Springvale Station Erosion Management Plan

Queensland Government

#31455

Prepared by: Department of Environment and Science

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Message from the Minister

In 2016, the Queensland Government announced the purchase of Springvale Station–a 56,295ha property in Far North Queensland–for the purposes of adding to the State's protected area estate.

Queensland's protected areas, including national parks and nature refuges, are world-renowned for their diversity, unique flora and fauna, and breathtaking scenery. They are the cornerstone of Queensland's nature conservation programs, protecting our state's rich biological diversity. This protection is increasingly important in the face of a changing climate.

Springvale Station's outstanding diversity of 52 mapped regional ecosystems provide important habitat for endangered or vulnerable plant and animal species.

The acquisition of Springvale Station represents a whole-of-catchment approach to managing a State protected area. As well as protecting the property's important natural and cultural values, this purchase, and its ongoing management, will improve the water quality within the Normanby River Catchment draining to the northern Great Barrier Reef.

Currently, Queensland's terrestrial protected areas cover just over 8% of the State. I am committed to expanding the protected area system to secure and conserve representative and resilient samples of all of Queensland's biogeographical regions. We will also continue to work towards the United Nations Convention on Biological Diversity target of 17% terrestrial protected area coverage.

The Department of Environment and Science has been managing Springvale Station while investigating options for long-term management and tenure arrangements.

The department has undertaken wider property planning and operational activities such as road and track management, fire management and pest (plant and animal) management to support improvement of the values on the property. This, combined with cattle removal, will reduce the risk of sediment leaving the property and allow the natural systems the opportunity to rejuvenate and improve ground cover.

I commend the multi-organisational team co-ordinated by Cape York Natural Resource Management Ltd and departmental staff for producing the actions contained in this Erosion Management Plan (EMP)—the first step in identifying, prioritising, and costing remediation that, over time, will address the significant erosion issues on Springvale Station.

I also acknowledge the Yalanji Joint Venture, a partnership between Jabalbina Yalanji Aboriginal Corporation and the Western Yalanji Aboriginal Corporation, for their involvement in the project and particularly the writing of the Cultural Heritage Protocol.

The EMP has three main objectives:

- identify priority erosion remediation areas and guide activities undertaken on the property to reduce sediment runoff to the Normanby River, Princess Charlotte Bay, and Great Barrier Reef lagoon
- ensure that remediation works carried out under the EMP will not compromise the property's cultural and biophysical values
- identify monitoring and evaluation activities necessary to assess the efficacy and potential for replication of these remediation techniques.

The EMP also details sensible options to minimise the risk of new erosion from gullies and tracks and recommends ways to trial different treatment methods on existing priority erosion sites.

I'm proud that we have started on-ground actions that will enhance and greatly contribute to the conservation of the property's significant natural and cultural values.

Leeanne Enoch

Minister for Environment and the Great Barrier Reef

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Acknowledgements

The Springvale Station Erosion Management Plan Project was funded through the Queensland Department of Environment and Science.

The department acknowledges and thanks the project team led by Cape York Natural Resource Management that developed the supporting technical report (Technical Report to the Springvale Station Erosion Management Plan) and provided the information reflected in this Erosion Management Plan.

The Department also acknowledges the independent technical reviewer for their comments and recommendations of this document.

The project team and traditional owners who undertook the substantive and comprehensive analysis included: Will Higham, Lyndall Scobell, (CYNRM), Jeff Shellberg (Consultant), Andrew Brooks, John Spencer, (Griffith University), James Hill (Consultant), Rebecca Trevithick, Dan Tindall (DSITI), Joe Rolfe (DAF), Jim Turnour, Anthony Czygan (Jabalbina), Brad Grogan, Alwyn Lyall, John Murison (WYAC)

Executive Summary

In 2016 the Queensland Government purchased Springvale Station, a 56,295ha property in Far North Queensland (Figure 1). Springvale Station was purchased to add to the State's protected area network and complement activities being taken to reduce sediment run-off entering the Normanby River catchment, a significant catchment that drains to the northern Great Barrier Reef. The acquisition of Springvale Station represents a whole-of-catchment approach to managing a State protected area. As well as protecting the property's important natural and cultural values, the ongoing management of Springvale Station coupled with activities on neighbouring properties will contribute to improving the water quality within the Normanby River catchment.

The Springvale Station Erosion Management Plan (EMP) and the supporting technical document titled Technical Report to the Springvale Station Erosion Management Plan (CYNRM 2017) were prepared by a team of experts and Traditional Owners, on behalf of the Department of Environment and Science. The EMP will inform the future management planning and activities to be delivered on Springvale Station, as well as identifying potential investment and collaboration opportunities for erosion control on the property.

The objectives of the EMP are to:

- identify priority erosion remediation areas and guide activities undertaken on the property to reduce sediment run-off to the Normanby River catchment according to best practice management and scientific and technical standards
- ensure that remediation works carried out under the EMP will not compromise the property's cultural and biophysical values
- identify monitoring and evaluation activities (in consultation with appropriate service providers) necessary to assess the efficacy and potential for replication of remediation techniques.

The EMP presents:

- a description of the Priority Sediment Management Areas
- an overview of soil and gully erosion types and guidelines
- potential activities that could be undertaken on the property between 2017-2022

The activities within the EMP will inform, and be adapted to complement, wider operational planning and implementation activities into the future. It focuses on management activities within a Priority Sediment Management Area on the station, i.e. those geologic units that are most sensitive to accelerated soil erosion. This includes landscape systems based on the Alluvium and Colluvium geologic units, as well as some areas of Basalt and Hodgkinson units.

The implementation approach for the period 2017 to 2022 includes:

1) Property-wide sediment maintenance and prevention response 2017-2022

Preventative and maintenance measures to improve the overall land condition (particularly native vegetation cover) and that will reduce soil erosion from direct and indirect land use activities in the Priority Sediment Management Areas include:

- feral cattle management
- fire management
- road and fence maintenance and abandonment.

These proposed activities will complement, and value-add, to wider operational activities, such as weed and pest management, undertaken to manage the station as part of the protected areas network.

2) Establish sediment reduction response on strategic sites in 2017-2018

In 2017 and 2018, put in place practical methods, experience, resources and capacity building that can be applied across the Priority Sediment Management Area, as part of the ongoing sediment and erosion response on Springvale Station.

This would focus on:

- reducing sediment loss at specific sites through:
  - road erosion and associated gully sites along the Keetings Road between the homestead and Keetings Yard including active road gullies caused by road run-off, road choke points restricting road access, and associated alluvial gully scarps near road choke points.
  - young (linear) rapidly advancing alluvial gully identified as the West Normanby Distal Gully.
- preliminary activities to support ongoing erosion management:
  - initiating a native seed collection program for use in ongoing rehabilitation.
  - improved gully prioritisation and site planning.

3) Targeted Sediment Reduction Response 2018-2022 – Within 500m of road network

Within the Priority Sediment Management Area, there are 195ha of mapped gullies within 500m of the property road network that could be initially targeted. This would:

- significantly reduce sediment loss from existing road network which intersects with the geologic units of concern of human land use disturbance
- minimise additional disturbance through the construction of new roads to isolated gully complexes.

Soil and gully erosion types and management

The remediation activities recommended by the EMP, are proposed to be implemented over several years and will be augmented, where possible, through external investment and leveraged funding opportunities. As part of the implementation and design for each site, consideration will be given whether the outcome for the landscape leads towards:

- Rehabilitation: broadly defined as slowing down erosion and attempting to recreate a semi-natural self-perpetuating state that would exist naturally in the area (e.g. in areas of higher landscape values).

  or / and

- Remediation: broadly defined as slowing down erosion, where the system may have crossed a threshold and using more interventionist measures with less concern for return to the natural state.

The document also presents an overview of ‘Surface and gully erosion management guidelines’ that could be applied in response to the soil and gully types occurring at Springvale Station. These draw on the latest information, including the Queensland Soil Conservation Guidelines (Carey et. al. 2015) and the Technical Guide for the Reef Trust Phase IV Gully and Stream Bank Erosion Control Program (Wilkinson et al. 2015).

Further information

The technical information underpinning this report can be found in: Technical Report to the Springvale Station Erosion Management Plan (CYNRM 2017)

Background

Springvale Station is a significant grazing property within the Normanby River catchment and has been degraded by erosion accelerated by historic land use activities (Brooks et al. 2013; Shellberg and Brooks 2013; Brooks et al. 2016). Catchment modelling, water quality monitoring and field assessments have identified Springvale Station as a major sediment producing property within the northern Great Barrier Reef region (Brooks et al. 2013). Current modelling estimates suggest that the gullies on Springvale Station are responsible for ~ 40% of the gully erosion within the Normanby River catchment (Figure 2). Management that could address these findings was outlined in the Water Quality Improvement Plan (WQIP) for Eastern Cape York that noted that such action was needed to improve both water quality and the resilience of the northern Great Barrier Reef to the impacts of climate change (CYNRM / SCYC 2015).

Reporting against the Reef 2050 water quality targets by the Paddock to Reef Integrated Monitoring, Modelling and Reporting (P2R) Program has similarly identified the Normanby River catchment as the major contributor of sediment from Cape York catchments to the Great Barrier Reef lagoon (McCloskey et al. 2014). The P2R Program uses a combination of monitoring, modelling, and regular reporting on land use changes at paddock through to catchment, then Reef scale, to assess progress against Reef Plan water quality targets. Land management changes implemented as part of annual property management are incorporated in P2R model outputs in subsequent years.

This EMP and supporting technical report CYNRM 2017 draws on reports, scientific literature and other information sources for the region and accessed information from both the Queensland Soil Conservation Guidelines (Carey et. al. 2015) and the Technical Guide for the Reef Trust Phase IV Gully and Stream Bank Erosion Control Program (Wilkinson et al. 2015).

Figure 1 Springvale Station, North Queensland.

The Springvale Station Erosion Management Plan (EMP) and supporting technical documents (CYNRM 2017) were prepared by a team of experts on behalf of the Department of Environment and Science to support future management planning and activities as well as to identify potential investment opportunities and collaboration for erosion control on the property.

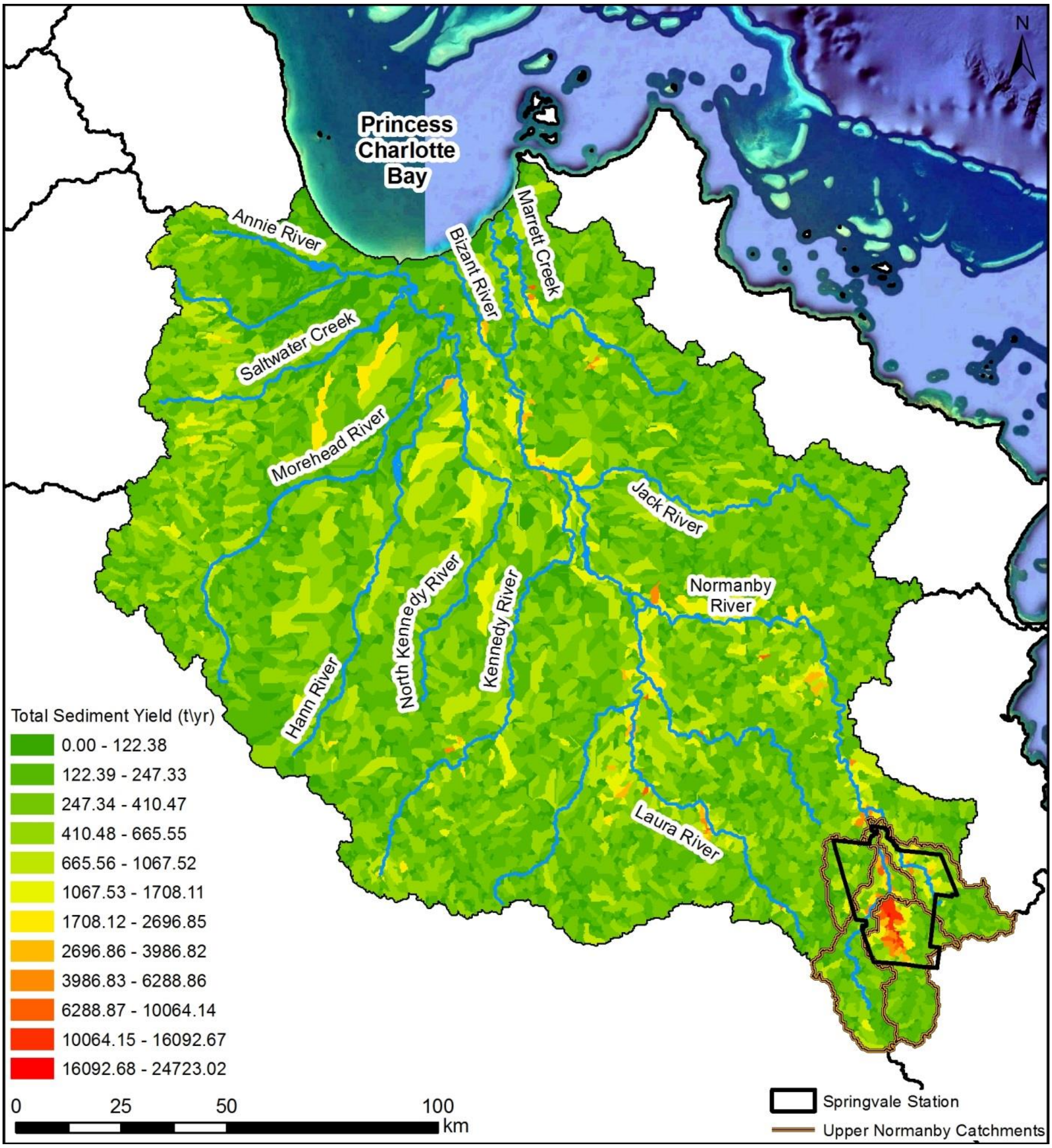

Figure 2 Map of the Normanby River catchment showing Springvale Station. Colour intensity (heat map) represents the model estimate of sediment yield from sub-catchments within the Normanby River catchment (Source: Griffith University based on Brooks et al. 2013).

Priority Sediment Management Area

The analysis of the available information for soil erosion at Springvale Station identified that:

- Annual sediment loss from gullies and associated soil erosion processes within Springvale Station ranged from 25t/ha/year to 2500t/ha/year from site to site.
- Road gully erosion had been measured at 800 to 1600t/ha/year.
- Many gullies on Springvale Station are producing more than 300t sediment/ha/year.

A Priority Sediment Management Area within Springvale Station has been identified which covers the area's most sensitive to accelerated soil erosion and associated nutrient loss.

Figure 3 shows the location of surface geologic units and major sub-catchments within Springvale Station (Alluvium, Colluvium, Basalt, Hodgkinson, Granite units) (CYNRM 2017). This takes account of field knowledge of geologic formations and their erosion issues; satellite remote sensing; aerial LiDAR imagery; other digital elevation models; road, track and fence line mapping; the Normanby Empirical Sediment Budget (Brooks et al. 2013) and expert analysis.

The Alluvium and Colluvium geologic units within the four major sub-catchments are the area's most sensitive to accelerated soil erosion and associated nutrient loss. Based on field knowledge and the analysis of modelled sediment loss (Figure 2), the priority units should broadly be addressed in the following order:

- Granite Normanby Alluvium and Colluvial Slopes
- West Normanby Alluvium and Colluvial Slopes
- East Normanby Alluvium and Colluvial Slopes
- Leichardt Creek Alluvium and Colluvial Slopes

(note: that the actual location and extent will need to be confirmed as part of site design and response).

Basalt and Hodgkinson geological units within the Priority Sediment Management Area are secondary priorities for management intervention to reduce soil and nutrient erosion. This can occur through less intensive measures focused on feral cattle and fire management, as well as strategic road and fence line management and targeted gully management in these units.

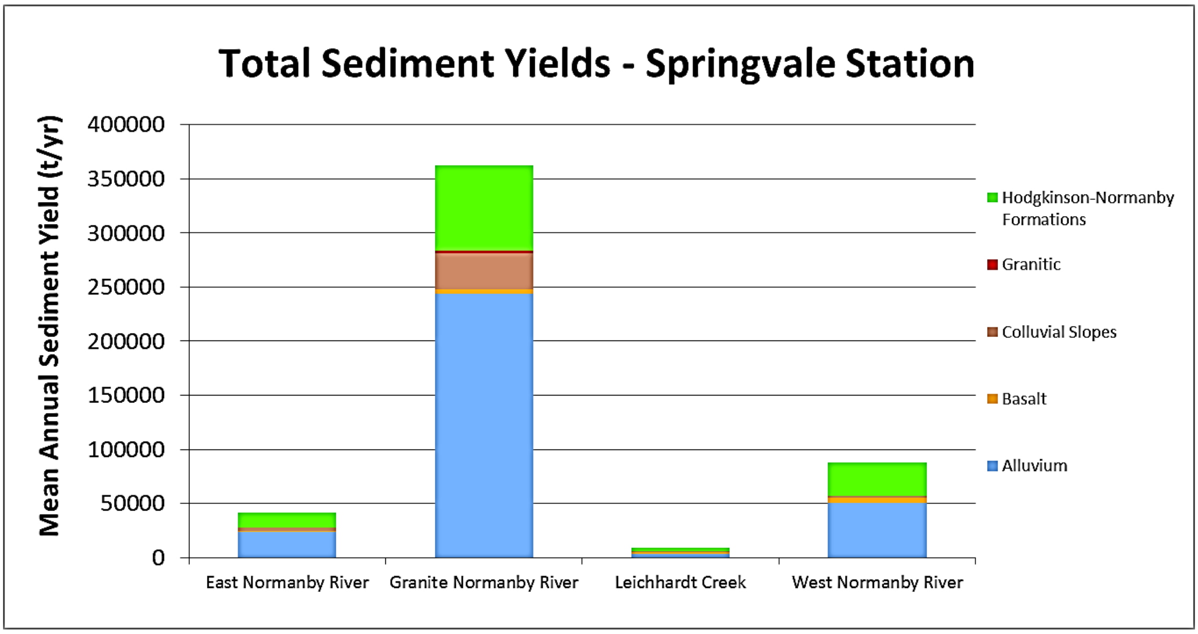

Figure 3 Model estimates of sediment yield, broken down by geologic unit, for the portions of the four major sub-catchments on Springvale Station (Source: Griffith University, based on Brookes et al. 2013).

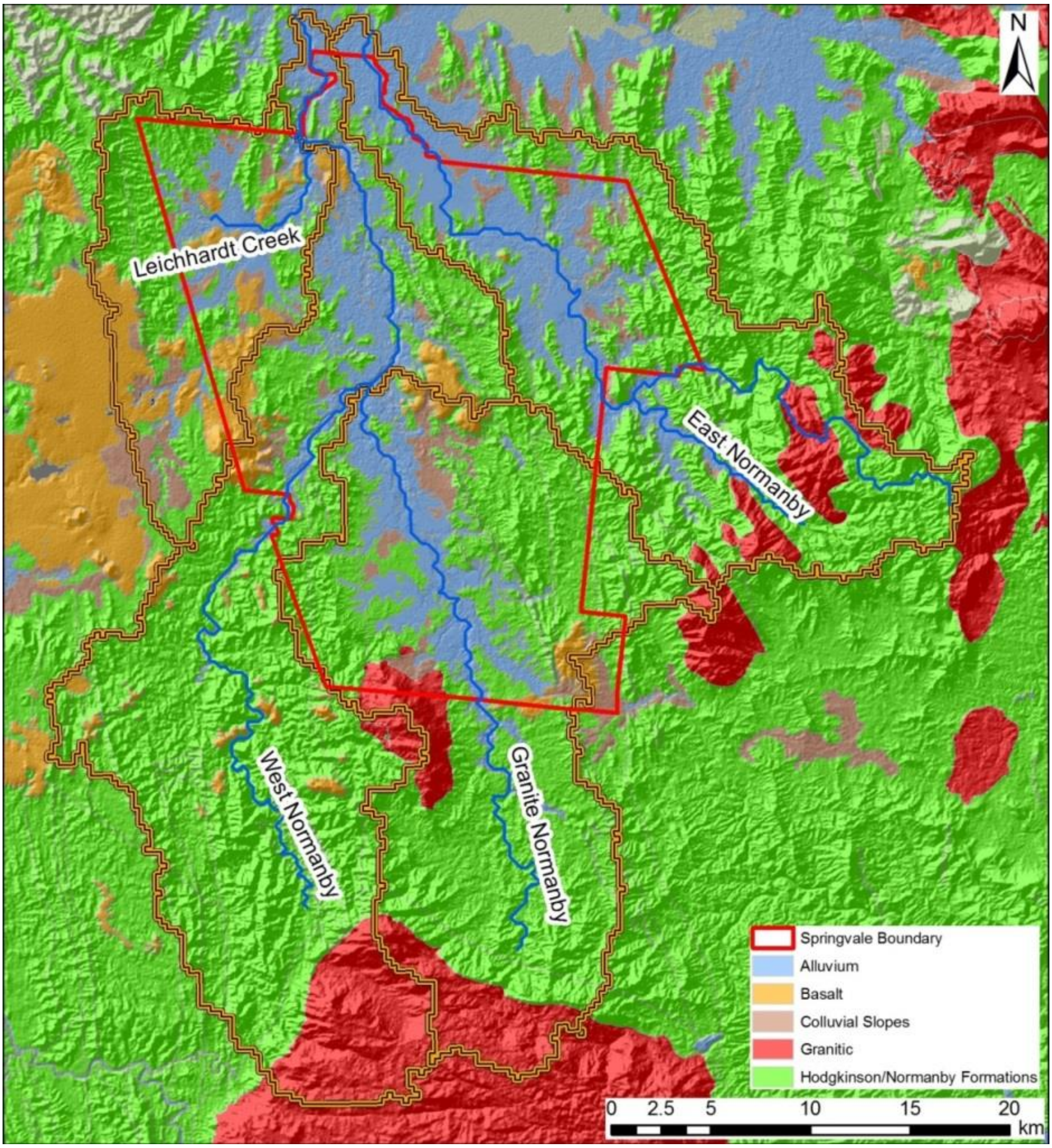

Figure 4 Location of surface geologic units and major sub-catchments within Springvale Station (water flows north from Springvale Station) (Source: Griffith University).

Soil and gully erosion types and repair

For cost-effective sediment reduction to be achieved on Springvale Station, it is critical to target specific rehabilitation and remediation actions to the specific soil and gully erosion types found in the landscape and the desired management outcome.

As part of the implementation and design for each site, consideration will be given whether the outcome for the landscape leads towards:

- Rehabilitation: broadly defined as to slow down erosion and attempting to recreate a semi-natural self-perpetuating state that would exist naturally in the area (e.g. in areas of higher landscape values)

  or / and

- Remediation: broadly defined as to slow down erosion, where the system may have crossed a threshold and using more interventionist measures with less concern for return to the natural state.

Figure 4 presents surface and gully types found on Springvale Station and management guidelines as to potential erosion response.

Table 1 presents a matrix of potential rehabilitation and remediation options for surface and gully erosion as a quick reference guide. More detail is presented for each gully type in Appendix A.

These management guidelines draw on a synthesis of all available gully management information and applies this to soil and gully erosion types present on Springvale Station.

The information includes:

- an EMP project team and expert workshop held at Springvale Station during May 2017
- other north Australian work reported in Shellberg and Brooks (2013) and Shellberg et al. (2016b)
- the Queensland Soil Conservation Guidelines (Carey et. al. 2015)
- the Technical Guide for the Reef Trust Phase IV Gully and Stream Bank Erosion Control Program (Wilkinson et al. 2015).

Table 1 Matrix of potential rehabilitation and remediation options for soil and gully erosion. (Yes means the option is appropriate, Maybe means the actions might be appropriate). Not all options must be taken at any given site, depending on geomorphic condition and other contingencies.

	Alluvial / Colluvial Slopes Above Gullies	Scalded Soils and Shallow Gullies	Colluvial Gullies	Young (Linear) Alluvial Gullies	Mature (Amphitheatre) Alluvial Gullies	Old (Deep / Revegetating) Alluvial Gullies	Roads and Fences	Cleared Paddocks
Cattle Destocking	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fire Management	Yes						Yes	Yes
Fire Exclusion		Yes	Yes	Yes	Yes	Yes		
Weed Control	Yes	Yes					Yes	Yes
Water / Soil Retention Structures	Yes	Yes		Yes				
Water Diversion Structures	Yes		Yes	Yes	Yes	Yes	Yes	Yes
General Revegetation (grass, shrub, trees)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intensive Grass Planting (plug/seed)		Yes	Yes	Yes	Yes	Yes		
Soil Amendments (Mulch/ Compost/Gypsum)	Maybe	Yes	Maybe	Maybe	Maybe	Maybe		
Head Cut Chute Drop Structures			Yes	Yes	Maybe (locally)			
Mechanical		Maybe	Maybe	Maybe	Maybe			

	Alluvial / Colluvial Slopes Above Gullies	Scalded Soils and Shallow Gullies	Colluvial Gullies	Young (Linear) Alluvial Gullies	Mature (Amphitheatre) Alluvial Gullies	Old (Deep / Revegetating) Alluvial Gullies	Roads and Fences	Cleared Paddocks
Reshaping / Battering								
Avoid Machine Disturbance	Yes	Maybe			Maybe	Yes	Maybe	Yes
Rock Capping			Maybe	Maybe	Maybe		Yes	
Geopolymer and Hydromulch			Yes	Yes	Yes			
Gully Channel Grade Control Structures (Brush, Wood, Rock)		Yes	Yes	Yes	Yes	Yes		
Promote Natural Recovery and Geomorphic Evolution	Yes	Maybe			Maybe	Yes		Yes
Basic Monitoring	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intensive Monitoring				Yes	Yes		Yes	

Proposed EMP activities 2017-2022

The following section describes the proposed activities that could be undertaken concurrently or sequentially:

- Property-wide Sediment Maintenance and Prevention Response 2017-2022.
- Establish Sediment Reduction Response 2017-2018 – Strategic Sites in the Priority Sediment Management Area.
- Targeted Sediment Reduction Response 2018-2022 – Within 500m of Road Network

Described against each response are the proposed activities, the basis for why the action is considered appropriate and potential costs and benefits.

Overall assumptions

For the purpose of the EMP, the following principles and assumptions apply across the proposed activities.

Preventing sediment loss from Springvale Station

- The implementation of the EMP will benefit reef water quality objectives. The Eastern Cape York WQIP (CYNRM/SCYC 2015) used a delivery ratio of 40% to identify the impacts of sub catchment management on water quality at the mouth of the Normanby River catchment.

Site design

- Cultural mapping and clearance surveys will be included in all action plans as determined by the Cultural Heritage Protocol available in the Technical Report to the Springvale Station Erosion Management Plan (CYNRM 2017).
- The causes and drivers of erosion should be assessed, and addressed as a priority at any given site, in contrast to just addressing symptoms. Not all gullies or gully types are suitable, or practical, for erosion control intervention.
- Treatments will be tailored to individual sites using expert advice and detailed designs. This will also aim to avoid additional disturbance that increases erosion due to exposure of highly dispersive soils with machinery or inappropriate action.

Prioritising response and cost-effective solutions

- Not all options (Table 1) will achieve sediment reductions over similar timescales, so consideration must be given to using combinations of treatments to produce the greatest sediment reductions over the shortest timescale.
- Not all options must be taken at any given site and combinations should be considered.
- Site assessments to support soil and gully erosion remediation designs should identify the erosion or gully type, its evolutionary stage, the degree that the erosion has been increased by land use, and include an estimate of the current erosion rate (t/ha/year).
- Soil and gully remediation designs should describe specific actions tailored to specific erosion types to achieve a cost effectiveness of $300/t/year reduction or less. This approach is consistent with the Reef Trust Gully and Stream Bank Erosion Toolbox (Wilkinson et al., 2016, CYNRM 2017).
- The calculation of cost-effectiveness should include a sediment reduction efficiency factor that represents the percentage reduction in sediment loss that will be achieved by the specific actions (including the risk of failure or additional disturbance). As an example, for a specific gully site assessments estimate that it is producing 400t/ha/year. The proposed gully remediation actions are estimated to reduce sediment loss by 50% (i.e. 200t/ha/year). The maximum cost of the proposed remediation actions (including site design, implementation supervision and monitoring) would be calculated as 400t/ha/year x 0.5 x $300/t = $60,000/ha.
- A delivery ratio can be used to compare the cost-effectiveness of gully remediation in different locations within a catchment. However, for the purposes of the EMP, it is considered that the same delivery ratio (WQIP used 40%, CYNRM / SCYC 2015) can be applied to all gully remediation sites.

Adaptive management over time

- As implementation progresses there is likely be a range of new, innovative and repurposed technologies that emerge. Applying new technologies at a large and commercial scale could reduce the total cost of achieving sediment reduction targets.
- Some remediation options are experimental and inherently riskier, and will need to be proven to be cost- effective and practical at scale before repeating across large areas.

1. Property-wide Sediment Maintenance and Prevention Response 2017-2022

Context

A desktop land condition assessment was carried out using available remote sensing data sets to interpret ground cover for the period 1992 to 2016. For this period, ground cover was consistently high, but varied with season and the amount of rainfall (CYNRM 2017). A rapid field assessment conducted in 2017 identified that, while ground cover is high, the main vegetation types are not desirable (i.e. many exotic annual weeds). As a result, the overall current land condition in the Priority Sediment Management Area is considered to be poor (D to C condition) in the Basalt, Alluvium and Colluvial slopes surface geologic units (Table 2).

Table 2 Land condition of surface geologic units within Springvale Station (Source: Joe Rolfe).

Surface Geologic Groups	Land Condition
Alluvium – general	C-
Alluvium – gullies	D
Basalt	C
Colluvial slopes – general	C
Colluvial slopes – gullies	D
Granitic	Not assessed
Hodgkinson/Normanby Formations – general	A-
Hodgkinson/Normanby Formations - areas of cattle concentration	C

The long-term ground cover pattern (Landsat) has been analysed for consistently bare areas (Figure 5). This pattern is consistent with the pattern of roads, gullies and stream channels.

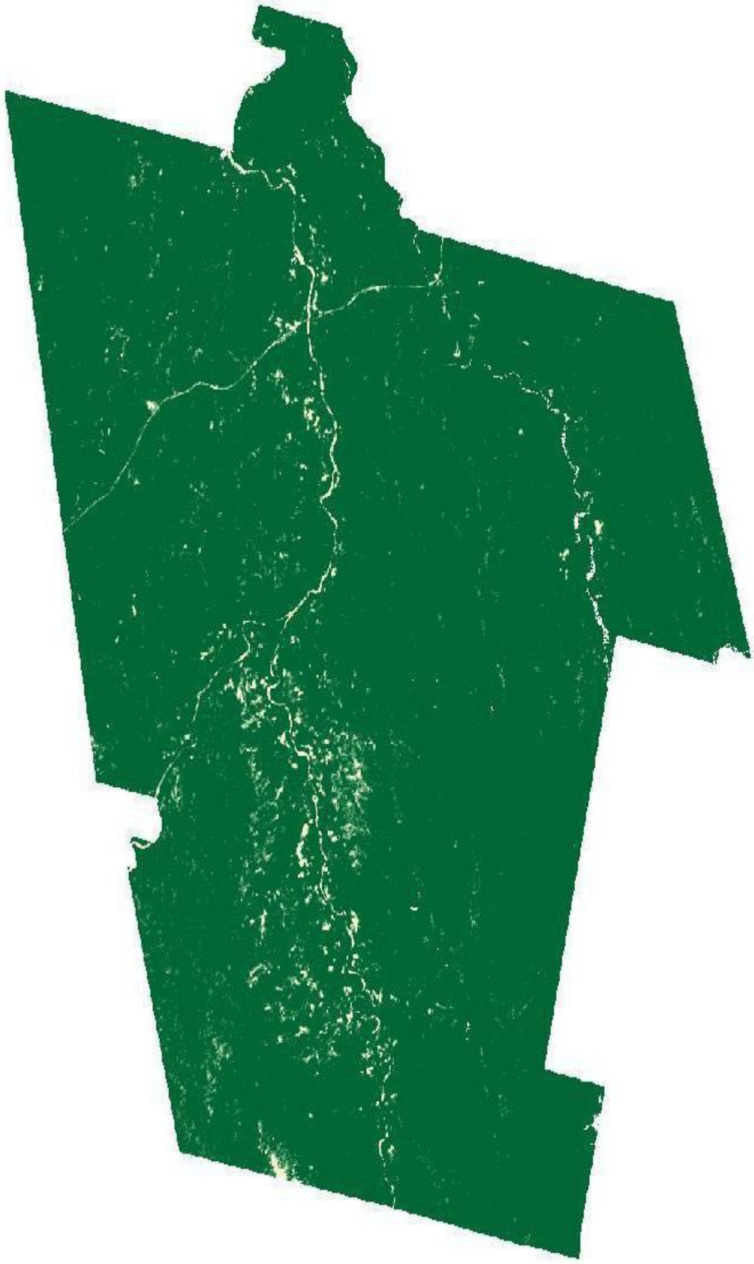

Figure 5 The persistent bare image identifies the areas (in white) where ground cover is always very low. This appears to align with the developed and most heavily grazed areas on Springvale Station.

Proposed activities

Preventative and maintenance measures to improve the overall land condition and reduce soil erosion from direct and indirect land use activities include:

- Aim to maintain very low to zero cattle grazing pressure across the property through the development and implementation of a feral cattle management plan. Consider strategic boundary fencing in appropriate stable locations and coordinated shooting and/or mustering program.
- Develop and implement a fire management plan to encourage natural regeneration of perennial native grass communities, as well as boundary and highway firebreaks to stop wildfire with early dry-season burning.
- Progressively undertake and implement a Road and Fence Maintenance and Abandonment Planning (RAFMAP) for all property roads and fences in order to assess existing condition, determine essential infrastructure and areas to abandon after rehabilitation, and design specific erosion control measures following best management practices (e.g. Shellberg and Brooks 2013).

Cost-effectiveness

The cost of the recommended property-wide activities is difficult to estimate and will need to be considered as part the budget for annual property planning across cattle, fire and road preventative and maintenance action and other activities. More detail is presented in CYNRM (2017).

An improvement in land condition will result in reduced sediment loss from hillslopes across all geologies, and may also increase water infiltration and reduce run-off from the catchment above active gullies, reducing their cumulative erosion rates over time. Sediment tracing has estimated that 10% of the total sediment load is from surface soils on various hillslopes (i.e. not channel, bank, or gully erosion). It is estimated that cattle, fire and road preventative and maintenance actions could reduce the sediment loss from hillslopes by ~20% percent (~2% reduction in total sediment loss of ~500,000 t/year from Springvale Station). This could equate to 10,000 tonne/year of sediment reduction from surface erosion after a 5 to 10 year period of implementation (2017-2022 and beyond). It is unclear how effective these activities will be in further reducing sediment loss from active gullies of various sizes on Springvale Station, but additional indirect benefits are likely at the decade scale (2017 to 2027).

If the annual cost could be estimated at approximately $300,000 (including basic site monitoring of on ground works), with an associated estimated long term reduction in annual sediment of 2,000t/year:

The estimated Cost Effectiveness for these activities = $300,000/2,000t/year = $150/t.

Monitoring to support these activities

Monitoring includes:

- remote sensing of ground cover and fire frequency
- keeping records of grazing, fire and RAFMAP on ground works (using standard site record sheets – grazing = land condition photo point record sheets, fire = ignition points and controlled burn record sheets, road = new road erosion record sheet)
- water quality monitoring to quantify the actual reduction in sediment loss from both hillslope and gully sediment sources as property-wide activities are implemented.

2. Establish Sediment Reduction Response 2017-2018 – strategic sites

Context

Four activities are recommended for the establishment phase (2017-2018) of a sediment reduction response which put in place practical methods, experience, resources and capacity building that can be applied across the Priority Sediment Management Area as part of ongoing sediment and erosion response on Springvale Station.

This would focus on reducing sediment loss at specific sites as well as preliminary activities to support ongoing erosion management (e.g. initiating a native seed collection program, improved gully prioritisation and site planning).

Proposed activities

i) *Road erosion and associated gully demonstration sites*

a) Focus on active road gullies caused by road run-off, road choke points restricting road access, and associated alluvial gully scarps near road choke points along the Keetings Road between the homestead and Keetings Yard (Figure 6a&b).
b) Develop detailed site designs that tailor specific remediation and rehabilitation actions to the specific sites using a range of different treatment options (including monitored control sites with no treatment) (Table 1; Figure 6a&b).
c) Estimated Cost is $450,000 for design, implementation (including native seed) and monitoring to a standard that can detect the difference in sediment concentrations between experimental control and treatments at both road gullies and associated mature alluvial gullies.

ii) *Young (linear) rapidly advancing alluvial gully demonstration sites*

a) Focus on the linear rapidly advancing West Normanby Distal Gully (Figure 6a&b).
b) Develop detailed site designs that tailor specific remediation/rehabilitation actions to the specific sites using a range of different treatment options (including monitored control sites with no treatment).
c) Estimated Cost is $310,000 for design, implementation (including native seed) and monitoring to a standard that can detect the difference in sediment concentrations between control and treatments.

Both activities outlined in (i) and (ii) will:

a) integrate monitoring as part of the detailed site design to enable the sediment reduction and cost-effectiveness of different remediation and rehabilitation options to be quantified to inform future implementation
b) maintain and adapt treatments over time to improve effectiveness (these are demonstration sites to inform implementation, not pure research sites)
c) produce case study communication products to enable the learnings to be shared.

iii) Native seed collection program to support ongoing rehabilitation

a) Focus on recommended native grass species required for demonstration sites (Tables 3 and 4).
b) Build capacity of local seed collectors in identification of grass species and their stage of reproduction (could include a field guide).
c) Define local areas (GPS locate) where sufficient grass seed can be sourced.
d) Provide support to seed collectors on efficient seed collection techniques.
e) Establish clear procedures and local facilities for seed drying and storage.
f) Estimated Cost is $40,000 (not including the cost of seed collection which should be borne by the remediation site).

iv) Improving gully prioritisation and site planning

a) Field surveys to support a Road and Fence Maintenance and Abandonment Plan (RAFMAP).
b) Detailed site design and cost-effectiveness estimates of remediation/rehabilitation options to fast track the Targeted Sediment Reduction Response.
c) Collection of topographic LiDAR data across all of Springvale Station to support future planning and prioritisation of erosion control sites.
d) Analyse complete LiDAR dataset and field surveys to improve prioritisation of locations and actions for the Targeted Sediment Reduction Response using processed-based geomorphic classification and stage of erosion evolution.
e) If and when extra data becomes available, update the Sediment Budget for Springvale Station to support improved estimation of sediment reductions achieved through 2017 to 2022 implementation actions. To facilitate this, funding could be sought from separate research and development funding streams.

The establishment of the demonstration sites and the native seed collection program should be undertaken in a way that fosters capacity building and practical experience for stakeholders that are likely to be involved in the targeted sediment reduction response.

Cost effectiveness of establishment of Sediment Reduction Response 2017-2018 – strategic sites

In 2017, the cost-effective and practical remediation of extensive areas of gully erosion in the Great Barrier Reef catchment should be considered experimental. The recommended demonstration sites will help quantify sustainable sediment reduction benefits, without major risks, additional disturbance, and impacts to biodiversity, aesthetic, or cultural resources of Springvale Station (CYNRM 2017).

Hence a detailed estimate of whether these establishment phase activities are cost-effective has not been attempted due to the extra cost of water quality monitoring and capacity building at these sites. The treatments themselves should be representative of treatments that could achieve a minimum of $300/t if applied at scale during the targeted sediment reduction phase of implementation.

Monitoring to support these activities

Monitoring includes:

- repeat aerial LiDAR (ideally before and after)
- drone photogrammetry to generate digital elevation models (DEM)
- terrestrial LiDAR (before and after) suitable for smaller sample areas (DEM)
- ground cover photo points and record sheets
- Gully Toolbox monitoring of on ground works before and after (Wilkinson et al 2016)
- sediment concentration and water runoff yield from treated/control gullies
- native seed germination and colonisation success.

Figure 6a: 'Road Gullies' (Source: Jeff Shellberg)

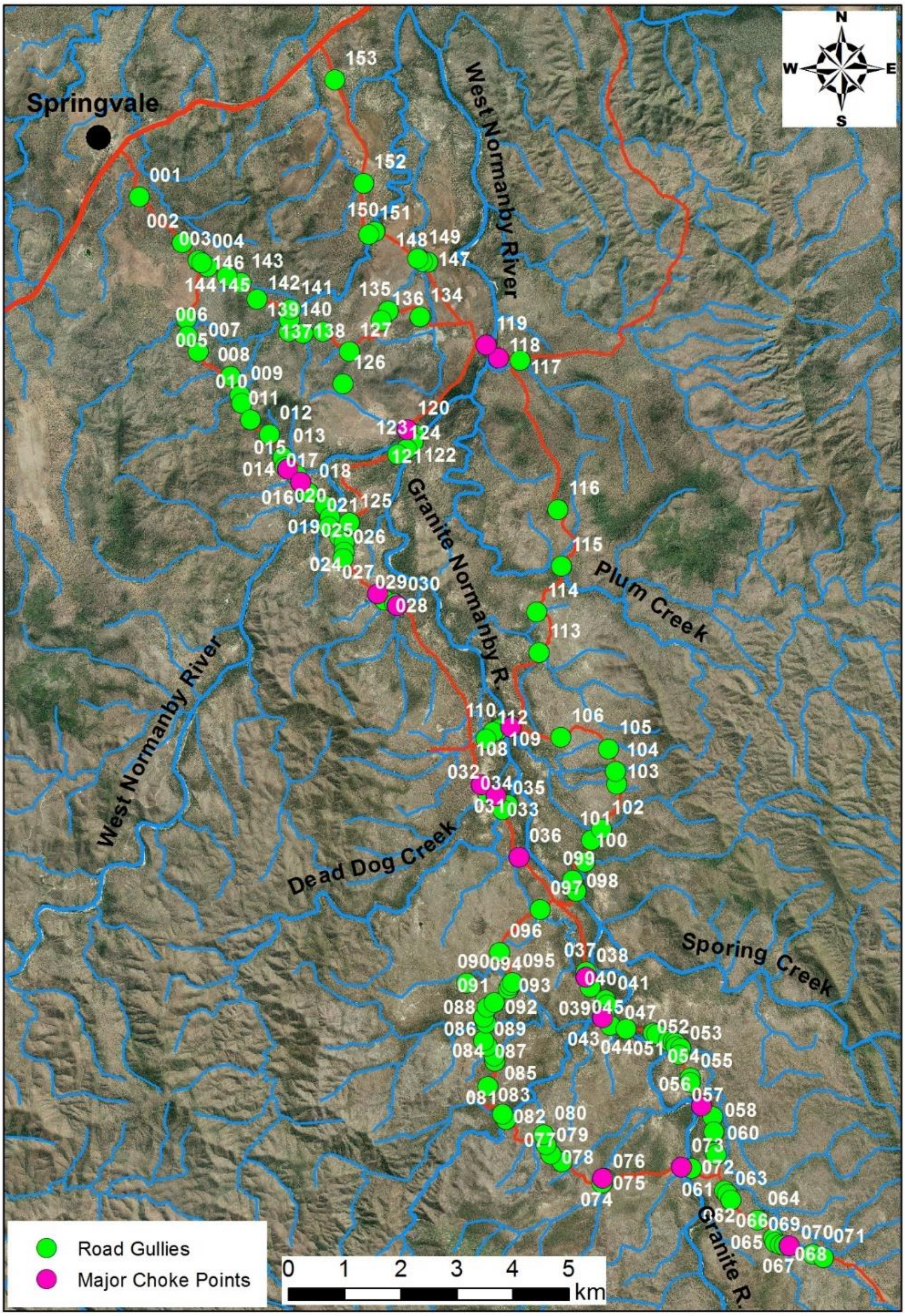

Figure 6b ‘Road Gullies’ caused or accelerated by road construction and use along the southern half of Springvale Station between the Springvale Homestead and the ‘Keetings Paddock’. Also included are road ‘Choke Points’ (photos on right side) where gully erosion is so severe that it almost completely restricts vehicle access without heavy machinery intervention with appropriate bioengineering and precautionary principles of erosion control (Source: Jeff Shellberg).

Table 3 Recommended seed mixture for direct seeding above gully complexes. Prices per kg are standard industry rates (Source: James Hill).

Species	Seed placement	Cost $/kg	Mixture (Kg/ha)	$/ha
Themeda triandra	Above	$400	2kg/ha	$800
Sarga plumosum	Above	$150	4kg/ha	$600
Heteropogon contortus	Within/Above	$150	5kg/ha	$750
Heteropogon triticeus	Above	$400	4kg/ha	$1600
Mnesithea rottboelloides	Within/above	$450	2.5kg/ha	$1125
Alloteropsis semialata	Within/above	$550	2.5kg/ha	$1375
Total			20kg/ha	$6250/ha

Table 4 Recommended seed mixture for direct seeding within gully complexes. Prices per Kg are standard industry rates (Source: James Hill).

Species	Seed placement	Cost $/kg	Mixture Kg/ha	$/ha
Heteropogon contortus	Within/Above	$150	5kg/ha	$750
Mnesithea rottboelloides	Within/above	$450	2.5kg/ha	$1125
Chrysopogon filipes	Within	$400	2.5kg/ha	$1000
Chrysopogon pallidus	Within	$400	2.5kg/ha	$1000
Imperata cylindrica	Within	$1000	3kg/ha	$3000
Arundinella nepalensis	Within	$450	2kg/ha	$900
Alloteropsis semialata	Within/above	$550	2.5kg/ha	$1375
Total			20kg/ha	$9150/ha

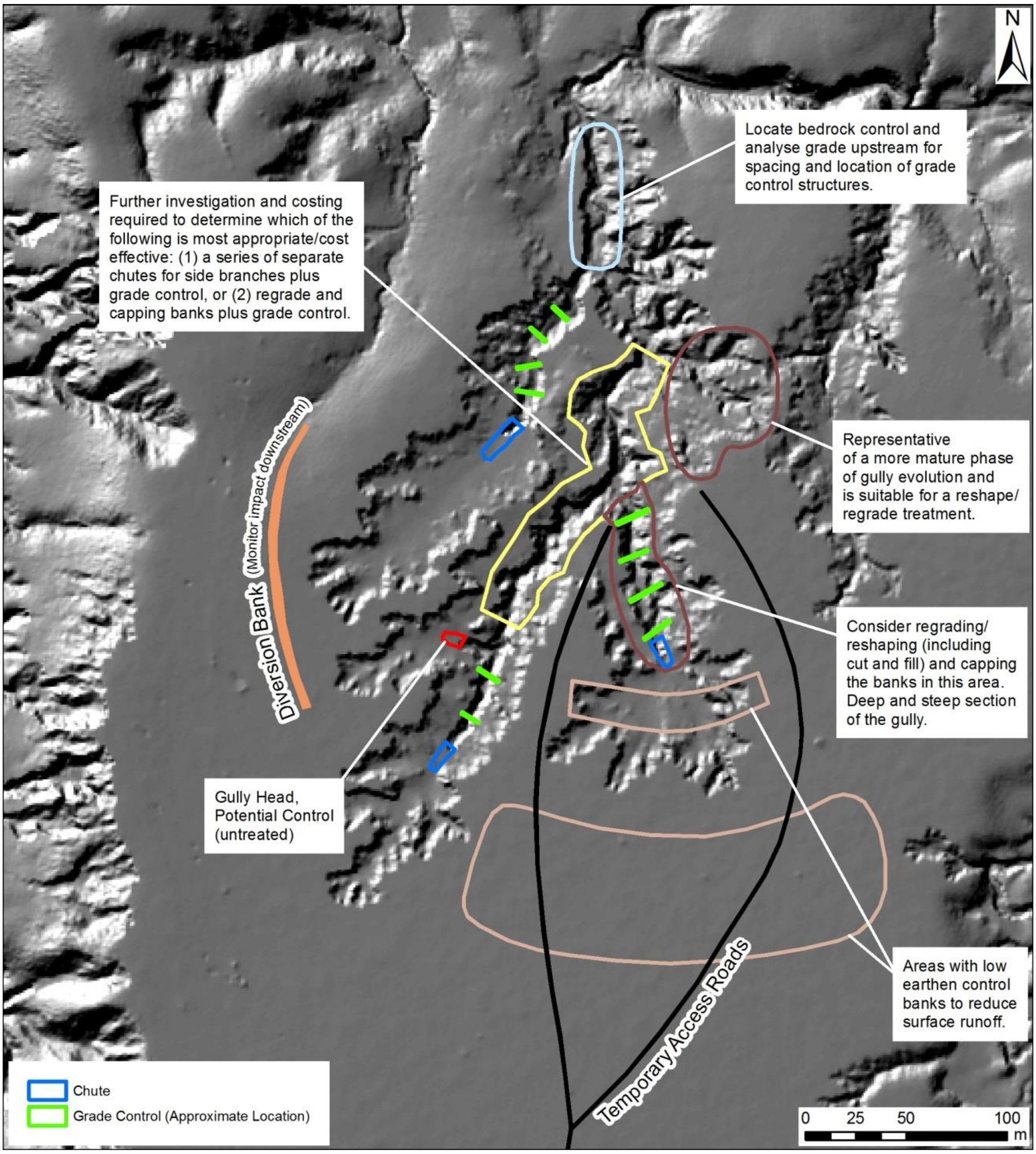

Figure 7a Conceptual gully remediation design for the West Normanby Distal Gully (LiDAR — aerial photograph over page). LiDAR is a very useful planning tool for developing gully remediation plans, where LiDAR is unavailable more detailed site surveys will be required (Source: Griffith University).

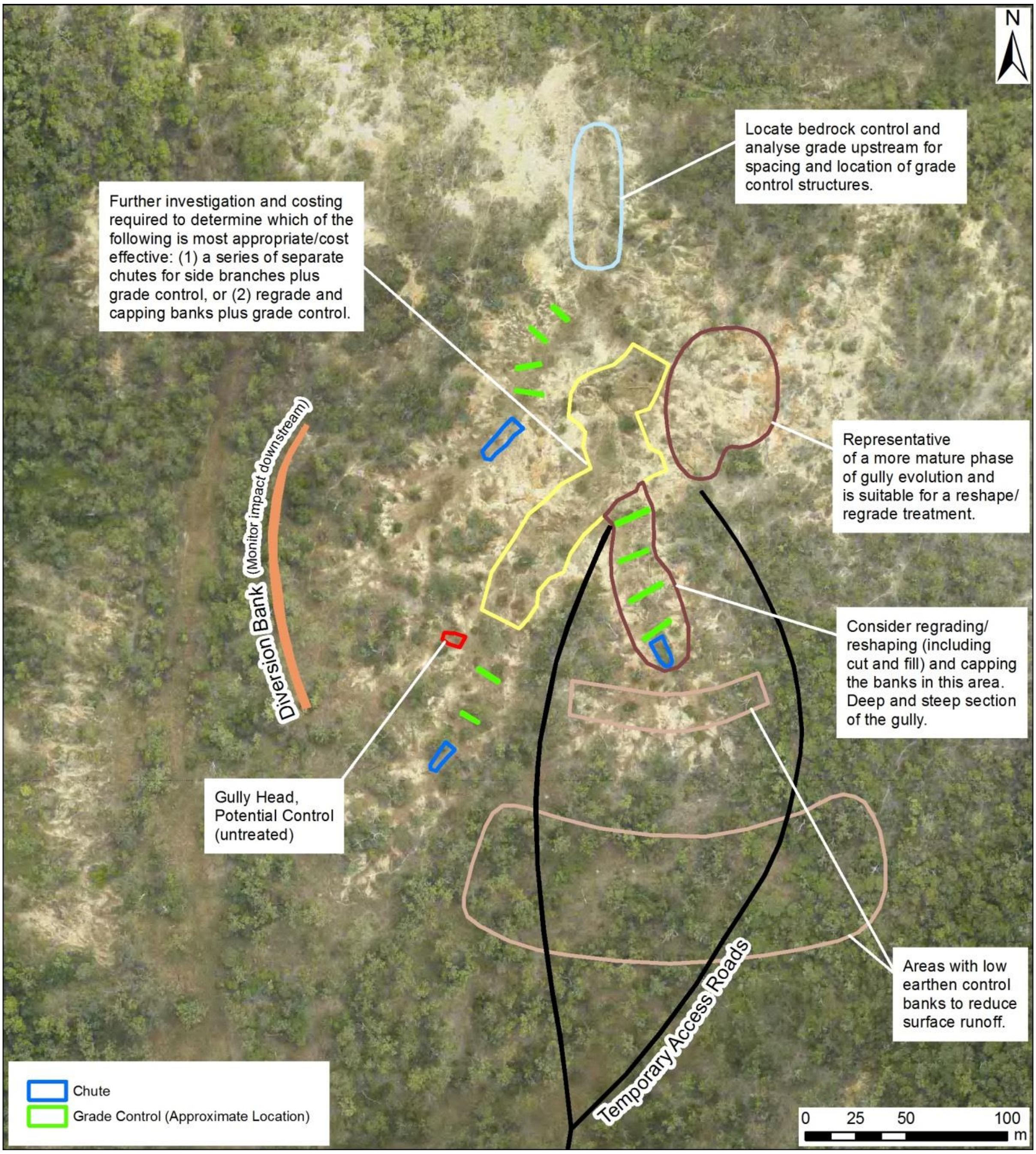

Figure 7b aerial photograph.

3. Targeted Sediment Reduction Response 2018 - 2022 – within 500m of road network.

Context:

The modelled top 25 sediment producing sub-catchments should be considered for future expansion of the Targeted Sediment Reduction Response, starting with the soil and gully erosion within 500m of the road network and expanding carefully to more isolated gully areas (within these sub-catchments) as successful gully remediation outcomes and avoidance of risks and additional disturbance are achieved.

The modelled top 25 sediment producing sub-catchments are currently estimated to produce approximately 60% of the current total sediment load from Springvale Station (Figure 8). These estimates and priority locations should be updated and confirmed as more LiDAR and field data become available over time across all of Springvale Station.

This phase should:

- build from the experience gained through implementation of the previous strategic sites sediment response
- draw on further Springvale Station LiDAR datasets and site assessments, to design and implement site specific soil and gully erosion remediation activities that aim to reduce erosion within 500m of the major road network
- up-scale lessons learned for the strategic sites to large areas of erosion
- acknowledge that implementation might pragmatically occur across several geologic units
- aim to achieve sustainable sediment reduction benefits without major risks, additional disturbance, and impacts to biodiversity, aesthetic, or cultural resources of Springvale Station.

Proposed Activities

Actively eroding soil and gully erosion within 500m of the existing property road network within the Priority Sediment Management Area should be targeted to significantly reduce sediment loss from the road network, while also minimising collateral damage through the construction of new roads to isolated gully complexes.

Specific sections of road, as priority for action, have been identified because they support property-wide operational activities (East Normanby, Cook Paddock) (Figure 7a&b). However most have been identified because they are located adjacent to, or within, the modelled top 25 sediment producing sub-catchments (the black shaded areas shown in Figure 9). These areas were identified by applying a 500m mask on each side of the roads identified in Figure 7a&b.

Approximately 195ha of gullies (bare earth) were mapped using Google Earth within the identified 500m road mask. These were suggested for further study in 2017/18 to inform potential active gully remediation actions in the 2018 to 2022 period. The recommended approach is to use available LiDAR datasets and site assessments to identify and develop costed remediation designs for the following highly active soil and gully erosion types based on their stage of channel evolution and degree of human disturbance. Consideration should be given to identify and develop costed remediation designs for a small number of soil and gully erosion types, mature alluvial gullies, scalded soils and shallow gullies, disturbed alluvial slopes. This is to demonstrate and quantify cost-effective treatments for other soil and erosion gully types commonly occurring on Springvale Station and in Normanby catchment.

LiDAR mapping plus on-ground site assessments are recommended to develop the detailed soil and gully erosion remediation designs and to confirm that the recommended approach, spatial location and costing estimate is sound. It is important to note that analysis of full LiDAR coverage of Springvale Station may reveal other high priority areas to target within the current modelled top 25 sediment producing sub-catchments, or additional sub-catchments beyond with limited current data. Targeting high priority areas using LiDAR and ground-truthing in the future will be based on stage of gully evolution, erosion rates, and practicality of intervention.

Cost-effectiveness of Targeted Sediment Reduction Response (2018-2022)

Estimate of cost and sediment saved

- It is estimated that there is at least 50ha of active soil and gully erosion (average sediment loss 400t/ha/year) that are of the type, evolutionary stage and current erosion rate that could be cost-effective and practical to treat within the identified 500m road mask (Figure 7a&b).
- The proposed remediation actions should be tailored to the specific site and aim to achieve a 50% sediment reduction across the 50ha of active erosion area (average sediment loss 400t/ha/year).
- The costs to treat 50ha of eroded area producing on average 400t/ha/year to achieve a 50% reduction in sediment loss will based on activities implemented at the strategic sites and a cost-effectiveness will subsequently be calculated prior to any works proceeding.

Monitoring to support these activities

Monitoring will include:

- repeat aerial LiDAR (ideally before and after)
- drone photogrammetry to generate digital elevation models (DEM)
- terrestrial LiDAR (before and after) suitable for smaller sample areas (DEM)
- ground cover photo points and record sheets
- Gully toolbox monitoring of on ground works before and after
- native seed germination and colonisation success
- sediment concentration and water runoff yield from treated/control gullies
- water quality analysis at the East and West Normanby Bridge Water Quality monitoring sites.

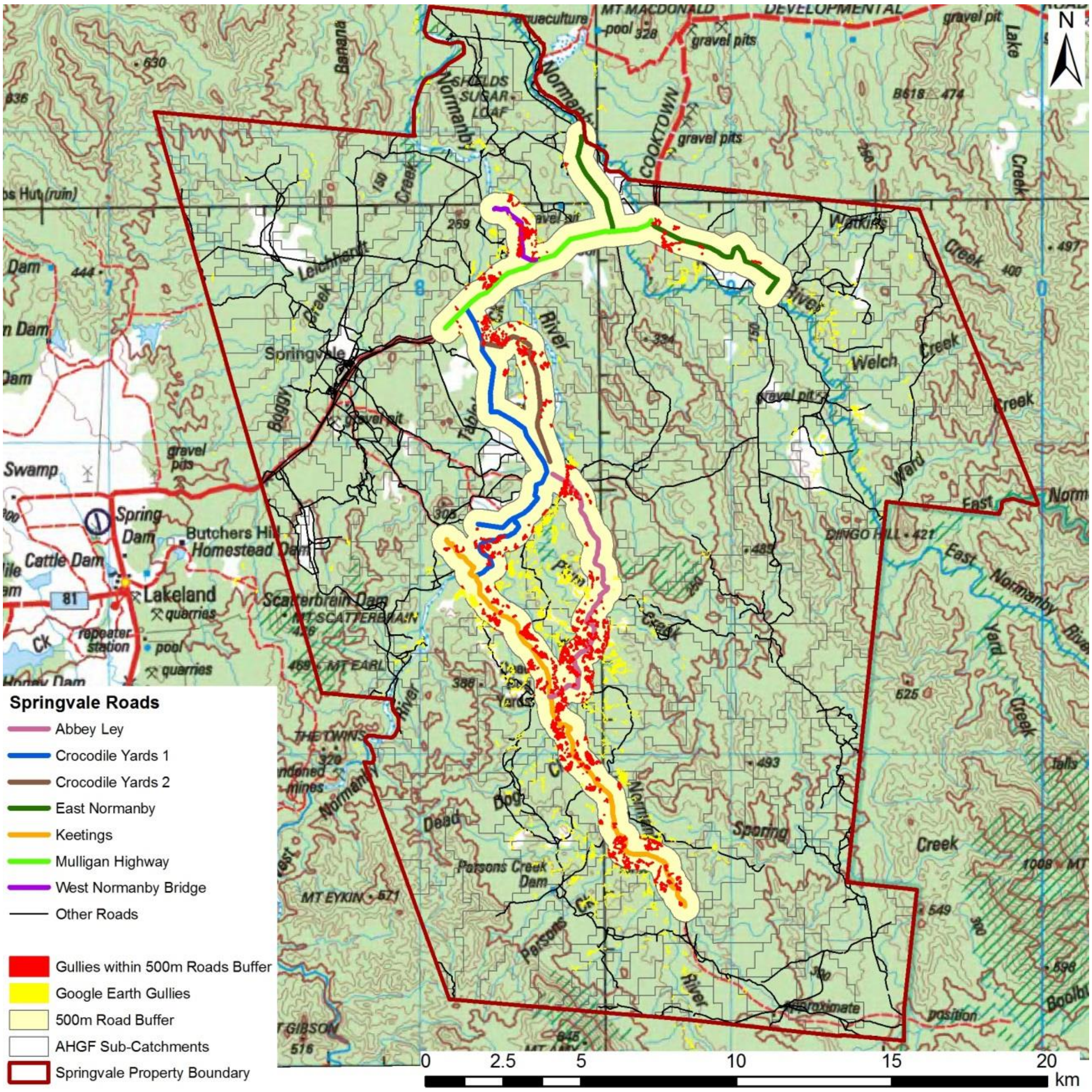

Figure 8 Selected major roads Springvale Station with gullies (red) that are within a 500m buffer of these main roads and are within the Alluvial/Colluvial Slopes geo units (Source: Griffith University).

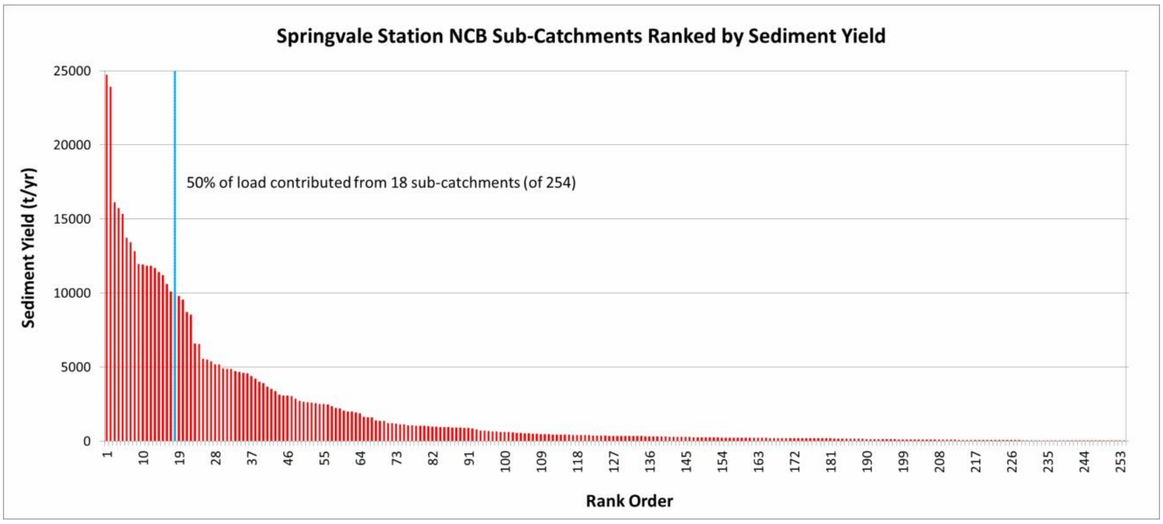

Figure 9 Modelled sediment yield of the 254 sub-catchments within Springvale Station arranged in rank order of estimated yields. Note that 50% of the total sediment yield is modelled from just 18 sub-catchments (Source: Griffith University).

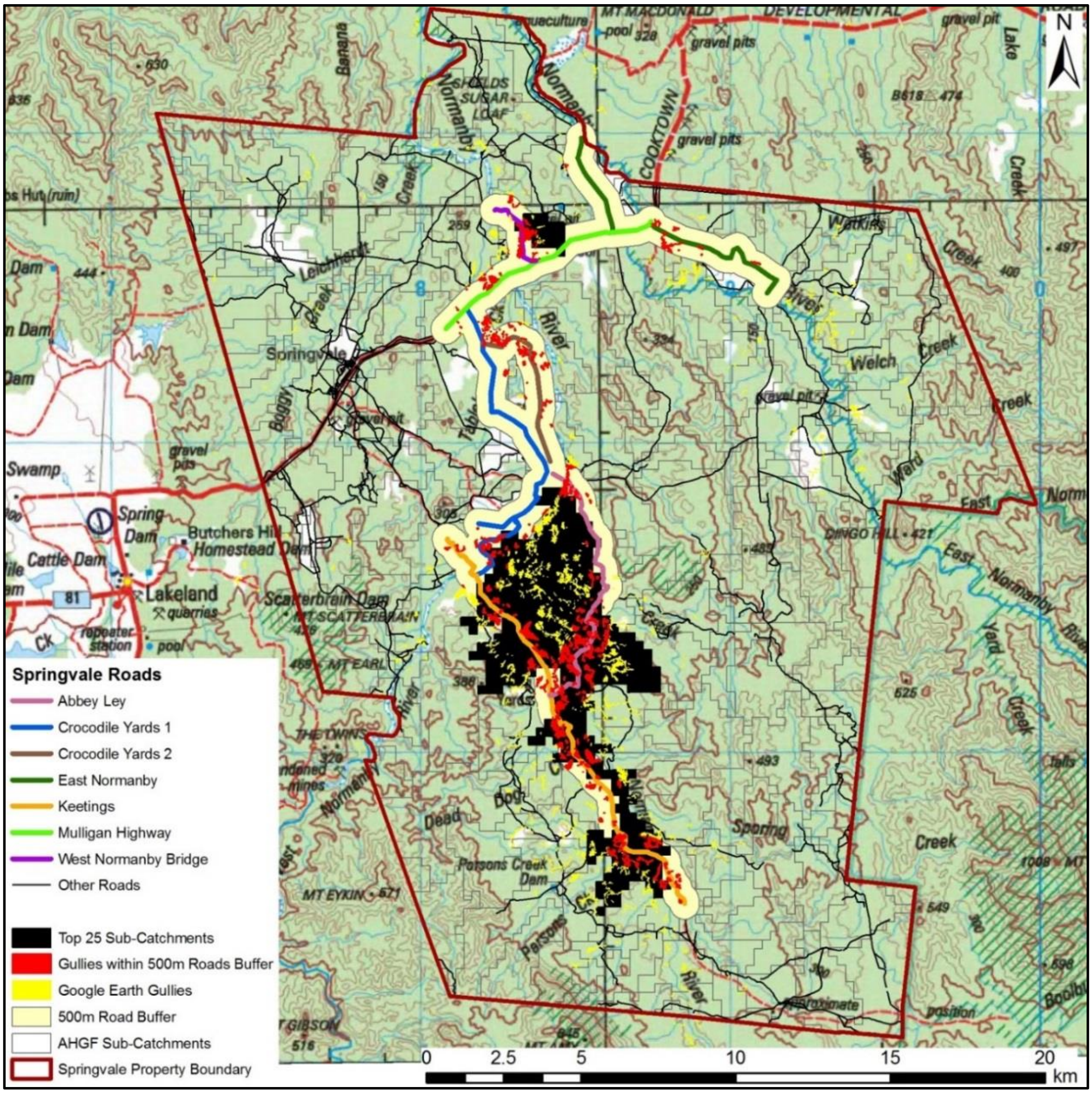

Figure 10 Alluvial/Colluvial Slopes gullies within a 500m road buffer are presented as red. The top 25 sediment producing sub-catchments are presented as the black background. Gullies that are within the top 25 gully sediment producing sub-catchments but are more than 500m from the road network are presented as yellow on black background (Source: Griffith University).

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Soil and Gully Erosion Management Guidelines

Map Erodible Soils and Erosion Features in High Resolution (LiDAR)

Fence to Land Type in Stable Fence Locations

Destock or Rigorously Spell Cattle from Large Areas of Erosion Prone Country

Classify Erosion Features Based on Stage of Geomorphic Evolution

Alluvial & Colluvial Slopes Above Gullies

Widespread Intervention
- Destock cattle.
- Revegetate upslope catchment.
- Fire management (exclude fire, fire breaks, infrequent storm burns).
- Weed control.
- Soil amendments at scalds.
- Revegetate scalded slopes.
- Retain or divert water runoff (brush and fibre structures).
- Earthen banks around gully heads to divert/retain water runoff.
- Water diversion banks (whoa boys) on roads and cattle pads.

Scalded Soils & Shallow Gullies

Modest Gully Intervention
- Exclude fires/cattle to maximise any potential vegetation cover.
- Control weeds such as rubber vine
- Revegetate grass, shrubs, trees.
- Add soil amendments (gypsum, compost, fibre mats, fertilizer).
- Avoid mechanical disturbance (localised ripping) if possible.
- Trial compost blankets mixed with seeds and fertilizer.
- Brush structures or fibre rolls on contour to retain water.
- Brush, fibre, or rock structures in dendric micro-gullies and across cattle pads to trap sediment.

Colluvial Gullies
Advancing Headcuts

Intensive Gully Intervention
- Revegetate upslope catchment.
- Retain or divert water runoff.

AND
- Rock chute drop structure.
- Bed grade control structures.
- Revegetate gully sidewalls.
- Maintain structures.

Young Alluvial Gullies
Advancing Headcuts
Finger Gullies

Intensive Gully Intervention
- Revegetate upslope catchment.
- Retain or divert water runoff.

AND
- Rock chute drop structure.
- Bed grade control structures.
- Revegetate gully sidewalls.

Or
- Batter gully slopes.
- Head cut and grade control structures.
- Soil amendments.
- Revegetate all slopes.

AND
- Maintain structures.

Mature Alluvial Gullies
Amphitheatre
Widening and Deepening

Experimental Gully Intervention
- Intervene only where accessible & practicable (near roads/material).
- Revegetate upslope catchment.
- Install earthen banks around gully scarps to reduce runoff.

OPTIONS:
- Intensive revegetation planting.
- Spray on geopolymer / hydromulch.
- Bulldoze slopes and recreate a swale or hollow drainage basin.
- Install grade control structures (rock, wood, brush) on bed.
- Treat sodic soil with gypsum, compost, fertilizer amendments.
- Revegetating slopes with direct grass seeding / tube stock.
- Rock capping on steeper slopes.
- Intensely monitor recovery and sediment yield output.

Old Alluvial Gullies
Deep and/or Revegetating

Promote Natural Recovery
- Revegetate upslope catchment.
- Install earthen banks around gully scarps to reduce runoff.
- Don't intervene with machinery on deep / steep slopes.
- Revegetate gully slopes & bed.
- Install brush grade control in gully bed (manual labour).
- Promote long-term recovery.

Dirt Roads, Tracks & Fencelines
With Rill & Gully Erosion

Cautious Mechanical Intervention
- Educate machine operators.
- Develop road / fence maintenance and abandonment plans (RAFMAP).
- Reduce road / fence network length
- Decommission un-needed roads.
- Minimize road and fence grading.
- Don't grade roads/fences for fire breaks (use slashing, herbicide or fire).
- Promote grass cover on native soils.
- Revegetate disturbed areas.
- Divert water to stable locations.
- Install frequent / large whoaboys.
- Armour whoaboys with gravel cap.
- Gravel roads over dispersible soils.
- Armour crossings with rock.
- Control road gully headcuts with rock chutes / grade control.
- Stabilise large road "choke points" and major gully erosion with intensive rehabilitation.

Cleared Paddocks
With Sheet, Rill & Gully Erosion

Promote Natural Recovery
- Avoid new disturbance, such as contour ripping that disturbs sodic soils.
- Allow to naturally revegetate with a mix of trees and grass.
- Promote water inception, infiltration, and surface runoff resistance.
- Introduce a natural fire regime.
- Manage weed infestations.
- Reduce water runoff from paddock to alluvial gullies prone edges and banks.
- Stabilise gully headcuts that are advancing into the paddock.

Appendix 1 Management guidelines for the soil and gully erosion types on Alluvial and Colluvial soils present on Springvale Station (Source: updated from Shellberg et al. 2016b) (Refer to Appendix 2 for more detail).

Appendix 2 Further detail on management guidelines for soil / gully erosion types on Alluvial and Colluvial soils present on Springvale Station (largely based on work from Shellberg & Brooks (2013) and Shellberg et al. 2016b).

<u>Alluvial & Colluvial slopes above gullies</u>

- **Photo examples**

- **Rehabilitation or remediation options**
  - Increase perennial grass cover
    - cattle destocking
    - active revegetation of grass – direct seeding or tubestock.
  - Fire management
    - locally tailor fire regimes to soil type and vegetation community for specific objectives (i.e. increase perennial grass cover, weed control)
    - in highly erodible locations, fire could be excluded altogether to maximise any potential vegetation cover
    - prescribed aerial and/or ground burning in the early-dry season to install fire breaks without soil disturbance (i.e., no grading)
    - early-wet season 'storm-burns' (1-3 days after first >25mm rain) could be used infrequently (> 5 years) and cautiously in highly-erodible river frontage to control weed and woodland thickening and promote increased grass cover, if it can be demonstrated that storm burns don't increase water runoff and gully erosion in the early wet season.
  - Weed management
  - Soil amendments treatment of scalded areas (gypsum, compost, fibre mats, fertilizer) with associated revegetation:
    - preferably without mechanical disturbance (localised ripping) to avoid the risk of additional disturbance
    - soil response to amendment (fertility, organic matter).
  - Reduce water run-off and sheet flow velocity to promote infiltration
    - brush structures or fibre rolls on contour to retain and spread water
    - contour banks are <u>not</u> advised on intact woodland terrain or sodic soil
    - earthen banks (bunds) around gully heads to retain water run-off and/or divert into safe disposal points, using locally imported material
    - water diversion banks (whoa boys) on roads and large cattle pads to retain and divert water run-off.

- **Monitoring Options to Document Success**
  - Photo Points (GPS located and star pickets)
  - Ground vegetation cover (percentage), grass basal area, native species diversity, weeds
  - Sediment retention behind micro- and macro-roughness elements
  - Surface erosion depth compared to reference points (erosion pins)
  - Water and sediment runoff yield from slopes (traps or flumes)
  - Gully scarp retreat at the bottom or base of hillslopes (shallow or steep).

Scalded soils and shallow gullies (Alluvium or Colluvium) (note these sites are often fringing larger more active gullies)

- **Photo examples**


- **Rehabilitation or remediation options**
  - Increase perennial grass cover
    - cattle destocking
    - active revegetation of grass, shrubs, trees – direct seeding / tubestock
    - treat scalded areas with soil amendments (gypsum, compost, fibre mats, fertilizer) without (preferred) or with mechanical disturbance (localised ripping), which has the risk of additional disturbance
    - trial innovative surface treatments such as sprayed compost blankets mixed with seeds and fertilizer.
  - Fire management
    - exclude fires to maximise any potential vegetation cover.
  - Weed management
    - control weeds such as rubber vine.
  - Reduce water run-off and sheet flow velocity to promote infiltration
    - brush structures or fibre rolls on contour to retain and spread water
    - brush, fibre, or rock structures in dendric micro-gullies and across cattle pads to trap sediment output and aggrade the channels for revegetation
    - grade control structures in linear gullies eroding into scald areas.

- **Monitoring options to document success**
  - Photo Points (GPS located and star pickets)
  - Ground vegetation cover (percentage), grass basal area, native species diversity, weeds
  - Sediment retention behind micro- and macro-roughness elements
  - Surface erosion depth compared to reference points (erosion pins)
  - Water and sediment run-off yield from slopes (flumes)
  - Gully scarp retreat at the bottom or base of hillslopes (shallow or steep)
  - Drone photogrammetry to generate digital elevation models (DEM)
  - Terrestrial LiDAR – small sample areas.

<u>Colluvial hillslope gullies (typically linear)</u>

- **Photo examples**


- **Rehabilitation or remediation options** (in combination above/at/below scarps)
  - Reduce water run-off from slopes above gully head (see sections on Alluvial and Colluvial Hillslopes, or Road and Fence Gullies)
  - Earthen banks (bunds) around gully heads to retain water run-off and/or divert into safe disposal points, using locally imported material
  - Rock chute (or other drop structure) at gully head to reduce head cut retreat
  - Grade control structures (brush, wood, rock) sequentially placed in the gully bottom, carefully embedded into the bed and banks to prevent outflanking
  - Stabilise gully side-walls with vegetation (grass, shrub) and grade control
  - Active revegetation of grass, shrubs, trees – direct seeding / tubestock
  - In extreme cases (not generally recommended), reshape the entire gully with machinery, install head cut and grade control structures, add soil amendments (gypsum, compost, fibre mats, fertilizer), and revegetate
  - Gully plug dams are <u>not</u> recommended on Springvale Station due to the need for long-term maintenance, risk of failure in sodic soils and intense rainfall events, and the biocultural conservation goals of the property.

- **Monitoring options to document success**
  - Photo Points (GPS located and star pickets)
  - Gully scarp and sidewall retreat rates (GPS, DEM etc)
  - Erosion depth compared to reference points (erosion pins)
  - Drone photogrammetry to generate digital elevation models (DEM)
  - Terrestrial LiDAR – small sample areas (DEM)
  - Ground vegetation cover (percentage), grass basal area, native species diversity, weeds.
  - Sediment retention (bed elevation) behind grade control structures
  - Sediment and water run-off yield from treated/control gullies (flumes).

<u>**Young alluvial gullies (finger gullies)**</u>

- **Photo examples**


- **Rehabilitation or remediation options** (in combination above/at/below scarps)

  Slopes Above Headcut
  - Reduce water run-off from slopes above gully head (see sections on Alluvial and Colluvial Hillslopes, or Road and Fence Gullies)
  - Earthen banks (bunds) around gully heads to retain water run-off and/or divert into safe disposal points, using locally imported material.

  Headcut
  - Rock chute (or other drop structure) at gully head scarp to reduce head cut retreat (typically with ~10% slope with cut-off trench, geofabric, dissipater)
  - Rock waterway (or grass) at gully head scarp to reduce grade (<2%) by removing larger volumes of earth, reshaping, geofabric, rock or grass capping, and grade control
  - Side slopes and aprons of chutes could be stabilised with cement/soil mixtures (pugging) or a variety of geopolymers, with caution to key into soil to prevent undermining.

  Channel
  - Grade control structures (brush, wood, rock) sequentially placed in the gully bottom, carefully embedded into the bed and banks to prevent outflanking
  - In-channel chutes for large drops in bed level
  - Stabilise gully side-walls with vegetation (grass, shrub, trees) (direct seeding / tubestock) and grade control
  - In extreme cases (not generally recommended), reshape the entire gully with machinery, install head cut and grade control structures, add soil amendments (gypsum, compost, fibre mats, fertilizer), and revegetate all slopes
  - Gully plug dams are <u>not</u> recommended on Springvale Station due to the need for long-term maintenance, risk of failure in sodic soils and intense rainfall events, and the biocultural conservation goals of the property.

- **Monitoring Options to Document Success**
  - Photo Points (GPS located and star pickets)
  - Gully scarp and sidewall retreat rates (GPS, DEM etc)
  - Erosion depth compared to reference points (erosion pins)
  - Drone photogrammetry to generate digital elevation models (DEM)
  - Terrestrial LiDAR – small sample areas (DEM)
  - Ground vegetation cover (percentage), grass basal area, native species diversity, weeds.
  - Sediment retention (bed elevation) behind grade control structures
  - Sediment and water runoff yield from treated/control gullies (flumes).

Mature alluvial gullies (amphitheatre)

- **Photo examples**


- **Considerations whether to intervene**
    - Ratio of gully area / to total catchment area (LiDAR derived) to assess contributing catchment area, potential for overland flow input, potential future erosion, and stage of channel evolution.
    - Rate of head scarp retreat *vs.* rate of incision *in situ* into pre-European hollows
    - Depth of head scarp and gully depth, and practicality of sending machines into deep gullies while minimising additional disturbance and costs
    - Slope of head scarp, compared to slope of outlet channel, and potential to erode back into the landscape in the future
    - Degree of natural revegetation and any slope feedbacks toward stability.
    - Volume of earth material that would need to be excavated to lay the slope back to an angle that feasibly could be stabilised (~10-20%) via bioengineering
    - Proximity to well-established & stable roads to gain machinery access
    - Proximity to borrow material (rock, soil, wood) that will not produce additional disturbance or other cultural, environmental, aesthetic, or conservation impact
    - None of these methods below have been tried at very large scales (whole alluvial gully complexes), and thus are experimental with risk and uncertainty
    - Maximum sediment reduction success for any treatment would be ~ 50%. That is, the gully will still continue to erode to some degree after treatment.

- **Rehabilitation or remediation options** (in combination above/at/below scarps)

  Slopes Above Gully Scarps

    - Reduce water run-off from slopes above gully head (see sections on Alluvial and Colluvial Hillslopes, or Road and Fence Gullies)
    - Earthen banks (bunds) around gully heads to retain water run-off and/or divert into safe disposal points, using locally imported material on original surface.

  Gully Scarps

    - Option 1: Active revegetation ONLY (without regrading):
      A knowledge gap exists to what extent *intensive* active revegetation of grass species in large alluvial gullies can be successful, and reduce surface or scarp gully erosion and trap sediment in the gully bed (cost/benefit). With up to $100,000 per hectare being utilised for more intensive gully retreatments, the question remains whether a fraction (say 1/3rd $33,000/ha) could be used for intensive revegetation efforts to assist and speed up natural recovery. Revegetation would entail hand planting grass plugs, seeds, or other innovative techniques using hardy native grass (e.g., *Mnesithea rottboelloides*) planted in the wet season when soils are loose. Experimentation to this effect could support the viability of larger proposals to aerially distribute pelletised grass seeds at dense rates into thousands of hectares of gullies during the wet.

    - Option 2: Full re-grading of mature amphitheatre gullies
        - bulldozing slopes into a more uniform shape
        - re-creating a swale or hollow catchment shape to promote natural flow paths and mimic pre-European hollow shapes

- laying the scarp slope grade back to a lower slope (from > 100% (45°) to less than < 20% (11.3°) = large volumes of earth
- installing grade control structures (rock, wood, brush) frequently along the wide hollow bed
- treating sodic soil with gypsum, compost, fertilizer amendments
- revegetating slopes with direct grass seeding / tube stock / hydromulch
- rock capping on steeper slope surfaces
- alternatively rock blanket all slopes
- alternatively use plastic lattic on soil surface and revegetate.

- Option 3: spraying geopolymers or shotcrete on slopes
  Numerous market products exist to spray on various polymers, glue binding agents, concrete, and/or hydromulch across steep unstable slopes. The advantage is that slopes would not necessarily need to be battered and material could be sprayed on *in situ.* However, thick blankets would be needed to ensure good fabric binding, as well as attention to detail around gully micro-features to prevent collapse or undermining. Any geopolymer blanket would need to be "keyed" into the soil at depth at the gully head (upslope) to prevent undermining from overland flow. Polymers could be used with hydromulch if grass vegetation is desirable (rehabilitation vs. remediation). Some degree of battering could assist geopolymers success, especially at the immediate gully scarp.

Channel

- Grade control structures (brush, wood, rock) sequentially placed in the gully bottom and outlet channel (in situ or battered) carefully embedded into the bed and banks to prevent outflanking
- Stabilise gully outlet side-walls with vegetation (grass, shrub, trees) (direct seeding / tube stock) and grade control.

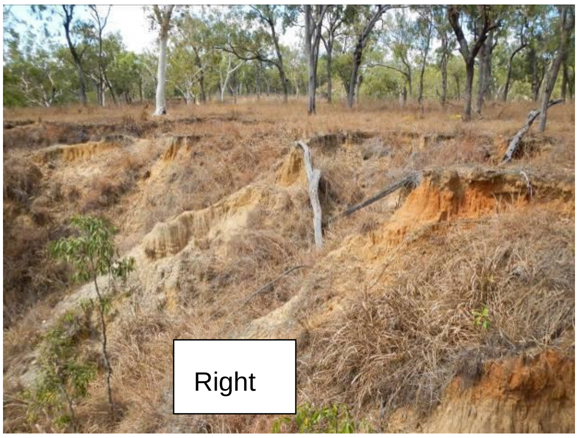
- **Monitoring options to document success**

Due to the highly experimental nature of these treatment of large unstable gully complexes, significant monitoring would be needed to accurately demonstrate sediment reduction success and different erosion processes influenced by intervention.

- Sediment and water run-off yield from treated/control gullies, using fully automatic continuous gauging stations with surrogate technologies
- Airborne LiDAR, before/after, treatment/control
- Drone photogrammetry to generate digital elevation models (DEM)
- Terrestrial LiDAR – suitable for smaller sample areas (DEM)
- Ground vegetation cover (%), grass basal area, native species diversity, weeds
- Photo Points (GPS located + star pickets).

<u>Old alluvial gullies (deep and/or revegetating)</u>

- **Photo Examples**



- **Considerations whether to intervene**
    - Some older alluvial gullies have been eroding for 100 years or more, and are still active in places. However, as they incise toward their ultimate base-level, their slopes begin to revegetate with trees and grass. This is especially the case toward the middle and lower reaches of the gully catchment where erosion started first and slopes are stabilising in their evolutionary cycle. Cattle access is often difficult in this very steep terrain.
    - Head scarps of older gullies that have reached their maximum limit at the divide with other gully catchments can have very steep and very deep scarps, 8 to 16 m deep in places.
    - While still raw and eroding, the practicality for mechanical intervention into very deep/steep slopes needs to be cautioned against, due to the large volumes of earth that would be required to be moved to lay the slope back to an angle that feasibly could be stabilised (~10%), and the potential for additional disturbance on nearby healing gully slopes and adjacent intact terrain.
    - Assess the erosion rate.
    - Many old and deep gullies are more remote on Springvale Station, due to roads and fencing actively avoiding these areas. Access practicality needs to be considered and potential for additional disturbance associated with intervention.

- **Rehabilitation or remediation options**

  Slopes Above Gully Scarps
  - Reduce water run-off from slopes above gully head (see sections on Alluvial and Colluvial Hillslopes, or Road and Fence Gullies)
  - If a terrace catchment area still exists above the headscarp, and is contributing accelerated water runoff onto the scarp (road, fence, cattle pad), earthen banks (bunds) around gully scarp could be used to retain water runoff and/or divert into safe disposal points, using locally imported material on original surface.

  Gully Scarps
  - Older gullies with active revegetation and feedback cycles toward stabilisation should not be disturbed with machinery or mechanical intervention
  - Vegetation established on slopes could be enhanced with proactive vegetation planting (grass, shrub, trees) via direct seeding or tubestock
  - Soil amendments may need to be considered.

  Channel
  - Brush and timber grade control structures could be sequentially placed in the gully bottom and outlet channel using hand crews (manual labour) with wood material harvested by hand from local terrace slopes or densely forested riparians zones at the gully outlet
  - Vegetation established on gully bottom and channel outlet could be enhanced with proactive vegetation planting (grass, shrub, trees) via direct seeding or tubestock, in order to promote sediment trapping from upslope scarps.

- **Monitoring options to document success**
  - Sediment and water run-off yield from treated/control gullies, using fully automatic continuous gauging stations with surrogate technologies
  - Airborne LiDAR, before/after, treatment/control
  - Drone photogrammetry to generate digital elevation models (DEM)
  - Terrestrial LiDAR – suitable for smaller sample areas (DEM)
  - Ground vegetation cover (percentage), grass basal area, native species diversity, weeds
  - Photo Points (GPS located and star pickets).

Dirt roads, tracks and fence lines (with rill and gully erosion)

- **Photo Examples**


- **Rehabilitation or remediation options**
  - Educate machine operators on Best Management Practices (BMPS)
  - Develop Road and Fence Maintenance and Abandonment Plans (RAFMAP)
  - Reduce road and fence network length through decommissioning and rehabilitation
  - Minimize road and fence grading
  - Promote grass cover on native soil roads, tracks and fences to provide cohesion (minimise grading)
  - Revegetate disturbed areas of roads and fence (grass, trees, shrubs)
  - Don’t grade roads and fences for fire breaks (use slashing or chemical breaks to burn off)
  - Gravel roads over dispersible soils with imported material
  - Divert water to stable locations
  - Install frequent / large whoaboys to divert water and maintain height and drivability
  - Armour whoaboys with gravel cap
  - Armour crossings and approaches to creeks and rivers with rock and gravel
  - Control road gully headcuts with rock chutes and grade control (see Young Alluvial and Colluvial Gully sections above)
  - Stabilse large road “choke points” and major gully erosion through intensive rehabilitation (see mature alluvial gullies and Young alluvial gullies sections above).

- **Monitoring Options to Document Success**
  - Photo Points (GPS located and star pickets)
  - Road / Fence Condition Surveys (condition, surface cover, grass cover, percentage eroded, rill depth, gully frequency, BMP function)
  - Drone photogrammetry to generate digital elevation models (DEM)
  - Terrestrial LiDAR – small sample areas (DEM).

<u>Cleared paddocks</u>

- **Photo examples**

- **Rehabilitation or remediation options**
  - Avoid any ongoing disturbance, such as contour ripping, which will further disturb sodic dispersible soils
  - Allow to naturally revegetate with both tree and grass mixes to promote water inception, infiltration, and surface runoff resistance
  - Introduce a natural fire regime that promotes a heathy mix of grass and trees in open woodlands.
  - Manage weed infestations in disturbed paddocks
  - Reduce water run-off from paddock edges into alluvial gullies or riparian zones of ephemeral creeks and rivers
  - Install earthen banks (bunds) around gully heads to retain water run-off and/or divert into safe disposal points
  - Stabilise gully headcuts that are advancing into the paddock from the terrace and paddock edge (see Linear rapidly advancing alluvial gullies above).

- **Monitoring options to document success**
  - Photo points (GPS located + star pickets)
  - Vegetation cover (%), basal area, native species diversity, weeds
  - Water runoff velocity and volumes per rainfall input
  - Gully scarp retreat at the edge of paddock.