Erosion along Unformed Roads, Tracks, Firebreaks and Fencelines in Eastern Cape York Peninsula and Best Management Practices (BMPs) for Erosion Control

Produced by
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Scope and Purpose

These erosion control '*Erosion Control Best Management Practices (BMPs) for Tracks, Firebreaks and Fencelines*' have been developed to provide guidance for land managers on Eastern Cape York Peninsula (CYP) and beyond to address erosion along these linear disturbances and primitive roads (Figure 1). The goal of the BMPs is to minimise annual and long-term erosion damage to road, track, firebreak and fenceline infrastructure, and reduce sediment delivery to the surrounding drainage environment and Great Barrier Reef (GBR). The Reef 2050 Water Quality Improvement Plan has the goal to reduce human-caused (anthropogenic) river sediment loads to the GBR by 10% by 2025 and 25% by 2030 for eastern CYP.

An unformed road has "*no constructed or maintained formation, or surface drainage*" in comparison to a formed road that has "*a constructed formation (shape) using local materials and formed table drains*" with the optional upgrade to a gravel road that has "a *layer of gravel imported, compacted and maintained atop the formation*" (QRA 2018).

A primitive road is a "*minor road system that is generally not maintained or paved, is not classified as part of the area's primary road system, has an average annual daily traffic of one hundred or fewer vehicles, and is typically natural dirt or gravel*" (WA Gov Legislation). Unformed and primitive roads are generally not maintained by local Shire Councils.

Figure 1 An example of an unformed primitive road in Eastern Cape York Peninsula.

These erosion control BMPs apply to the placement, installation and maintenance of dirt tracks, firebreaks and fencelines across eastern CYP, where primitive tracks cross a variety of rolling hills, floodplains, watercourses, and other drainage features. Dispersive soils are common near creek and gully crossings and are highly erosion prone. The application of these erosion control BMPs on unformed roads, firebreaks and fencelines' will 1) reduce sediment delivery to waterways and the GBR, 2) provide long-term track resilience, 3) minimise infrastructure damage, 4) improve trafficability and access for land management (e.g. weeds, fire, grazing, conservation, culture), and 5) lessen the whole-of-life road costs.

Part 1 of this document contains background, survey results, erosion rate measurements, and literature review. Part 2 contains the '*Erosion Control Best Management Practices (BMPs) for Tracks, Firebreaks and Fencelines*'.

PART 1

Unformed Road Locations and Maintenance in Eastern Cape York Peninsula

On the Cape York Peninsula, there are tens of thousands of hectares of roads, tracks, firebreaks and fencelines ('linear disturbances') with bare soils vulnerable to erosion. This covers more area than many other intensive land-uses (i.e., agriculture). For example, in the Normanby and Stewart catchments, there are 10,800 km (7990 ha) of linear disturbance features and 8950 stream intersection points; the largest categories are fencelines (30%), main dirt roads (14.3%) and minor farm tracks (11.4%) (Spencer et al. 2016).

In southeastern CYP (Figure 2) (Annan, Endeavour, McIvor, Starke, Jeannie, Muck), there are 4100 km of roads, tracks, and fencelines mapped and targeted for ground surveys and erosion control prioritisation. The majority of linear disturbances in this area are primitive dirt tracks (2539 km, 62%), fencelines (887 km 22%), and Council Streets and Roads (556 km, 14%) (Figure 2).

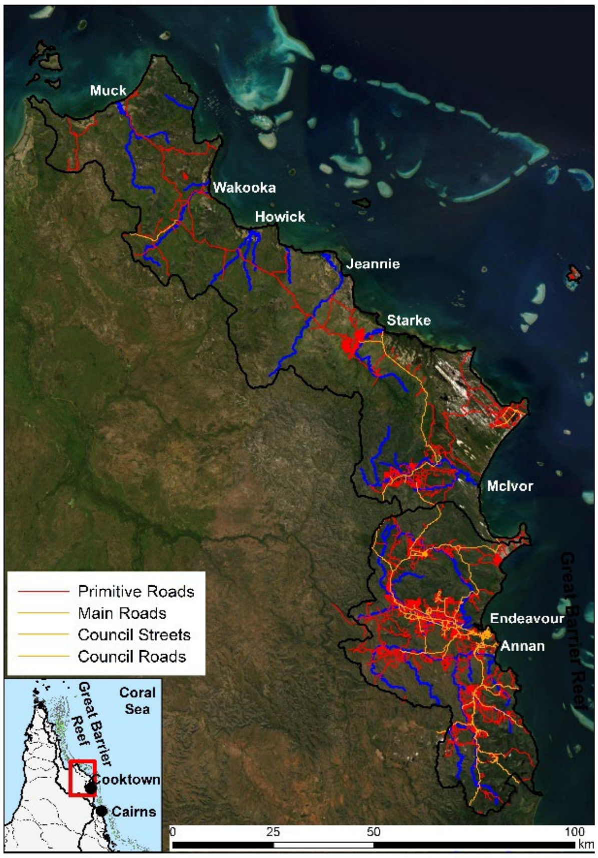


Figure 2 Primitive Roads in Coastal SE CYP

Unformed and primitive roads have been part of the CYP development history since European settlement in the 1800s. For example, the Annan Catchment was historically impacted by European settlement starting in 1873 in Cooktown to access both the Palmer Gold fields and Upper Annan Tin fields (Carroll et al. 2007). The old coach road to the Palmer Gold fields in 1873 ran parallel to Oaky Creek (the largest Annan tributary) near where the current Oaky Road is located. Similar tracks were also established in the late 1800s to Rossville, Shipton's Flat, Mt Poverty, Trevethan and Archer Point in the Annan Catchment. Both early and subsequent roads through these areas have caused significant erosion damage to the environment.

Erosion caused by tracks is especially problematic near stream crossings with highly erodible dispersive[1] and sodic[2] sub-soils associated with small floodplains, terraces and weathered regolith[3]. Once these soils are disturbed by roads (plus cattle and fire), gullies can be initiated into sub-soils, creating a historic legacy (e.g., Shellberg et al. 2016; Shellberg and Brooks 2013).

[1] Dispersive soils: the soil aggregates collapse when the soil gets wet and individual clay particles disperse into solution.
[2] Sodic soil: a soil with an exchangeable sodium of greater than 6% of the cation exchange capacity.
[3] Regolith: the blanket of unconsolidated, loose, surface deposits covering solid rock, including soil, alluvium, weathered bedrock and biota.

Today, there are a large variety of primitive roads present in Eastern Cape York Peninsula.

- General Access Tracks
    - Rural property access tracks and driveways (cattle stations, Aboriginal freehold, private land, conservation land, national park)
    - Cattle mustering tracks for grazing management
    - Community access tracks to Country for fishing, culture, camping
    - 4x4 adventure tracks to local or remote locations
- Fencelines
    - Cattle stations
    - Conservation areas
    - Peri-urban settings
- Firebreaks
    - Rural properties (cattle stations, Aboriginal freehold, private land, conservation land, national park)
    - Peri-urban settings
- Agricultural tracks and machine paths/rows.
- Peri-Urban roads and driveways
- Power Lines and their access tracks (e.g., Ergon)
- Logging Tracks and log skid tracks (e.g., forestry)
- Mining
    - Access tracks
    - Haul routes
    - Mineral exploration tracks
- Illegal Tracks (poaching and hunting, drugs, trespass)

Primitive roads often begin as simple tracks created by 4x4 vehicles over grass. Others are bulldozed or graded in once, and then kept clear of vegetation by traffic or grading. Repeated annual grading of tracks, firebreaks, and fencelines on CYP is common practice. Rills and gullies from the wet season are smoothed out “just to get through” each year, pushing soil directly into creek crossings. Small whoa-boys using native soils are utilised where cheap and possible. They often fail or are graded away by machine operators. Alternatively, some operators attempt to form road prisms and drains out of native soils, which leads to enhanced rill and gully erosion in dispersive sub-soils without major imported rock sheeting. Funding, time and proper machinery and materials are often lacking to address and fix local problem areas properly.

All of this leads to repeated cycles of grading, erosion, and land degradation. Entrenched roads, gully erosion at crossings, and abandoned tracks are the results, which are costly to repair and leave an erosion legacy impacting local creeks and the GBR.

All primitive roads degrade over time. However, tracks can be more resilient if they are put in stable locations, not degraded by over-use or inappropriate management, left with good grass cover and not repeatedly graded, strategically maintained only where problems arise, and improved with erosion control BMP interventions to maintain access and resilience.

Figure 3   Typical primitive road (2-wheel dirt track) on CYP with intercepted water flow in the wet season.

Figure 4   Typical primitive road gully erosion issues at small creek and hollow crossings.

Figure 5   Annual grading before (left, June 2022) and after (right July 2022) track preparations for firebreak access, repeatably filling in erosion holes to be re-eroded the next year in the same location.

Figure 6   Annual grading before (left, June 2022) and after (right July 2022) track preparations for firebreak access. The cycle continues of erosion, re-grading for access, and re-erosion the next wet season.

Figure 7   Annual grading before (left, June 2022) and after (right July 2022) track preparations for firebreak access. The cycle continues of erosion, re-grading for access, and re-erosion the next wet season.

Figure 8   Typical annual grading along a fenceline that will accelerate wet season sheet and shallow rill erosion.

Figure 9   Examples of fenceline erosion problems, such as gullying and rilling due to fenceline machine disturbance.

Mapping Hotspots of Erosion Along Roads, Tracks, Firebreaks and Fencelines

The Cape York Water Partnership (CYWP) and landowner partners (private, traditional owner, national parks, shire councils) have conducted road and track erosion mapping surveys (Figure 10) in Southeast Cape York Peninsula (SE CYP, Endeavour and Jeannie Basins) draining to the GBR (2022-2024). The objectives of the project were to:

1. Map and assess erosion along unformed dirt roads, tracks, fencelines and firebreaks.
2. Locate hotspots of severe erosion.
3. Guide priorities for future investment in erosion control.
4. Trial erosion control BMPs at prioritised hotspots with local land managers and adapt BMPs.

Figure 10 The majority of primitive road erosion surveys were conducted by 4x4 buggy.

In 2022-2024, over 2800 km of roads, tracks, and fencelines were surveyed, and over 1280 km of unique primitive roads were mapped. Hundreds of thousands of georeferenced photos (one every 5 m) were collected and processed through an erosion defect software system and data dictionary. Erosion defects maps were created for specific sub-catchments and properties (Figure 11).

A regional prioritisation model was developed to locate and rank erosion hotspots. Prioritization was based on 7 key variables to determine sites with the highest sediment delivery risk to the GBR (Figure 12):

- Erosion Type and Volume (gully erosion, rill erosion, road entrenchment).
- Soil / regolith material and percentage of fine sediment.
- Road slope averaged at 10 m distance intervals.
- Distance to the closest streamflow path from 30 m topographic data.
- Association with additional surrounding or off-track gully sites.

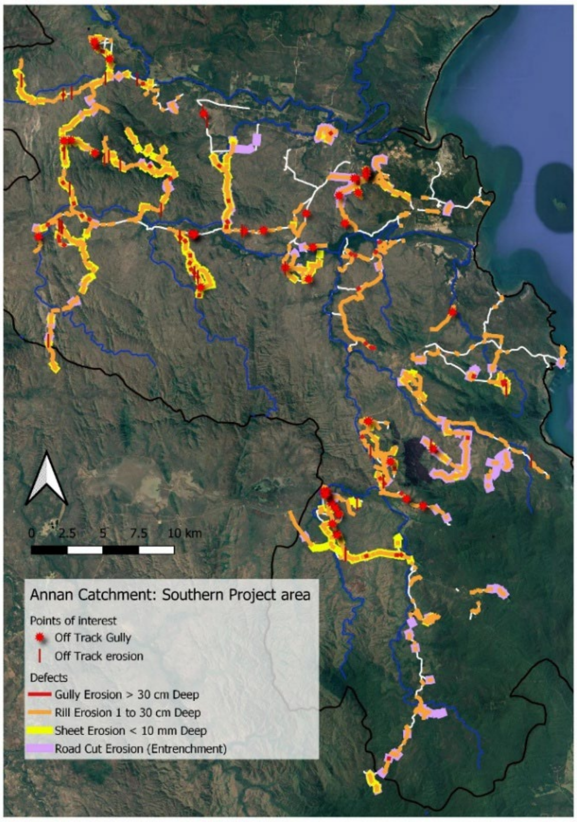


Figure 11 Erosion defect mapping in the Annan catchment.

Out of a total of 232,892 data input points, the erosion prioritisation model ranked 61 sites as Very High Priority and 564 sites as High Priority. All these sites had major rill and gully erosion (Figure 12).

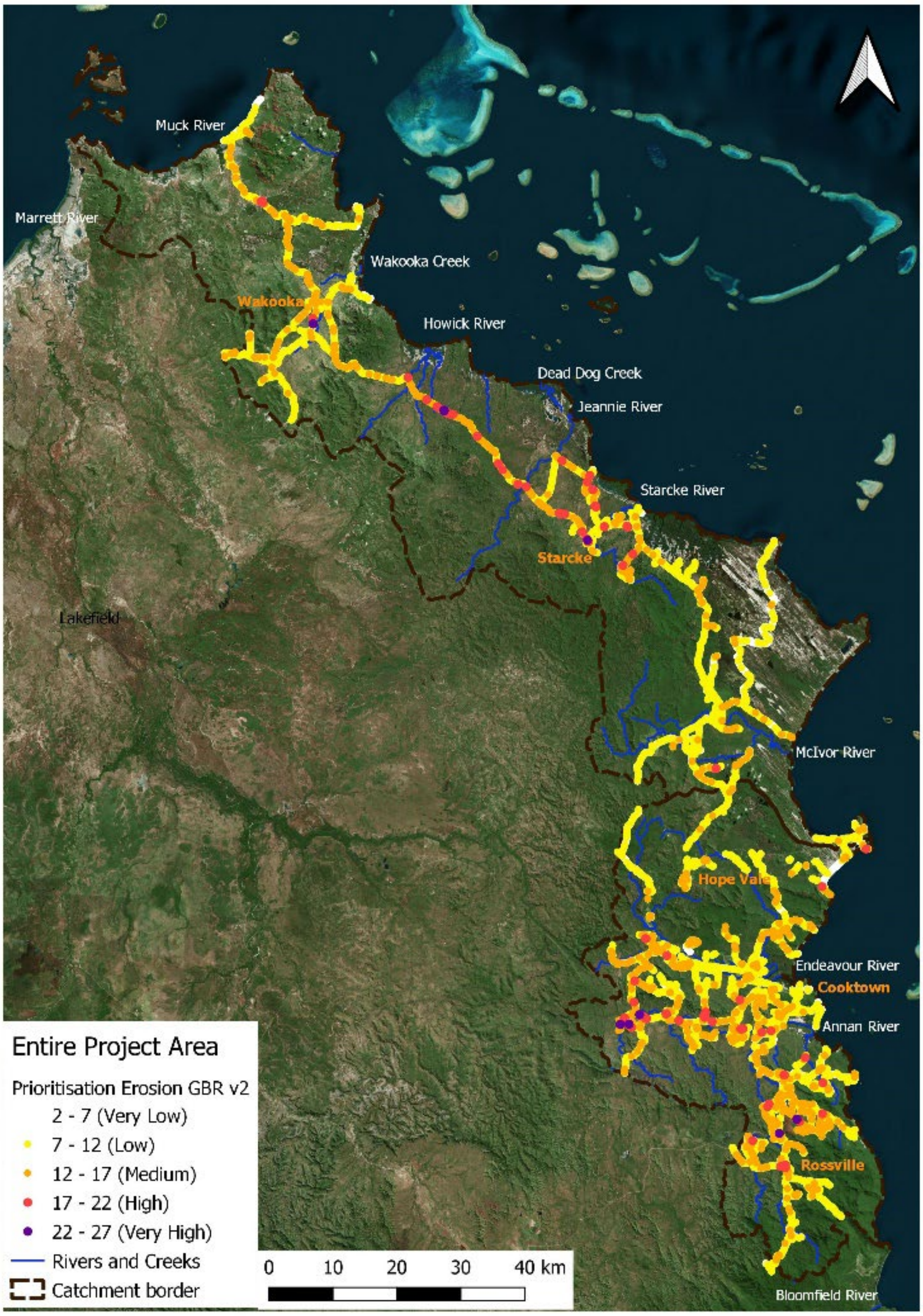


Figure 12 Prioritized erosion hotspots across Eastern Cape York (right) with high connectivity to the GBR.

Erosion Rates along Unformed Primitive Roads

Background Literature

Globally, roads and road development have a major impact on catchments, rivers, and ecosystems (Kareiva et al. 2007; Laurance et al. 2014; Alamgir et al. 2017). Roads are a classic cumulative effects issue for catchment sediment yields. Cumulative effect can be defined as "*any environmental change influenced by a combination of land-use activities*." (Reid 1993). Roads locally and cumulatively alter water runoff processes and create overland flow (Reid and Dunne 1984; Luce and Cundy 1994; Ziegler and Giambelluca 1997; Ziegler et al. 2001; Coe 2004), rapidly route water to the stream network (Wemple et al. 1996; Wemple and Jones 2003) and extend channel networks through gullying and stream piracy (Montgomery 1994; Wemple et al. 1996; Veldhuisen and Russell 1999; Croke and Mockler 2001; Wemple et al. 2001). Due to these hydrologic and geomorphic impacts, roads increase coarse and fine sediment supply to the stream network (Sidle et al. 1985; Montgomery 1994; Veldhuisen and Russell 1999; Lane and Sheridan 2002; Douglas and Guyot 2005) and increase gully frequency (Montgomery 1994; Croke and Mockler 2001; Jungerius et al. 2002; Nyssen et al. 2002; Grip et al. 2005).

Unsealed road erosion rates vary depending on rainfall, slope, traffic, and surface material, with literature values ranging from 2.4 to 273 t/ha/yr, with median values around 22 t/ha/yr for all size classes (Fu et al. 2010).

On Cape York Peninsula (CYP), repeat Terrestrial Lidar Scanning (TLS) was used to quantify the primitive road erosion at steep road cuts into terraces at alluvial river crossings (Shellberg and Brooks 2013). The slopes were typically re-graded each year with loaders to gain access through deep rill erosion. Annual erosion rates of sheet erosion, deep rilling, and some gullying up to 0.5 m deep varied between 80 to 160 kg/m^2/yr for slopes of 10 to 20%. This equates to 800 to 1600 tonnes/ha/year, which is high on a global scale for both roads (Cederholm 1981; Reid and Dunne 1984; Sidle et al. 2006) and gullies (Shellberg et al. 2013).

Rainfall simulation on CYP at experimental plots (1.5 m x 1.5 m) under controlled rainfall intensity found that primitive roads (tracks) in yellow earth and sodic soils had the second highest erosion rates behind gullies in sodic soils, but well above erosion rates in pasture, cropping or even banana rows. "*Roads produced 16-28 times more sediment than pasture on the same soil type*" (Rohde 2015).

Erosion Rates Measured with Terrestrial Laser Scanning (2021-2025)

Track Sites

Between 2021-2025 as part of the Eastern Cape York Water Quality Program (GBRF funding to CYWP), five (5) primitive track segments were selected for high-resolution monitoring of erosion rates in the Annan and Starcke catchments. Sites selected were a subset of road sections treated with erosion control BMPs (whoa-boy water diversion banks, rock sheeting, rock armouring). Segment lengths varied from 100 to 500 m and track widths were between 5 and 8 m. Segments were selected near stream crossings where tracks had high connectivity to streams and typically had varying sheet, rill, and gully erosion problems.

Survey Methods

Terrestrial Laser Scanning (TLS) each segment occurred before (Nov) and after (June) each wet season. TLS data were collected using a tripod mounted Riegl VZ-400i or VZ-600i scanner. The point density of each scan position was 27,700 points per m^2. Approximately 20 to 40 scan positions were surveyed at each track segment, with spacing and positioning altered to ensure good coverage and beam angle. Scanned point cloud data were combined in RiSCAN Pro and aligned with repeat scan data and ground control points (n = 6 per segment), which were installed using star pickets driven deep, with 100 mm dia PVC pipe surrounding them, encased in concrete. Aligned point clouds were down-sampled to a 1 mm grid using a polynomial surface fit. Ground points were identified using a Progressive Morphological Filtering Algorithm. An elevation grid digital elevation model (DEM) was generated at 10 mm resolution, using a "Smoothed Inverse Distance Squared Nearest Neighbours" algorithm on the ground points.

For each wet season period, the first DEM (Nov) was subtracted from the second DEM (June) to quantify change and create a DEM of Difference (DoD). The DoD quantifies the volumetric change (positive or negative) between successive topographic surveys by integrating the cell-by-cell change at the 10 mm pixel resolution. A vertical Limit of Detection (LoD) of 1 mm was applied to the DoD data to account for measurement errors and alignment error with ground control points (see Shellberg et al. 2024b). DoD data from TLS were used to calculate either 1) degradation (scour) erosion, or 2) aggradation (deposition) of a given pixel depending the pixel value being less than or greater than zero. These data were aggregated up into scour or fill volumes for individual track segments.

Representative soil samples were collected at each site and used to measure bulk density and particle size distribution. Bulk density data were used to estimate tonnage of erosion (scour degradation) from volumetric data. The % < 20 µm particle fraction (very fine silt and clay) was used to estimate the fine sediment load relevant to the GBR and eroded at the source (Wilkinson et al. 2022).

The DEM of Difference (DoD) data from TLS were used to calculate the volume of degradation (cut or scour) erosion of a given pixel below the LoD (values < 1 mm) and the erosion volume sum for a given track segment. The deposition (aggradation or fill) measured in the DoD represented either deposition of coarser sediment > 20 µm (coarse silt, sand, gravel, cobble), or grass vegetation growth after the wet season. This deposition of coarser sediment > 20 µm in the TLS DoD was not included in the analysis, despite influencing both the track network and the local stream system, just not the GBR.

For suspended sediment < 20 µm, a river sediment delivery ratio (RSDR) of 92-95% was applied using P2R data (McCloskey et al. 2021). The RSDR is the fraction of fine sediment that is delivered to the river mouth after being transported into a fluvial channel from an erosion process. A track sediment delivery ratio (TSDR) was used to factor in some fine sediment deposition (< 20 µm) between the track scour location and the adjacent stream, which was estimated to be 75% for track flow paths < 100 m from the track to highly connected stream (Shellberg et al. 2024b).

Survey Results

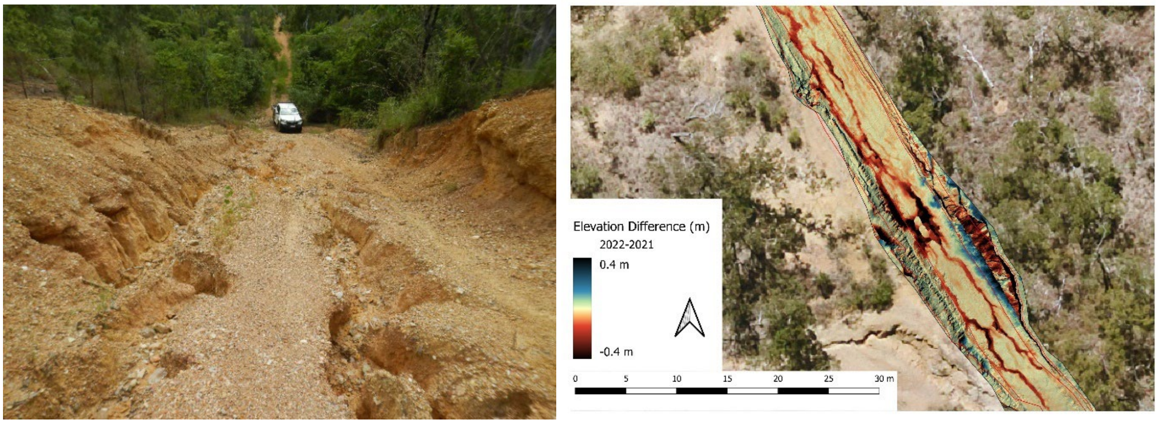
Annual erosion rates measured at 5 track segments with repeat TLS surveys varied between 6.4 and 68.1 kg/m^2/yr or of local erosion (gravel, sand, silt, clay) (Table 1). Local erosion at these approaches to stream crossing depended on road slope, soil type and texture, degree of entrenchment, and any potential grass cover. Larger erosion rates were associated with deep rill and gully erosion and high percentages of fine sediment in dispersible soils. Unit erosion rates of fine sediment delivered to the GBR ranged from 9.9 to 235 t/ha/yr < 20 µm to GBR. The lowest rates were associated with rilling into sandy dispersive soils with low percent fines, compared to high rates in dispersive clay soils with major gully erosion.

Erosion rates within surveyed track sections varied by erosion process. As an example from the Oaky-Flaggy track (Figure 13), sheet erosion on a 3% slope was on the order of 7 kg/m^2/yr all sizes locally or 35 t/ha/yr of fines <20 µm to GBR. Steeper slopes (12-13%) with rilling and shallow gullying had rates of 26-38 kg/m^2/yr all sizes locally or 137 to 198 t/ha/yr of fines <20 µm to GBR. The steepest slopes (18%) with deep gully erosion into dispersive soils blocking road access had rates of 68 kg/m^2/yr all sizes locally or 352 t/ha/yr of fines <20 µm to GBR.

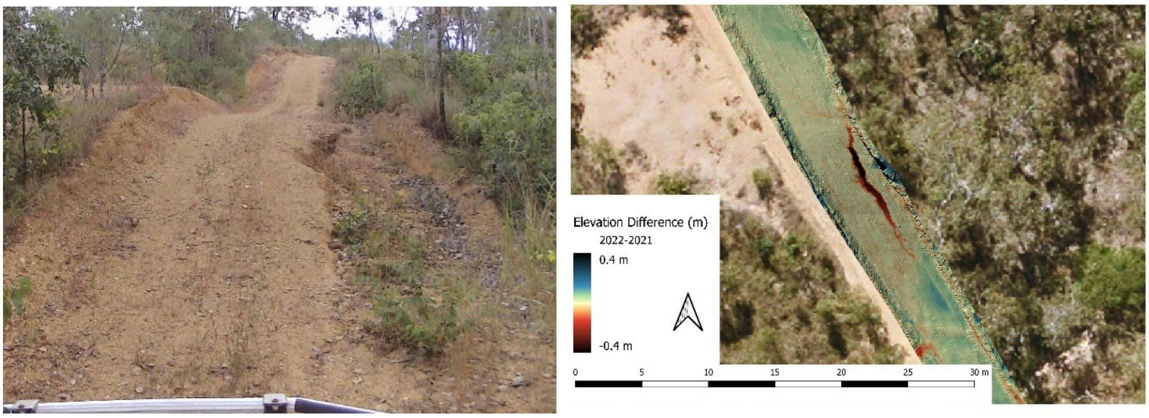
Application of erosion control BMPs such as whoa-boys and rock sheeting on these primitive tracks resulted in a significant reduction in erosion rates over time, at a cost-effective price. For example, the Oaky-Flaggy site experienced a 34% reduction in erosion after BMP application, including with the additional rainfall of extreme Cyclone Jasper (Table 1; Figure 14). Normalised to average rainfall, a 64% reduction would have been expected. The total cost-effectiveness of the work was $2,400 t/y during a wet rainfall year and $1,300 t/y if rates were normalised to an average rainfall year (Table 2). Installing whoa-boys to divert water was slightly more cost-effective ($1,240 t/y normalised) than rock sheeting ($1,336 t/y normalised). However, the whoa-boy section required additional costs and maintenance after TC Jasper and needed to be rock sheeted in patches to maintain long-term access.

At the Trevathan Black Mountain sites with sandy dispersive soils derived from granite, the treatment site during the first year had 23% less erosion compared to the control site (Table 1; Figure 15). Including the second year, the whoa-boy treatment site had 72% less erosion the second year as the project site settled down and re-grassed, while the control site had similar erosion rates between years despite rainfall differences. The cost-effectiveness was $4,192 t/yr using just the 2023-2024 data comparing control and treatment, or $8,140 t/y normalised to rainfall average (Table 2). This higher cost-effectiveness was due to the sandy nature of the soils at this site with 22% fines < 20 µm.

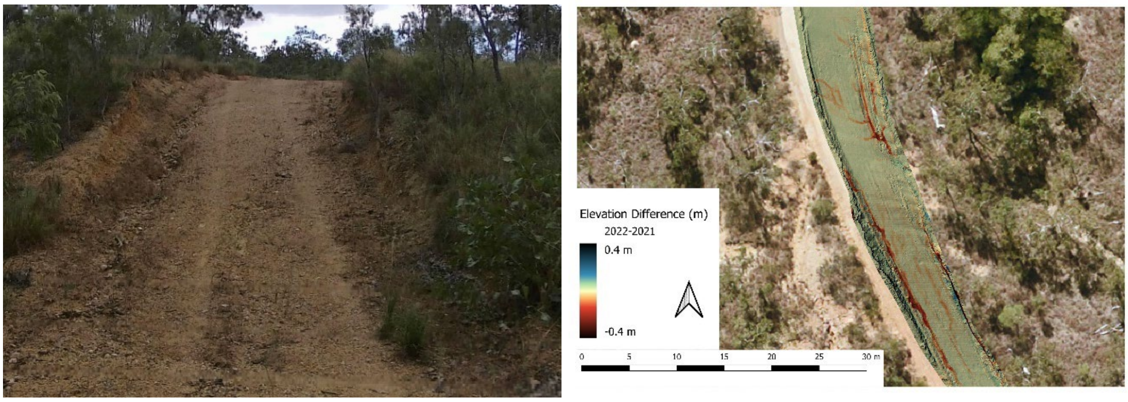
At the Munburra Starcke site, erosion rates reduced 45 to 56% at both sites before-after treatment, but rainfall was higher the first year than the second. Normailised to an average rainfall year, erosion rates decreased from 16 to 32% (Table 1; Figure 16; Figure 17). The rainfall-normalised cost-effectiveness was between $500 to $1500 t/yr to GBR due to the economies of scale treating many sites with local ridge rock (Table 2). Improved coarse rock armouring of gullies within these sites could have saved even more sediment cost-effectively, via extra time for a sieve bucket to process rock at the pits. Follow up maintenance may be needed.



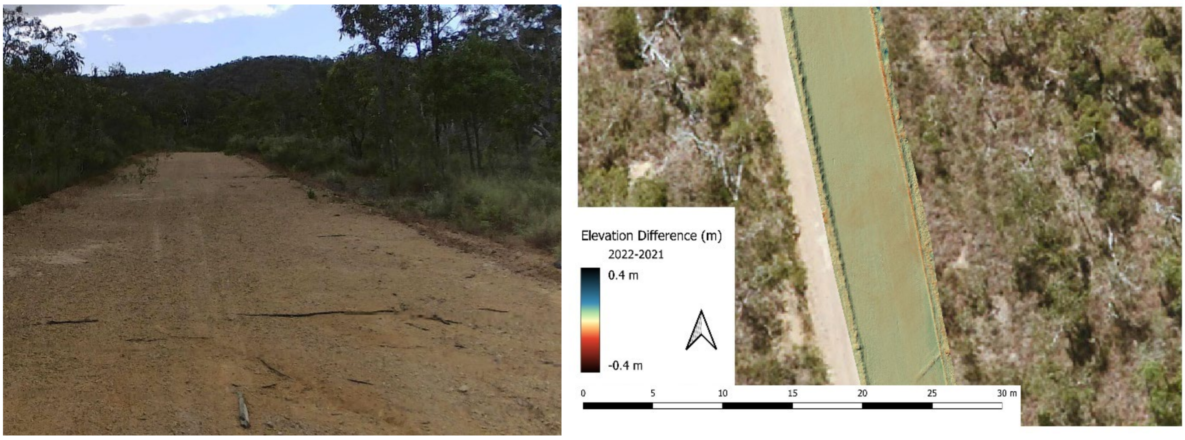
a) 68 kg/m²/yr all sizes locally (18% slope) or 352 t/ha/yr of fines <20 µm to GBR



b) 38 kg/m²/yr all sizes locally (13% slope) or 198 t/ha/yr of fines <20 µm to GBR



c) 26 kg/m²/yr all sizes locally (12% slope) or 137 t/ha/yr of fines <20 µm to GBR



d) 7 kg/m²/yr all sizes locally (3% slope) or 35 t/ha/yr of fines <20 µm to GBR

Figure 13 Variation in road erosion rates over the 2021-2022 wet season measured by terrestrial LiDAR at Oaky-Flaggy 1.

Table 1 Primitive track TLS survey sites and erosion rates (2021-2025)

Water Year (WY) (Oct-Sept)	Track Segment	Treatment / Control Before / After	Annual Rainfall (mm)	Track Segment Length (m)	Survey Area (m^2)	Erosion Volume (m^3)	Bulk Density (t/m^3)	Erosion Local (t/yr)	Erosion Local ($kg/m^2/yr$)	Fines < 20 µm (%)	TSDR Track to Stream (%)	RSDR River to GBR (%)	Load to GBR (t/yr < 20 µm to GBR)	Unit Load to GBR (t/ha/yr < 20 µm to GBR)
WY 22	Oaky-Flaggy 1	Before Treatment	1479	434	2616	36.4	1.76	63.9	24.4	72	75	95	33.0	126.2
WY 24	Oaky-Flaggy 1	After Treatment	2404	434	2616	25.3	1.76	44.5	17.0	72	75	95	21.7	82.9
WY 24	Black Mnt 1	Control	2905	91	337	6.1	1.65	10.0	29.8	22.3	75	93	1.6	46.4
WY 25	Black Mnt 1	Control	1180	91	337	6.5	1.65	10.7	31.9	22.3	75	93	1.7	49.6
WY 24	Black Mnt 2	After Treatment	2905	160	731	10.2	1.65	16.9	23.1	22.3	75	93	2.6	35.9
WY 25	Black Mnt 2	After Treatment	1180	160	731	2.8	1.65	4.7	6.4	22.3	75	93	0.7	9.9
WY 24	Starcke 1	Before Treatment	2196	182	1400	25.4	1.70	43.2	30.9	50	75	92	14.9	106.6
WY 25	Starcke 1	After Treatment	1452	182	1400	13.9	1.70	23.7	16.9	50	75	92	8.2	58.4
WY 24	Starcke 2	Before Treatment	2196	258	1735	69.5	1.70	118.2	68.1	50	75	92	40.8	235.0
WY 25	Starcke 2	After Treatment	1452	258	1735	30.9	1.70	52.5	30.3	50	75	92	18.1	104.4

Table 2 Primitive track treatments, costs, sediment savings, and cost-effectiveness of sediment saved to GBR.

Year-Month of Treatment	Track Segment	Treatment Method	Cost ($)	Sediment Reduction Before-After* or Control-Treatment# to GBR (t/yr < 20 µm to GBR)	Sediment Saved to GBR Before-After* or Control-Treatment# Normalised to Rainfall (t/ yr < 20 µm to GBR)	Cost-Effectiveness ($/t/yr)	Cost-Effectiveness Normalised to Rainfall ($/t/yr)
2023-May	Oaky-Flaggy 1	Whoa-boys, Rock Sheeting, Gully Control	$27,477	11.33*	21.28*	2,424	1,291
2023-Oct	Black Mnt 1	Control	$0	0	0	0	0
2023-Oct	Black Mnt 2	Whoa-boys	$3,215	0.77#	0.39#	4,192	8,140
2024-Sept	Starcke 1	Whoa-boys, Rock Sheeting, Gully Control	$6,432	6.74*	4.42*	955	1,455
2024-Sept	Starcke 2	Whoa-boys, Rock Sheeting, Gully Control	$7,230	22.66*	14.87*	319	486

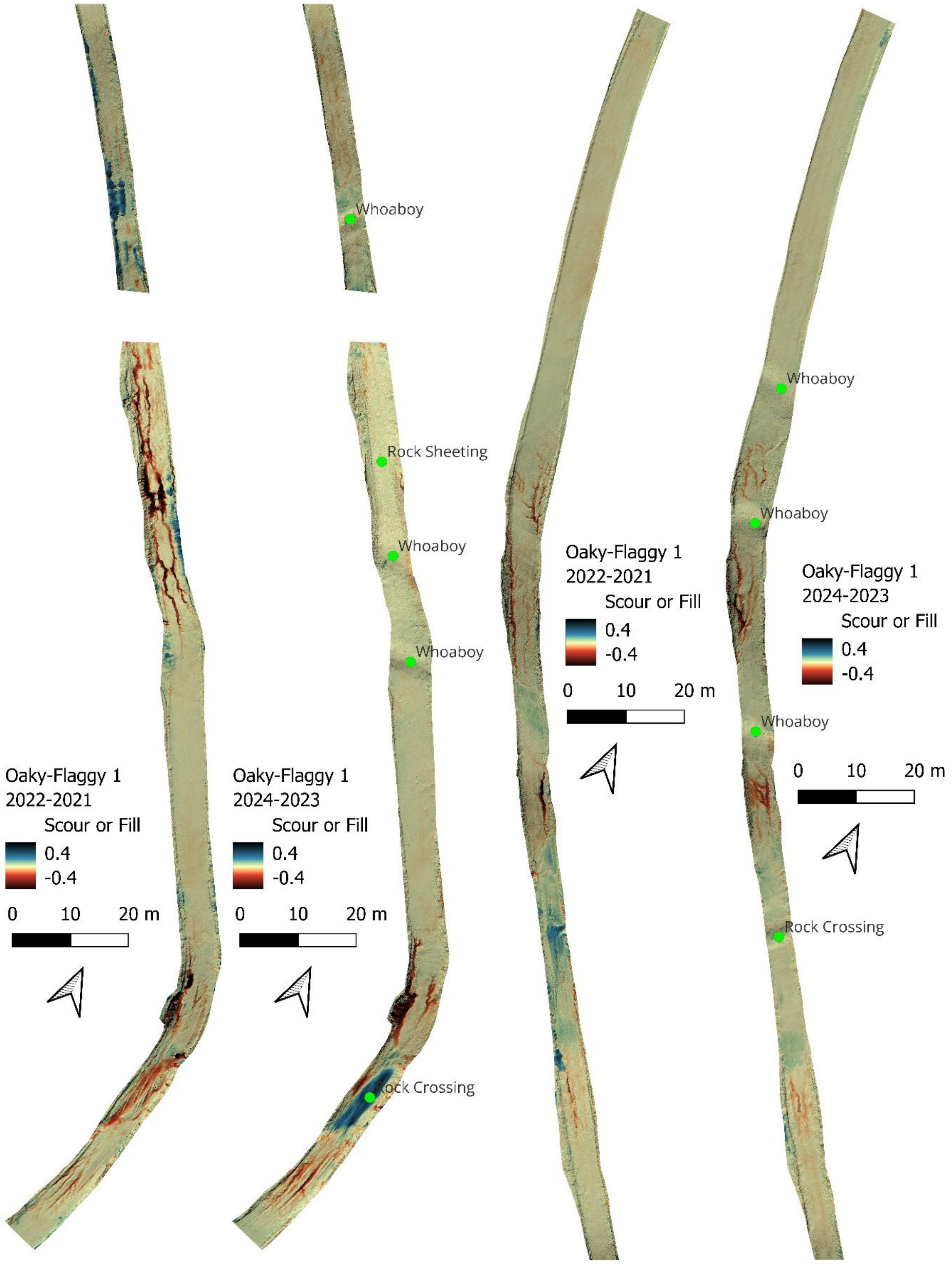


Figure 14 Annual erosion changes at Oaky-Flaggy track over WY 2022 and WY 2024 (split into north and south sections), with treatments occurring in May-2023.

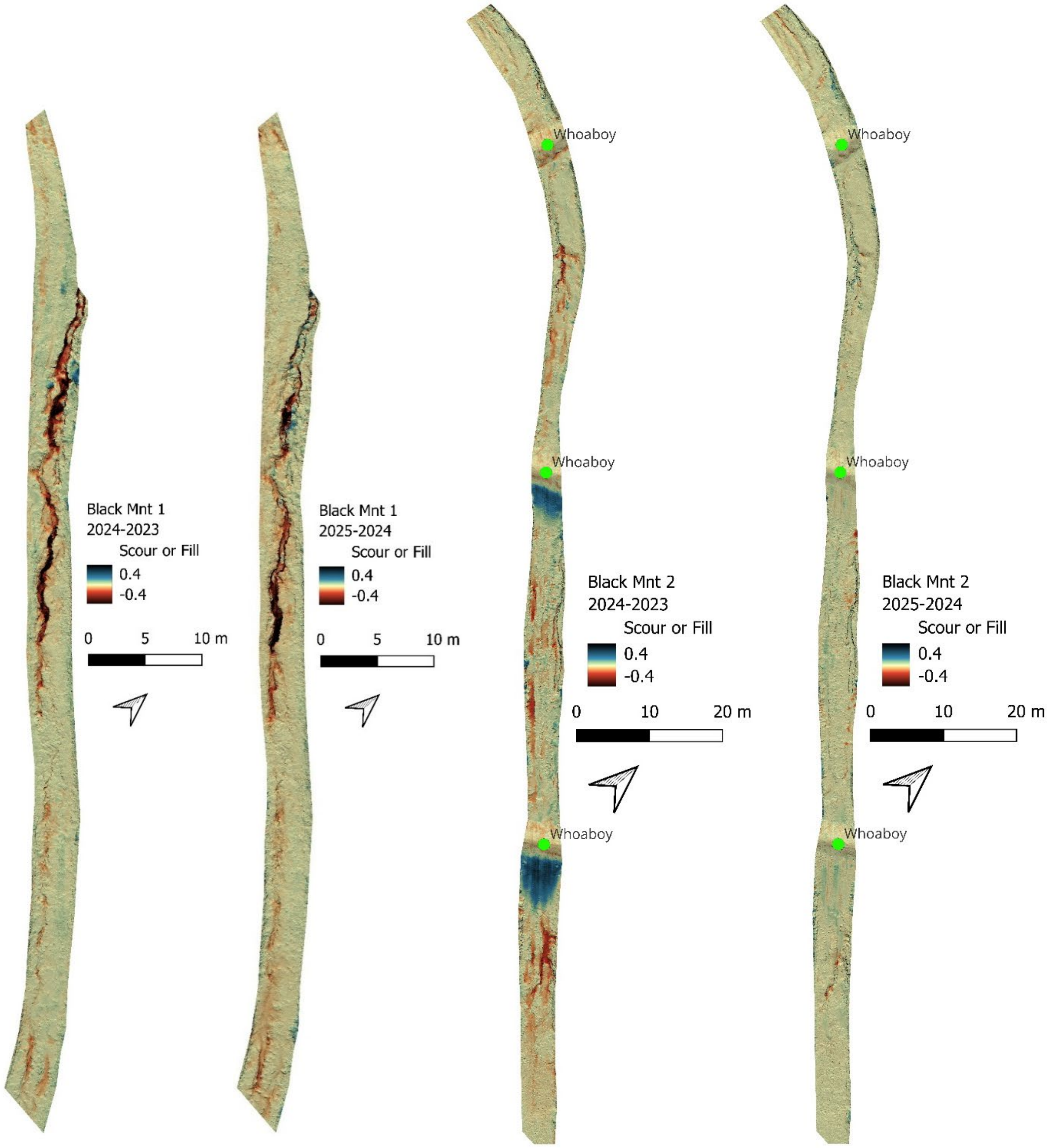


Figure 15 Annual erosion change at Black Mountain track over WY 2024 and WY 2025 (Blk Mnt1 was a control with no treatments, and Blk Mnt2 was treated with whoa-boys both years).

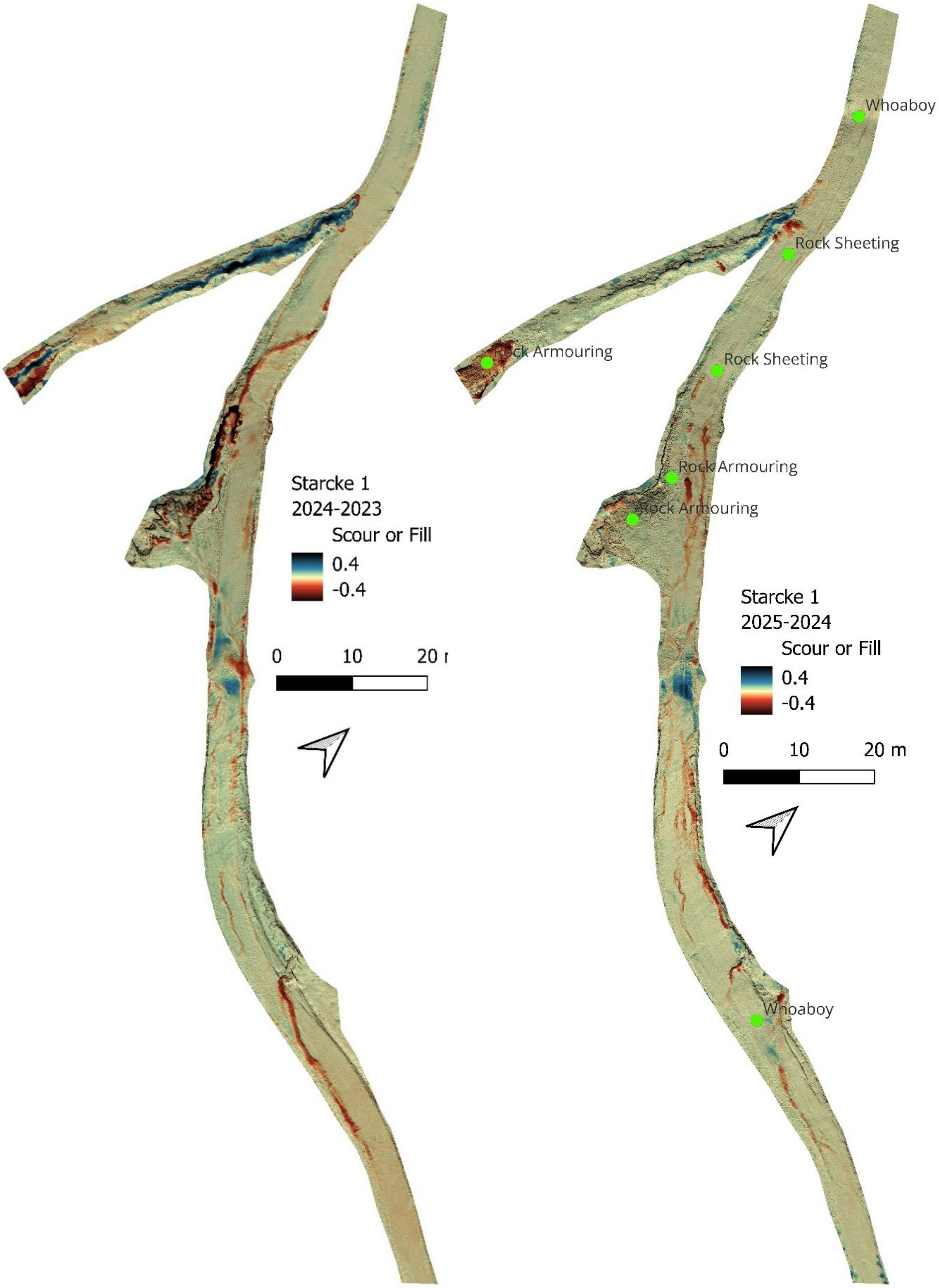


Figure 16 Annual erosion changes at Starcke 1 track over WY 2024 and WY 2025, with treatments occurring in Sept-2024.

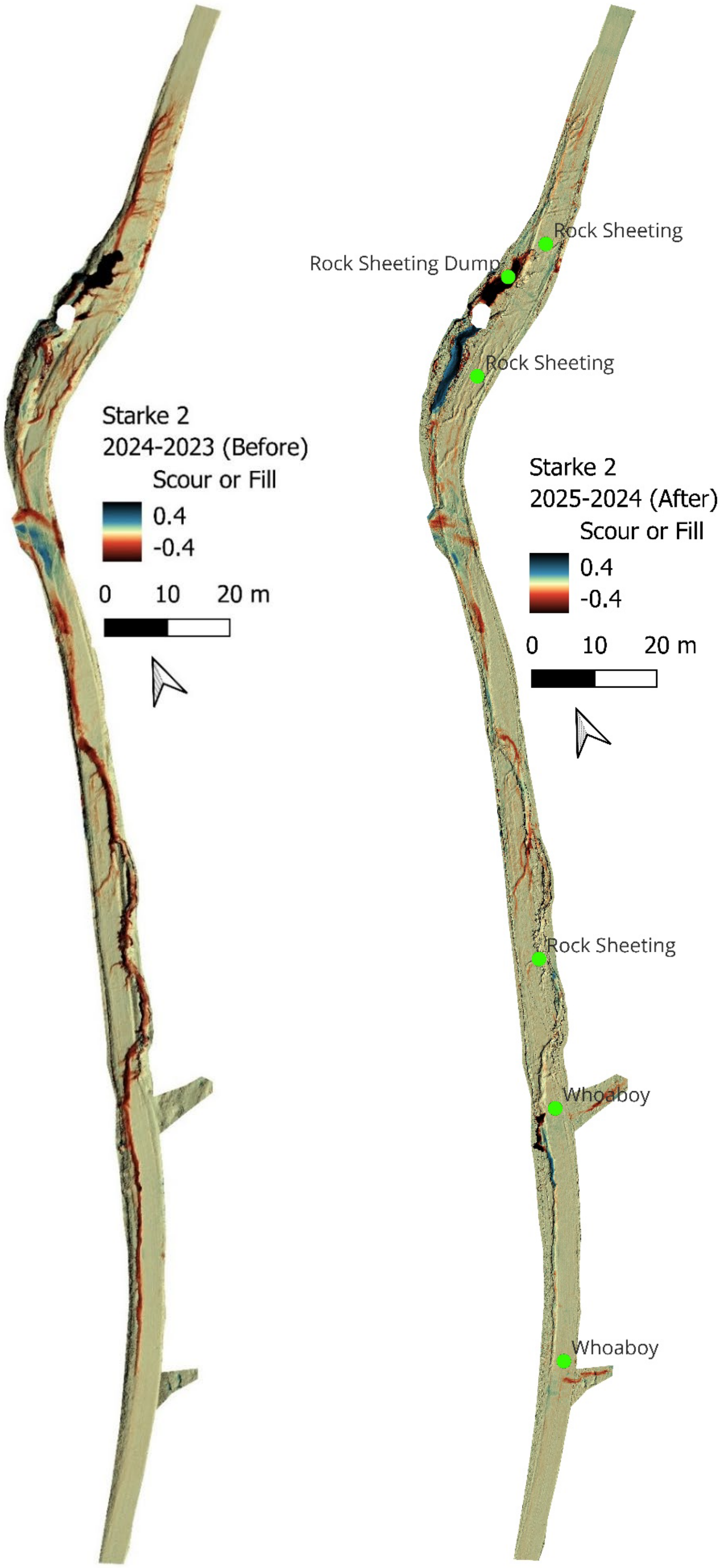


Figure 17 Annual erosion changes at Starcke 2 track over WY 2024 and WY 2025, with treatments occurring in Sept-2024.

Discussion
Local unit erosion rates along these primitive tracks (range 64 and 681, median 271 t/ha/yr) are higher than literature values for unsealed formed gravel roads (range 2.4 to 273, median 22 t/ha/yr; Fu et al. 2010). They are also higher than Council formed gravel road erosion rates in the Annan catchment on Cape York Peninsula, averaging 142 t/ha/yr locally of all size classes (Shellberg et al 2024b). Unit erosion rates of fine sediment delivered to the GBR (range 9.9 to 235, median 71 t/ha/yr < 20 µm to GBR) are similar to gully erosion rates in Northern Australia and GBR catchments (Shellberg et al. 2013; Khan et al. 2023; Daley et al. 2023). These median track erosion rates are > 47 times higher than background sheet and rill erosion rates from moderately grazed catchments in northern Australia (0.2 to 1.5 t/ha/yr; Brooks et al. 2014; Koci et al. 2020). They are also higher than global agricultural land on erodible soils with poor agricultural practices (15 t/ha/yr, Nearing et al. 2017) or sugar cane agricultural lands in GBR catchments (< 7 t/ha/yr, Visser et al. 2007).

For Cape York Peninsula, an overall average cost-effectiveness of $1,624 t/yr < 20 µm to GBR was estimated for Reef Trust investments in sediment reduction circa 2015-2022 (Erlandsen et al. 2024). Wilkinson et al. (2019) estimated that the GBR wide gully program (2015-2018) had a cost-effectiveness of $1,500 t/yr, which is lower than the Cape York Peninsula average, due to less remote work areas. More recently, the target erosion control program cost (projects plus administration) for Reef Trust investment on the Cape York Peninsula for the period 2024-2030 was $3,100 t/yr < 20 µm to GBR (CYRNM). µm

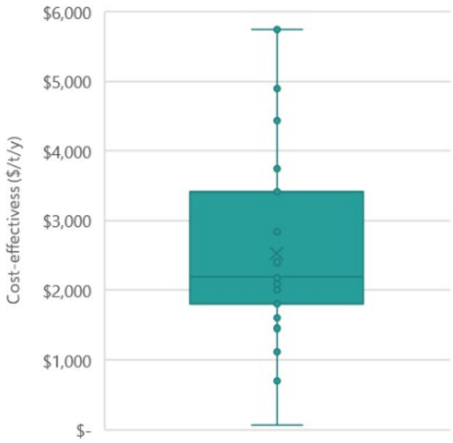


Figure 18 Cost-effectiveness of Reef Trust gully investments in Cape York to reduce fine sediment (< 20 µm) to the GBR (circa 2015-2022, inflated to 2024 dollars, Erlandsen et al. 2024).

The cost-effectiveness of erosion control at primitive track sites in this project ranged from $486 to $8,140 t/yr normalised to average rainfall, averaging $2,843 t/yr (Table 2). This average is higher than past gully erosion estimates (Wilkinson et al. 2019; Erlandsen et al. 2024), but lower than the current target of $3,100 t/yr < 20 µm to GBR. Therefore, these investments in track erosion control are regionally viable for effective erosion reduction. If primitive track erosion sites are targeted at the road approaches to stream crossings - with dispersive clay soil, high connectivity to streams, and rill and gully erosion - then the cost-effectiveness will be even lower around $1,077 t/yr < 20 µm to GBR (Oaky and Starcke sites). Track locations with sandy soils (low percent fines) and low stream connectivity will have less viable cost-effectiveness, unless economies of scale can be improved.

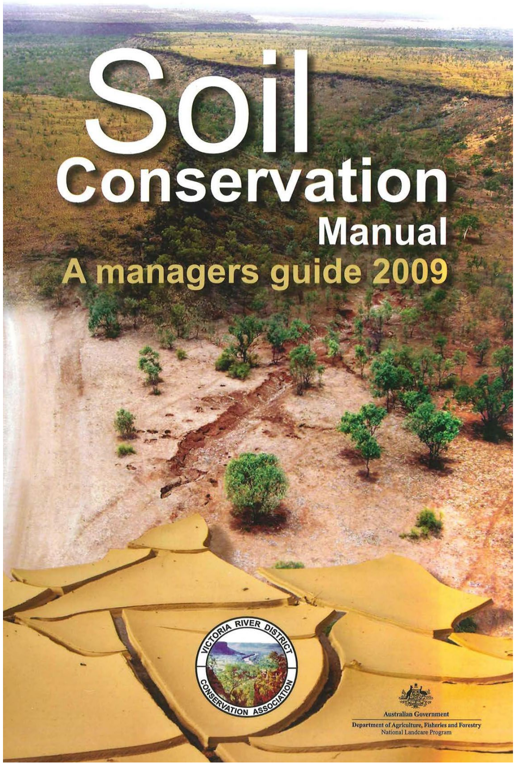
The prioritisation model for primitive track erosion across Southeastern Cape York Peninsula identified 61 sites as Very High Priority and 564 sites as High Priority (out of 232,892 points) (Figure 12). All of these sites had major rill and gully erosion near streams and are likely cost-effective project sites for future investments.

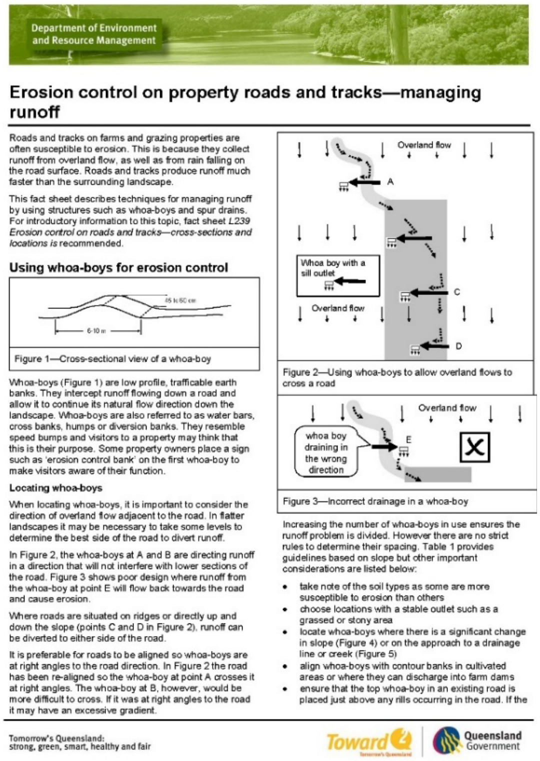
Literature on Unformed Road Erosion Control Best Management Practices

Road Best Management Practice (BMP) guidelines for erosion control mostly focus on large main gravel roads or paved road construction sites (Witheridge 2009; 2012; Kemp 2012, NSW OEH 2012; QPWS 2014, QTMR 2019; Grobler et al. 2020; QTMR 2021; Klye et al. 2024; 2025). While these references have valuable information that can be drawn upon for potential application, they also could be misapplied to primitive roads or highly erosive soils like dispersive sodic sub-soils common on CYP. For example, cutting drains in dispersive soils can promote gully erosion, as can 'forming' roads out of sodic sub-soils that are inherently unstable (QTMR 2021).

A variety of erosion control BMP guidelines have been developed for primitive roads and tracks in rural Australia on native soils (e.g., Bartlett 1991; Herbert and Evans 1992; Hadden 1993; Jolley 2009; NTAA 2010). Additional road fact sheets have been developed for Queensland rural settings in peri-urban, agriculture, and grazing situations (QDERM 2010b; 2010c). International literature can also be drawn upon (e.g., Johansen et al. 1997; Copstead et al. 1998).

Information is less available on how to best install, manage and maintain simple dirt roads and tracks in highly dispersive or sodic sub-soils in northern Australia (e.g., old alluvium or colluvium associated with fans, creeks and rivers). Some recent pilot studies on erosion control on dispersive soils in the Normanby catchment can help guide future work (Shellberg and Brooks 2013; Shellberg and Hughes 2019). These results can then be combined with standard primitive road BMPs applicable across northern Australia (Hadden 1993; Jolley 2009; QDERM 2010b; 2010c). Synthesis BMPs are outlined below from these references and case studies in this report.




Department of Environment and Resource Management

Erosion control on property roads and tracks—managing runoff

Roads and tracks on farms and grazing properties are often susceptible to erosion. This is because they collect runoff from overland flow, as well as from rain falling on the road surface. Roads and tracks produce runoff much faster than the surrounding landscape.

This fact sheet describes techniques for managing runoff by using structures such as whoa-boys and spur drains. For introductory information to this topic, fact sheet *L239 Erosion control on roads and tracks—cross-sections and locations is* recommended.

Using whoa-boys for erosion control

Figure 1—Cross-sectional view of a whoa-boy

Whoa-boys (Figure 1) are low profile, trafficable earth banks. They intercept runoff flowing down a road and allow it to continue its natural flow direction down the landscape. Whoa-boys are also referred to as water bars, cross banks, humps or diversion banks. They resemble speed bumps and visitors to a property may think that this is their purpose. Some property owners place a sign such as 'erosion control bank' on the first whoa-boy to make visitors aware of their function.

Locating whoa-boys

When locating whoa-boys, it is important to consider the direction of overland flow adjacent to the road. In flatter landscapes it may be necessary to take some levels to determine the best side of the road to divert runoff.

In Figure 2, the whoa-boys at A and B are directing runoff in a direction that will not interfere with lower sections of the road. Figure 3 shows poor design where runoff from the whoa-boy at point E will flow back towards the road and cause erosion.

Where roads are situated on ridges or directly up and down the slope (points C and D in Figure 2), runoff can be diverted to either side of the road.

It is preferable for roads to be aligned so whoa-boys are at right angles to the road direction. In Figure 2 the road has been re-aligned so the whoa-boy at point A crosses it at right angles. The whoa-boy at B, however, would be more difficult to cross. If it was at right angles to the road it may have an excessive gradient.

Figure 2—Using whoa-boys to allow overland flows to cross a road

Figure 3—Incorrect drainage in a whoa-boy

Increasing the number of whoa-boys in use ensures the runoff problem is divided. However there are no strict rules to determine their spacing. Table 1 provides guidelines based on slope but other important considerations are listed below:

- take note of the soil types as some are more susceptible to erosion than others
- choose locations with a stable outlet such as a grassed or stony area
- locate whoa-boys where there is a significant change in slope (Figure 4) or on the approach to a drainage line or creek (Figure 5)
- align whoa-boys with contour banks in cultivated areas or where they can discharge into farm dams
- ensure that the top whoa-boy in an existing road is placed just above any rills occurring in the road. If the

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Case Studies of Erosion Control Trials on Primitive Tracks in Eastern CYP

Case Study: Oaky-Flaggy Road Firebreak, Before-After TLS Erosion Rates

The Oaky-Flaggy firebreak road (6 km) was bulldozed 15+ m wide by Cook Shire Council circa 2012. It has been repeatedly graded each year without erosion control measures, resulting in significant entrenchment. A 2 km gullied section often blocked property access for weed and fire management. An erosion control project in May 2023 was developed to install BMPs to change annual grading cycles that caused access issues and erosion fine sediment to the GBR.

Treatments included 15 water diversion banks (whoa-boys), 6 rock crossings of creeks, and a large gully where the road cut through a stream terrace. A small rock quarry (25m x 25m x 4m deep) was established on a local stable ridge to produce 800 tonnes of rock (cost $7.60/tonne). Culture heritage surveys ensured heritage and aesthetics were protected. The total 2 km project cost $70,000, including a 500 m long monitoring section costing $27,500 for erosion control.

A 500 m road section was surveyed in 2021-2022 with Terrestrial Laser Scanning as a baseline before treatment. Differential surveys measured 33 t/yr of fine sediment < 20 µm to the GBR from a 2615 m^2 area (12 $kg/m^2/yr$ or 126 t/ha/yr < 20 µm) during a below average rainfall year (1476 mm). After erosion treatment with BMPs, differential surveys in 2023-2024 measured 21.6 t/yr of fine sediment < 20 µm to the GBR (8.3 $kg/m^2/yr$ or 83 t/ha/yr < 20 µm) during a wet rainfall year (2400 mm including Cyclone Jasper). This was a 34% reduction in erosion even with TC Jasper.

The total cost-effectiveness of the work was $2,400 t/y during a wet rainfall year and $1,300 t/y if rates are normalised to an average rainfall year (1600 mm). Installing whoa-boys to divert water was slightly more cost-effective ($1,240 t/y normalised) than rock sheeting ($1,336 t/y normalised). However, the whoa-boy section required additional costs and maintenance after TC Jasper and needed to be rock sheeted in patches to maintain long-term access. Rock sheeting steep track sections next to creeks can be essential for long-term access and erosion control.




Case Study: Ergon Black Mountain Powerline Track

CYWP together with Ergon Energy completed a cost-share erosion control project in 2023 along a 10 km powerline track between Black Mountain Kalkajaka and Trevethan Falls. The goal was to reduce sediment runoff to local creeks and the GBR, and provide long term resilience for track access and powerline maintenance. Working closely with Traditional Owners for cultural heritage clearance, Ergon's local civil contractors completed works on 33 sites over a four-week period. 2000 tonnes of ridge soil and rock were used to construct erosion control measures including:

- 46 Whoa-boys (to divert track water runoff)
- 18 Check dams (for reducing water runoff velocity in gullies)
- 1000 m^2 of Rock Sheeting at 17 sites (to prevent track erosion)
- 300 m^2 of Rock Armouring at 29 sites (to reduce creek/gully erosion).

Cyclone Jasper in December 2023 was a significant test of the treatment works, with 1200 mm of local rainfall in five days. Out of the 46 whoa-boys, only one failed, while five had major erosion and 40 were functionally stable with minor to modest erosion. The creek crossings had more erosion due to the flood impacts, with 19 of the 29 crossings with significant erosion of placed rock. In contrast only a few check dams installed in gullies experienced significant scour. As with many erosion control structures after extreme rainfall, some maintenance will be required for long-term resilience.

Monitoring using Terrestrial Lase Scanning (TLS) was conducted at a control and treatment segment between 2023-2024 (2900 mm) and in 2024-2025 (1200 mm). The control site had similar erosion rates between years (46 to 50 t/ha/y <20 µm GBR) despite rainfall differences. The whoa-boy treatment site had 72% less erosion the second year (36 to 10 t/ha/y <20 µm GBR) as the project site settled down and regrassed. For just the 2023-2024 period including TC Jasper, the treatment site had 23% less erosion (36 t/ha/y <20 µm GBR) compared to the control site (46 t/ha/y <20 µm GBR). Site treatment cost $3,215 to install 4 whoa-boys. The cost-effectiveness was $4,192 t/yr using just the 2023-2024 data comparing control and treatment, or $8,140 t/y normalised to rainfall average. This higher cost-effectiveness was due to the sandy nature of the soils at this site with 22% fines < 20 µm.

Before-After Cyclone

2023-2024 Changes

Case Study: Junjuwarra Munburra Track

In 2024, Cape York Water Partnership (CYWP) and Juunjuwarra Aboriginal Corporation (JAC) engaged a local civil contractor to complete erosion control measures along the Munburra Track, an unmanaged road reserve (Cook Shire). The track was known for its access problems, periodic deep grading with no BMPs, and deep rill and gully erosion. It is primarily used as access to Country for fire, cattle and weed management, as well as access to a mining lease(s).

Planning included mapping erosion hotspots, measuring baseline erosion rates with terrestrial laser scanning, conducting cultural heritage surveys, and applying for permits and permission from Qld State and Cook Shire. Locally sourced gravel came from 3 small ridge gravel pits. A crew camp worked over 10 days using an excavator, small bulldozer, and moxi (articulated dump truck).

Over 5 km of the 9 km track were worked on using basic Best Management Practices (BMPs):

- 51 Water Diversion Banks (Whoa-boys) using 1475 tonnes of rock/gravel.
- 3.2 km of Rock Sheeting of dispersible soils and batters using 2950 tonnes of rock.
- 5 Rock Chutes to reduce erosion down deep gullies, using 450 tonnes of rock.

The $80,000 project was monitored using Terrestrial Laser Scanning (TLS) before and after treatment at two monitoring sites with rill and gully erosion at stream approaches. Erosion rates reduced 45 to 56% at both sites before-after treatment (107 to 58 and 235 to 104 t/ha/y < 20 um to GBR), but rainfall was higher the first year (2196 mm) than the second (1452 mm). Normailised to an average rainfall year, erosion rates decreased from 16 to 32%. The treatment costs for each site varied from $6,400 to $7,200 for whoa-boys, rock sheeting, and rock capping gully hotspots. The rainfall-normalised cost-effectiveness was between $500 to $1500 t/yr to GBR.

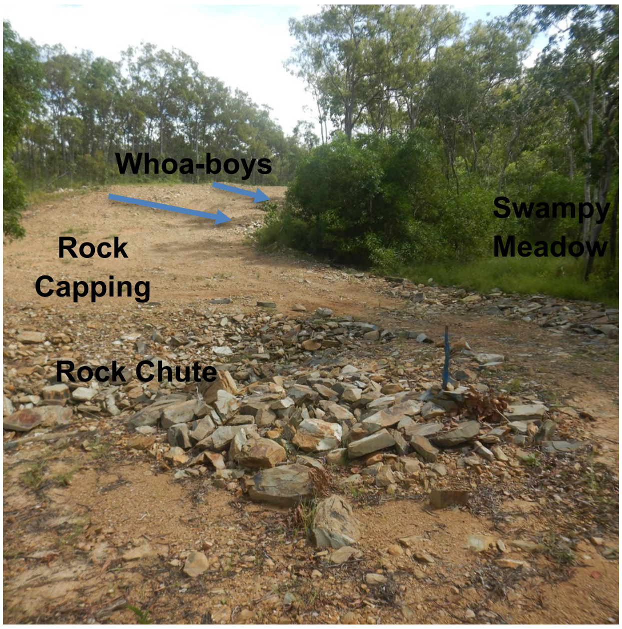
These sites had the benefit of 'economies of scale' where 5000 tonnes of borrow pit material treated 5 km of track. However the extremely rough track and difficultly in hauling water trucks over rough terrain resulted in track 'blowouts' into bull dust where the haul truck traversed patches of silty soil. These patches were capped with additional rock sheeting, increasing costs. In the long-term those vulnerable patches would degrade from erosion and bogging; thus rock sheeting vulnerable sections provided important long-term resilience for access.

Case Study: Jabalbina-Ergon Powerline and Firebreak

In June 2023, the Jabalbina Yalanji Aboriginal Corporation (JYAC) as principal contractor, additional sub-contractors, and Cape York Water Partnership completed erosion control works along an Ergon Powerline track that also provides key access to JYAC country. The aim was to reduce the fine sediment load entering the Annan River, while also improving track resilience and reducing the annual need to grade and patch the track for access and as a firebreak between JYAC property and Beesbike Station.

Over 25 whoa-boy water diversion banks, 500 m of rock sheeting of stream crossings, and one large rock chute at a gully were completed for a total of $80,000 inclusive of planning and guidance. The rock chute was designed with underlying geofabric, cut-off wall, and energy dissipation. Following cultural heritage guidance and clearance, 2000 tonnes of rock was extracted from a local ridge quarry (30 m x 30m x 5m deep) at a cost of $6.84/t. Erosion rates were measured from repeat aerial LiDAR (Ergon data) before the project commenced. Cost-effectiveness was estimated at $2800/t < 20 um fines saved from the GBR.

The works have held up well after Cyclone Jasper and > 2700 mm of annual rainfall at the nearby Beesbike gauge. Track management has now shifted from struggling with access and erosion control, to herbicide boom spraying track edges as a firebreak (to early burn later for bare earth) and invasive weed control. This will minimise annual machine disturbance of the soil and track.



Case Study: Wuthathi Acccess to Country via Skid Steer Mulcher

The Wuthathi Aboriginal Corporation (WAC) and Traditional Owners have prioritised sustainable track access and management as an important part of reconnecting to country for management. Most old tracks in this sandy country were installed by previous cattle station managers, settlers, or mining companies. They were in a primitive natural state, overgrown with vegetation, and with erosion gullies in places where vehicles have cut or damaged the track or sandy soil. WAC approached the CYWP and the QPWS Heavy Plant Unit to advise on using machines to open old tracks, control past erosion damage, and maintain access into the future.

Through on-ground and helicopter surveys in July 2022, Wuthathu Rangers, TOs and invited partners agreed to use a Skid Steer Mulcher for clearing saplings and small trees from tracks to access country. The sandy loose nature of the soils highlighted the importance of root vegetation in holding those soils together. Using a bulldozer, grader or loader to push and dig trees out of the ground would have worsened the erosion and access situation, and not heeded the lessons learned from the gully damages caused to country the last time large machines cleared tracks for mining.

In September 2022, a Skid Steer Mulcher was used along almost 40 km of track from the Ranger Base to the middle Harmer River. Before-after pictures show drivability improvements by November 2023. The maintenance effort has now shifted to ongoing tractor slashing and spot herbicide spraying vegetation regrowth. Additional mulching is planned, along with regulating traffic volumes and speed to minimise the disturbance of sandy soils from vehicle tyres and turning. Gully control efforts have also begun at erosion hotspots preventing sustainable access.




PART 2

Erosion Control Best Management Practices (BMPs) for Tracks, Firebreaks and Fencelines

Purpose of Guide

There are a variety of erosion control Best Management Practice (BMP) guidelines for unformed primitive roads, tracks, fencelines and firebreaks in rural Australia. Less information is available on how to best manage unformed tracks in erosion prone soils and complex terrain of Cape York Peninsula (CYP) to significantly improve downstream water quality in the Great Barrier Reef (GBR). This BMP guide is based on a 4-year program of track erosion control in southeast CYP. It provides guidance for land managers to understand and address erosion along primitive tracks to: 1) reduce sediment delivery to waterways and the GBR, 2) provide long-term track resilience, 3) minimise infrastructure damage, 4) improve trafficability and access for land management (e.g. weeds, fire, grazing, conservation, culture), and 5) lessen the whole-of-life road costs.

Track Erosion across Eastern Cape York Peninsula

Across CYP, there are tens of thousands of hectares of roads, tracks, and fencelines accounting for more cleared area than many other intensive land-uses (i.e., agriculture). High levels of rainfall, dispersive soil types, fire frequency, reduced accessibility, material costs and travel distances all mean that primitive roads across CYP are very prone to erosion. Excess sediment runoff impacts the health of creeks, rivers, estuaries, seagrass meadows and inshore reefs.

Roads and tracks through dispersive soils have erosion rates that are second only to large gullies in the region, and produce > 20 times more sediment (dirt) than grazing land on the same soil type. Erosion rates along tracks near stream crossing (5 sites, 1100 m length total) were measured with high resolution terrestrial laser scanning (this report). Rates varied from 6 to 75 $kg/m^2/yr$ or 68 to 730 t/ha/yr locally, or 11 to 311 t/ha/yr < 20 µm to GBR. Rates also varied by erosion process and slope, with typical values as follows:

- Sheet Erosion: 7 $kg/m^2/yr$ all sizes (3% slope) or 35 t/ha/yr fines <20 µm to GBR.
- Rill Erosion: 26 $kg/m^2/yr$ all sizes (12% slope) or 137 t/ha/yr fines <20 µm to GBR.
- Gully Erosion: 68 $kg/m^2/yr$ all sizes (18% slope) or 352 t/ha/yr fines <20 µm to GBR.

Primitive roads often begin as simple tracks created by 4x4 vehicles over grass. Others are bulldozed or graded in once, and then kept clear of vegetation by traffic or grading. Repeated annual grading of tracks, firebreaks, and fencelines on CYP is common practice. Rills and gullies from the wet season are smoothed out "just to get through" each year, pushing soil directly into creek crossings. Small whoa-boys using native soils are utilised where cheap and possible. They often fail or are graded away by machine operators. Alternatively, some operators attempt to form road prisms and drains out of native soils, which leads to enhanced rill and gully erosion in dispersive sub-soils without major imported rock sheeting. Funding, time, proper machinery and materials are often lacking to address and fix local problem areas properly. All of this leads to repeated cycles of grading, erosion, and land degradation. Entrenched roads, gully erosion at crossings, and abandoned tracks are the results, which are costly to repair and leave an erosion legacy impacting local creeks and the GBR.

The 11 Key BMP's for Erosion Control on Primitive Roads

All primitive roads degrade over time. However, tracks can be more resilient if they are put in stable locations, not degraded by over-use or inappropriate management, left with good grass cover and not repeatedly graded, strategically maintained only where problems arise, and improved with erosion control BMP interventions to maintain access and resilience. This guide reviews the top 11 BMP considerations for effectively controlling erosion on unformed roads, tracks, firebreaks, and fencelines in CYP.

1. Locate Tracks on Stable Soils, Geology, and Slopes: Plan for Resilience
2. Minimise the Number of Road Crossings through Gullies and Creeks
3. Minimise Annual Grading Disturbance
4. Manage Vegetation to Maintain Grass Cover and Root Cohesion
5. Manage Firebreaks to Reduce Soil Disturbance
6. Maintain Natural Drainage Flow Paths and Minimise Excess Water Runoff
7. Source Appropriate Rock & Soil Materials Before Beginning the Project
8. Rock Sheet Steep Road Sections & Rock Amour Creek and Gully Crossings
9. Avoid Annual Re-routing of Roads Around Erosion Problems
10. Control Gully Erosion Caused by Primitive Roads
11. Develop Annual Track, Firebreak, and Fenceline Maintenance Plans

Figure 19 Examples of primitive track erosion issues across eastern CYP.

Locate Tracks on Stable Soils, Geology, and Slopes: Plan for Resilience

Prevention is the key to erosion control and cost savings along primitive roads, tracks, fencelines, and firebreaks. Proper placement of infrastructure is critical to provide the least amount of effort and cost to maintain resilience. Arbitrary property boundary lines have especially forced inappropriate location decisions that are not sustainable. Persistent and severe erosion issues often occur due to frequent creek crossings, steep slopes, road cuts, or disturbance of highly dispersive or sodic sub-soils. These hotspots of erosion have high connectivity to local creeks and the GBR.

Location BMP's:

- Locate roads and fencelines on stable soils and geology.
- Follow subtle ridge and spur crests between drainage catchments.
- Avoid creating roads through or along hollows, gullies, creeks, rivers and frontage country with dispersive soils.
- Adjust line accordingly to avoid erosion hazards, especially gully prone areas, steep slopes, and sodic or dispersive soils.
- Keep back from hollow or terrace edges where gullies can form.
- Scout and map the best routes far ahead of time. Use available technology such as GPS, topographic maps, Google Earth satellite images, and LiDAR topography.
- Local non-profit organisations are available to help with new mapping tools.
- Include erosion control BMPs as part of primitive road construction.
- Map out where erosion control BMPs will be installed.

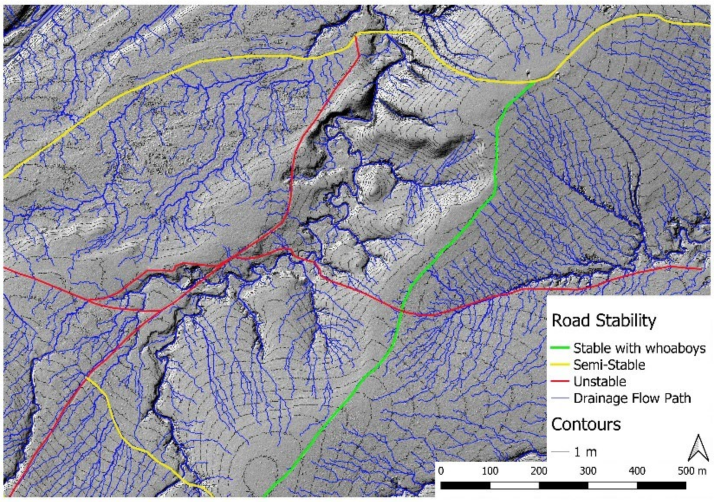


Figure 20 Location examples of track or fenceline stability (stable, semi-stable, unstable) (above).

Figure 21 Primitive road locations on A) a stable ridge track with good grass cover and low maintenance (right above) and B) an unstable alluvial slope with chronic erosion along a fenceline track (right below).

Minimise the Number of Road Crossings through Gullies and Creeks

Erosion of primitive tracks and fencelines is especially problematic near stream crossings with erodible dispersive soils associated with small floodplains, terraces and weathered regolith. Machine grading and cutting of tracks at the approaches of crossings leads to road entrenchment that concentrates water runoff and promotes rill and gully erosion. Road gullies present at many crossings often create historic legacies that are difficult and costly to remediate. The fewer stream crossings present on a track, the less work required to maintain track or fenceline integrity in the future. The connection between tracks, streams and the GBR is avoided.

Stream Crossing BMP's:

- Minimise the number of road crossings through hollows, gullies, and creeks.
- Choose a key stable crossing, rather than creating multiple crossings.
- If a crossing is required, scout and locate the most stable locations with lowest slopes, rocky bars, and least need for road cuts at approaches.
- Apply erosion control BMPs to key stream crossings (see below).
    - Avoid road cut entrenchment and frequent grading of approaches.
    - Install whoa-boys to divert water runoff early along flow paths to prevent concentrated flow at steeper approaches.
        - Avoid diverting water into gullies, toward creek/river banks, or into hollows susceptible to gullying
    - Rock sheet the approaches to creek crossings and dispersive soil areas.
    - Rock amour creek and gully bed crossings where unstable or blown out.
- Planned and constructed creek crossings will maintain long-term track accessibility.

Figure 22 Typical eroded stream crossings and approaches along primitive tracks.

Minimise Annual Grading Disturbance

Track degradation from rill and gully formation is often caused by graded tracks that collect and concentrate water flow. Over-grading and annual grading will result in entrenched tracks with poor drainage, especially in silty or dispersive soils. Even under the best of intentions of lightly grading the grass off a track, entrenchment will result from repetitive annual light grading. Attempts at road formation (prism and drains) in silty or dispersive soils on primitive tracks often makes the situation worse. Silty topsoils are not stable or cohesive, and exposure of dispersive sub-soils promotes rill and gully erosion. Cutting drains into dispersive soils causes gully erosion on and off the track. Tracks should be kept vegetated and well drained naturally, or with whoa-boy diversion banks and imported rock sheeting in low places.

Maintenance BMP's:

- Minimise annual maintenance disturbance such as grading and cutting soils.
- Address the actual cause of erosion (sheet, rill, gully, creek etc) - grading disturbance, entrenched road, hillslope water capture, unmanaged water runoff.
- Refrain from trying to form road prisms or cut drains in unstable silty or dispersive soils. These formations will accelerate erosion unless capped with imported gravel/rock.
- Maximise perennial grass cover along roads and tracks to bind soil together.
  - Slash or mow to maintain grass root cohesion and soil stability.
- Instead of scraping it bare, use herbicide to manage invasive weeds such as grader grass or broad leaf weeds along tracks and fencelines.
- Strategically fix problem areas, such as installing extra whoa-boys, building up the road up with rock sheeting, or rock protection on steep slopes or dispersive sub-soils. These areas will require minimal maintenance in the future.
- Use a 4-in-1 bucket (backhoe, loader) rather than a grader to strategically maintain primitive roads on dispersive soils or in rolling, hilly or woody country.
- Avoid regrading or filling in creek crossing and gullies each year just to gain immediate access, these will wash out into local streams and reef systems.

Figure 23 Grading the road down each year creates entrenchment and erosion.

Manage Vegetation to Maintain Grass Cover and Root Cohesion

Grass vegetation cover protects and binds the soil and reduces erosion. Instead of grading the soil bare, encourage groundcover by slashing grass and sapling regrowth along tracks, fencelines and firebreaks. Mulchers on skid steer loaders can be used for clearing saplings, brush, and trees along tracks. Selective herbicides can be used to manage grass or woody weeds along tracks and fencelines, and be integrated into weed or fire management programs. Implementing other erosion control BMPs (rock sheeting and armoring crossings, gully hotspots, and boggy areas) can further provide sustainable access for vegetation management.

Vegetation Cover BMP’s:

- Maximise grass cover and root strength for erosion control along tracks.
- Slash or mow grass and sapling regrowth rather than grading to bare soil.
- Mulchers on skid steer loaders can be used to clear brush and trees.
- Fence tree-to-tree over steep stream banks without clearing trees.
- Use selective herbicides to manage weeds along tracks and fencelines.

Figure 24 Slash or mow tracks, fencelines and firebreaks (for later burning if needed).

Figure 25 Use skid steer mulchers for clearing saplings and small trees from fences and firebreaks.

Figure 26 Fencing tree-to-tree over steep banks to reduce erosion and soil disturbance.

Manage Firebreaks to Reduce Soil Disturbance

Firebreak management can be adjusted to minimise the need for grading soil bare. A paradigm shift is needed to correct the assumption that wide bare firebreaks are needed to stop large wildfires, which can easily jump wide breaks during windy dry conditions. Rushing out to grade breaks or fill in crossings just before wildfires or planned burns has resulted in major land degradation on CYP. Firebreak tracks are best used for prescribed fires in the early-dry season, and for access to perform back burning to control late-dry season wildfires. Stable, resilient, erosion-free breaks can maintain this access for management

Figure 27 Two-wheel track firebreak with prescribed burning with water and blower support.

- Two-Wheeled Track Firebreaks
  - Two-wheel tracks of bare ground are enough to be used with prescribed fire in the early-dry season to create larger firebreaks.
  - Wet-lines from mobile tanks or leaf-blowers are needed to control creep of fire.
  - The timing of early-dry season prescribed burns is critical to ensure fire control.
- Slashed or Mowed Firebreaks
  - Slashed firebreaks can cure vegetation faster and allow the residual material to be burned earlier than surrounding greener vegetation, or for back-burns later.
- Chemical Herbicide Firebreaks
  - Use knock-down herbicides for bare ground breaks without soil disturbance.
  - Target herbicide early in the dry season (March-June, after the wet).
  - Burn residual cured grass while surroundings are still green. Or let grass hay off.
  - Use less toxic non-selective herbicides (e.g., glufosinate-ammonium).
  - Annually rotate knockdown herbicides and fire on either side from the track.
  - Target invasive weeds at the same time for integrated management.

Figure 28 Mowed firebreaks with prescribed burning with water and blower support.

Figure 29 Herbicide chemical boom spraying firebreaks.

- Early-Dry Season Burn Firebreaks
    - “*The solution to late fires is early fires on CYP*” (Daryl Killin).
    - Use early-dry season burning (May-July) and prescribed fire (controlled burns) across large areas to break up country into burnt and unburnt patches.
        - Aerial helicopter incendiary burning of 10-30% along strategic fire lines.
        - Rotate burn locations every year to reduce impacts (3+ year burning cycles).
        - Connect mosaic burnt patches into fire lines to stop late-dry season wildfires.
    - Use natural firebreaks such as rivers, creeks, and wetlands in early-dry (May-July)
        - Avoid frequent burning of river frontage soils (e.g., fragile sodic sub-soils) that can lead to loss of ground cover and increased gully erosion.
    - Ground crews can ensure that aerial burn areas are connected and effective.
        - Primitive tracks strategically placed and maintained help access county.
        - Use side-by-side 4x4 buggies to drive along primitive tracks and light fires via drip torches, or via shooting incendiary balls 20-50 m into the bush.
        - Lit fires can back-burn into the track and be put out with leaf blowers, wet-lines or bare earth of two-wheel track.
    - Emphasise “low impact firebreaks” or “soft infrastructure” in conjunction with select hard infrastructure such as erosion control (whoa-boys and rock crossings).

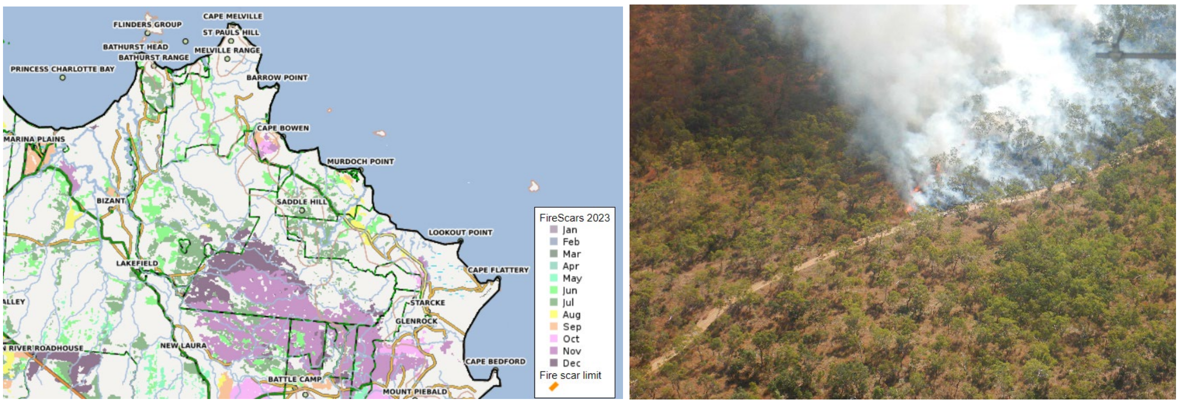


Figure 30 Early-dry (green) and late-dry (purple) season burnt mosaics (left) and connecting burns using track access (right).

Figure 31 Prescribed fire lighting unit that can shoot incendiary balls 50 m from tracks to create effective firebreaks and rotate the location of annual burning (courtesy of Tropical Fire Technologies, Daryll Killin).

Maintain Natural Drainage Flow Paths and Minimise Excess Water Runoff

"*The washout is the result and not the problem; Reinstate the natural flow direction as often as possible*" (Darryl Hill).

If your track or fenceline is graded lower than the surrounding soil, it will naturally collect water. Entrenched roads function as channels during heavy rain events. Windrows from deep grading can block natural flow paths and prevent water from draining, increasing water flow along tracks. Installing frequent and appropriately placed whoa-boys (water diversion banks) will minimise water travel along tracks and maintain natural flow paths across hillslopes.

Water Management BMP's:

- Divert surface water runoff early along flow paths to prevent concentrated flow.
    - Avoid diverting water into areas susceptible to gullying (hollows, creek banks).
- Install frequent, large whoa-boys on top of the existing soil surface (Figure 32).
    - Frequency depends on topography, slope, soil erodibility, opportunity (Table 3).
    - Whoa-boys should be high (>0.6 m) and wide (5-10 m along road) for long-term functionality and drivability. Around 25 tonnes per whoa-boy is typical.
    - Cap whoa-boys with gravel/rock if dispersive soils are used as material.
- Windrows can be breached to allow water to naturally flow, used to build whoa-boys, or partially build up entrenched eroded roads.
- On stable soils, use the local material dug from a small borrow pit (silt pond) next to the track to construct the whoa-boy (Figure 33). Divert water into the pond and include a sill outlet on contour for water dissipation.
- In dispersive soils (such as near creek crossings), import angular gravel from local borrow pits on ridgelines to make whoa-boys. Or use local soils and cap with gravel.
- Use a 4-in-1 bucket on a loader or backhoe, rather than a grader, to maintain primitive roads in rolling, hilly or wooded country, or in dispersive soils.

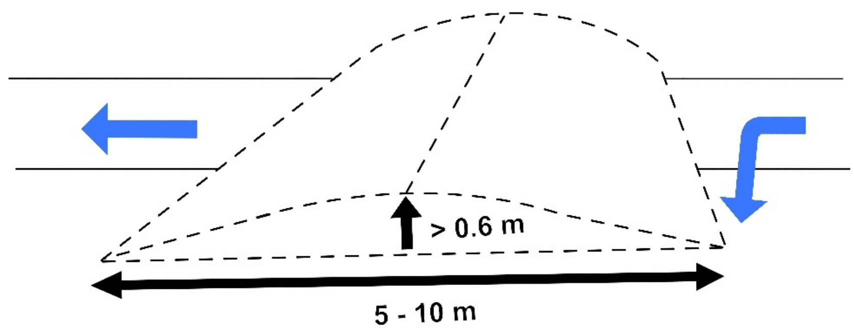
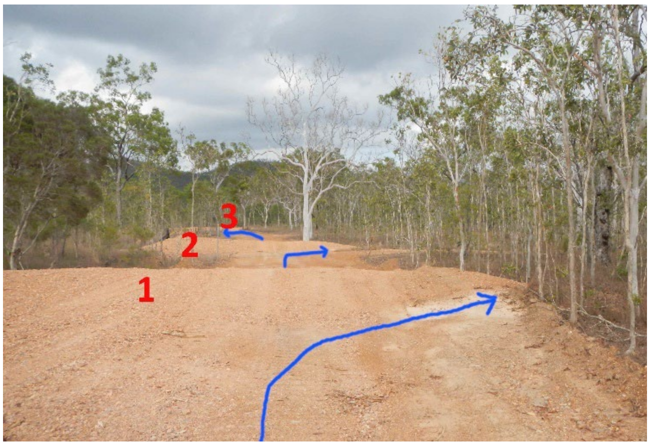


Figure 32 Dimensions of water diversion banks (whoa-boys) used frequently to divert water off roads.



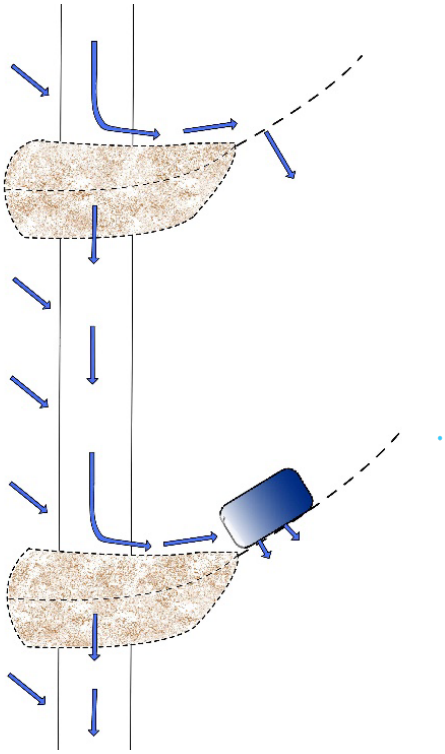


Figure 33 Flow paths and whoa-boy water diversion directions along a primitive track (left and right).

Table 3 Recommended water diversion bank spacing (m) on highly erodible.

Soil Type	High Soil Erodibility
Slope (%)	**Bank Spacing (m)**
1 %	75 m
2 - 3 %	50 m
4 - 6 %	40 m
7 - 10 %	30 m
10 – 15 %	20 m
>15 %	15 m

Figure 34 Example of water diversion banks (whoa-boys) sequentially installed every 30 m on a primitive track using local gravel/soil from ridgeline borrow pits.

Source Appropriate Rock & Soil Materials Before Beginning the Project

Creating a stable resilient track is a substantial investment, but can save money and time in the long-run compared to business-as-usual annual grading. Sourcing rock and stable soil material can be critical for controlling erosion hotspots in native dispersive soils and creek crossing approaches. Importing quarry rock is expensive, and is not realistic in remote areas. Local ridgeline sources of rock, gravel and soil become invaluable in remote areas, depending on the BMP techniques to be used. Scouting areas for ridgeline borrow pits and testing their material suitability for local purposes are crucial for project success.
Uses include:

- Whoa-boys: non-dispersive soil, gravel or rock mixtures.
- Rock Sheeting: gravel and/or rock mulch.
- Rock Armouring: mixed angular rock.
- Bed Crossings: larger angular rock.

Sourcing Materials BMP's:

- Source rock from local borrow pits on stable bedrock ridges to reduce costs.
- Conduct Cultural Heritage Surveys at potential new disturbance sites to ensure legal compliance (all tenures, Cultural Heritage Act) to protect the cultural landscape.
- Apply for vegetation clearing and quarrying exception permits for small extraction areas (< 1 ha and < 5000 t/yr).
- Rehabilitate borrow pits annually to prevent additional erosion and weed invasion.
- Minimise distances of hauling local rock where possible by accessing more frequent local borrow pits,
    - Minimize track damage by haul trucks, which can require rock sheeting.
- Adapt to local conditions and material availability where needed.
    - On floodplain areas with dispersive soils, it will be impractical to import ridge gravel from far away due to haul damage to tracks.
    - Use local soils for whoa-boys, revegetate and maintain grass cover, avoid deep grading and road formations, and close unstable tracks in the wet season.

Figure 35 Source rock from local borrow pits on stable bedrock ridges (minimise area to 20 m x 20 m) and rehabilitate area after completion including any drainage erosion control.

Rock Sheet Steep Road Sections & Rock Amour Creek and Gully Crossings

Steep road sections at creek crossing approaches or on hillslopes are inherently unstable, due to increased energy of water flow. Washouts near creek crossings are extremely common (gully erosion hotspots). Annual quick fixes to fill them in and gain access perpetuates a cycle of erosion and land degradation. Rock armoring crossings and rock sheeting steep approaches increases their resistance to erosion. Dispersive sub-soils on less steep country can also be unstable or boggy and need rock sheeting. Investments in rock sheeting and armoring can save time and money in the long-run and sustain longer seasonal access for other land management purposes.

Rock Protection BMP's.

- Rock sheet steep approaches to creek crossings with dispersive soils.
- Rock amour creek and gully crossings (beds and banks).
- Cap road cut batters with rock mulch to prevent rilling and gullying.
- Source rock/gravel from local stable ridgeline borrow pits.
    - Large angular rock may need to be imported from regional quarries.
- Rock size depends on slope, stream size, and flood water discharge.
    - Use well-graded unscreened rock mixtures to fill larger rock pore spaces.
- Install whoa-boy banks down steep road cut to slow the water.
    - Rock cap whoa-boy features, with or without diversion outlets.
- Rock sheet problematic boggy or entrenched road sections.
- Use a 4-in-1 bucket (loader or backhoe) or excavator to spread rock, an excavator to source ridgeline rock material, and a dump truck to transport.

Figure 36 Before, During and After rock armouring of a gullied stream crossing.

Figure 37 Before/After rock sheeting of a gullied road cut approaching a stream crossing.

Avoid Annual Re-routing of Roads Around Erosion Hotspots

Erosion hotspots such as gullies or washouts are the result of another source problem, such as excess water runoff down a track, road cuts and grading disturbance, catchment management (fire, grazing), or poor landscape planning. When new tracks are re-routed around gully hotspots created by the track, a cycle of land degradation is created. Legacy erosion issues become worse and more costly to remediate over time, or can require frequent management intervention.

Erosion Problem BMP’s:

- Refrain from re-routing tracks around erosion problem areas created by past disturbance.
- Address the cause of the problem. Look at the wider landscape.
    - Excess water runoff, road entrenchment, steep slope, poor soils, lack of rock capping, uncontrolled traffic, etc.
- Only move tracks to long-term stable locations and construct any new tracks to improved erosion control standards (these BMPs and others).
- Control erosion at hotspot problem areas.
    - Address major water drainage issues with diversion banks (whoa-boys).
    - Stabilise gullies with rock grade control structures (chutes and check dams).
    - Promote natural vegetation re-colonisation and sow native seeds.
- Rehabilitate or assist in the recovery of abandoned road sections.

Figure 38 Track locations over 8 years avoiding a gully created by the track (above left). Abandoned track still eroding and unvegetated after many years (above right).

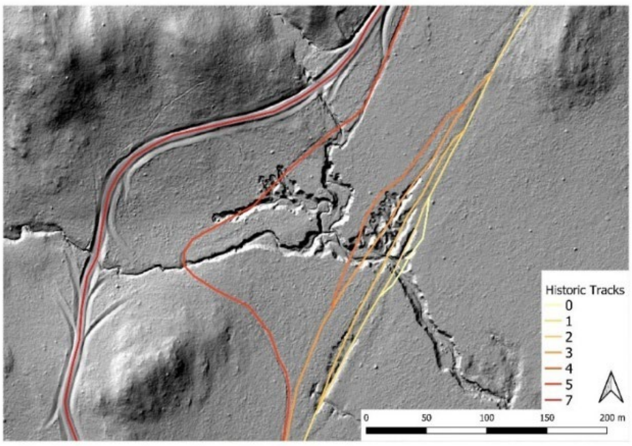


Figure 39 Changes in historic track locations to route around gullies caused by the tracks.

Control Gully Erosion Caused by Primitive Roads

Gully erosion can be initiated and accelerated by road, fenceline, or firebreak disturbance by machinery and changes in catchment flow paths. Prevention is the key to gully erosion by applying the BMPs above. However once started, gullies need to be controlled by managing their water inflow, lowering their slope, and installing rock resistance to erosion.

Gully Control BMP's:

- Divert water flow away from gully heads using whoa-boys, or earthen/rock banks.
- Rock line drains or hollows that are prone to gully erosion.
- Install rock chutes at gully heads to control water energy from road to creek.
  - Reshape gully to reduce slope to stable form before applying rock.
- Install rock grade control structures (check dams) to prevent scour and incision.
- Promote natural vegetation recolonisation of eroded gully areas.
  - Add local organic material and native tree/native grass seeds to gullies.
- Monitor site over time, and make slight adjustments as needed.

Figure 40   Divert water flow away from gully heads using water diversion banks (ridge gravel).

Figure 41   Road gully at a drain outlet (left) addressed with a rock chute (middle) to control flow energy. Check dams installed in an old track and gully (right).

Develop Annual Track, Firebreak, and Fenceline Maintenance Plans

The maintenance style of primitive roads and tracks can either make erosion worse or better over the long-run (i.e. accelerate or control erosion). Changes in management paradigms, upfront investment, and planning can go a long way toward stability that reduce maintenance costs over time for tracks, fencelines and firebreaks.

Maintenance Plan BMP's:

- Annually survey property track networks to assess erosion issues (GoPro Time Lapse).
- Map priority areas to work on each year and progressively implement over a 10 year period.
- Identify usable source areas for material (e.g., ridge rock or whoa-boy soils).
- Proactively address problem areas before they develop into large problems.
- Install resilience measures to control erosion (whoa-boys and rock crossings).
- Repair drainage structures and other track infrastructure BMPs.
- Take advantage of training or guidance in erosion control for machine operators.
    - Attend workshops on erosion control.
- Seek co-funding and cost share in track erosion control
    - Neighbors, land management partners, conservation groups, government.
    - Collaborate with field practitioners, scientists and machine operators.
- Merge projects with similar goals, i.e. weeds, firebreak and track management.

Figure 42 Surveying erosion control measures before (left, 2023) and just after (middle, 2024) and a year later (right, 2025).

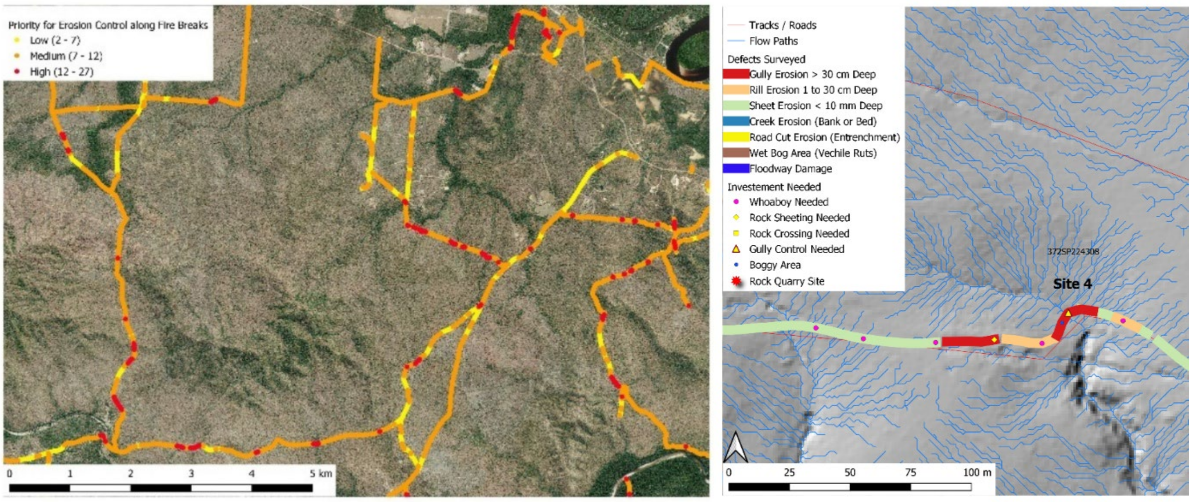


Figure 43 Priority mapping for erosion control along tracks and firebreaks.

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