Learnings and Observations – Review of Reef Trust Partnership Water Quality Improvement Projects: Updated Report

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TABLE OF CONTENTS

1 FOREWORD

As its title indicates, this document provides an update of a previous report.

The update has been prepared to include observations made on additional water quality project works that are specifically relevant to issues identified and recommendations made in the previous report. The initial report considered evaluations made of remediation projects addressing accelerated erosion affecting:

- 7 streambanks; and
- 21 gullies.

Since that report was completed in early 2024, remediation works have been carried out and assessed on an additional:

- 1 streambank; and
- 10 gullies.

Some observations made in assessment of these subsequent remediation works are relevant to recommendations made initially, and are presented in this update report.

2 EXECUTIVE SUMMARY

2.1 Background

Landloch was engaged as an independent technical advisor to review the extent and quality of remediation works undertaken by delivery partners through the Reef Trust Partnership (RTP) between the Australian Government and the Great Barrier Reef Foundation. Landscape remediation projects as part of the RTP Water Quality Component included incised gully systems and streambanks subject to accelerated erosion. Investment ranged from $350,000 to $5,000,000 per site.

Individual site inspections have been completed and detailed reports disseminated to appropriate delivery providers. This updated overview report provides a summary of overall findings and consequent recommendations as prepared initially, and includes additional learnings from the subsequent site inspection.

The initial reported noted that in general, the works carried out had used accepted industry practices and techniques, were broadly consistent with the designs prepared and – in the short term – were delivering anticipated reductions in sediment loads. However, the inspections identified a number of issues that create risks for the medium and long-term effectiveness of some of those works, particularly for the incised gully systems.

Based on the initial inspections, recommendations to minimise or avoid creating similar risks in future projects were developed. They are provided below in priority order within each of the project components (Planning, Implementation, and Maintenance).

Because of significant differences in typical erosion processes and risks and in works carried out for incised gully and streambank projects, variations in the application of recommendations to each erosion system are noted in the following tables.

2.2 Initial Recommendations

2.2.1 Planning and design

No.	Recommendation	Application to: Incised gully (IG) Streambank (SB)
1	Projects should include provision for monitoring and maintenance over specified periods after completion of works, with longer periods preferred where soil materials treated are saline, sodic, or both.	IG: 10-20y SB: 5-10y
2	Sampling and analysis of soil materials that will be used or exposed in site works should be carried out in accordance with guidelines[1] for soil survey at a scale of 1:5,000 or smaller. Analyses should consider issues of soil stability, hostility to plant growth, and fertility.	Both
3	Small (low) rock barriers to flow that are intended to reduce flow velocities in channels rather than to trap significant quantities of sediment should not be included in designs.	IG
4	Target levels for vegetation cover and species mix found necessary in design to achieve erosion control should be identified and specified.	IG: Pasture SB: Riparian vegetation
5	Agreements with landholders should be based on provision of appropriate management of project areas for periods appropriate to each site and prevailing risks.	IG: ≥20 y (grazing) SB: up to 10 y
6	Designs for rock chutes should be based on an average return interval (ARIs) of either 50 or 100 years, depending on an assessment of the likely costs of repair and maintenance.	IG
7	Hydraulic model runs and, for stream banks, geotechnical slope stability model runs, should be carried out with planned 'works in place' to identify any residual high-risk areas.	Both

2.2.2 Implementation

No.	Recommendation	Application to: Incised gully (IG) Streambank (SB)
1	For moderate or major projects (value >$250 000), works should be audited by a Suitably Qualified Person for compliance with design specifications at a series of hold points during construction.	Both

[1] *Guidelines for Surveying Soil and Land Resources* (NJ McKenzie, MJ Grundy, R Webster, AJ Ringrose-Voase, 2008).

2	Specialist oversight or supervision of rock chute construction should be provided to ensure consistent outcomes.	IG
3	Diversion banks or bunds should be constructed to gradients no steeper than specified in local Land Management Manuals.	IG
4	Fencing is essential in any project that involves establishment of vegetation to provide stability and should be constructed to a standard sufficient to reliably exclude or control access by grazing animals.	Both

2.2.3 Monitoring and Maintenance

No.	Recommendation	Application to: Incised gully (IG) Streambank (SB)
1	All moderate and major projects should have a formal and funded programme of regular monitoring of the continuing functionality of all components of the project works. This should extend until vegetation establishment meets the completion criteria targets.	Both
2	Maintenance and repairs should be carried out promptly when the need for such work is identified, with funding being provided for such works.	Both

3 BACKGROUND TO INITIAL RECOMMENDATIONS

The following information specifically refers to observations and conclusions presented in the initial report.

3.1 Planning and design

3.1.1 Provision for monitoring and maintenance.

3.1.1.1 Incised gullies

At least two factors have potential to create a need for maintenance works.

In gully prone landscapes, the soil materials exposed in the banks and bed of the flow lines are typically subsoils, of quite poor productivity and stability as they are commonly saline, sodic, and infertile. In consequence, despite application of gypsum and fertiliser, soil response to those treatments will be slow, and vegetation re-establishment will be both slow and patchy. Nonetheless, development and sustainability of vegetation (grass) cover close to the soil surface is important for erosion control. Impacts of climate variation and of grazing on vegetation cover and development will be quite significant, and the period of soil and vegetation recovery is likely to be relatively long (5 - 20 years). In most instances, revegetated gullies will never reach the productivity (grass biomass production) that would have been delivered by the original flow line, and may, in consequence, require careful grazing management in perpetuity.

For incised gullies, there is no potential to replace the soil that has been removed. Consequently, there is a permanent change to surface hydrology, with flows in the incised flow lines being more concentrated, with consequently greater flow velocities and potential to cause erosion. Therefore, the flow control structures constructed in incised gullies are required to deliver a permanent increase in flow line stability.

As observed in Landloch inspections, issues with revegetation (soil or grazing related) and with structures (resulting from construction limitations, soil, and drainage variability) should be expected to result in a need for maintenance for a proportion of project sites to ensure they continue to meet the design intent.

3.1.1.2 Streambanks

Generally, risks of erosion are lower than for incised gully repair. This can be attributed to two factors:

(i) The use of pile fields to deliver an immediate, relatively reliable, and moderately lasting (~20 years) reduction in flow impacts on re-shaped stream banks, and

(ii) The considerably better quality of the soil materials generally present in the sites treated.

Nonetheless, there will inevitably be sites for which repair becomes necessary.

For example, there has been one instance of a large flow occurring and causing damage while works were not completed, and other large, low frequency events will no doubt occur in the future and affect other sites in their early recovery phase.

Similarly, although riverbank materials are generally of better quality than subsoils in incised gullies, and vegetation growth is more rapid and reliable, vegetation growth that meets site targets is by no means assured. Impacts of drought and grazing are quite possible.

As well, there still remains potential for unsuitable (saline, sodic/dispersive, infertile, or acid sulphate) materials to be excavated and placed on or in the surface layer to be revegetated, thereby causing vegetation establishment to fail to show appropriate progression towards established completion criteria.

3.1.1.3 Overview

For a range of reasons, including site and climatic variability, it is highly likely that some projects will require remedial works and repairs to greater or lesser extents, particularly projects with engineered structures. Consequently, funding provision should be made for monitoring of site functionality and for repair works to be carried out promptly if found necessary.

Such funding should be sufficient for the life of monitoring and maintenance periods as noted in the recommendations section. These costs should be included in the cost benefit analysis during the design planning stage as they will influence the selection and sizing of controls and design. For example, it may be more cost effective to design a rock chute for a 1:100 event rather than a 1:50 event, because the maintenance cost will be lower due to the lower frequency of runoff events exceeding the adopted design standard.

3.1.2 Sampling and analysis of soil materials.

3.1.2.1 Incised gullies

In incised gullies, the soil materials exposed in the banks and bed of the flow lines are subsoils; typically, saline and/or sodic, and of low fertility. Gypsum treatment is generally essential to reduce clay dispersion and potential for hard setting, generation of suspended sediment, and development of tunnel erosion under rock chutes. Fertiliser is essential to achieve vigorous vegetation growth, thereby shortening the window of erosion risk in the period when the soil surface is either bare or poorly covered. Soil analytical data are essential to identify optimal and most cost-effective rates of ameliorants and fertiliser.

3.1.2.2 Streambanks

Riverbank materials are commonly composed of alluvium. As such, they are generally of better quality than subsoils in incised gullies. Nonetheless, soil material sampling and analysis is still strongly recommended, as:

(i) there still remains potential for unsuitable materials, or soil layers to be collected and placed within the root zone, and for vegetation establishment to be drastically reduced, as was observed at one site that contained appreciable quantities of fill that was supporting limited plant growth; and

- optimisation of fertiliser application is still desirable to ensure vigorous vegetation growth and to minimise the window of risk when vegetation cover is not sufficient to completely stabilise the site.

Analyses should include pH, salinity, exchangeable cations (including sodium), and a range of fertility tests for macro and micronutrients.

Soil samples should be collected from the materials that will be used in the stabilisation works at a sampling density consistent with detailed mapping at 1:5,000 scale, as outlined in the Recommendations (Section 1.2).

3.1.3 Small (low) rock barriers to flow.

Note: this feature was observed in incised gullies only.

Construction of “leaky weirs” or “porous check dams” is a well-established strategy for trapping coarse bedload sediment that might later be vegetated and change flow path stability. This section does not refer to the use of leaky weirs to trap relatively larger volumes of sediment, as no structures of that type were observed.

Somewhat similarly, but with considerable differences in construction and function, erosion and sediment control work on construction sites commonly use temporary low barriers (e.g., 10 – 20 cm high) of rock or other materials to spread and slow flow and to deposit relatively small quantities of sediment. In Landloch’s experience, this relatively small-scale approach is generally unsuccessful, tending to concentrate or divert flows at some point, with the resultant plunge pool and/or concentration of flow actually increasing erosion rate.

Typically referred to as “rock check dams,” these structures were observed at most incised gully sites. Where a wet season had occurred post construction, incidence of erosive damage/failure was 100% at one site, and approximately 75% at the other. Poor construction (e.g., use of inappropriate rock sizes, inadequate keying into channel sides) commonly contributed to failures, but this methodology is quite unsuited to the unstable soils typically exposed in gully beds.

Channel re-shaping to reduce flow velocities and soil amelioration to increase vegetation cover are preferred alternative approaches.

3.1.4 Target levels for vegetation cover/growth should be identified.

3.1.4.1 Incised gullies

In gullies, development of vegetation cover that provides a high degree of soil contact is important for erosion control, meaning that there needs to be a strong focus on establishing and maintaining grass.

One of the key site attributes that will need to be monitored in terms of functionality is the level of vegetation cover achieved and maintained. Consequently, a specified target level of vegetation (grass) cover will need to be set as a trigger level for monitoring to determine whether the site requires some form of maintenance/remediation, or whether grazing should cease locally until sufficient recovery has occurred.

3.1.4.2 Streambanks

For streambanks, with focus on establishment of riparian vegetation, target levels for vegetation should include not only grass cover, but also tree/shrub stem density, species diversity, and vegetation height. Given potential for relatively rapid vegetation establishment, achievement of vegetation targets will generally be a major milestone for the decision to cease the monitoring and maintenance period.

3.1.5 Agreements with landholders should be based on provision of appropriate management of project areas for periods as specified in Recommendations (Section 1.2)

3.1.5.1 Incised gullies

Key considerations here are that:

i. Impacts of climate variation and of grazing will be quite significant, and the period of vegetation recovery is likely to be relatively long.

ii. In most instances, revegetated gullies will never reach the productivity (grass biomass production) that would have been delivered by the original flow line and require careful grazing management in perpetuity.

3.1.5.2 Streambanks

For streambanks, establishment of riparian vegetation should be relatively rapid relative to soil amelioration and grass establishment in gullies. Consequently, the period during which the site may require landholder management (e.g. of grazing animals) can be expected to also be shorter.

Nonetheless, there will be some need for landholders to take responsibility for grazing animal management and any other local risks, for the design life of the controls.

3.1.6 *Rock chute designs should be based on a return period of either 50 or 100 years depending on potential costs of repairs.*

This issue applies to incised gullies only.

For incised gully systems, there is seldom, if ever, potential to replace the soil that has been removed, leaving a permanent change to surface hydrology, with more concentrated flows in the incised flow lines, with greater flow velocities and potential to cause erosion. Therefore, rock chutes in gullies provide an essential long-term and reliable increase in resistance to erosion.

Repair of rock chutes (re-shaping the site, sourcing, transporting, and placing rock) will be generally very difficult and expensive in the relatively remote areas being treated; though more so in some areas than others (e.g., if there is no access to durable rock for a very long distance).

Statistically, there is a 33% chance of a 1:50 year ARI flow occurring, and the chute design capacity being exceeded within a 20-year period, compared with an 18% (roughly 1 in 5) probability of a 1:100-year ARI flow in the same period. To balance those differences in risk and cost, it is recommended that where repair of rock chutes will be particularly expensive, chutes should be designed to a 100-year return period. A cost benefit analysis conducted at the design stage that considers the maintenance requirements and risks should influence the design standard adopted.

(Rock chutes assessed were largely designed on the basis flows of 50- or 100-year ARIs, but there were two that were designed to a 2-year ARI.)

3.1.7 *Carry out prior computer model runs with 'works in place' to identify any high-risk areas.*

This recommendation applies to all project areas.

Hydrologic and hydraulic computer modelling of flows was generally used as part of the design process. Typically, both the pre-treatment land surface and the surface with the proposed remediation measures in place were considered. In some cases, this modelling did not consider the full suite of remedial works included to allow assessment of any residual 'at risk' points prior to design finalisation. Model runs with these works 'in place' may have highlighted potential problem areas and led to design alterations.

When danger signs (e.g., high flow velocities) seem to have been overlooked within the design process, subsequent runoff events will almost certainly result in soil erosion at those points.

Further, for one major streambank stabilisation project, a slope stability analysis was carried out – this should be part of the design process for all major streambank stabilisation projects involving high banks.

3.2 Implementation

3.2.1 *For moderate and major projects, works should be audited for compliance to specification at a series of hold points during construction.*

This applies to all projects.

Although no major departures from design were observed, all four incised gully projects and one (1) in seven (7) streambank projects had elements that could have been better constructed. The lower frequency of departures for streambank works is consistent with a much longer history and experience with streambank remediation relative to incised gullies.

Many of the anomalies have potential to cause minor or major erosion in the short to medium term. These include rock check dams (noted previously), rock chute issues (as noted below), incorrect bund gradients (noted below), and other issues including fencing and soil surface preparation and amelioration that are noted in the detailed reports.

These issues reflect challenges with supply of materials and access to appropriate equipment working in a relatively remote area, or possibly some failure by contractors to fully appreciate the design requirements.

In some instances, there are necessary changes that were made during construction to adapt to unexpected conditions or changes in the site in the period between design and construction. But in other instances, this was no apparent justification for not conforming with the design specifications.

Having a set requirement for staged auditing of works across all relevant projects and all contractors makes the audit process an accepted standard and will give more reliable outcomes. This process is standard practice for most construction works in other.

3.2.2 Specialist oversight or supervision of rock chute construction

As noted previously, rock chutes are critical for the long-term stability of incised gully projects.

Importantly, of the sites inspected, none of the rock chutes were found to be constructed fully to specification, with departures from design including incorrect construction of inlet and outlet areas, incorrect rock sizes, inadequate keying to banks, lack of freeboard, and (possibly) inadequate stabilisation of the underlying soil. Although none had been tested by exposure to large runoff events, three sites had already suffered some erosion, with two being subject to further erosion after self-funded repair. This is clearly an area where construction performance needs to be improved.

Construction of rock chutes is a specialised activity, and it is unreasonable to expect the average earth moving contractor to have the necessary knowledge or experience. In the short term (2 – 5 years), it is advisable that a person suitably experienced in rock chute construction be made available to supervise rock chute construction in all projects where it is part of a gully remediation design.

3.2.3 Diversion banks or bunds should be constructed to flow gradients no steeper than specified in local Land Management Manuals.

Bunds are largely part of incised gully projects, though some streambank projects also used diversion bunds. At all times, they should be constructed to gradients no greater than specified for the specific soil on which they occur, as specified in relevant Land Management Manuals (There are 17 manuals available from the Qld Government, covering most, though not all, of the areas relevant to funded projects.)

Some erosion of bund channels and outlets was observed at two of the incised gully sites inspected. This was due to gradients being too steep for the soil materials on which they were located.

3.2.4 Fencing

Adequate fencing is essential in any project that involves the establishment of vegetation to provide stability and should be constructed to a standard such that they will remain functional over the period during which control of grazing animals is required.

Specific concerns include fences crossing channels (ensuring stock cannot move under the fencing) and stability of strainer posts in particular.

3.3 Monitoring and Maintenance

3.3.1 Monitoring and maintenance programming

As noted for this topic in the Planning and Design section, provision for monitoring and maintenance is an essential component of all sediment reduction projects.

Particularly for moderate and major projects, the project design should include a monitoring strategy with specified monitoring occasions (e.g., following large runoff events and/or every 1 – 2 years at the minimum) to ensure that the remediation works remain functional.

Specific trigger values and/or observations should be set to indicate when maintenance works should be initiated. Such maintenance should be carried out promptly.

Adequate funding should be allocated for the life of the monitoring and maintenance program.

Monitoring should continue beyond the life of one program into subsequent programs. While government funded programs have shorter terms than the planned life expectancy of works, subsequent programs with similar scope provide the opportunity for a strategic approach to be taken around monitoring and maintenance at the regional level.

These costs should be included in the cost benefit analysis during the design planning stage as they will influence the selection and sizing of controls and design. For example, it may be more cost effective to design a rock chute for a 1:100 event, rather than a 1:50 event because the maintenance cost will be lower due to the lower frequency of runoff events that exceed the design standard adopted.

3.3.2 Prompt delivery of maintenance/repair works

Invariably, if erosion develops on a site, the cost and difficulty of repair will increase rapidly if repair works are delayed. If repair works are not undertaken, the accounted for sediment savings may not continue to be realised.

4 OBSERVATIONS FROM SUBSEQUENT REMEDIATION ASSESSMENTS

Important aspects of projects assessed later in 2024 are listed below.

4.1 Sampling and analysis of soil materials

This is listed as Recommendation 2 in the table shown in Section 2.2.1.

For the gully systems projects, an intensive soil sampling and analysis programme was carried out. It identified a range of soil limitations, including high salinity in some sample, low water holding capacity, and a range of deficiencies in macro and micronutrients. Based on analytical data, fertilisers and ameliorants (gypsum and bagasse) were applied and straw spread. The resulting vegetation growth was excellent, despite the low initial quality of the soil materials as growth media.

This highlights the importance of the recommendation with respect to soil sampling, analysis, and (resultant) remediation.

For the stream bank project, it is understood that topsoil and subsoil samples were analysed and rates of ameliorants based on those test results. However, details of the sampling and analytical data were not reviewed, and there has been little vegetation establishment at the site due to lack of rainfall. Consequently, the impact of that improved planning practice was not able to be assessed for this site.

We note that for rehabilitation of minesites, which commonly deals with soils and growth media of challenging properties (saline, dispersive, infertile), soil analysis is viewed as an essential first step in rehabilitation planning (Commonwealth of Australia 2016). As the data collected for the recent gully projects demonstrated, the growth media available for gully rehabilitation works are equally challenging, and soil sampling, analysis, and amelioration is equally important.

4.2 Porous check dams

Recommendation 3 in the table shown in Section 2.2.1 suggests that low rock barriers to reduce flow velocities should not be used due to their high potential to be either outflanked or overtopped at low points and cause erosion.

The is a subtle distinction here between low barriers for velocity control and slightly higher barriers intended to trap sediment.

The recent gully studies used Porous Check Dams (PCDs) of approximately 30 cm height to trap sediment. They were installed with care, and none were outflanked. Several did show small rills developing at overflow points, and it may be desirable for the design to include some surface protection at such points to eliminate development of plunge pools and rills.

Equally, several PCDs had filled with silt, but there was no evidence of vegetation developing on the sediment. That may require direct seeding and fertilisation, and such follow-up works could usefully be included in the design specifications for such structures.

Nonetheless, it is worth noting that correct installation of PCDs clearly provides a drastic improvement in their success.

4.3 Rock chutes

Recommendation 6 in the table shown in Section 2.2.1 and Recommendation 2 in the table shown in Section 2.2.2 refer to rock chute design and construction.

The gully projects did design rock chutes to carry 1:50 year (2% AEP) flows as recommended.

As well, all rock chutes inspected were found to be constructed to design, including compliance with requirements for:

- Stilling areas at entry and exit points; and
- Correct rock size.

This demonstrates that correct design and construction are achievable. As noted previously in this document, rock chutes are critical for the long-term stability of incised gully projects, so it is encouraging to see reliable design and construction being delivered.

4.4 Hydraulic model runs for planned 'works in place'

Recommendation 7 in the table shown in Section 2.2.1 refers to use of computer modelling as part of the design process.

For the streambank stabilisation project inspected, hydraulic model runs with 'works in place' highlighted elevated bed shear stress levels in isolated sections of the stream bank. Additional protection works were put in place to counter the possibility of future scour in this section,

This preventative action shows the usefulness of carrying out such modelling exercises.

4.5 Diversion bund design and implementation

Recommendation 3 in the table shown in Section 2.2.2 refers to the design and construction of diversion banks (bunds) to gradients no steeper than specified in local Land Management Manuals.

Despite hydraulic modelling showing elevated bed shear stress levels in several of the bund channels, the bunds were constructed with bed gradients higher than that recommended in local / relevant Land Management Manuals. Those recommended gradients were developed via experience for similar soils.

It appears that 'straight' bunds (with high channel gradient sections) are 'preferred' to those surveyed in following the hillslope (with lower channel gradients) with consequent 'danger signals' emanating during hydraulic modelling as described in the previous section. There is potential for erosion in those bunds at some point in the future unless high levels OF anchored vegetative cover are maintained in those bund channels.

5 REFERENCES

Commonwealth of Australia (2016). *Mine Rehabilitation*. Australian Government, Leading Practice Sustainable Development Program for the Mining Industry.

NJ McKenzie, MJ Grundy, R Webster, AJ Ringrose-Voase (2008). *Guidelines for Surveying Soil and Land Resources*. CSIRO Publishing.