vertosols and Chromosol are well represented in this group.

The third major group (5 sites, Green in Table 2) are sites where only the contributing catchment was treated. Two of these sites were in alluvial terraces of low relief while the remaining three were more directly connected to hillslopes. A variety of soil types are represented in this group as described in Table 2.

Table 2. A summary of the 24 gully erosion sites - site characteristics, design process and remediation activities.

Site	Year remediated	Gully scale	Soil characteristics	Landscape components that were treated	Expert input	Grazing management	Remediation activity 1	Remediation activity 2	Remediation activity 3	Remediation activity 4	Remediation activity 5
1	2019	Large	Hypernatric Brown Sodosol, dispersive	Alluvial gully & catchment	Engineer designed & supervised	Stock exclusion then short grazes	Contour line rehab. in catchment	Reshape, ameliorants, seed	Rock chutes		
2	2020	Large	Yellow or brown Sodosol	Alluvial gully & catchment	Engineer designed & supervised	Stock exclusion then short grazes	Reshape, ameliorants, seed	Porous check dams	Cut off wall	Bund	
3	2020	Large	Yellow or brown Sodosol	Alluvial gully & catchment	Engineer designed & supervised	Stock exclusion then short grazes	Reshape, ameliorants, seed	Rock chutes	Porous check dams	Cut off wall	
4	2020	Large	Yellow or brown Sodosol	Alluvial gully & catchment	Engineer designed & supervised	Stock exclusion then short grazes	Contour line rehab. in catchment	Reshape, ameliorants, seed	Rock chutes	Porous check dams	Bund
5	2020	Large	Yellow or brown Sodosol	Alluvial catchment & light reveg. of scarps	Engineer designed & supervised	Total stock exclusion	Contour line rehab. in catchment	Limited to gully scarp -Seed, ameliorants	Rock chute	Porous check dams	Bunds
7	2019	Small	Chromosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock management improved	Banks and spreaders	Gully reshape	Seed		
8	2019	Small	Chromosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock management improved	Banks and spreaders	Gully plug dam	Seed		
9	2019	Small	Sodosol	Alluvial gully - (bywash and adjacent terrace)	Expert written advice, Limited supervision	Minimal change in grazing	Rock chute	Reshaping	Seed		
10	2019	Small	Sodosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock management improved	Contour line rehab in catchment	Seed	Repair diversion bank	Bunds	Rock chute
12	2020	Small	Sodosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock exclusion - 2 years	Contour line rehab in catchment	Seed			
13	2020	Small	Sodosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock management improved	Contour line rehab in catchment	Rock chute	Porous check dams		
14	2019	Small	Black/ brown Chromosols & Brown Sodosols	Alluvial gully (valley)	Expert designed & supervised	Stock exclusion - 2 years	Gully plug dams	Porous check dams			
15	2019	Small	Vertosol	Hillslope gully	Expert written advice, Limited supervision	Minimal change in grazing	Gully plug dam	Bank and spreader			

Site	Year remediated	Gully scale	Soil characteristics	Landscape components that were treated	Expert input	Grazing management	Remediation activity 1	Remediation activity 2	Remediation activity 3	Remediation activity 4	Remediation activity 5
16	2019	Small	Vertosol	Hillslope gully	Expert written advice, Limited supervision	Minimal change in grazing	Gully plug dam	Bank and spreader			
20	2019	Small	Sodosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock exclusion - 4 years	Contour line rehab in catchment	Gully head fill	Manure treatment		
22	2020	Small	Sodosol	Alluvial gully only (floodplain)	Expert written advice, Limited supervision	Stock exclusion - 2 years	Bund	Reshape, ameliorants, seed	Rock chutes		
23	2019	Small	Vertosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Sound stock management continued	Banks and spreaders				
24	2020	Small	Vertosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Sound stock management continued	Banks and spreaders	Rock chute			
25	2020	Small	Grey duplex	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock exclusion - 2 years	contour line rehab in catchment	Seed			
6	2019	Small	Alluvial sandy	Hillslope catchment only	Expert written advice, Limited supervision	Minimal change in grazing	Banks and spreaders				
21	2020	Small	Alluvial terrace, Kurosol	Hillslope catchment only	Expert written advice, Limited supervision	Minimal change in grazing	Banks and spreaders				
18	2019	Small	Vertosol - catchment work Chromosol - gullies	Hillslope catchment only	Expert written advice, Limited supervision	Minimal change in grazing	Banks, no spreaders				
19	2019	Small	Kurosol	Hillslope catchment only	Expert written advice, Limited supervision	Stock exclusion- 1 year	Soil ameliorants,	Seed			
11	2019	Small	Chromosol	Hillslope catchment only	Expert written advice, Limited supervision	Sound stock management continued	contour line rehab in catchment	Seed			

TREATMENTS AT LARGE-SCALE SITES

All large-scale sites were designed and supervised by engineers and revegetation specialists. The components of each large-scale site treatment is summarised in Table 2. The landholders had limited input during implementation, except for the construction of the fence. All sites had standard permanent fencing installed to enable grazing to be restricted. Four of the five sites had fencing immediately around the area of work, while the remaining site (Site 1) had fencing that included the adjacent riparian area and was thus a larger area.

The collated numbers of the erosion control structures and treatments implemented across the five large-scale sites are displayed in Figure 2. All of the catchments (pre-existing or created by reshaping) were treated with ameliorants/ fertiliser and planted with pasture seed along the contour. Four of the five sites had the gullies reshaped, ameliorants of gypsum and some form of fertiliser/organic matter applied (e.g. granular fertiliser, mill mud, bagasse or hydro-mulching) and pasture seed sown (pasture mixtures including legume species). One site had four distinct rehab areas; therefore the total displayed in Figure 2 is seven. Sites 2, 3 and 4 employed water trucks to achieve ideal soil moisture for compaction while Site 1 compacted dry. Site 5 concentrated efforts on treating the catchment; the gullied area was not reshaped or treated intensively.

None of the large-scale sites used irrigation or planted woody stems. The many porous check dams installed were constructed of gabion-sized rock and are mostly sited in the channels of reshaped gullies – typically about every 5m (horizontal distance) (refer to Figure 3). The bulk of these check dams are at Sites 2, 3 and 4. These totals include additions during maintenance work: one bund and three rock check dams across three sites.

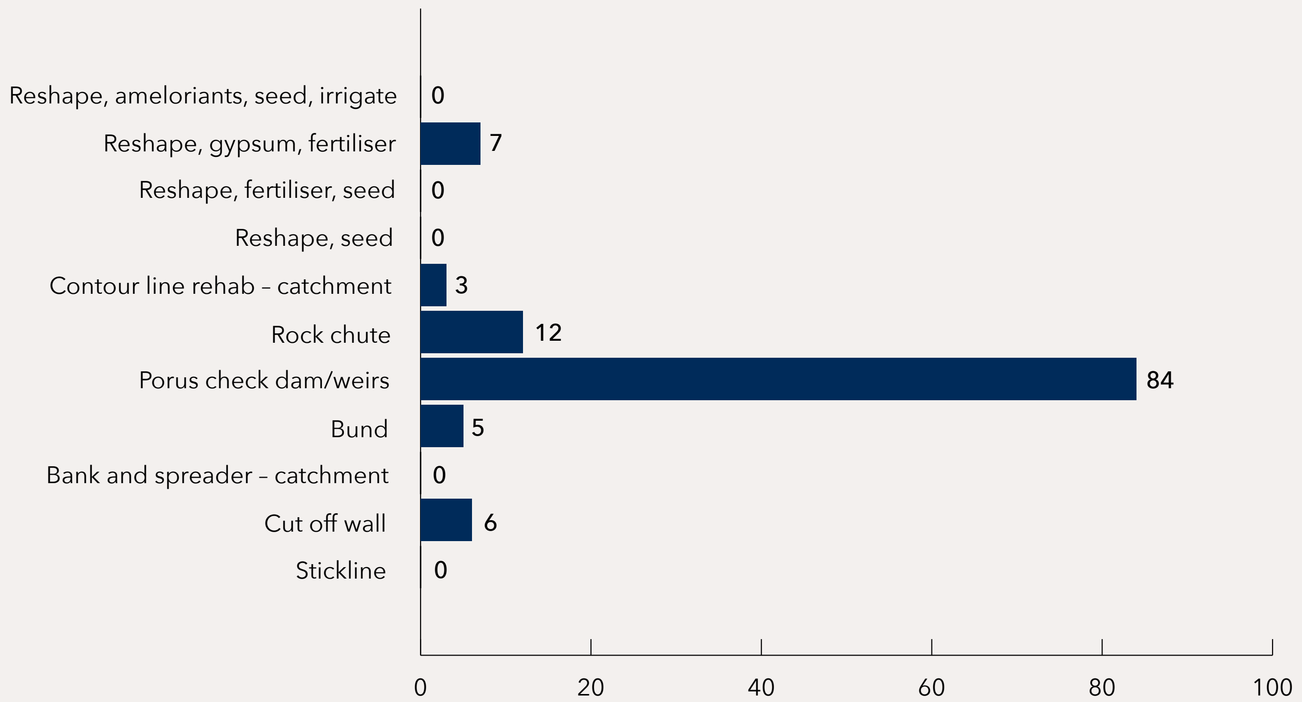


Figure 2. Total erosion control structures and treatments at the large-scale gully sites (from inital construction until December 2024).

Figure 3. Porous check dams constructed with gabion-size rock on the large-scale Site 1 following the reshaping, ameliorants, seeding and fencing.

TREATMENTS AT SMALL-SCALE SITES

For the small-scale sites, suitably qualified specialists (e.g. soil conservation officers and other experienced practitioners) were engaged to work with landholders and NQ Dry Tropics to devise and write remediation plans. At this early stage, decisions were made around whether the catchment, the gully, or both, would be treated.

Nine of the 19 sites had the gully and at least the immediate catchment treated while five sites had only the catchment treated and at another five sites only the gully was treated, the catchment being in good condition or, for one site, the catchment was a council road. (Figure 4 and Table 2).

During the site visit(s), the landholders were supported by NQ Dry Tropics staff and soil conservation experts to build their understanding of, and capacity to manage, erosion. There was a strong focus on grazing land management

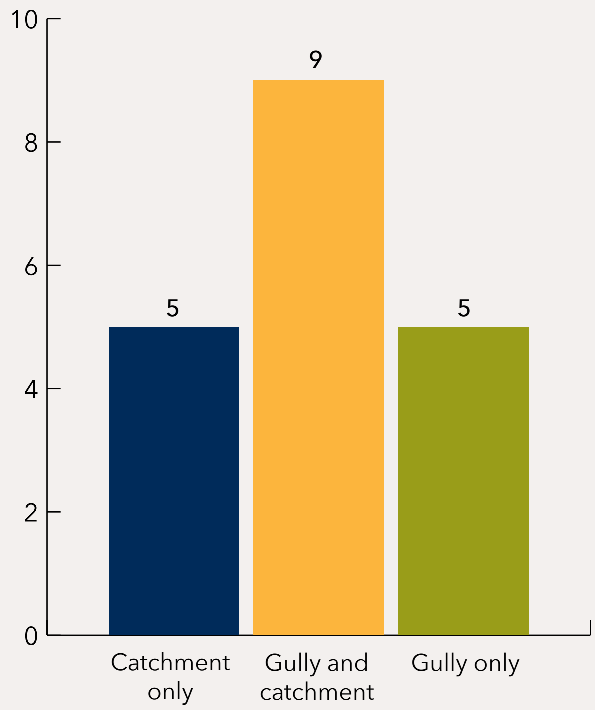


Figure 4. A breakdown of the landscape features that were treated at the 19 small-scale gully remediation sites.

and planning fencing to control cattle. These are essential prerequisite activities because having high ground cover and plant diversity on site is fundamental to successfully remediating small-scale gullies for the long term (Wilkinson et al., 2022, p.22; Day & Shepherd, 2019, p.20).

Seven of the 19 sites had fencing installed to better manage grazing of the eroded area. Four of these sites had temporary electric fencing with a solar-powered energiser. The remaining three had standard fencing of wooden or steel posts and three strands of wire. At the remaining 12 sites landholders managed grazing via their established grazing and rest regimes, some modified to promote recovery of the eroded area such as giving the site a rest every wet season.

The structures and treatments for the catchments were banks and spreaders, contour line rehabilitation (e.g. rip, scarify, fertilise, seed), bunds, stick lines on the contour and some porous check dams.

Direct gully treatments and structures included reshaping, gypsum and fertiliser applications, seeding, rock chutes, porous check dams and weirs. One of the reshaping sites did not involve soil disturbance; rather filling the active gully heads (Figure 6). The collated numbers of structures and treatments implemented across the 19 small-scale sites are displayed in Figure 5.

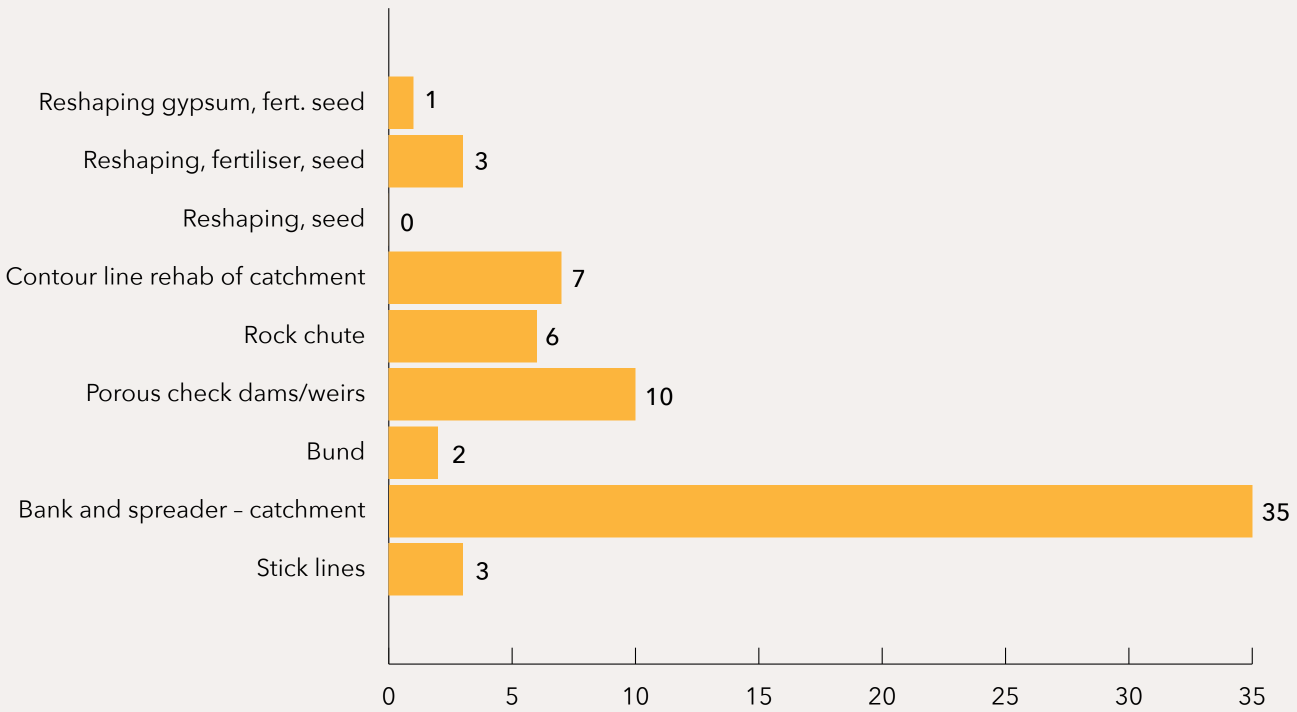


Figure 5. Total erosion control structures and treatments at the small-scale gully sites.

Figure 6. One of the gully heads that was treated by reshaping but with minimal soil disturbance – a rock and soil fill, fertiliser (cow manure) and seeded at Site 20. Note the lack of tussocks after the unplanned graze in 2024. This is discussed in the results section.

METHODS

MONITORING METHODS

The monitoring approach was consistent across the 24 sites. Sites were monitored in the dry season during the years of 2022, 2023 and for most sites in 2024. Sites that underwent maintenance in the 2024 dry season were monitored in early 2025 instead of 2024 to capture the effects of the work done.

The monitoring method used follows recommendations in the Gully and Streambank Toolbox (Wilkinson et al., 2022, pp.71-73). Most of the data was recorded in two applications on the Survey 123 platform: the Land Condition Assessment Tool (LCAT) and the Gully Monitoring Tool (GMT) developed by Queensland Department of Agriculture and Fisheries (DAF). These tools formed the bulk of each site's yearly report. Other observations included the rainfall and grazing history for the past 12 months, maintenance requirements and landholder communications. In addition, drones were used to capture aerial footage before, during and after maintenance activities.

The LCAT (Advanced version) offers insight into a site's progress towards attaining a stable soil and resilient, diverse vegetation, and therefore, is used here to address a key objective of this study - to monitor the level of stability of sites; and their progress towards long-term stability. Whilst the Advanced LCAT collates site data, including erosion, puts some measurement around land condition, it was not designed to assess gully stability, rather land condition is used as a proxy for gully stability. *"The LCAT is designed as a simple, fit-for-purpose science-based method, to determine ABCD grazing land condition; indicate potential hazards related to ecological processes or grazing land management principles; and to provide land condition data for analysis. It is not intended to replace quantitative or more rigorous assessment methods"* (Hassett, 2020, p. 4).

The advanced LCAT includes in the assessment the standard components, such as plant diversity, plant density, desirable or undesirable species, soil condition, feral animals and grazing pressure, in addition to indicators of woody vegetation health (understorey and overstorey) and details on the nature of soil erosion at the site. LCAT results are presented in four main ways: A score out of 100, an A, B, C, D rating, environmental risk alerts levels and, important to this study, a list of the key drivers that informed the result (i.e. that reduced the land condition score).

This report concentrates on changes in LCAT scores at sites during the three years of monitoring and notes the key drivers of land condition. This data was used to inform and verify field observations regarding sites' progress towards no erosion (stability). As the sites were remediated in 2019 and 2020, and this monitoring project began in 2022, the first two or three years following remediation are not tracked. In the absence of LCAT scores before the works were done, control sites were established where possible. In addition, a CSIRO study investigated the effectiveness of remediation activities in gullies from 2017 - 2024. Three of the CSIRO sites were also monitored in this project - Sites 1, 2 and 24. In addition to collecting and analysing runoff and suspended sediment, the CSIRO study assessed a number of vegetation measures, including ground cover and biomass to evaluate vegetation recovery. This data helps to inform this report, particularly to understand changes in stability prior to 2022.

The GMT application was developed by the Department of Primary Industries (DPI) following the Gully and Stream Bank Toolbox recommendations for monitoring gullies (Wilkinson et al., 2022, Pp.71-74). Information captured in this app includes photographs, rating the integrity of structures, ground cover and plant species immediately upslope of structures.

MAINTENANCE METHODS

Between 2022-2024 there were two lots of maintenance organised and funded through the project. Cluster 1 occurred in the dry season of 2023 and Cluster 2 in 2024. Important factors considered in prioritising sites for maintenance work included: the risk to the initial investment if maintenance wasn't undertaken and the associated sediment saving, the cost of the initial investment, and the amount of work required. Three of the small-scale sites had some modifications done to the initial design as part of maintenance, to improve the chances of success.

Maintenance works took three different pathways. For the five large-scale sites the engineering contractor who undertook the initial construction project managed the maintenance. The project funded the maintenance of large-scale gullies after maintenance budgets from the initial project were expended. For the 19 small-scale projects, two landholders did earthworks maintenance on their site (in-kind) as necessary after the first rains. For five other sites maintenance was managed by NQ Dry Tropics and funded by the project.

RESULTS

STABILITY OF SITES OVERVIEW

The results of the monitoring and maintenance of the 24 sites is summarised in Table 3. This table retains some columns from Table 2 and maintains the same order of the projects and colour coding to ease cross-referencing. All 24 gully sites were assigned a stability rating in January 2025: stable, mostly stable, partly stable or unstable. All available data collected from the time of construction to January 2025 was used to make this judgement on the stability of the gully erosion. Refer to Appendix 2 for further details on results of the land condition assessments.

Table 3. Summary Results Table

Site ID	Year of work	Scale	Soil characteristics	Land scape components treated	Specialist input	Summary of Initial treatment	Significant Inkind	Maintenance undertaken under GMM project	Gully stability Dec 2024	Driver of reduced land condition 1	Driver of reduced land condition 2	Driver of reduced land condition 3
1	2019	Large	Hypernatric Brown Sodosol, dispersive	Alluvial gully & catchment	Engineer designed & supervised	Stock exclusion, then control grazing Contour line rehab in catchment Reshape, ameliorants, seed Rock chutes	Nil	2020: Gully 1a & b, Gully 10, Gully 2 - top chute and Chute 5- repair reoccurring slumping/tunneling, constructed sediment trap, new berm, tidying up. Gully 1b & chute 5- 3rd time to repair. G1 tunnel in undisturbed soil repaired and Gully 2 hole repaired. 2024: Reoccurring slumping /tunnelling repaired at Chutes 5, 5HC, 8, 9, 10, Gully 2HC, Gully 3HC and Gully 4HC. Bund extended at Chute 5HC area.	Mostly stable	Soil erosion	Dominant pasture sp. (Desmanthus)	
2	2020	Large	Yellow or brown Sodosol	Alluvial gully & catchment	Engineer designed & supervised	Stock exclusion Reshape, ameliorants, seed Porous check dams Cut off wall Bund	Nil	2021- Repaired major rills. 1 new check dam, 1 check dam repair	Stable	None		
3	2020	Large	Yellow or brown Sodosol	Alluvial gully & catchment	Engineer designed & supervised	Stock exclusion contour line rehab in catchment Reshape, ameliorants, seed Rock chutes Porous check dams cut off wall	Nil	2021 - Repaired 2 cut off walls, repaired rills & mulch, & 3 check dams, added 1 bund, 1 new check dam.	Stable	Dominant pasture sp. (Desmanthus)		

Site ID	Year of work	Scale	Soil characteristics	Land scape components treated	Specialist input	Summary of Initial treatment	Significant Inkind	Maintenance undertaken under GMM project	Gully stability Dec 2024	Driver of reduced land condition 1	Driver of reduced land condition 2	Driver of reduced land condition 3
4	2020	Large	Yellow or brown Sodosol	Alluvial gully & catchment	Engineer designed & supervised	Stock exclusion contour line rehab in catchment Reshape, ameliorants, seed Rock chutes Porous check dams Bund	Nil	2021 - Repaired 3 rills & 1 new check dam, added 1 check dam.	Mostly stable	Soil erosion	Dominant pasture sp. (Desmanthus)	
5	2020	Large	Yellow or brown Sodosol	Alluvial catchment & light reveg. of scarps	Engineer designed & supervised	Stock exclusion Contour line rehab in catchment Rock chute Bunds Limited gully scarp treatment -Seeding of halophyte/ moonscape zone and fertilising grassed flats of the creek	Nil	2021 & 2024 Southern section: Advancing head cuts treated (filled & berm installed) in two locations between scarp front and bund; treated rills on rock chute abutment and constructed small bund to divert runoff from abutment away from chute. Northern section: extended the bund on southern end/ corrected turn out.	Partly stable	Soil erosion	Dominant pasture sp. (Indian couch)	Total perennial pasture density
7	2019	Small	Chromosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock management improved Bank and spreaders gully reshape Seed	Nil	Nil	Mostly stable	Soil erosion	Dominant pasture sp. (Indian couch)	

Site ID	Year of work	Scale	Soil characteristics	Land scape components treated	Specialist input	Summary of Initial treatment	Significant Inkind	Maintenance undertaken under GMM project	Gully stability Dec 2024	Driver of reduced land condition 1	Driver of reduced land condition 2	Driver of reduced land condition 3
8	2019	Small	Chromosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock management improved Gully plug dam Banks and spreaders Seed	2020 Treated small side gully	Nil	Mostly stable	Soil erosion	Dominant pasture sp. (Indian couch)	Dominant pasture density
9	2019	Small	Sodosol	Alluvial gully - (bywash and adjacent terrace)	Expert written advice, Limited supervision	Rock chute reshaping seed	Nil	2024 Repaired rilling on side abutment/slope Capped with stable soil Seed	Partly stable	Soil erosion		
10	2019	Small	Sodosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock management improved Contour line rehab in the catchment Seed Repair dam wall Bunds Rock chute	Nil	2024 Modified busted dam wall into rock mattress spillway installed 5 Porous check dams - 1 large rock, 4 stick	Partly stable	Soil erosion	Dominant pasture sp. (Indian couch)	
12	2020	Small	Sodosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock exclusion 2 years Contour line rehab in catchment seed	2020/21 - Installed 4 Porous check dams - 2 large rock and 2 stick	Nil	Mostly stable	Soil erosion	Dominant pasture sp. (Indian couch)	

Site ID	Year of work	Scale	Soil characteristics	Land scape components treated	Specialist input	Summary of Initial treatment	Significant Inkind	Maintenance undertaken under GMM project	Gully stability Dec 2024	Driver of reduced land condition 1	Driver of reduced land condition 2	Driver of reduced land condition 3
13	2020	Small	Sodosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock management improved Contour line rehab in catchment - banks and sediment trap Rock chute Porous check dams	2020/21 Repaired damaged banks, extended one bank, decommissioned adjacent dam, repaired rock chute x 3	Nil	Partly stable	Soil erosion	Dominant pasture sp. (Indian couch)	
14	2019	Small	Black/ brown Chromosols & Brown Sodosols	Alluvial gully (valley)	Expert designed & supervised	Stock exclusion gully plug dams Porous check dams	Nil	2021, 2024 Repaired gully plug dams x2 Repaired porous check dams	Mostly stable	Soil erosion	Dominant pasture density	
15	2019	Small	Vertosol	Hillslope gully	Expert written advice, Limited supervision	Gully plug dam Bank and spreader	Nil	Nil	Mostly stable	Soil erosion	Dominant pasture sp. (Indian couch)	
16	2019	Small	Vertosol	Hillslope gully	Expert written advice, Limited supervision	Gully plug dam Bank and spreader	Nil	Nil	Stable	Dominant pasture sp. (Indian couch)		
20	2019	Small	Sodosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock exclusion - 4 yrs Contour line rehab in catchment Gully head fill - large rock and soil Manure treatment	Nil	Nil	Mostly stable	Soil erosion		

Site ID	Year of work	Scale	Soil characteristics	Land scape components treated	Specialist input	Summary of Initial treatment	Significant Inkind	Maintenance undertaken under GMM project	Gully stability Dec 2024	Driver of reduced land condition 1	Driver of reduced land condition 2	Driver of reduced land condition 3
22	2020	Small	Sodosol	Alluvial gully only (floodplain)	Expert written advice, Limited supervision	Stock exclusion Bund Reshape, ameliorants, seed Rock chutes	Nil	2024 Repaired entrance to Rock chute x 2, Repaired rilling Mulch 8 Porous check dams - 2 large bale style + 5 wire mesh, posts & mulch style Seed	Unstable	Soil erosion	Dominant pasture sp. (Indian couch)	Dominant pasture density
23	2019	Small	Vertosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock management continued Catchment - Banks and spreaders	Nil	Nil	Stable	Dominant pasture sp. (Indian couch)		
24	2021	Small	Vertosol	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock management continued Catchment - Banks and spreaders Rock chute	Nil	2024 Rebuild of wing bank of rock chute (failed by Dec 2025)	Mostly stable	Soil erosion	Dominant pasture sp. (Indian couch)	
25	2020	Small	Grey duplex	Hillslope gully & catchment	Expert written advice, Limited supervision	Stock management continued contour line rehab in catchment - banks Seed	Nil	Nil	Mostly stable	Dominant pasture sp. (Indian couch)		
6	2019	Small	Alluvial sandy	Hillslope catchment only	Expert written advice, Limited supervision	Catchment - Banks and spreaders	Nil	Nil	Catchment stable, gully not treated	Dominant pastue plant density	Dominant pasture sp. (Desmanthus)	
21	2020	Small	Alluvial terrace, Kurosol	Hillslope catchment only	Expert written advice, Limited supervision	Catchment - Banks and spreaders	Nil	Nil	Catchment stable, gully not treated	Dominant pastue plant density	Dominant pasture density	

Site ID	Year of work	Scale	Soil characteristics	Land scape components treated	Specialist input	Summary of Initial treatment	Significant Inkind	Maintenance undertaken under GMM project	Gully stability Dec 2024	Driver of reduced land condition 1	Driver of reduced land condition 2	Driver of reduced land condition 3
18	2019	Small	Vertosol - catchment work Chromosol - gullies	Hillslope catchment only	Expert written advice, Limited supervision	Catchment - Banks, no spreaders	Nil	2024 Modified busted bank into spillway Spreader installed Exit armoured with rock	Catchment stable, gully not treated	Soil erosion	Dominant pasture sp. (Indian couch)	
19	2019	Small	Kurosol?	Hillslope catchment only	Expert written advice, Limited supervision	Stock exclusion - 1 year Soil ameliorants, seed	Nil	Failure No maintenance undertaken	Unstable	Soil erosion		
11	2019	Small	Chromosol	Hillslope catchment only	Expert written advice, Limited supervision	Stock management continued Contour line rehab in the catchment Seed	Nil	Nil	Catchment stable gully not treated	Soil erosion		

LARGE-SCALE SITES

Grazing land management

All sites had fencing maintained in working order during the monitoring period. One site maintained total cattle exclusion since the works were undertaken in 2020. The other four sites excluded cattle for at least two wet seasons and then grazed strategically in the dry season to promote vegetation growth (i.e. to reduce the height of old grass and stimulate new growth). There were moderate impacts from feral deer at Sites 2, 3 and 4, particularly during the early stages of vegetation establishment (*pers comm*. landholder).

Maintenance

Some maintenance was undertaken at all five large-scale sites prior to the start of the Monitoring and Maintenance project in 2022 (i.e. most occurred after the 2021 wet season). Sites 1 and 5 received additional maintenance during the life of the project (2022-2024).

Components of the site works that required and received maintenance were: seven reshaped areas, five rock chutes, four porous check dams, one bund and one cut off wall (Figure 7). The need to repair rills in the reshaped areas was common with seven of the eight areas affected. This damage was mostly caused by direct rainfall on recently reshaped, ameliorated and seeded gully slopes and was most prevalent after the 2021 wet season (Figure 8). Seven of the 12 rock chutes required maintenance, and this involved repairing the earthen abutments or removing tunnels at the edges of the rock chute. Four of the 84 porous check dams required maintenance. This was usually because they had filled, retaining maximum sediment and then outflanked. Like the rills in the reshaped areas, most check dam outflanking happened in the first wet season after construction.

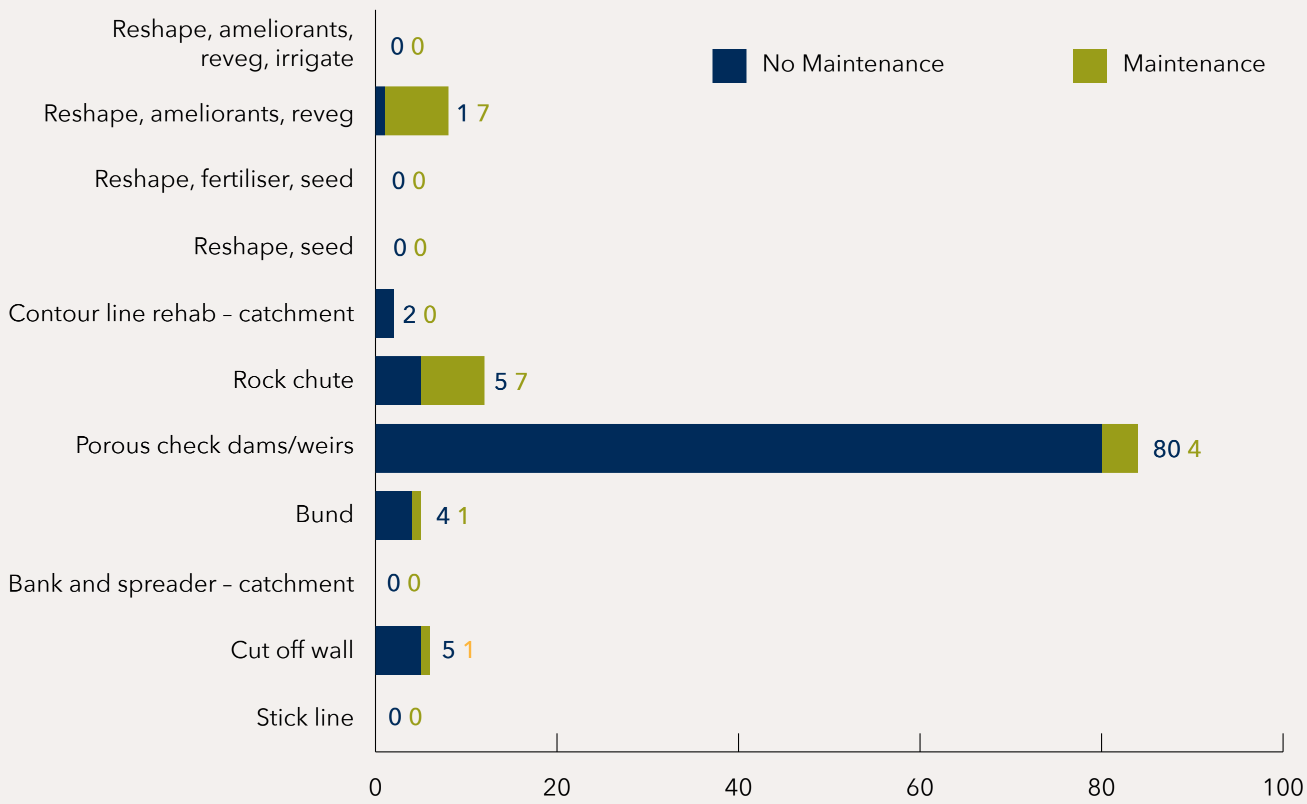


Figure 7. The number of erosion control structures and treatments at large-scale sites that received maintenance compared to those that did not (post-construction up until December 2024).

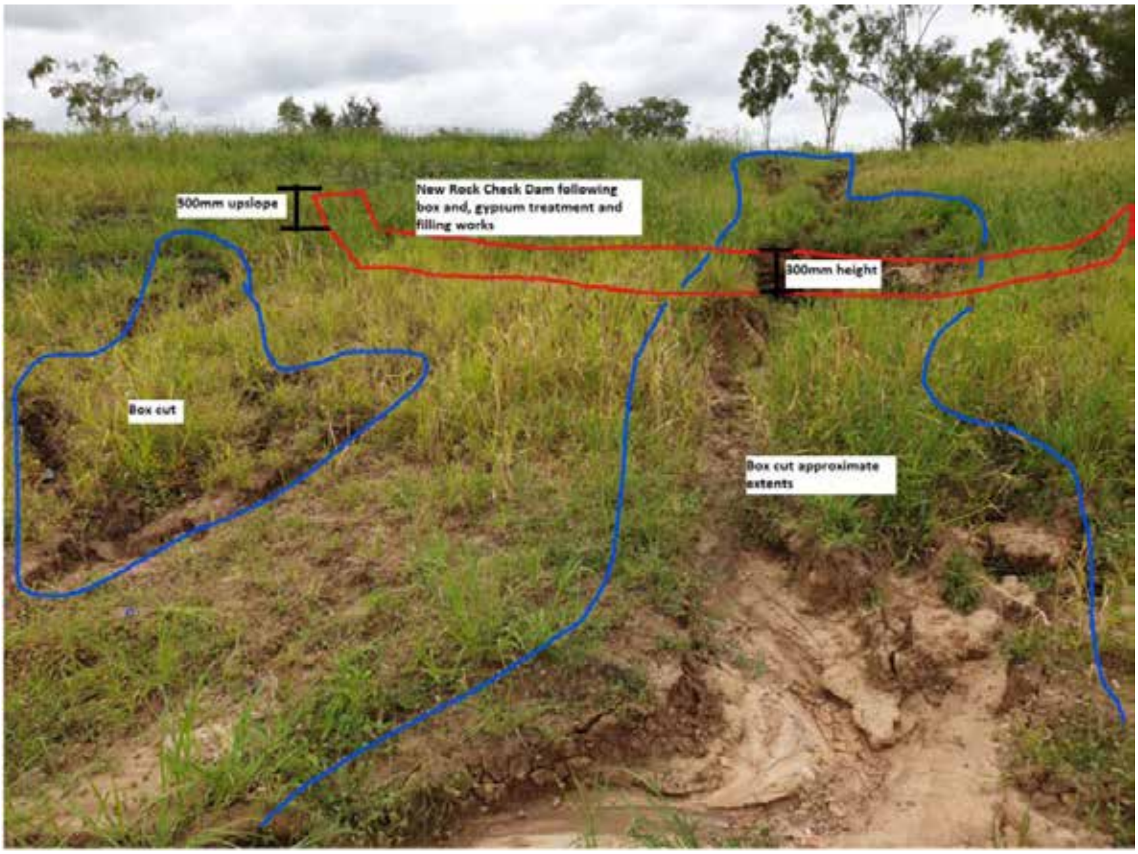


Figure 8. A photograph taken at Site 3 following the 2020-21 wet season. Rills formed during uncontrolled overland flow. The engineer's maintenance plan is overlaid on the photograph. A bund was constructed above the site to prevent this from happening again.

Stability achieved

The stability ratings given to the large-scale sites are displayed in Figure 9 and in Table 3. Sites 2 and 3 were given a 'Stable' rating in January 2025, approximately 4½ years after initial works were undertaken. However, this rating comes with a caveat: while these sites are stable for a reshaped landscape; they will not have the stability and associated resilience of comparable intact landscapes with soil profiles that have never been disturbed and with complex, biodiverse vegetation. Furthermore, these sites have not been tested with drought or flood. Sites 1 and 4 were deemed to be 'mostly stable' and Site 5 'partly stable'; the partly stable rating reflects the limited treatment of the extensive 'badlands' together with the success of the revegetation in the immediate catchment.

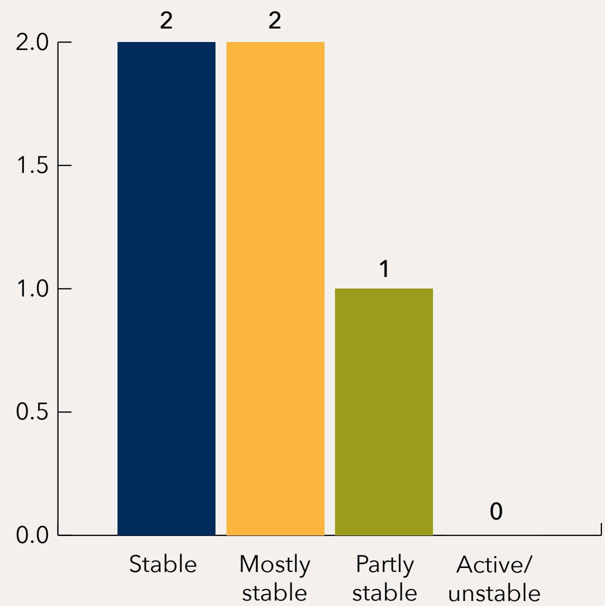


Figure 9. Level of stability achieved at treated large-scale gullies 4–5 years after the initial treatment (assessed December 2024).

Land condition assessments (LCAT) offer insight into a site's progress towards achieving a stable soil that supports resilient, diverse vegetation. Figures 10, 12 and 14 display the LCAT scores for Sites 1, Sites 2, 3 and 4 and Site 5 respectively. Site 2, 3 and 4 have been clustered together because they are situated close together (on the one property), share soil and vegetation properties and have common control sites. The legend gives details on the relative position of each LCAT monitoring location at the site and some colour coding is used to assist interpretation. All control LCATs are shown with a grey line. Refer to Appendix 2 for more details.

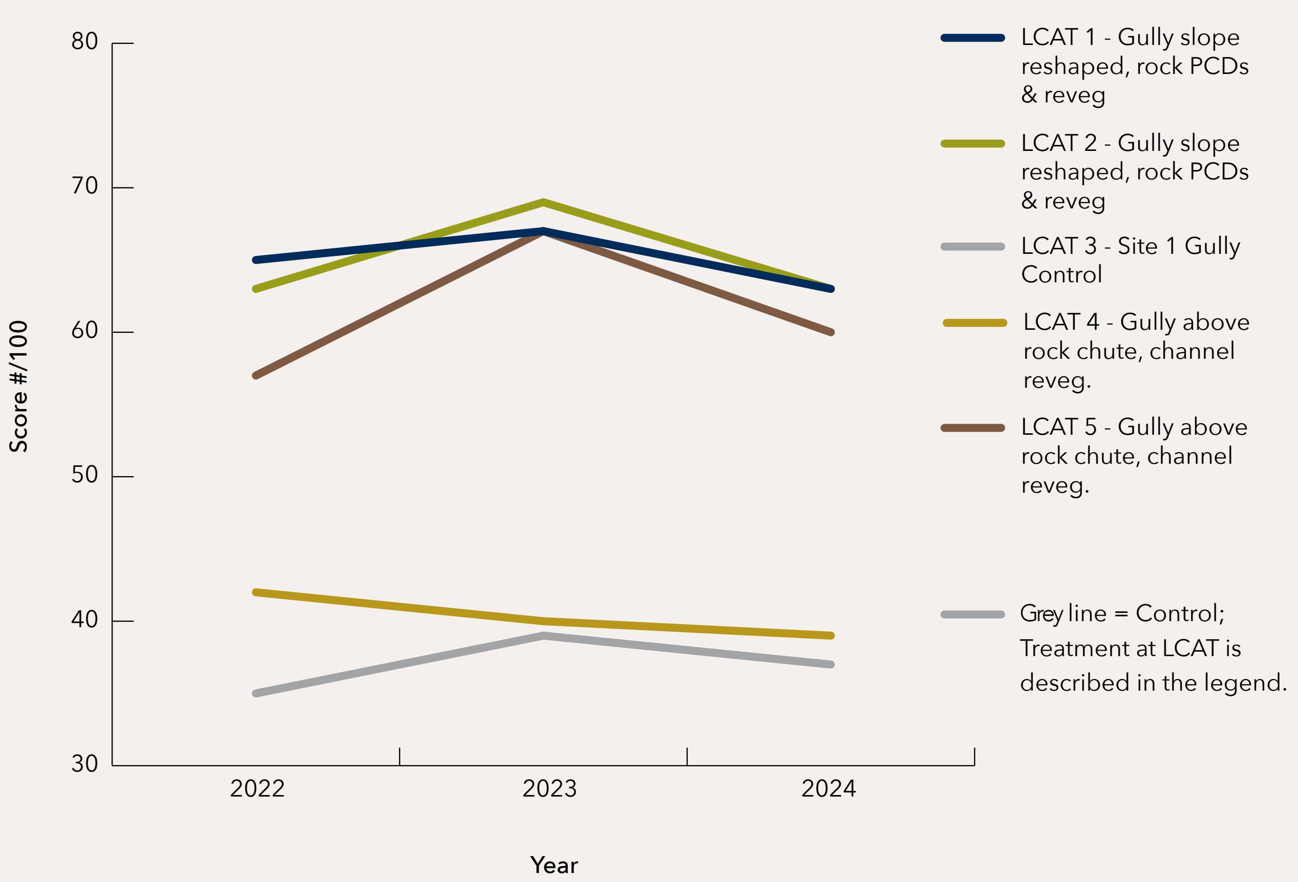


Figure 10. Land Condition scores for large-scale gully remediation Site 1 and its control (untreated gully) over three years of monitoring.

Site 1 LCAT scores have changed little during the three years and all except one hovers around 60/100. However, prior to the treatment in 2020 it can be assumed that the LCAT scores were similar to the control, 35-40. Therefore, the site moved from around 40 to 60 in two years (2020-2022). The drivers of reduced land condition at all sites at the last monitoring (November 2024) was 'Soil erosion' and 'Dominant pasture species' which is Desmanthus, a palatable hybrid legume. At the control site the dominant pasture was Indian couch, which also reduced the land condition score. Figure 11 shows monitoring photos taken at LCAT 1 site over the three years. These photos are typical of the reshaped, revegetated areas at Site 1 and illustrate the change in dominance from grass to the legume, Desmanthus *"Progardes"* over the monitoring period.

Figure 11. Photographs of Site 1, LCAT 1 over the three years of monitoring; represented in Figure 10 by the blue line. The green pasture vegetation and tall stalks in the 2024 photograph is Desmanthus "Progardes".

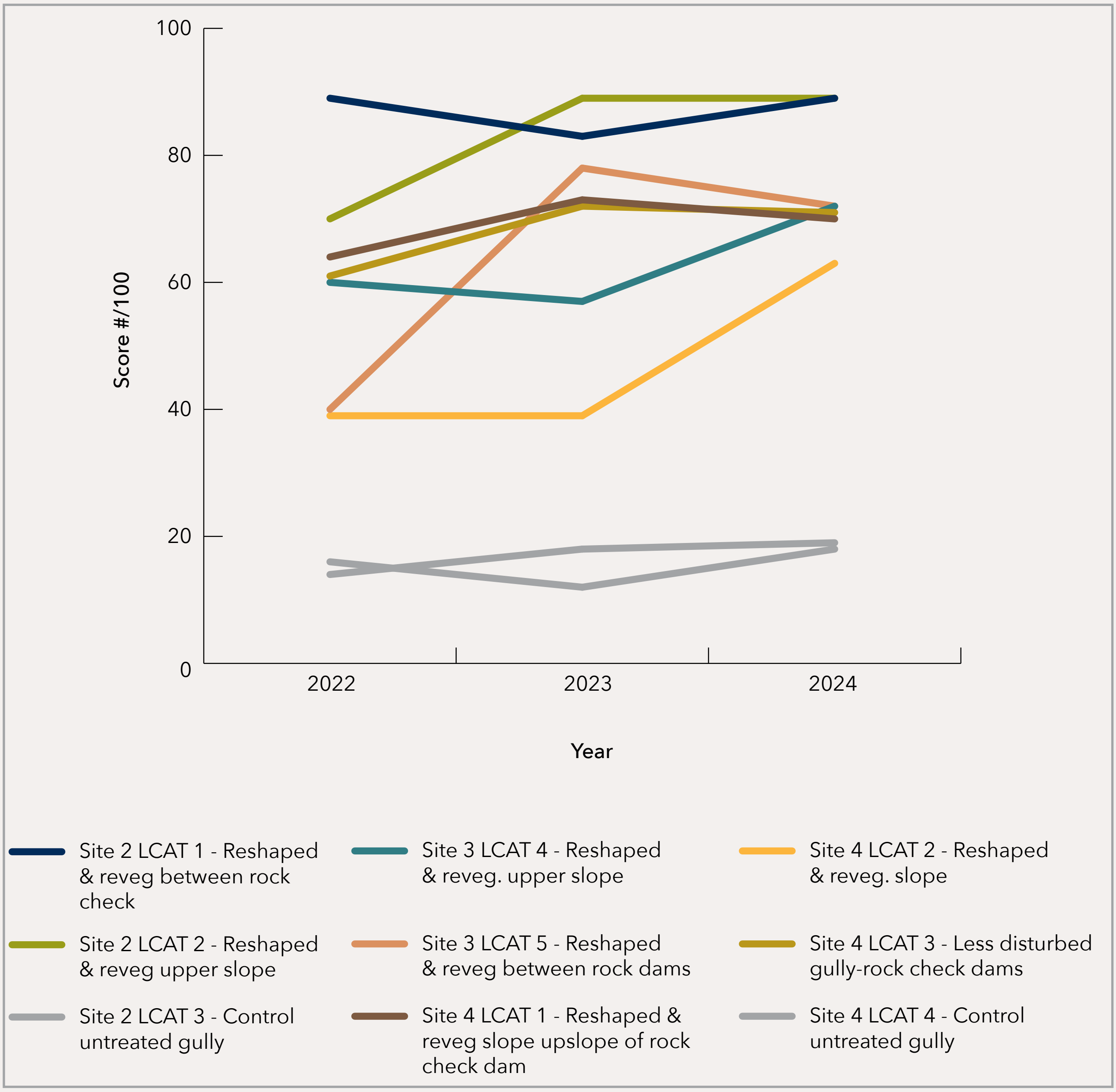


Figure 12. Land condition scores for large-scale gully remediation Sites 2, 3, 4 and control (untreated gully) over three years of monitoring.

Land condition assessment scores at Sites 2, 3 and 4 have generally increased over the three years of monitoring (Figure 12). Site 2 was treated six months earlier than Sites 3 and 4. Scores indicate that it was already in high land condition when the monitoring project began, and that this high land condition has been maintained. Land condition at Site 3 and 4 is lower than at Site 2. Like Site 1, the drivers of reduced land condition at Sites 3 and 4 were also 'Soil erosion' and 'Dominant pasture species' Desmanthus "Progardes". Site 2 was in A condition in 2024 and had no drivers of land condition listed.

Figure 13. Photographs of Site 3, LCAT 5 during the three years of monitoring; represented in Figure 12 by the orange line. The decrease in grass and increase in Desmanthus "Progardes" is evident in these photographs.

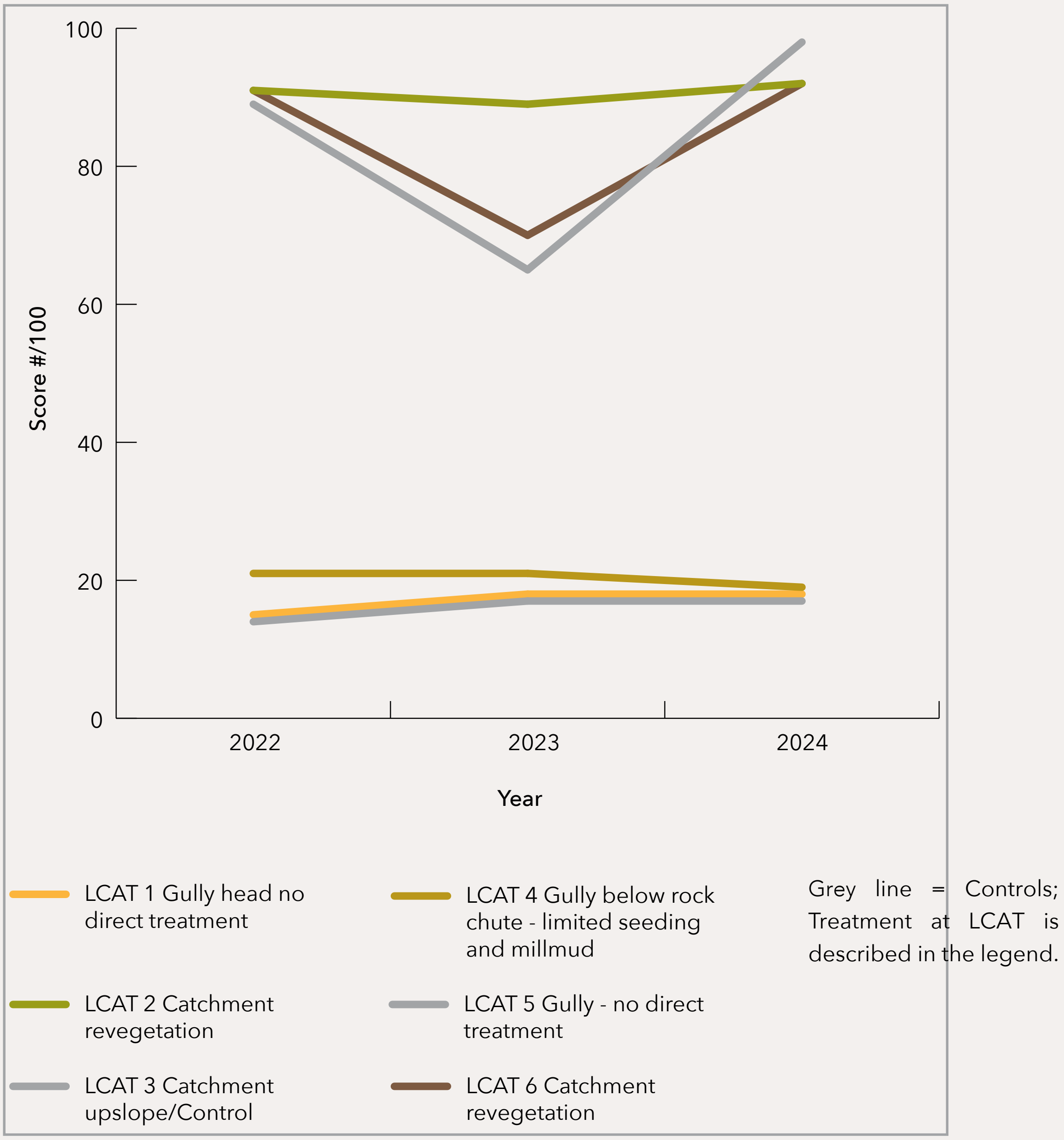


Figure 14. Land Condition Scores for large-scale gully remediation Site 5 over three years of monitoring.

The LCAT scores at Site 5 reflect the success of the revegetation in the catchment contrasted with the limited work in the gullies (Figure 14). As for Site 2, the high results for LCAT 2 in the revegetated catchment indicate that the good land condition was reached prior to the monitoring program. LCAT 3 is in the catchment further upslope away from the gully. The LCAT score for the treated catchment was likely to have been around 50/100 prior to treatment in 2020. Site 5's LCAT 4 (Figure 15) is situated at the transition zone between the intense revegetation work in the catchment and on to the rock chute and the 'badlands' that did not receive treatment. In the last set of three photographs in Figure 15 (view north) some of the scarps are visible. In the initial treatment the scarps received some ameliorants without soil disturbance. Some maintenance earthworks were undertaken on some of the scarps that continued to erode.

Figure 15. Site 5 - Series of photographs taken at LCAT 4 site (below the rock chute) represented by the line that is **this colour** in Figure 14.

Small-scale sites

Grazing land management

At the small-scale sites there were various levels of restriction on grazing following remediation. These are listed in Table 2. Three of the four sites with electric fencing, specifically around the treated area, failed within the three years of monitoring. Two had failed by 2022 and were not repaired by the grazier, and one site was effective until mid-2024. For the remaining sites most of the landholders managed grazing by modifying their established grazing and rest regimes. A common practice was to exclude cattle for two wet seasons and then to manage the site as part of the larger paddock (e.g. giving full or partial rest in the wet season).

Maintenance

An overview of the maintenance requirements at the 19 small-scale sites are provided in Table 3 and Figure 16.

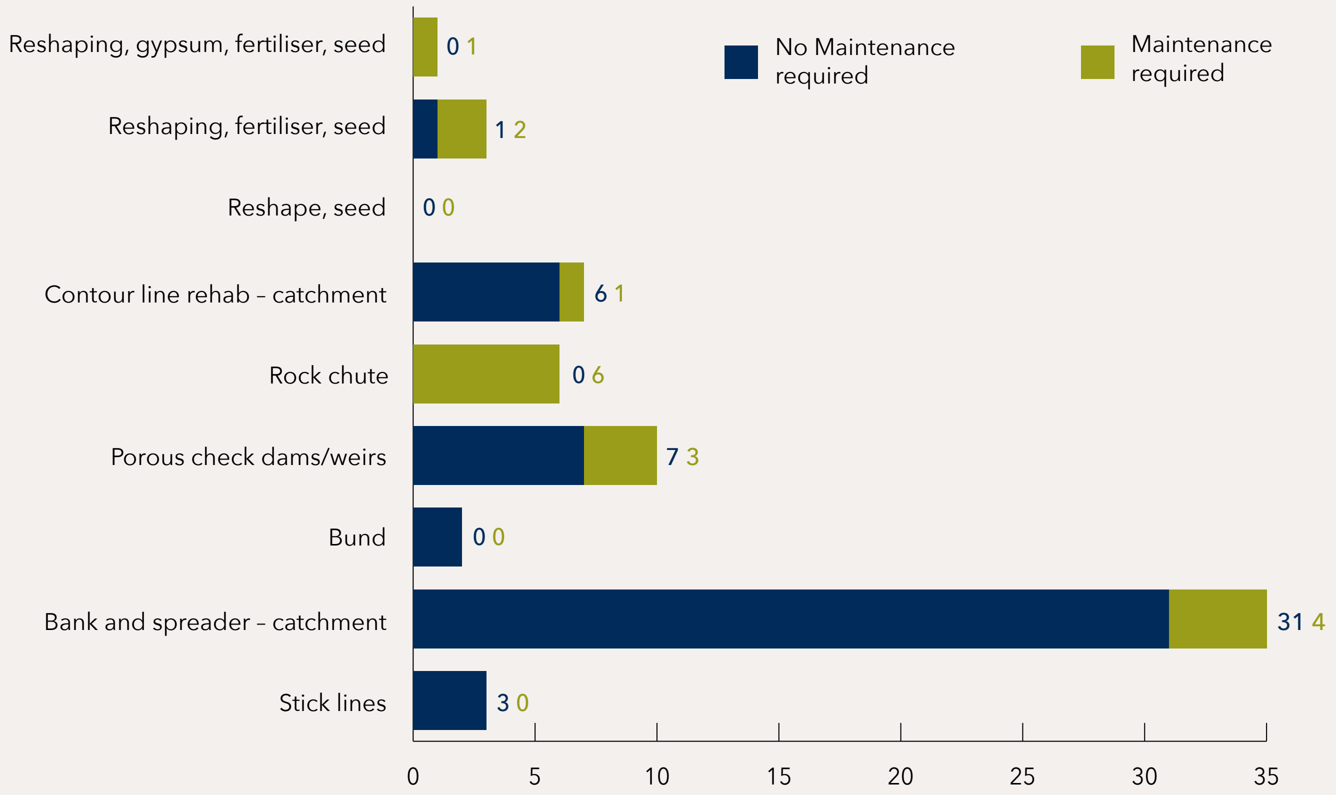


Figure 16. The number of the structures and treatments at the 19 small-scale gully sites that required maintenance compared to those that did not.

Works in the catchment required less maintenance than works in the gullies. One of seven sites with catchment rehabilitation along contour lines required maintenance. This site (Site 19) was not prioritised for maintenance; it is a small site (<0.5ha) in a remote area. In the initial treatment the site was ripped, fertilised and seeded very close to the gully edges; the rehabilitation failed in the area upslope of the gully heads, leading to further, and probably, exacerbated erosion. The rehabilitation was more successful on the treated side of the gully.

Only four of the 35 banks and spreaders installed in catchments required maintenance. One diversion bank breached during the first rains following construction and the landholder repaired it immediately, on Christmas Eve 2020, in-kind. The remaining three that required repair were all holding water against the bank rather than draining water away. Two were in Downs country Vertosol soil and one in dispersive Sodosol soil. The native land crab, that excavates burrows into banks and aestivates in them during the dry season, was found at two of the three sites –1 vertosol and 1 Sodosol site (refer to Figure 33).

Three sites had treatments involving major soil disturbance (reshaping) to the gully itself, followed by soil ameliorants (gypsum and fertiliser or just fertiliser) and seeding. All sites that were highly disturbed required maintenance to address rill erosion. At one site (Site 12) the landholder responded quickly to the rilling that appeared in the first wet season, installing extensive rock and stick check dams (in-kind). The second site (Site 22) was repaired in 2024 and, by this late stage, rilling in the reshaped bowl was deep and starting to form gullies. Site 20, the less disturbed site (gully head fill and manure; Figure 6), seemed to be doing well with high and diverse vegetation cover but now it requires maintenance; during the 2024 dry season cattle breached the exclusion fence and grazed down the area which exposed tunnels at the gully head. The site that is recorded as not receiving maintenance to the reshaping in Figure 16 is Site 13. It has a small area of revegetation on near level ground that is stable, however the maintenance that was required at this site has been recorded under the rock chute category. The two highly disturbed sites that required maintenance were on sloped landforms.

All six rock chutes required maintenance and are likely to require maintenance into the future. This is despite the moderate wet seasons since construction. Anecdotal evidence suggests there has been limited engagement of these rock chutes; water has not yet flowed down one, four appear to have had small flows and one has been fully engaged during high rainfall events (Site 13). Site 13's chute received timely repairs by the landholder (in-kind). Four chutes have suffered from gradual erosion of the abutments and two of these also have erosion immediately upslope of the crest (Figure 17). Two sites (Sites 22 and 9) received maintenance to the erosion around the rock chute in 2024. Five of the six chutes are in the highly erodible Sodosol soil type.

The sixth rock chute (Site 24) is in Downs country Vertosol soil, a 'soft' erodible cracking clay. Maintenance is not required to this structure, but it has proved difficult to keep engaged. Site 24's chute is situated downslope of a series of low-grade diversion banks to safely discharge runoff to the gully floor. However, the flows are bypassing the chute; cutting through a wing bank and emptying in the gully channel a little further upstream of the chute. The failed wing bank was repaired in 2024 with a new design. However, the wall was again breached in the same place early in the 2024/25 wet season. Soil from the bank has built up immediately above the chute, further reducing the likelihood of the chute taking runoff. Refer to Figure 32 for more information on these works.

Figure 17. The five rock chutes at small-scale sites on highly erodible Sodosol soils. All have active erosion that will require continued maintenance to be effective.

Of the 10 check dams and weirs constructed across four sites, three required maintenance. These three are substantial earth and log weirs with rock armouring at Site 14. This site is situated low in a valley where velocities and volumes of flow are high. Two lots of relatively minor but timely maintenance have been done at this site to maintain the integrity of the structures while they 'settle' into the landscape.

Stability achieved in catchments

Remediation works in the catchments of gullies had a high level of success. Of the 14 sites, 11 catchments were stable after 4-5 years, two catchments were mostly stable and one was deemed unstable (Figure 18). The unstable catchment is at Site 19; a small site not prioritised for maintenance; described in the maintenance section above.

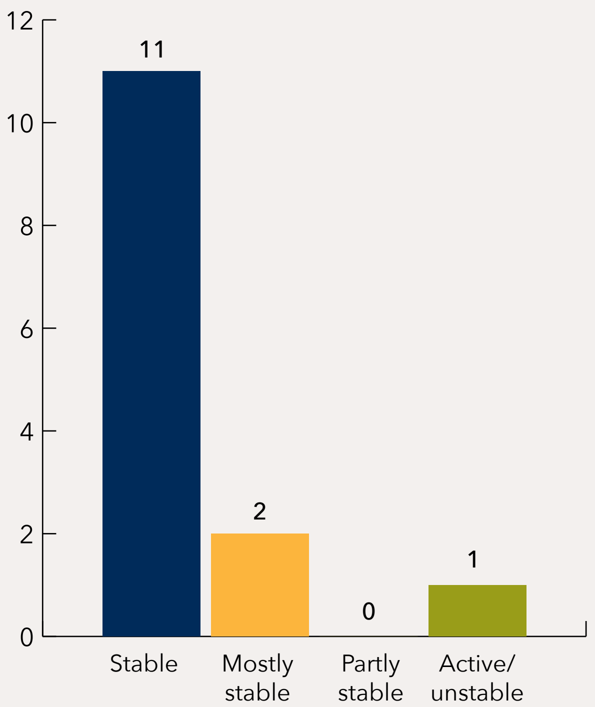


Figure 18. The level of stability achieved in the treated catchments of small-scale gullies 4–5 years after the inital treatment. Assessed December 2024; sites where only the gully was treated are excluded.

Land condition assessments (LCAT) offer insight into the catchments' progress towards achieving stable soils that support resilient, diverse vegetation. These have been displayed graphically, separated by soil type.

Figure 19 displays three years of LCATs scores from treated catchments with Sodosols; duplex soils with highly erodible subsoil. All these sites are within the Scottville area. Some of the catchments had soils that graded into Chromosols; erodible duplex soils that tend to slake but not disperse. Site 13 is one of these where there was dispersive duplex soil at the gully and the lower parts of the catchment and slaking duplex soil in the higher parts of the catchment. Site 13 is the only site with Sodosol soil that was deemed to be 'mostly stable' (Figure 18). The other five sites represented in Figure 19 achieved a 'stable" rating (Figure 18).

In Figure 19 there are a broad range of LCAT scores with some sites reaching similar conditions to the well vegetated and stable control sites. Land conditions tended to rise and then fall over the three years. Drivers of reduced land condition were similar across the sites: Dominant pasture species, soil erosion and, less commonly, dominant pasture density. Common pasture species are Sabi grass (*Urochloa mosambicensis*), Indian couch (*Bothriochloa pertusa*) and Seca stylo (*Stylosanthes scabra*). These are the dominant species at Site 8 shown in Figure 20. At several sites Seca stylo increased in density during the three years of monitoring while the sown grass species seemed to decline. This was observed at Site 10 (Figure 20). Factors causing this may include a decline in fertility following the initial disturbance and grazing pressure.

The consistency of the land condition scores for the catchments of the four small-scale gullies in Vertosol (Downs country) soils are shown in Figure 21. The four sites are classified as stable in Figure 18. The consistent scores suggest that the interventions had little effect on land condition, and this reflects field observations over the three years. The treatment at all sites involved installing banks to slow runoff and divert it away from gully heads. Therefore, the intervention did not concentrate on pasture renovation. However, the sites with banks designed to hold water changed the vegetation in the vicinity and while they prevented runoff from entering gully heads, the banks did not appear to improve the land

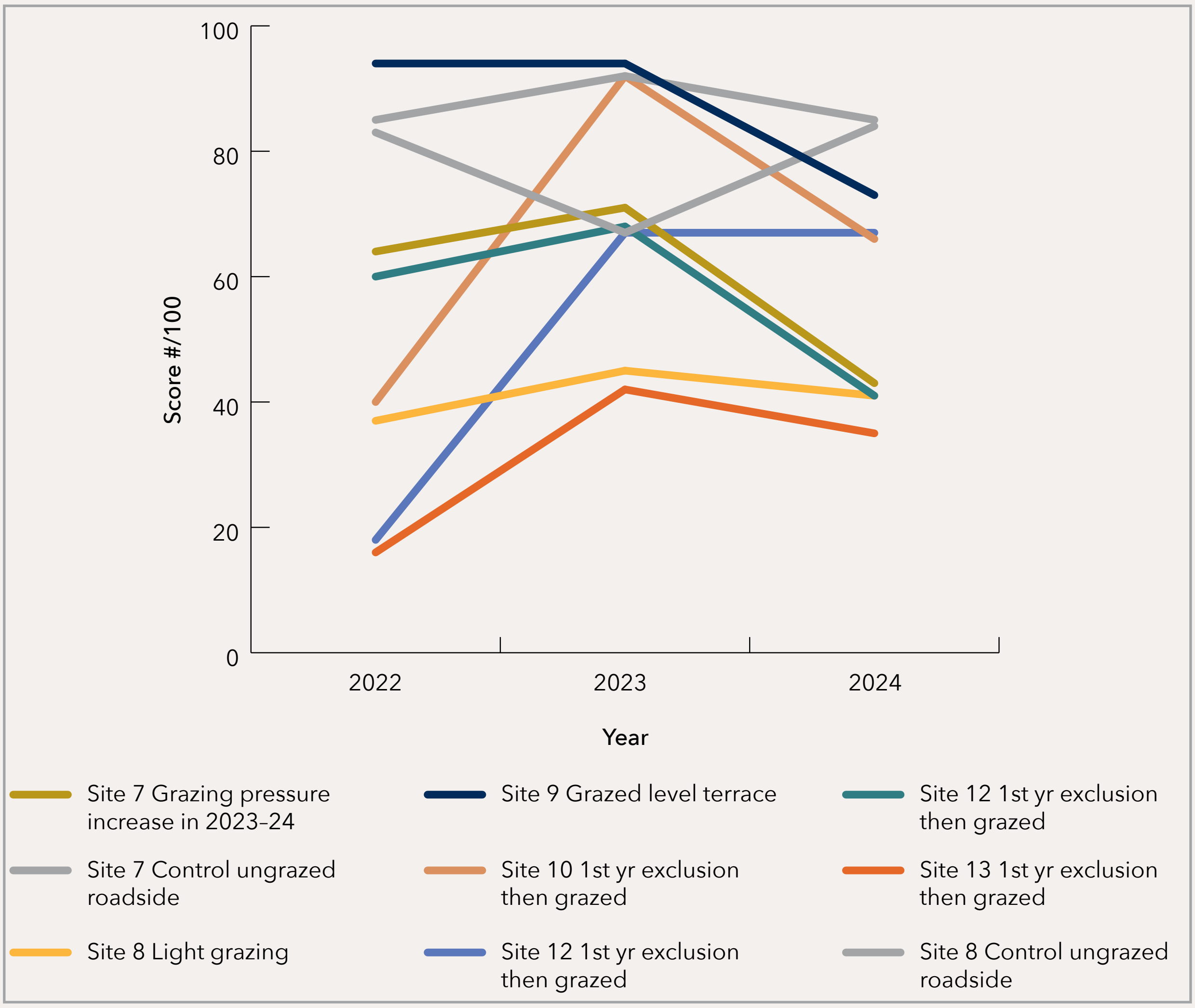


Figure 19. Land condition assessment scores for the catchments of small-scale gullies in erodible duplex soils (Sodosols) following pasture renovation works.

condition at the catchment (Figure 22). At Site 18 the pasture in the wetter zones, behind the banks changed from predominantly Indian couch to couch grass, annual forbs and Parthenium weed (*Parthenium hysterophorus*). The pasture at all sites was dominated by Indian couch (*Bothriochloa pertusa*) before and after the works. Consequently, the ground cover was consistently high, but LCAT scores depressed as Indian couch is considered undesirable.

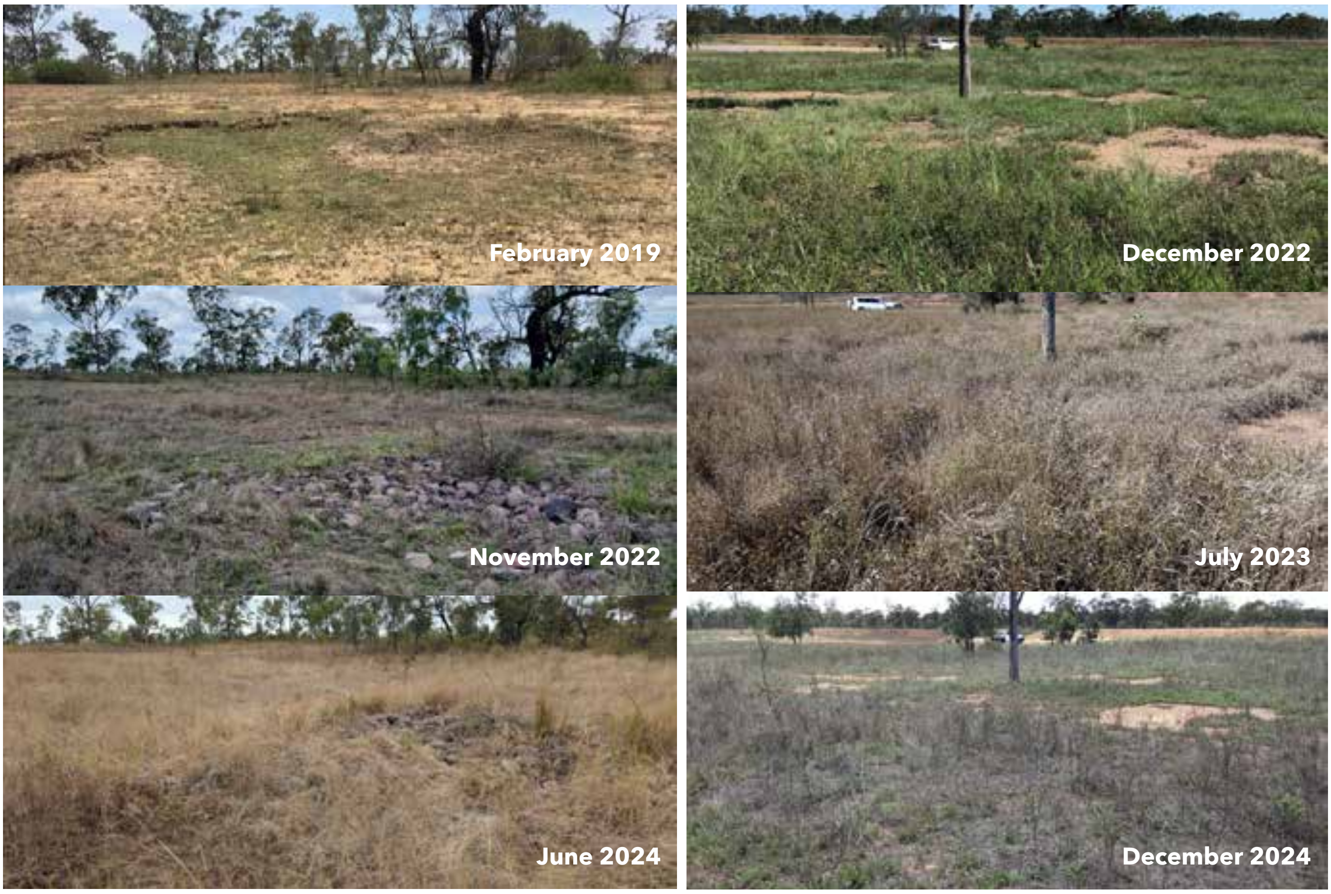


Figure 20. Monitoring point photographs of remediated catchments at Sites 8 and 10. LCAT results for these sites are represented by this line and this line respectively in Figure 19.

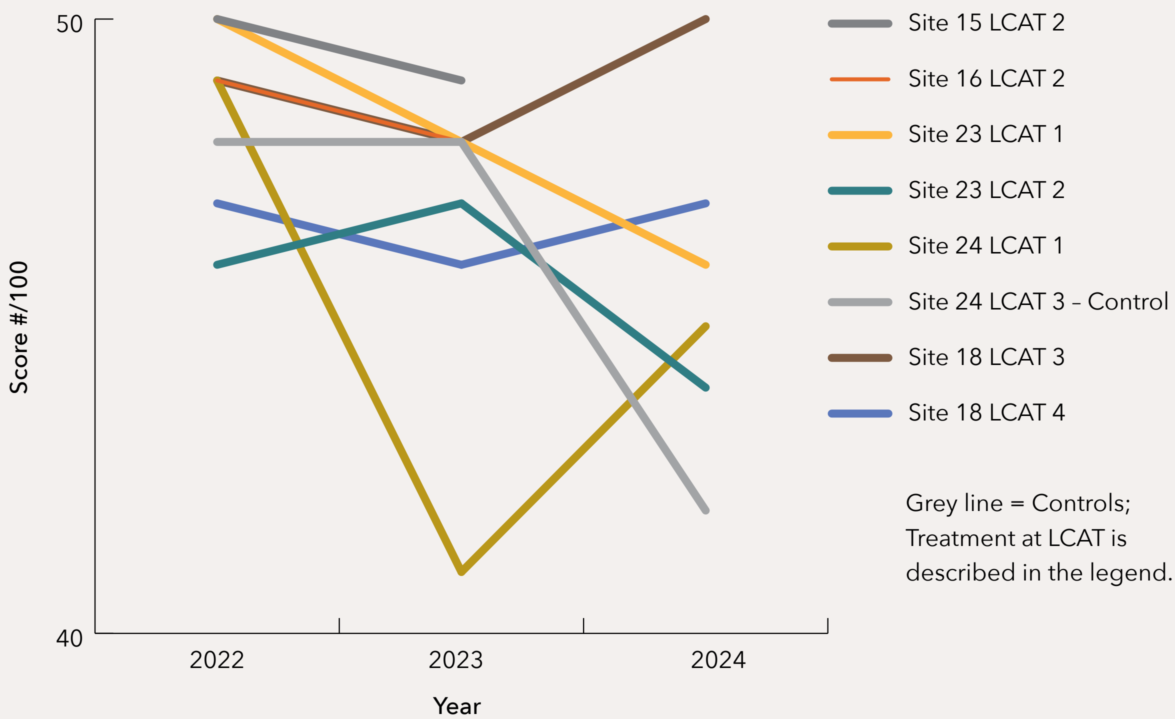


Figure 21. Land Condition Assessment scores clustered around 45-50 for the catchments of four Small scale gullies in vertosol soils (Downs Country) following erosion remediation work involving banks to manage overland flows into gullies.

Figure 22. At Site 18 catchment work to control runoff into adjacent gullies involved a series of 'rehydration' banks. Photograph taken April 2024.

Stability achieved in gullies

Thirteen of the 14 gullies treated have achieved some level of stability (stable, mostly stable or partly stable) and may be considered to have moved in the desired direction since remediation work was undertaken (refer to Figure 23 and Table 3).

At the unstable gully (Site 22) initial works included reshaping, gypsum, fertiliser, seed, a bund and two rock chutes. Some remediation works were undertaken on the rock chutes prior to this monitoring and maintenance project. This site received more comprehensive maintenance in 2024. Refer to Figure 29 for details. While the initial response following this maintenance is positive, more time is required to see if the site is on a pathway to stabilising.

Four of the partly or mostly stable sites had maintenance works done: Site 13 - landholder in-kind, Sites 9 and 10 received maintenance in 2024 and Site 14 had two lots of maintenance between 2021 and 2024. Site 12 received early

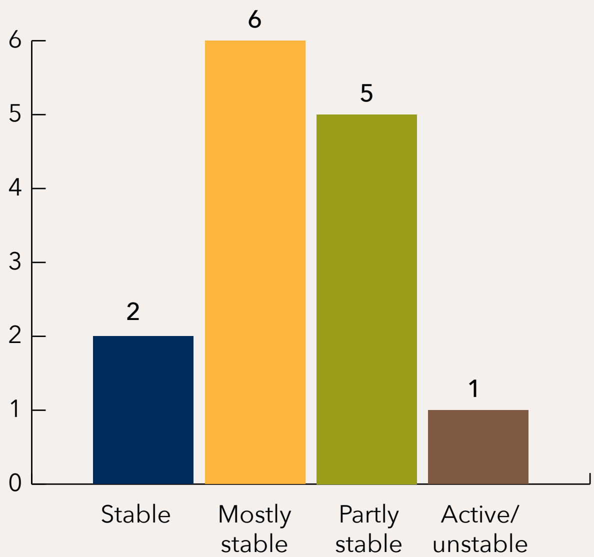


Figure 23. Level of stability achieved at treated small-scale gullies 4–5 years after the initial treatment. Assessed December 2024; sites where only the catchment was treated are excluded.

maintenance by the landholder (in-kind) and was mostly stable in December 2024.

No remediated gullies in Sodosol soil achieved the stable rating (Figure 24).

The changes in land condition scores for remediated gully sites are displayed in Figure 25. Lines have been colour coded by soil type and line thickness indicates the depth of the site's subsoil. Gullies remediated in erodible Sodosol soils (brown lines) generally showed a modest change over time (Figure 26 as example). The exception, Site 9, had maintenance work two months prior to the 2024 assessment and reflects the early success of that. The two gullies in Downs country Vertosols (purple lines) increased in score reflecting the successful stabilisation of the gullies. The blue line represents Site 14 which is situated in a valley with relatively stable alluvial soils.

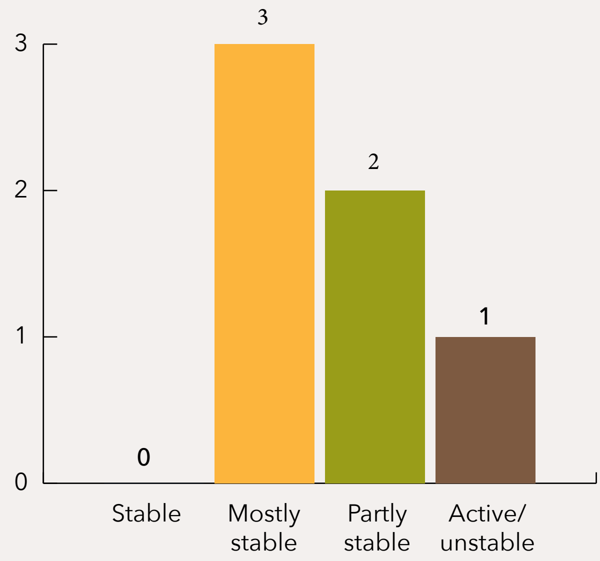


Figure 24. Level of stability achieved at remediated gullies with Sodosol soils by December, 2024.

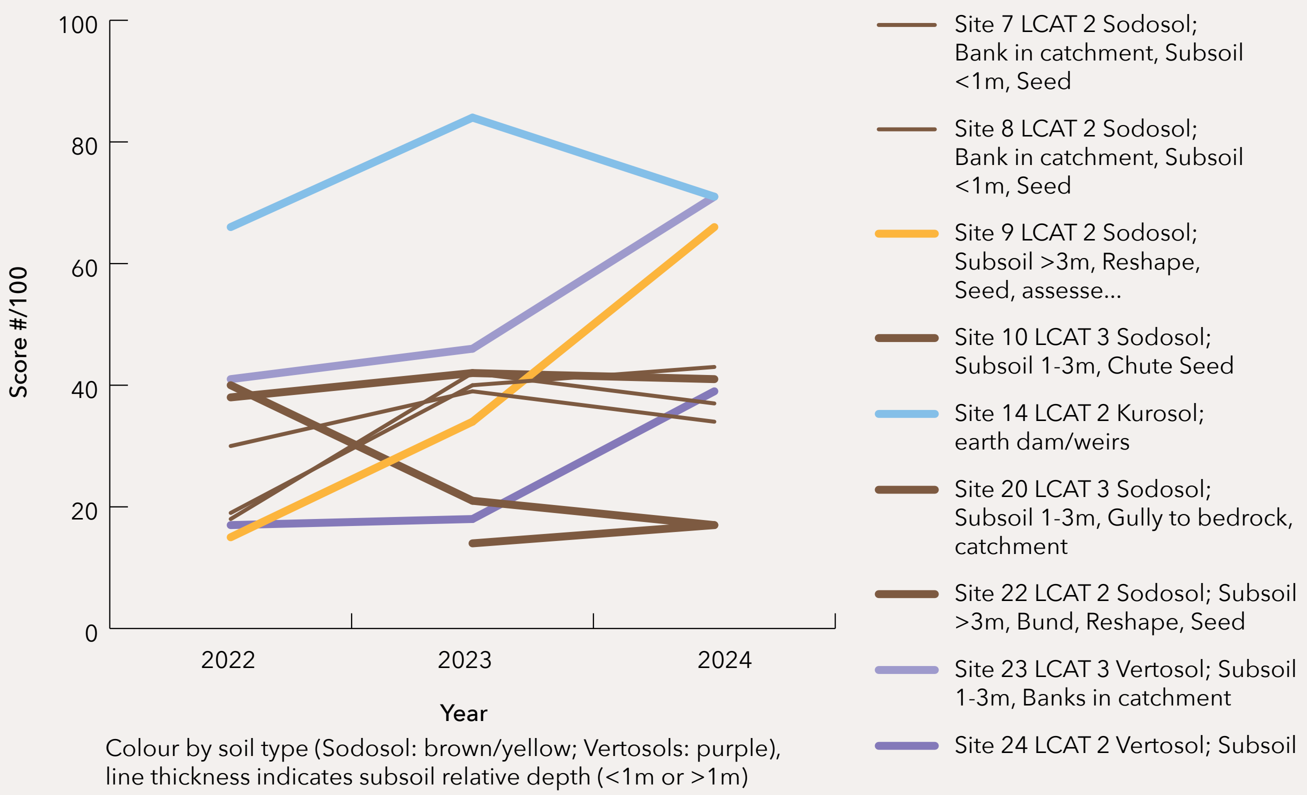


Figure 25. Land condition assessment scores for gullies at small-scale gully remediation sites.

Figure 26. Site 12 was remediated in 2020.

Stability and grazing land management

The level of control over grazing at gully sites is an important factor affecting the success of remediation efforts (Wilkinson et al., 2022, p22; Day & Shepherd, 2019, p. 20). Trends between the stability achieved at small-scale sites and the landholders' level of management towards improving land condition at the site was investigated. This is expressed as the level of 'Focus on land condition' with three categories: High, moderate and low focus. An example of 'high focus on improving land condition' is excluding cattle for the first year, then giving the gully area a short graze (e.g. one day) when the soil is firm but plants are still growing, (to stimulate plant growth root and shoot), and adapting management to promote the establishment of a diverse suite of plants. On the other hand, an example of 'low focus on land condition' is grazing the gully area with the rest of the paddock with no scheduled wet season rest. Most landholders' management of the sites was classed as: Moderate focus on land condition which tended to involve a rest in the wet season and 2-5 months of grazing in the dry season with the rest of the paddock.

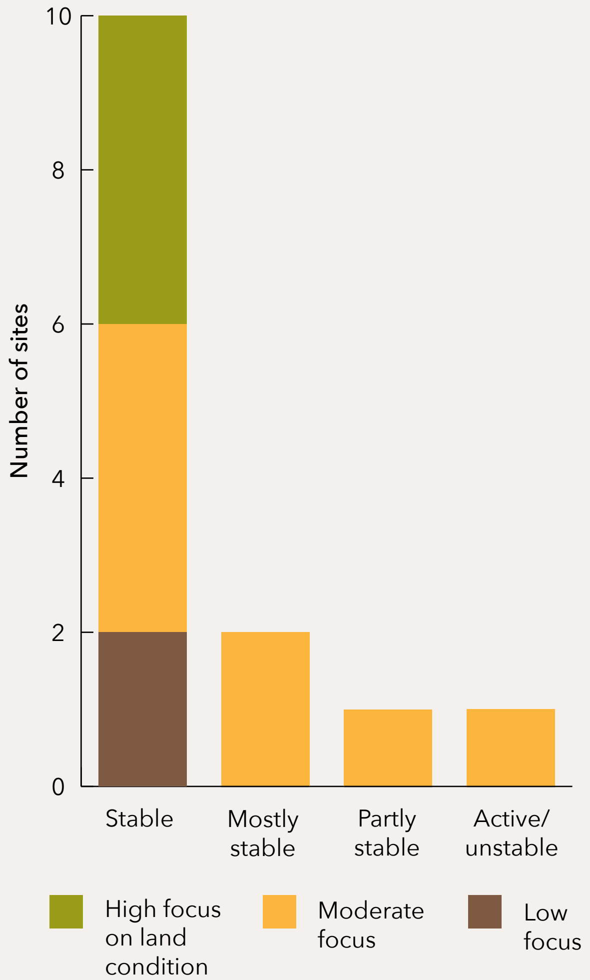


Figure 27. The level of stability achieved at treated catchments of small-scale gully sites verses the landholder's focus on improving land condition (2019/20-2024).

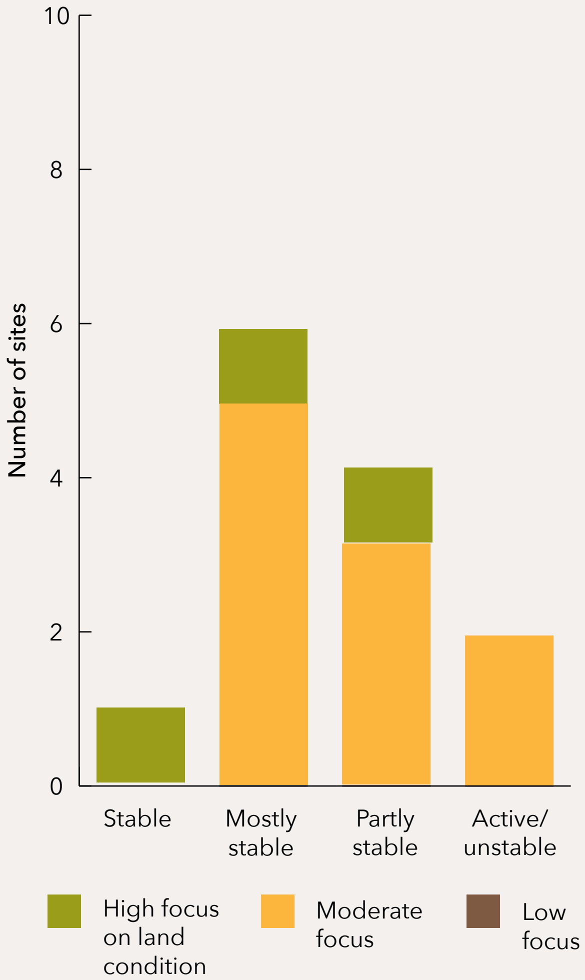


Figure 28. The level of stability achieved at treated gullies of small-scale gully sites verses the landholder's focus on improving land condition (2019/20-2024).

Figure 27 displays the results of stability achieved versus grazing land management for the treated catchments. The two catchment sites deemed to be under management with a low level of focus on land condition achieved stability but were on near-level ground; old floodplain terraces that only had banks installed to attenuate flows into gullies. The remaining 12 sites were on sloped land (above hillslope gullies). Of those that achieved stability, half were managed by graziers who were considered to have a high focus on improving land condition at the site.

Where the graziers had a moderate level of focus on improving land condition in the treated catchments there were a variety of results (stable to still active).

Figure 28 displays the results of stability achieved versus grazing land management for treated gullies. All sites had moderate or high ratings for the landholder's grazing land management expressed as 'Focus on land condition'. Overall sites managed with a high focus on land condition performed better than those with a moderate focus.

One of the unstable sites (Site 22) had high grazing pressure by wallabies which is one of the factors leading to the poor result. Cattle were excluded from the site and the rest of the paddock was stocked lightly (cattle) and rested in the wet season. The one stable site that had a high level of pasture management, was in Downs country Vertosol soil. The eight gullies that received maintenance after construction are found across all categories: in levels of stability and in the landholders' 'Focus on improving land condition'.

RESULTS - MAINTENANCE COSTS AND COST EFFECTIVENESS

A summary of the costs and cost-effectiveness, initial and following maintenance, for each project is summarised in Table 4. Note that only on-ground work is included. These costs do not include a range of additional costs such as site identification, project development and management, monitoring, maintenance, and reporting.

For the four large-scale sites where the gully was intensively remediated (Sites 1, 2 3 & 4) maintenance costs ranged from $10,644 to $48,231 (Table 4). The cost effectiveness estimates, reported in the Burdekin Major Integrated Project, Year 4 Performance Report (NQ DryTropics 2022) have been updated in Table 4 to include the maintenance costs, however as uncertainty remains around the sediment estimates, these figures come with much uncertainty. Maintenance expenditure for intensively remediated sites (1-4) ranged from 1.7-5.4 per cent of the initial project costs (Table 4, final column). The remaining large-scale site (Site 5), that had limited remediation work done on the gullies, had maintenance costs of $25,416; 9.9 per cent of the initial project cost. The sediment saving estimate for Site 5 was 922t annually which gives an updated cost-effectiveness of $306/t, but this is almost certainly an over-estimate.

Table 4. Cost, estimated fine sediment saved and estimated cost effectiveness for the 24 sites. * data drawn from (NQ Dry Tropics, 2022, 142-145).

Site ID	Gully status	Sediment saving (t/y)*	Implementation cost ($) - public investment	Maintenance cost ($)- Public investment	Maintenance cost ($) - inkind contribution	Total Maintenance costs- Public investment + inkind	GMM Monitoring & reporting cost - Public investment	Total Monitoring & Maintence cost ($)	Total cost ($) - Implemention + maintenance (public and inkind)	Cost effectiveness ($/t) - Initial	Cost effectiveness ($/t) - Updated	20 yr total cost ($)*	Cost effectiveness ($/t) (from 20yr total cost)*	Maintenance costs as % of initial construction cost
1	Mostly stabilized	1498	$1,304,790.00	$48,231.00		$48,231	$24,149	$72,380	$1,353,021	$871	$903	$1,766,534	$41	3.7
2	Stabilised	1488	$613,584	$8,144	$2,500	$10,644	$9,120	$19,764	$624,228	$412	$420	$2,130,857	$49	1.7
3	Stabilised	741	$266,746	$13,130	$1,250	$14,380	$9,120	$23,500	$281,126	$360	$379	$1,172,508	$54	5.4
4	Mostly stabilized	741	$527,089	$10,475	$1,250	$11,725	$9,120	$20,845	$538,814	$711	$727	$1,172,508	$54	2.2
5	Partly stabilised	922	$257,311.00	$25,416.00		$25,416	$9,899	$35,315	$282,727	$279	$307	$777,438	$29	9.9
7	Mostly stabilised	15	$8,223					$0	$8,223	$548	$548	$24,339	$26	0.0
8	Mostly stabilised	52	$20,118		$500	$500		$500	$20,618	$387	$397	$59,550	$32	2.5
9	Partly stabilised	5	$17,600	$14,014		$14,014		$14,014	$31,614	$3,520	$6,323	$52,096	$152	79.6
10	Partly stabilised	26	$27,925	$12,650		$12,650		$12,650	$40,575	$1,074	$1,561	$82,658	$67	45.3
12	Mostly stabilised	9	$16,000		$9,000	$9,000		$9,000	$25,000	$1,778	$2,778			56.3
13	Partly stabilised	36	$24,000		$15,000	$15,000		$15,000	$39,000	$667	$1,083			62.5
14	Mostly stabilised	27	$101,400	$30,390		$30,390	$11,590	$41,980	$131,790	$3,756	$4,881	$289,192	$369	30.0
15	Mostly stabilised	1	$5,290					$0	$5,290	$5,290	$5,290	$15,659	$117	0.0
16	Stabilised	8	$5,290					$0	$5,290	$661	$661	$15,659	$117	0.0
20	Mostly stabilised	7	$14,260					$0	$14,260	$2,037	$2,037	$42,210	$54	0.0
22	Failed to stabilise	138	$42,591	$21,635		$21,635		$21,635	$64,226	$309	$465	$126,069	$31	50.8
23	Stabilised	17	$29,402					$0	$29,402	$1,730	$1,730	$87,030	$176	0.0
24	Mostly stabilised	34	$42,680	$6,017		$6,017		$6,017	$48,697	$1,255	$1,432	$126,333	$128	14.1
25	Mostly stabilised	7	$9,120					$0	$9,120	$1,303	$1,303	$26,995	$116	0.0
6	Catchment stabilised, gully not treated	11	$31,623					$0	$31,623	$2,875	$2,875	$93,604	$293	0.0
21	Catchment stabilised, gully not treated	5	$10,844					$0	$10,844	$2,169	$2,169	$32,098	$240	0.0
18	Catchment stabilised, gully not treated	43	$19,684	$16,400				$0	$36,084	$458	$839	$58,266	$8	83.3
19	Failed to stabilise	31	$16,000					$0	$16,000	$516	$516			0.0
11	Catchment stabilised, gully not treated	2	$7,500					$0	$7,500	$3,750	$3,750			0.0

To analyse remediation and maintenance costs, the small-scale sites were again separated into the two groups (catchment and gully treated and catchment only treated). The sediment saving estimate for projects varied considerably, ranging from 1 -138 t/y at the site (Table 4). Like the large-scale projects these estimates lack certainty. The variation in sediment savings has a large influence over the cost effectiveness for each site. Table 5 presents average cost effectiveness metrics. The two small-scale sites that failed to stabilise, Sites 19 and 22, are not included in Table 5. The median cost effectiveness for the two groups, small-scale catchments and gullies and small-scale catchments only, are $1560/t and $2522/t respectively. Maintenance at the eight small-scale sites was relatively expensive compared to the initial costs; maintenance at 50 per cent of the initial implementation costs was not uncommon. There were no maintenance funds spent on catchment only sites.

Table 5. Summary of the cost effectiveness of the 24 sites *.

Cost effectiveness statistics**	Mean ($/t)	Range ($/t)	Median ($/t)	Number of samples (n)
Large scale	$607	$ 420 - $ 570	$573	4
Small - gully + catchment	$2,309	$6,322 - $548	$1,561	13
Small - catchment only	$2,408	$3,750 - $1230	$2,522	4

* Caveats: 1. There is considerable uncertainty around the sediment saving estimates (t) for all sites. 2. Sample numbers are small. **Outlier sites not included: 5, 19, 22.

DISCUSSION

LIMITATIONS OF THE DATA

This study had a small number of sample sites (24) in a relatively small region of Queensland and most were in highly erodible soils. In addition, sites were only monitored for three years during relatively moderate climatic conditions. With regards to cost estimates and cost effectiveness calculations in this report, there is some uncertainty in the sediment reduction estimates and construction costs only included direct materials and labour. Cost estimates did not include those associated with site identification, surveying, design, compliance with legislation, project management, contracting and monitoring. Therefore, caution should be exercised when applying any of the conclusions or recommendations in this discussion as every erosion site is unique and methods of estimating sediment loss are still being refined.

LARGE-SCALE SITES

Although there are only five large-scale gully remediation sites some useful analysis is possible because the sites are similar across important variables commonly accepted to drive success or failure. These are:

- Climate – the sites are in the same regional area, and since construction there has been average yearly rainfall totals. However, it is likely that high intensity events have occurred,
- Soil type – all sites have Sodosols, fragile soils with dispersive and slaking subsoils, Site 1 seemed to be more prone to tunnel erosion.
- Implementation – all sites were supervised by professionals, design plans were followed, and maintenance was timely.
- Focus on improving land condition - All sites were fenced, cattle were excluded for two or more growing seasons, and any grazing was for a moderate term (one week to two months).

The discussion of the large-scale sites will address four key questions:

1. How long did it take for the large-scale sites to stabilise?
2. What were the primary causes of reduced success/soil stability at the sites and how can these be remedied?
3. What changes to planning and design are recommended to improve large-scale gully remediation?
4. What maintenance schedules and maintenance costs should be embedded in the remediation plan?

How long did it take for the large-scale sites to stabilise?

In the absence of major weather or climate events and with timely maintenance, an intensive landforming, amphitheatre-like reshaping treatment on gullies in erosive, Sodosol soils (Sites 2, 3 and 4) may stabilise with high pasture cover within four years. Sites with tunnel erosion such as Site 1 are likely to take longer to achieve stability and will rely on continued yearly monitoring and timely maintenance. All sites are vulnerable to damage during extreme events. Although sites were considered stable or mostly stable this is determined from surface appearance and above ground vegetation condition. Monitoring in this project did not investigate how soils were developing towards stability at depth, nor the depth of the roots of the vegetation present. Hence, monitoring and maintenance may be required at all sites for many years, particularly after extreme rainfall events. Landloch Pty Ltd (2024) advises that, with the impacts of climate variability and grazing, the recovery period for soil and vegetation in incised gullies following large-scale remediation like Sites 1-4 in the BBB is likely to be relatively long (5-20 years).

A high level of vegetation cover is essential to stabilise highly disturbed, reshaped gullies. As expected for a cropping-like revegetation approach, most of the increases in vegetation cover took place in the first two years following the remediation works. These improvements had occurred before monitoring of Sites 1-4 under this project began. Figures 8 and 9 display vegetation condition scores for years 3-5 for Site 1 and years 2-4 for Sites 2, 3 and 4, respectively. When monitoring began most sites were already in B or even A condition, having improved from an estimated D or C condition (15-35/100). The CSIRO-based research at Site 1 captured vegetation data in the first two years, before this project started, and results support the observation that large improvements in land condition and related vegetation metrics were achieved in the first 1-2 years. Bartley et al., 2025 (p. 26) conclude that at Site 1 *"statistically significant increases in vegetation metrics (vegetation cover and biomass) occurred in the first year and this can be attributed to the remediation works. In the following years metrics tended to climb more slowly or plateau till 2022. In 2023 Site 1 biomass declined to near pre-treatment levels"* (Bartley et al., 2025, p.35). This is discussed further below.

Site 5 was given the lower 'partly stable' status in December 2024. This is mainly because neither of the gully areas (northern section and southern section) were given a comprehensive treatment. However, the southern section provides an example of successful low impact facilitated revegetation. This is described in more detail below under key question 3, Light remediation works. While slower to 'get going', the vegetation that has established is suited to harsh conditions and may prove to be more long-lasting than the treatments implemented at Sites 1, 2, 3 and 4. In contrast, the treatments in the catchments at Site 5 greatly increased vegetation cover, reaching A condition in three years.

What were the primary causes of reduced success/soil stability at the sites and how can these be remedied?

The main drivers of reduced stability at the large-scale sites were:

- patches of erosion (mainly sheet, rill and tunnel erosion);
- reduced ground cover (e.g. <70 per cent); and
- Lack of biodiversity (dominance of *Desmanthus sp*. or Indian couch, *Bothriochloa pertusa*) (Table 3).

Sheet and rill erosion is primarily caused by runoff over bare ground, particularly during the wet season (December - March). As ground cover increases, this erosion will typically reduce. LCATs are designed to capture resilient ground cover, primarily the amount of perennial grass tussocks so changes will be relatively slow as perennial species replace annuals, or the reverse for declining land condition. In contrast, ground cover and biomass can change quickly in response to seasons and grazing pressure. Bartley et al., 2025 measured ground cover and biomass at Sites 1 and 2. For Site 2, the 'Stable' site, bare areas reduced markedly in the first two years as ground cover increased, achieving >70 per cent cover in two years (p.39). At Site 1, ground cover and biomass increased significantly (compared to the control site) in the first year following treatment. Subsequent years saw declines in biomass (although not statistically significant) and this was attributed to climate, rainfall and grazing (Bartley et al. 2025, p. 35). *"The increase in grazing pressure at the treatment site after year 1, reflected by higher defoliation rates post-treatment, suggests potential co-benefits for grazing productivity. Nevertheless, careful grazing management will be essential to sustain vegetation cover and biomass levels"* (Bartley et al., 2025, p. 35).

At Site 1, cattle tracks were noted by the construction specialists in their regular monitoring; these were repaired during maintenance to prevent erosion developing. The grazes at Site 1 occurred in conjunction with the larger paddock and tended to be longer than graze periods at the other large-scale sites. The grazing regime was typically 100 weaners twice for two months in the dry season. The smaller areas of Sites 2, 3 and 4 led to shorter graze periods which reduced the likelihood of cattle pads which can rapidly develop into rill and gullies. Similarly, Landloch Pty Ltd (April, 2024) in their report on the performance of 11 large-scale gully sites in the BBB, noted that five were impacted by cattle or feral animals despite fences being in place.

At Sites 1, 2, 3 and 4, *Desmanthus* species was planted as part of the pasture seed mix after the earthworks and along with ameliorants such as gypsum and fertiliser. At the end of the monitoring project, *Desmanthus sp*. (most likely Progardes) dominated Sites 1, 3 and 4; reducing land condition scores. The contracted engineer for Sites 3 & 4 has also noticed the dominance of D. "Progardes" over time at sites and the use of less domineering legumes is being considered, which might see the removal of D. "Progardes" from proposed rehabilitation seed mixes for future sites (pers. Comm. J. Allen). Factors driving this increase in the legume D. progrades over grass species may include the depletion of the initial fertiliser, a lack of grazing of the legume and/or the sheer resilience of the legume. Inorganic and organic fertilisers were used at all large-scale sites (Sites 1-5). Organic fertilisers included bagasse, mill mud and hydromulch. The grass may have been relying on the fertiliser applied during the initial works and this may now be depleted. Without effective recycling of nutrients such nutrient sensitive plants will struggle. In contrast, the legume can fix nitrogen, a major plant nutrient (refer to Figure 11 and Figure 13). Secondly, to establish a balance of legumes and grasses, the legume may need to be grazed down while the plant is still establishing (*Pers. comm.* C. Poole). Early grazing of a site would have to be very carefully planned and managed.

Results indicate that Site 2 has achieved a balance of grass and *D.* "Progardes"; Rhodes grass (*Chloris gayana*) was the primary species. Site 2 has maintained a high score with no drivers of reduced land condition. Future monitoring will be required to see if Sites 3 and 4 develop a better balance of legumes and grasses. At sites 1, 3 and 4 the Desmanthus tended to be tall (~1.5m). This is not the type of vegetation recommended for stabilising the sites - rather grass species are needed to provide cover close to the soil surface (Landloch Pty Ltd, 2024, P. 4). There are several more prostrate legumes that drop their leaves during the dry season that may be more suitable (*pers. comm. C. Poole*).

Sites lacked diversity in the plant species present. This is understandable given the harsh soil conditions for plant growth. Nevertheless, efforts should continue to improve seed mixes and revegetation techniques on the large-scale remediated gullies.

The treated catchments at Site 5 achieved high land condition rating (A condition) and were deemed fully stable. The bunds, rock chute and revegetation have maintained their integrity and have 'settled' into the landscape (refer to Figures 14 and 15). Works on the gullies and 'bad lands' only occurred in the upper parts of the southern section. The reduced stability of the gullies by December 2024, is attributed to the lack of remediation work in the gullies themselves. In the southern section, limited works were planned after costing revealed that the amount of ameliorants needed to make the older, lower areas suitable for revegetation would be uneconomical. The extensive landforming works that were planned for the northern gully section were not undertaken after discovering a large amount of rubbish at the site. Consequently, Site 5 ended up being like a small-scale treatment.

What changes to planning and design are recommended to improve large-scale gully remediation?

Focus on revegetation

The revegetation was impacted in the initial stages by sheet and rill erosion due to rainfall events. The subsequent repair work impacted the sites further. Site recovery is likely to be faster when the revegetation is dominated by grasses and is successfully established in the first year.

Refinements to the revegetation approach could include:

- Grass seed mixes with careful consideration of the inclusion of legumes. More information on legumes and sown pastures is available through the North Queensland Pasture Resilience Program. This program can be found on the Future Beef website where there are fact sheets, resources and contact details for personalised support.
- Functional trait-based species selection (e.g. Halophytes at Site 5).
- Improved seedbed preparation and soil-seed contact: Tilling, seed tackifiers, hydromulch, mycorrhizal fungi inoculants, soil microbiome enhancements.
- Irrigation to get initial grass establishment but with plans (e.g. fencing) for managing wild grazing animals (e.g. wallabies) that could, subsequently, be attracted to the site.
- Mulch and/or crushed rock to cover all reshaped gully areas (Wilkinson et al., 2022, p.51). When rolled or spread out on the contour the mulch can provide effective

raindrop impact, reduce sheet flow and thus reduce the need for check dams. The hollow grass stems of the straw collect and bind a surprising amount of fine sediment. Also, mulch will create a better bed for vegetation to establish. In contrast, the rock surfaces of check dams don't support grass and tend to provide ideal habitat for rubbervine (Cryptostegia grandiflora). Mulching requires considerable manual labour or, alternatively a round bale unroller could be used. Some unrollers are simple implements that can be pulled by a 4x4 farm utility vehicle. The application of mulch may need to be refined for sites, climates and soil types; experimenting with types of hay, thicknesses, distance between mulch berms and light soil covers. Figure 29 describes experimental mulching on Site 22 in September 2024.

- Mulch straw could also be used to make berms and may reduce the number of rock check dams required.

Site 22 underwent maintenance work in October 2024. After lowering the height of the bund and addressing the rill erosion in the reshaped bowl, mulch was placed in berms on the contour. Large square bales were used. The mulch was placed as biscuits (~10 cm thick). As an experiment, the mulch lines in the leading third of the gully (right side in Figure 29) was partially covered with some local soil (topsoil and subsoil mix). A tropical pasture seed mix was hand sown over all disturbed areas. In January 2025, 16 weeks after the maintenance work pioneering forbs, particularly Tar vine (Boerhavia erecta), was covering a significant part of the treated area where soil had been placed on the mulch. Unfortunately, Bellyache bush had also germinated rapidly. The sown seed had not germinated yet. The yellow dot in the bottom left photo indicates position where the bottom right photo was taken, facing towards the gully head.

Figure 29. Maintenance at Site 22 in September 2024 included mulch strips on the contour to cover as much bare area as possible.

Site specific grazing plans

Current advice around grazing of remediated sites is that grazing needs to be carefully considered and monitored to ensure treatments are not compromised (Bartley et al., 2025 in draft, p. 35; Landloch Pty Ltd, 2024, p. 3). The results of this project support this advice and, in addition, recognize the need for more investigation around maximizing the benefits while minimising the detrimental effects of grazing remediated sites.

The landholders with large-scale sites followed the advice in the Gully and Stream bank Toolbox guidelines – fencing around the site, excluding cattle in the initial years and then grazed lightly. However, what 'light grazing' looks like varies between graziers. At Site 1 grazing each year tended to be two lots of two months by around 100 light cattle (weaners) as part of a larger paddock. Impacts by cattle were noted by the contract engineers, was discussed by (Bartley et al. 2025, p. 35) in relation to dips in biomass and ground cover data and is believed to have contributed to the dip in LCAT scores in this project, due to increased erosion along cattle tracks (Figure 7. 2023-2024). Sites 2, 3 and 4 were grazed for shorter periods than Site 1 (e.g. 1 week). Given the negative impact of cattle padding at these large-scale sites it is recommended that grazing is for shorter periods so that no cattle tracks are created.

There is no single grazing regime that will suit all remediated sites. Furthermore, given the intended progression towards stability and landscape functionality there will be no one grazing schedule that suits the same site every year. Each gully site has a unique suite of characteristics: soil, history, treatment, land type, slope, land use objectives, and management. Grazing can be employed to boost soil development and therefore, soil stability through the interactions of plant growth and soil biological activity.

Decisions around grazing are complex and require considered thought. Grazing, as a tool to improve land condition, needs to be adapted to the specific needs of the site at a point in time. It is recommended that grazing specialists be engaged to assist in managing grazing at large-scale remediated sites and that a written grazing plan is maintained as a 'living' document; grazing plans, site monitoring and adaptations to the plan for the next graze are recorded. Landloch Pty Ltd (2024 p.2) suggest that such plans include:

- Specific target levels for vegetation cover/ biomass and,
- Subsequent agreements with landholders based on the provision of appropriate management to maintain these targets into the future, 20 or more years.

Continue to address maintenance requirements early

The large-scale gullies that were intensively remediated, Sites 1, 2, 3 and 4, required maintenance after the first wet season and at least once more in the following four years. The initial maintenance at all sites was primarily repairs to rilling on the recently reshaped areas; for some more gypsum was applied, and some reseeding, including hydromulching at Site 2. At Site 1 maintenance activities included repairs to reoccurring slumping / tunnelling, particularly around rock chutes, while Sites 2, 3 and 4 maintenance involved adding bunds and extending or adding rock check dams. Without this timely maintenance, these large-scale sites would mostly likely be unstable and not on their positive trajectory toward stabilising.

Consider low impact remediation works

Site 5's low impact remediation works in the upper gully scarps and channels of the 'badlands' were relatively successful and should be considered for the remediation of similar sites (Figure 30). It is likely to be a cost-effective and practical alternative on old gully sites where rates of soil loss are diminishing and therefore costs need to be kept relatively low.

Such light approaches focus on facilitating natural regeneration and therefore, it suits for work to be carried out in stages; utilising an adaptive plan, tailored to the site and responding to the progress achieved in previous stages. It is anticipated that if Site 5's southern section had another one or two stages, it may have been 'mostly stable' in five years with a diverse, primarily native, cover of vegetation.

The works in Site 5's southern section were low impact because landforming earthworks were deemed to be uneconomical due to the advanced stage of the erosion, the poor fertility of the remaining soil material and the hostile conditions for vegetation. The plan avoided soil disturbance and concentrated in the upper scarps and channels of the 'badlands' where more subsoil remained.The treatment was tailored to the soil materials' deficiencies, involved ameliorants of gypsum, fertilizer and millmud, seeding (specialist plants- halophytes) and mulching of the channels. Together, with total exclusion from grazing, this treatment has facilitated revegetation, creating a habitat that is favourable to the native woody shrubs, particularly the Spiny fan flower (*Scaevola spinescens*) and Currant bush (Carissa sp.). Spiny fan flower is regenerating rapidly, responding to the favourable conditions that were created. These low shrubs act as a living weir in the channels; reducing flow velocity causing soil to drop out of suspension. More plants then flourished in the deposited soil material.

Figure 30. Additional information on the low impact works at Site 5.

What monitoring and maintenance schedules and maintenance costs could be embedded in large-scale gully remediation plans?

The monitoring and maintenance schedules adopted in this project was appropriate and is recommended for future sites: Monitoring the site at the end of the wet season each year, then planning and undertaking any required maintenance in the dry season. The results of this project indicate that a minimum of four years of monitoring following construction would suit the most successful large-scale sites. Longer monitoring and subsequent maintenance would be required for more 'difficult' sites such as Site 1, or if the site is impacted by flood, drought or over-grazing. The Gully and Streambank Toolbox recommends at least two, or ideally three years of monitoring, recognising that time limits are placed on publicly funded projects and that, at the completion of projects, future monitoring and maintenance will be the responsibility of the landholder (Wilkinson et al., 2022, p.29, Landloch Pty Ltd, 2024, p2).

The total maintenance costs (public investment and in kind) for the five large-scale sites varied from $48,231 (Site 1) to $10,644 (Site 4). Compared to the initial project costs, Site 2 had the smallest maintenance expenses (1.7 per cent of the initial on-ground project costs) and Site 5 the largest (9.9 per cent). For the four intensively treated sites (1-4), these figures concur with those given in the Gully and Streambank Toolbox - typically 1-4 per cent of total construction costs (Wilkinson et al., 2022, p. 28). If not already doing so, project managers would be advised to conduct a risk assessment on the proposed remediation works and use it to inform how much money to allocate to future maintenance, drawing on the maintenance required at previous sites, such as those described here and in Landloch Pty Ltd (2024).

SMALL-SCALE SITES

The small-scale sites varied more than the large-scale sites with regards to Soil types, Implementation (expert input) and the landholders' Focus on improving land condition (Grazing management) (Table 2). Nevertheless, the discussion will be presented around the same key questions:

1. How long did it take for the small-scale sites to stabilise?
2. What were the primary causes of reduced success/soil stability at the sites and how can these be remedied?
3. What changes to planning and design are recommended to improve small-scale gully remediation?
4. What maintenance schedules and maintenance costs should be embedded in the remediation plan?

How long did it take for the small-scale sites to stabilise?

Catchment only works

The results of this study indicate that, if remediation works are implemented following standard soil conservation guidelines and near average weather conditions follow, renovated catchments of gullies in Sodosol soils are likely to stabilise within three years. Gully catchments in the Open Downs land type with Vertosol soils may take only two years. This is expected given that catchments tend to still have sufficient topsoil to support vegetation, and when released from excessive grazing pressure, land condition improves. This is not the case when the thin, but essential topsoil has eroded away.

Gully remediation works

For the remediated small-scale gullies, results suggest that, if soil conservation officer's plans are followed and there are average weather conditions after the work, a site is likely to be 'mostly stable' within three years (Table 3, 9/12 sites, Figure 14 with sites removed if poorly implemented/ plans not followed). All the sites were monitored in years 3-5 following the works, 2022-2024, but the last two years of monitoring recorded few improvements. More often than not there was a slight reduction in stability/land condition and this coincided with the re-introduction of grazing (Table 3, Appendix 2 and Figures 13 and 16). This will be discussed further in the next section. The two sites deemed to be stable were in Vertosol soil of the Downs country land type. Notably, these results cast doubt on the ability for small gullies in Sodosols to achieve full stability.

What were the primary causes of reduced success/soil stability at the sites and how can these be remedied?

The main drivers of reduced stability at the remediated small-scale sites (catchments and gullies) were:

- presence of erosion (sheet and rill erosion);
- reduced ground cover (e.g. <70 per cent, there was a pasture deficit due to overgrazing at 19/58 LCATs across six sites, five attributed to cattle grazing, one wallaby grazing); and
- lack of biodiversity (Indian couch, *Bothriochloa pertusa* dominated at almost half of the LCATs 28/58 over nine sites) (Table 3).

These three causes of reduced land condition, recorded through the land condition assessments, reflect the observations made at the small-scale sites across the three years. It is expected that, for most sites, the impact of these three drivers of land condition would be eased by a more concentrated focus by land managers on improving land condition at the recovering site.

In 2022, the first year of monitoring, sites had typically been protected from regular grazing for two or three years, vegetation biomass was relatively high, some desirable pasture species present and bare areas seemed to be reducing. Some remediated catchments were in B condition and the remediated gullies were mainly in C condition. Over the next two years of monitoring, sites in the Vertosol and Kurosol soils tended to continue to improve in stability, despite a return to light or moderate grazing. However, the condition of sites in the Sodosol soils tended to dip for the treated catchments (Figure 12) and plateau for the treated gullies (Figure 16). This dip coincided with when most graziers reintroduced grazing to the site. Of course, there are other likely influences, particularly rainfall; 2022 (first year of monitoring) was a wetter year than 2023. This project was not a scientific research project; isolating the effect of grazing of the Sodosol sites from other factors is not possible. However, there does seem to be broad, not-unexpected patterns in the relationship between the level of stability/success of remediation and the land manager's 'Focus on improving land condition'. This is displayed in Figures 17 and 18.

Catchment remediation is more likely to achieve a high stability rating despite the grazing land management, particularly on flat terrain (Figure 17). In contrast, remediation works in gullies are likely to do better under management that focuses on improving land condition, but this does not guarantee success e.g. achieving stability within five years (Figures 18 and 15). This concurs with the advice of many erosion management practitioners – exercise caution when planning to remediate gullies in erodible soils (e.g. Sodosols), and vegetation (ground cover, biomass, plant diversity) is essential for long-term stability (Carey et al., 2015, Ch. 13 p.21; Wilkinson et al., 2022; Landloch Pty Ltd, 2024,p.2). For gully sites that are fenced out, a forage budget will likely reveal that grazing the recommended 10 per cent of the standing dry matter is unlikely to have a significant production benefit.

What changes to planning, design and implementation are recommended to improve small-scale gully remediation?

Plan for tropical deluges, limited infiltration and high runoff

The BBB is in the topics and, therefore, most of the rain falls in summer with a lot being delivered during high intensity events (Table 1). Consequently, most of the rainfall is likely to become overland flow rather than infiltrate into the soil. Furthermore, Hawdon et al. (2025, p.2) found that, while sediment was reduced through effective remediation works, runoff was not significantly reduced at the four sites which included Sites 1 ,2 and 24. This challenges a commonly held assumption that remediation works, together with the establishment of deep resilient vegetation, will reduce the quantity of runoff that flows into channels, gullies and creeks.

Consequently, structures need to be designed to an appropriate intensity of rainfall event (with little or no discounting for assumed improved infiltration) and most structures should aim to spread flow rather than concentrate it. Furthermore, it is the ground cover (vegetation) that is driving the sediment reduction so, for long-term success, structures need to be supported with revegetation and this needs to be carefully managed, including protection from grazing pressure (Hawdon et al., 2025, p.37).

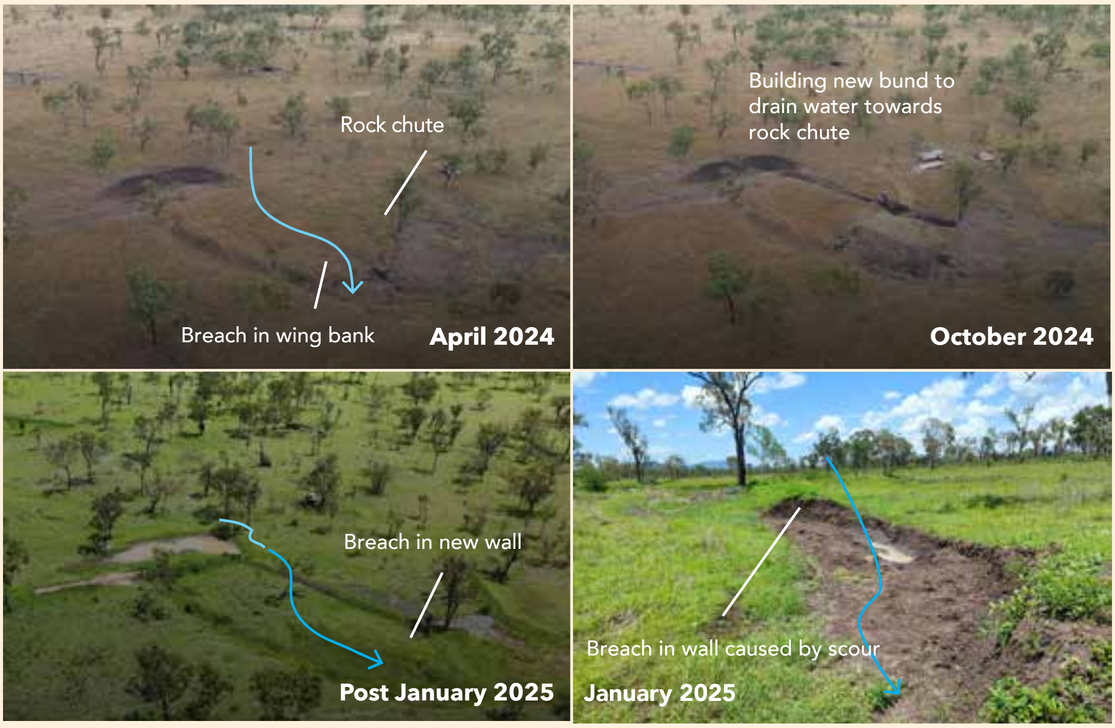
Adhere to the plan

Of the 19 sites, nine are deemed to have underperformed; they either required maintenance or failed to stabilise. For two thirds of these sites (6/9) the deficiencies can be attributed to not following best practice when implementing the plan. Inadequate site supervision was common and there were relatively small, but significant departures from plans. There were no documented post-construction surveys. This is an identified area needing improvement for both small and large-scale sites (Landloch Pty Ltd, 2024,p.3) and reflects the general lack of suitably qualified people in the sector.

Understand the soil and plan accordingly

Catchment works are low risk and can be an important first step in managing gully erosion. However, as for the gullies themselves, the soil in the catchment needs to be well understood to plan appropriate catchment works. Important soil characteristics to investigate are infiltration rate, stability (stable, slaking or dispersive), depth of topsoil and the fertility (structural and chemical) of the subsoil. Diversion banks, stick lines and shallow ripping to slow runoff need to be justified and cost-effective, and should only be considered after changes in grazing land management have been explored. Sometimes mechanical intervention is not warranted; land condition can be improved sufficiently through exclusion or resting in the wet season. If ripping is implemented, the depth of the effective soil for the desired plants needs to be known; there is little benefit in ripping into a subsoil that the roots of pasture plants cannot penetrate or survive in. This is usually the case for the Sodosols of Box country; the most common soil type amongst the small-scale gullies monitored in this project.

Similarly, the characteristics of the Vertosol soils in the Downs country land type in the BBB have unique properties that may confound gully remediation. Most importantly the soil develops cracks in the dry season which makes banks vulnerable to tunnel erosion in the wet season, particularly during intense first rains before the soil has swelled to full water-holding capacity. In addition, this cracking clay, unlike the Vertosols of Brigalow country, is friable, crumbles easily and is vulnerable to all forms of erosion. This was illustrated at Site 24 (see Figure 31).



Site 24 – Lessons from a rock chute installation

At Site 24, a rock chute was installed below a series of diversion banks. Over the following four years, the sharp gully edges gradually battered down and vegetated quite quickly. However, while the diversion banks successfully increased the length of the flow path and slowed runoff, this had no significant effect on the overall runoff volume (Hawdon et al., 2025, p.23). This is likely due to the site's shallow soils (less than 2m deep in the lower gullies) and a slope of approximately 6 per cent, both of which limit water infiltration.

Standard twin wing banks were installed either side of the rock chute to direct runoff safely onto the stable gully floor. However, the eastern wing bank retained water instead of draining freely. This led to tunnel erosion and ultimately caused a break in the bank. Interestingly, dead land crabs were found in the dried pond that had formed behind the bank, and may have contributed to the failure.

As a result, the rock chute was bypassed. Sediment buildup in front of the chute's crest may also have contributed to this change in flow direction.

Remediation works were undertaken in the 2024 dry season. The eastern wing bank was rebuilt on higher ground to promote free drainage. However, due to limited space and a steep drop into one of the gully branches, the structure became a bund linking the final diversion bank to the chute. Despite being well constructed, the bund was scoured out during the first rains, and much of the material was deposited in front of the chute, leaving it high and dry once again.

It's worth noting that the original design by a highly experienced soil conservation officer did not include a rock chute. Instead, the plan featured broad spreaders placed on a firmer ridge.

Key takeaway:

Rock chutes are generally unsuitable for the mobile soils of the Downs country. They are costly, challenging to site correctly, and require ongoing maintenance to remove sediment buildup. Keeping broad, flat flow paths clear is essential to reduce water velocity and erosion. Most importantly, maintaining high vegetation cover remains the most effective strategy for preventing and repairing erosion in these landscapes.

Figure 31. Additional information on the maintenance at Site 24.

Plan banks that slow down rather than retain water

If constructing earthen banks in the catchments of a gully, build them to slowly drain runoff, not to retain runoff. These structures tend to be called diversion banks on grazing land and contour banks on cropping land. Diversion banks and contour banks are designed to intercept runoff before it concentrates and starts to cause erosion, and then safely channel it into a more stable area (Carey et al., 2015, Ch. 8 p.6). They need to have a low slope on the channel (0.1 per cent - 0.4 per cent) and not hold water behind them, as opposed to a dam bank or pondage bank.

Dams, retention (rehydration) banks and other structures that hold water are not likely to suit catchments above gullies because:

- Many soils at gullies in the BBB, when wet, are prone to tunnel erosion that leads to bank failure. In this study, well-constructed banks failed at three sites, two of which had land crabs in the vicinity that are suspected of initiating the tunnel (see Figure 32), and the other occurred at a soil change where a cracking clay met a sandy loam.
- Retained water must be released at the outlet with minimal erosive force. This requires a well-designed, properly constructed, and regularly maintained bywash (for dams) or spreader (for banks). Achieving this can be particularly challenging in dispersive or slaking soils.

An inland freshwater crab species, likely Austrothelphusa transversa, was found at Sites 10 and 24 near earthen walls that had held water but failed during the wet season due to tunnel erosion. While not conclusive, there is a reasonable possibility that crab burrows contributed to these failures, particularly at Site 10, where the soil is sodic (Sodosol).

These crabs are adapted to life in ephemeral waterholes across northern Australia. They dig burrows into the sides of channels and banks to reach the water table, where they aestivate (remain dormant) until the wet season (Waltham et al., 2014, pp. 1–2). Individual crabs can create burrows up to one metre deep in dense clay soils along freshwater rivers, creeks, drainage channels, swamps, pools, and farm dams (Queensland Museum, n.d.). During dormancy, they seal their burrows with earth to retain moisture, allowing them to survive dry conditions. Females also care for their young during this time, keeping them in a thin film of water beneath their abdomens. When the rains arrive, the burrows rehydrate, and the crabs emerge, releasing their fully developed young into the water. In prolonged droughts, the juveniles can remain in suspended development for up to six months, waiting for suitable conditions (Queensland Museum, n.d.).

At Site 10, 11 crab holes were observed in October 2023, along with two dead females, within a 3-metre stretch of the earthen wall, precisely where the wall had previously failed, both before and after gully remediation works. In 2024, two additional burrows were found at the base of the same wall, around the highest level reached by dam water.

It is believed that these burrows, being long, sloped downward, and potentially reaching up to one metre in depth as described by Waltham et al. (2014, p. 2), could have initiated piping in the sodic soil when the dam water level was high, ultimately contributing to wall failure.

Figure 32. Additional information – Site 10 Freshwater land crabs may have undermined remediation efforts

- Dams and other water bodies attract animals and so are high impact areas, so erosion remediation nearby is likely to fail.
- Banks designed to rehydrate the land through subsurface flow downslope will only work in specific parts of the landscape (e.g. colluvial deposits), in specific soils (sandy), and where there is enough depth in the soil to take in sufficient water to justify the cost of the infrastructure, including the on-going maintenance. This is not where gullies tend to be in the BBB.

Once remediated, gullied areas should be away from high impact areas. Attempting to combine catchment remediation earthworks above gullies with other property infrastructure such as a dam risks failure on both accounts.

Rock chutes in gullies - commit to high maintenance or avoid

Rock chutes can be effective if planned and installed well, and repairs are attended to promptly. All the rock chutes at small-scale sites needed repairs. Many of the issues were associated with erosion of bare earthen abutments as vegetation was difficult to establish on the poor soil.

Protect rock chute abutments

The earthen abutments on the sides of rock chutes often required maintenance. Establishing resilient vegetation on these slopes will prevent their erosion. When rock chute abutments are formed in sodic soil material they should be covered with 20-30cm of stable soil, along with the rest of the chute foundation (Carey et al., 2015, p.68). However, it is understood that, for most of the rock chutes on sodic soil at large-scale sites, instead of importing stable soil, sodic subsoil material was mixed with gypsum, and other ameliorants as necessary, to 'make' a stable soil. For small-scale sites, if a rock chute is decided as the best option, stable soil should be imported to cover the sodic foundation. The revegetation of all exposed soil around a rock chute is an essential part of its installation and this should be managed by a qualified person. Rock capping on the steeper slopes may be an effective addition. Also modifications to the abutment design may be possible to improve the likelihood of vegetation establishing. For example, a wider chute might lower the necessary height of the abutments leading to a gentler grade on the abutments which will assist vegetation establishment (Cary et al. 2015). Livestock needs to be kept away to prevent damage to the structure.

Rock chutes in Downs country should be avoided as explained in Figure 31 - Site 24.

Concrete matting could be an appropriate alternative to rock chutes in gullies with small catchments and instead of rock capping of channels (Landloch Pty Ltd (2024, p. 6) (Figure 33). The matting needs to be subjected to the same rigorous hydraulic assessment during the design stage that rock chutes are. Unlike a rock chute, concrete matting allows for vegetation to more readily grow through it, enabling the soil surface in the channel to strengthen over time. The concrete matting relies on vigorous, deep-rooted perennial plants growing within it to achieve maximum stability. Achieving such vegetation growth is likely to be challenging in many gully sites in the BBB where the only soil material is poor fertility subsoil.

Limit grazing at sites that have little topsoil

Gullies and other erosion areas with little or no topsoil are unlikely to provide much feed in a paddock. However, cattle activity can cause significant damage to a remediated gully site. Results of the monitoring of small-scale sites suggest that restricting cattle access to remediated sites in Sodosols is essential. If done well, restricted grazing will give the site a chance of achieving a stable state but there are no guarantees. None of the six remediated gullies in Sodosols achieved stability (Figure 24) but sites under more control (i.e. high focus on land condition) performed better than those under less restriction (i.e. moderate focus on land condition). The 'moderate focus' rating represents the grazing management for the bulk of the sites with remediated gullies (10/14). Grazing management for the moderate rating typically involved resting for two wet seasons and then grazing the site as part of the larger paddock for 2-5 months at a time in the dry season. Results suggest that this type of management does not provide enough protection to the fragile vegetation, particularly for sites with Sodosol soils and creates tracks that invite erosion. Short grazes

Figure 33. Concrete matting was placed at Site 10 as a trial. Here it was placed at the crest of a spillway.

may benefit sites by promoting fresh plant growth and this is discussed in the previous section – large-scale sites: Site specific grazing plans.

One of the remediated gully sites in Sodosol soil that failed to stabilise was impacted by overgrazing by wallabies. With the benefit of hindsight, this site should only have been remediated when the grazing by wallabies could be much reduced.

Fencing around gullies is one way to restrict cattle but this is often impractical where there are many small gullies. However, there are a number of creative ways in which grazing can be effectively limited and, given Australia's history of clever innovation in the bush, there are probably more ideas yet to be devised.

Use low impact remediation techniques for better cost effectiveness and low risk

Light works in the gullies, that do not disturb erodible soil, has many advantages:

- Much reduced risk of exacerbating the erosion compared to earthworks.
- Work can be done in stages, starting with the control of grazing.
- Work can be tailored to the site's recovery, avoiding costly interventions that may not have been necessary.
- Small gullies that are partially filled or covered with stable material such as fill material, sand, soil or straw can revegetate quickly.
- Gully head works can concentrate on the most active erosion only, achieving high cost effectiveness (Hawdon et al., 2025, p. 37).
- Light works facilitate natural regeneration, and this is more likely to result in a steady increase in gully stability of time.

Refer to Section – large-scale gullies – Consider low impact remediation works and Figure 30.

What monitoring and maintenance schedules and maintenance costs could be embedded in small-scale gully remediation plans?

Monitoring and maintenance schedules

The results of this study suggest that most sites would benefit from two to five years of monitoring and maintenance, with longer times frames for difficult sites. A site-specific risk assessment done at the planning stage will help determine an appropriate time frame.

The monitoring of land condition at catchment sites should take place every year, preferably at the same time (e.g. end of dry season). These can be included in the annual round of land condition assessments carried out on the property. Structures installed in catchments and in gullies should be monitored during and/or at the end of each wet season. In this way, any maintenance required can be planned for the dry season, perhaps coinciding with other earth works such as track maintenance.

Maintenance costs on catchment works

Maintenance schedules and budgets should be low for catchment works although any earthen structure such as diversion banks will require maintenance in time to maintain its integrity. One of the five catchment only sites required maintenance, and this was around 80 per cent of the initial costs. The repairs were required because the initial construction did not follow basic soil conservation guidelines.

Maintenance costs on gully works

Half (7/14) of the remediated small-scale gullies required maintenance and this had a large negative impact on the cost-effectiveness of the site (Table 4). For five of the seven sites maintenance costs were between 30 per cent and 80 per cent of the initial costs. When total maintenance costs are shared across all the remediated small-scale gullies the average maintenance costs was $8,600, which is around a third of the average initial cost. Even though mobilisation costs constitute a large proportion of this expense, maintenance costs should be lower. The main reason for this is that most of these maintenance jobs were at sites where initial works did not follow best practice. It is anticipated that if expert advice is followed and the recommendations such as those derived from this project are considered, maintenance requirements for similar sites under average environmental conditions would be fewer and less costly.

Timely maintenance, especially during the first wet season following initial works, was essential for the success of two of the small-scale gullies, as well as for four of the large-scale gullies. The two small gullies are in a favourable condition (mostly stable) because of the landholders' commitment to their project. They mobilised machines, sourced rock and made repairs as soon as the first rains started to cause damage, despite it being Christmas.

Landholders who do not have earthworks machinery readily available, or are unlikely to organise repairs should be discouraged from undertaking remediation that involves heavy earthworks, such as rock chutes and diversion banks. Low risk alternatives such as gully head fills, shallow ripping or stick lines are likely to be more appropriate in the long term.

Lesson learnt: It is important to do a good job during the initial work to avoid high maintenance costs. Sometimes repairs will need to be done promptly, while at other sites such as in the catchment, maintenance can be done strategically to share mobilisation costs.

ASSESSMENT OF THE MONITORING PROTOCOL

The protocol used to assess the condition of remediated sites was satisfactory, however better methods could be devised, particularly now that drones are used more widely. They can capture images (UAV photography), elevation data (UAV photogrammetry) and, hopefully soon, ground cover data at a small enough scale that is currently not available from satellites. The advanced LCAT provided a way of indicating the stability of the soil at the site because, in the more natural landscapes of extensive grazing, land condition reflects soil stability. The Gully Monitoring Tool (GMT) was useful to collect images and information on the various structures, but it doesn't have any summarising capability, such as a stability rating.

Ideally, landholders would be more involved in the monitoring of the sites and this would help to develop ownership of the site, as well as enable timely maintenance. While it is accepted that the ability for a grazing operation to conduct regular monitoring will vary, it would be good to have more clearly established the landholder's agreed level of involvement at the beginning of the project.

CONCLUSION

Remediated gullies, large and small-scale, in highly erodible soils in the BBB can reach a 'stable' state, as defined in this report, within four years. However, only four of 24 sites achieved stability and this occurred under favourable weather conditions and with a high standard of implementation and maintenance. Also stable sites are still fragile and will likely decline if vegetation is reduced and soil exposed. Most of the 24 sites monitored in this project were classed as 'mostly stable' or 'partly stable' at the end of the project (December 2024) and therefore, while considered to be on the trajectory to achieving stability, their fate depends on future events; particularly monitoring, maintenance, grazing pressure and extreme weather.

Although this study lacks scientific rigor, results suggest that the 'moderate grazing' pressure implemented by many of the landholders, negatively impacted the sites. The two small-scale gullies that did achieve the 'stable' rating by December 2024 were in Downs country Vertosol soils, a more fertile soil that is more easily revegetated. The small-scale gullies in Sodosol soils proved difficult to remediate. In contrast, the catchments of these gullies may stabilise within three years after renovation work as long as there is sufficient topsoil remaining and the area is managed well. Works in the catchments in the Downs country Vertosol soils may take only two years.

The costs of maintenance for the large-scale sites was relatively low and within a generally acceptable proportion of initial costs. In contrast, the cost of maintenance works (all earthworks) at small-scale sites was high, often more than half the cost of the initial works.

Ideally, the learnings garnered from this project will help to inform future gully remediation plans. Suggestions for improvement include:

- Sufficient time is spent in the early stages of planning to understand the erosion processes occurring at a site to ensure the efficacy of remediation works.
- Remediation plans are informed by a site-specific risk assessment/s that provides logic to the approach taken, suggests the duration of monitoring and outlines the likely issues to monitor.
- Suitably qualified people are available to plan, supervise construction and over-see the maintenance of engineered structures such as rock chutes.
- Revegetation specialists are engaged during planning, implementation and monitoring (e.g. 5-10 years).
- Monitoring, maintenance and grazing schedules are worked out collaboratively, involve grazing specialists and are documented.
- The requirements of the landholder with regard to protecting the revegetation, monitoring and maintenance responsibilities are clearly understood, and are formally agreed to by all parties.
- Low impact remediation methods are considered for improved cost-effectiveness or when the risk assessment indicates that it is pertinent to do so.

As a consequence the planning stage is likely to take longer and require more collaboration, but is likely to achieve better remediation outcomes and greater cost-effectiveness.

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Appendix 1. Rainfall data closest to remediation sites (Separate pdf doc)

Appendix 2. Land Condition Assessment Tool (LCAT) summary (Separate pdf doc)

Queensland Government

The Burdekin Major Integrated Project Gully Maintenance and Monitoring project is part of the Landholders Driving Change project funded by the Queensland Government through the Queensland Reef Water Quality Program.

NQ DRY TROPICS