



Quantifying the effectiveness of gully remediation on off-site water quality: results from demonstration sites in the Burdekin catchment

Rebecca Bartley, Aaron Hawdon, Anne Henderson, Brett Abbott, Scott Wilkinson, Nick Goodwin, Kahlytah Ahwang [Damon Telfer, Barbara Colls, Rod Kerr; Peter Zund, Seonaid Philip et al]

CSIRO, QDSITI, NQ Dry Tropics, Fruition Environmental

Australian Government

National Environmental Science Programme

Queensland Government

LANDHOLDERS DRIVING CHANGE
BURDEKIN MAJOR INTEGRATED PROJECT

NQ DRY TROPICS

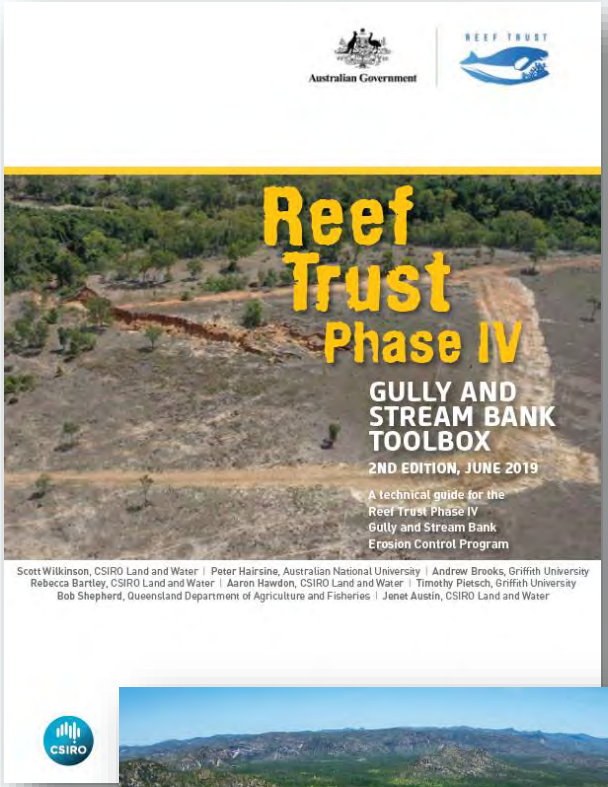
CSIRO

Why are we doing this work?

- Gully erosion supplies ~40% of the fine sediment (from 0.1% of the area)
- Australian Government Reef Trust ~$40 m, Queensland Government is ~$10 m into gully remediation (incl. LDC Project)
- This project is evaluating a range of remediation approaches
  - land condition, terrain changes and water quality







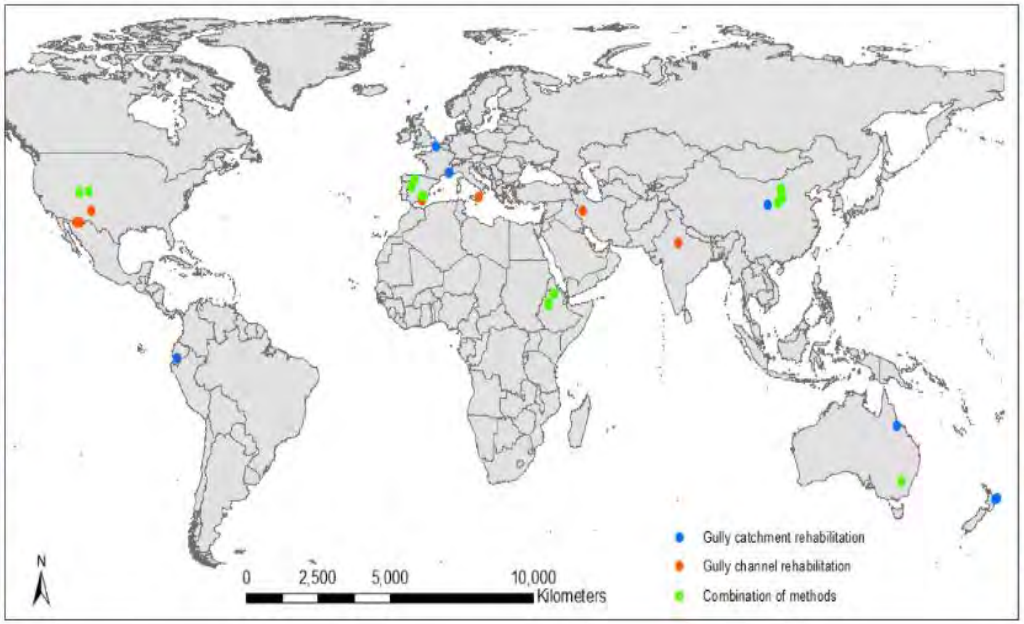


Global review on gully remediation effectiveness

- Decline in sediment yield will be faster when both the area above the catchment and the gully are treated
- You need both (soft and/or hard) engineering + vegetation to stabilise the site, but vegetation (and improvements in biomass) will be key in the long term


Democratic Republic of the Congo


Ethiopia

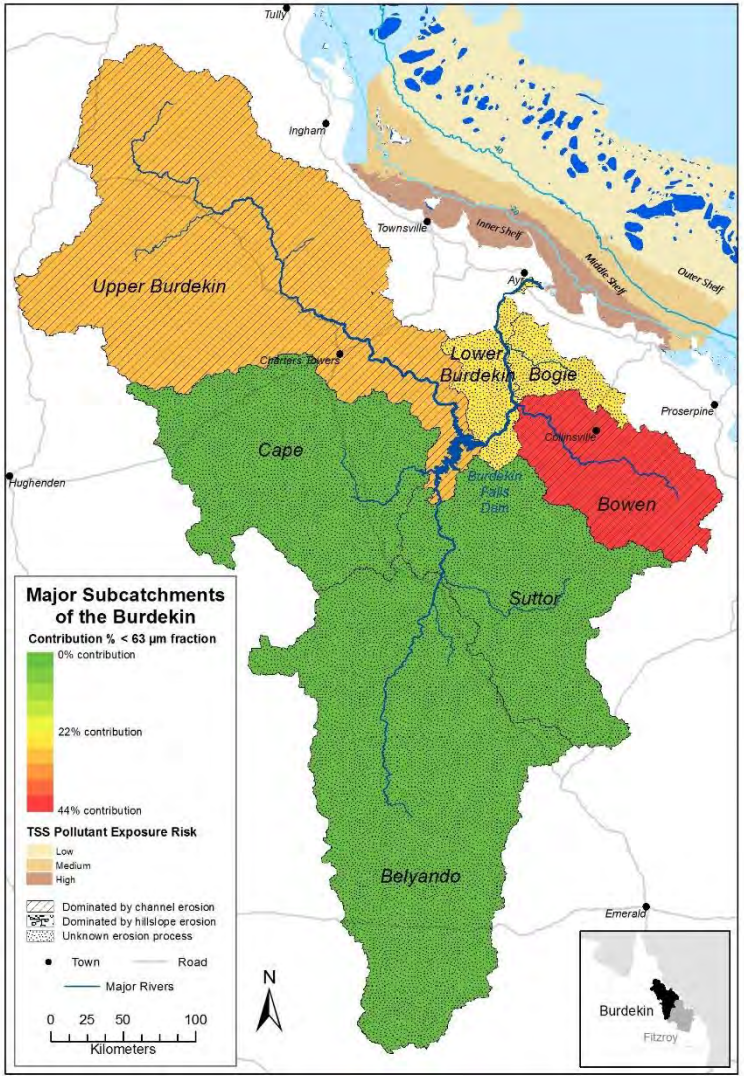



Iran


Australia

Bartley, R., Poesen, J., Wilkinson, S. and Vanmaercke, M., 2020. A review of the magnitude and response times for sediment yield reductions following the rehabilitation of gullied landscapes. Earth Surface Processes and Landforms, 10.1002/esp.4963.

Why the Burdekin? and where in the Burdekin catchment?





Agriculture, Ecosystems and Environment

Using sediment tracing to assess processes and spatial patterns of erosion in grazed rangelands, Burdekin River basin, Australia

Scott N. Wilkinson, Gary J. Hancock, Rebecca Bartley, Aaron A. Hawdon, Rex J. Keen

AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE

Fine-suspended sediment and water budgets for a large, seasonally dry tropical catchment: Burdekin River catchment, Queensland, Australia

Zoë T. Bainbridge, Stephen E. Lewis, Scott G. Smithers, Petra M. Kuhnert, Brent L. Henderson, and Jon E. Brodie

Science of the Total Environment

Review

Relating sediment impacts on coral reefs to watershed sources, processes and management: A review

Rebecca Bartley, Zoe T. Bainbridge, Stephen E. Lewis, Frederieke J. Kroon, Scott N. Wilkinson, Jon E. Brodie, D. Mark Silburn

Anthropocene

Combining contemporary and long-term erosion rates to target erosion hot-spots in the Great Barrier Reef, Australia

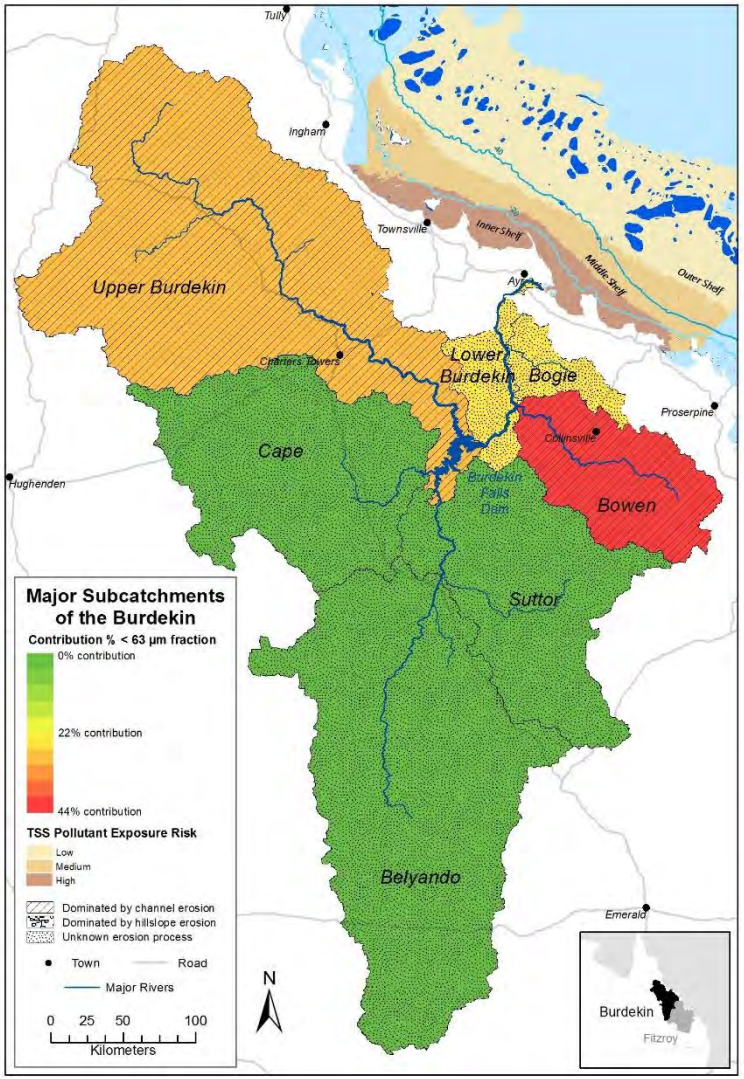
Rebecca Bartley, Jacky Croke, Zoe T. Bainbridge, Jenet M. Austin, Petra M. Kuhnert

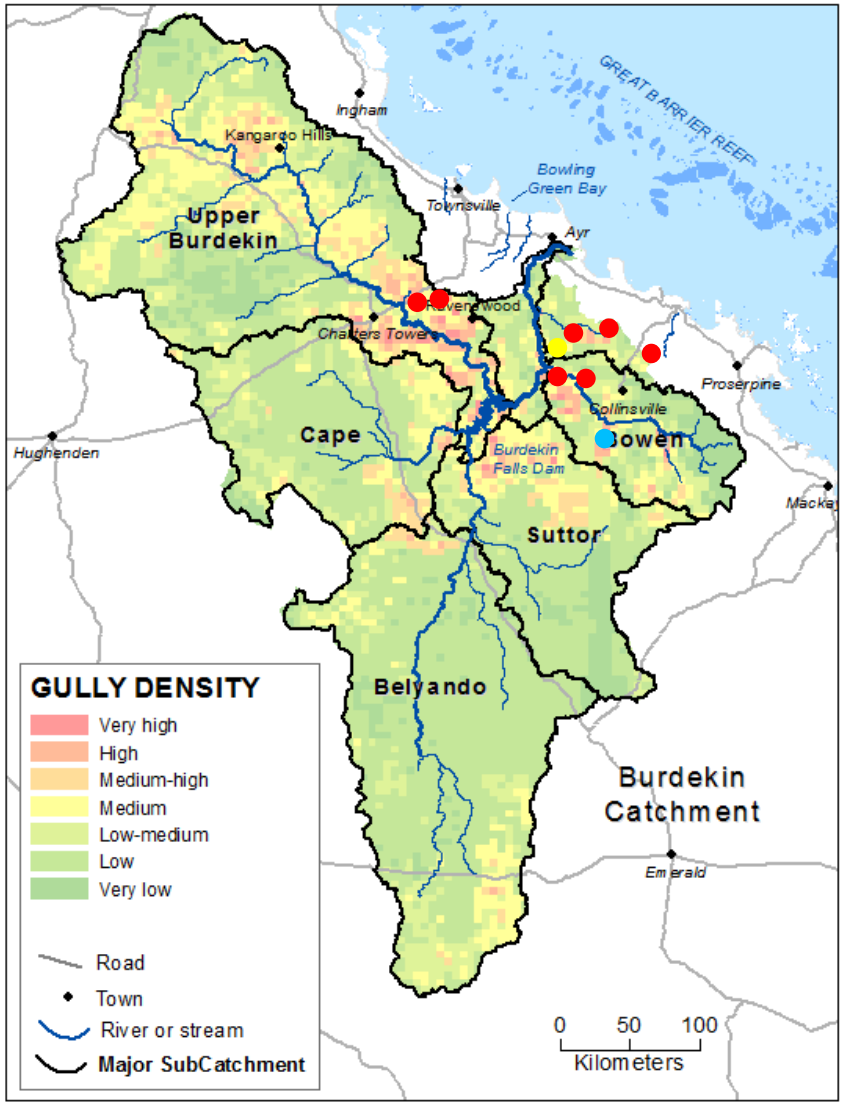
Marine Pollution Bulletin

Fine sediment and particulate organic matter: A review and case study on ridge-to-reef transport, transformations, fates, and impacts on marine ecosystems

Z. Bainbridge, S. Lewis, R. Bartley, K. Fabricius, C. Collier, J. Waterhouse, A. Garzon-Garcia, B. Robson, J. Burton, A. Wenger, J. Brodie

Why the Burdekin? and where in the Burdekin catchment?



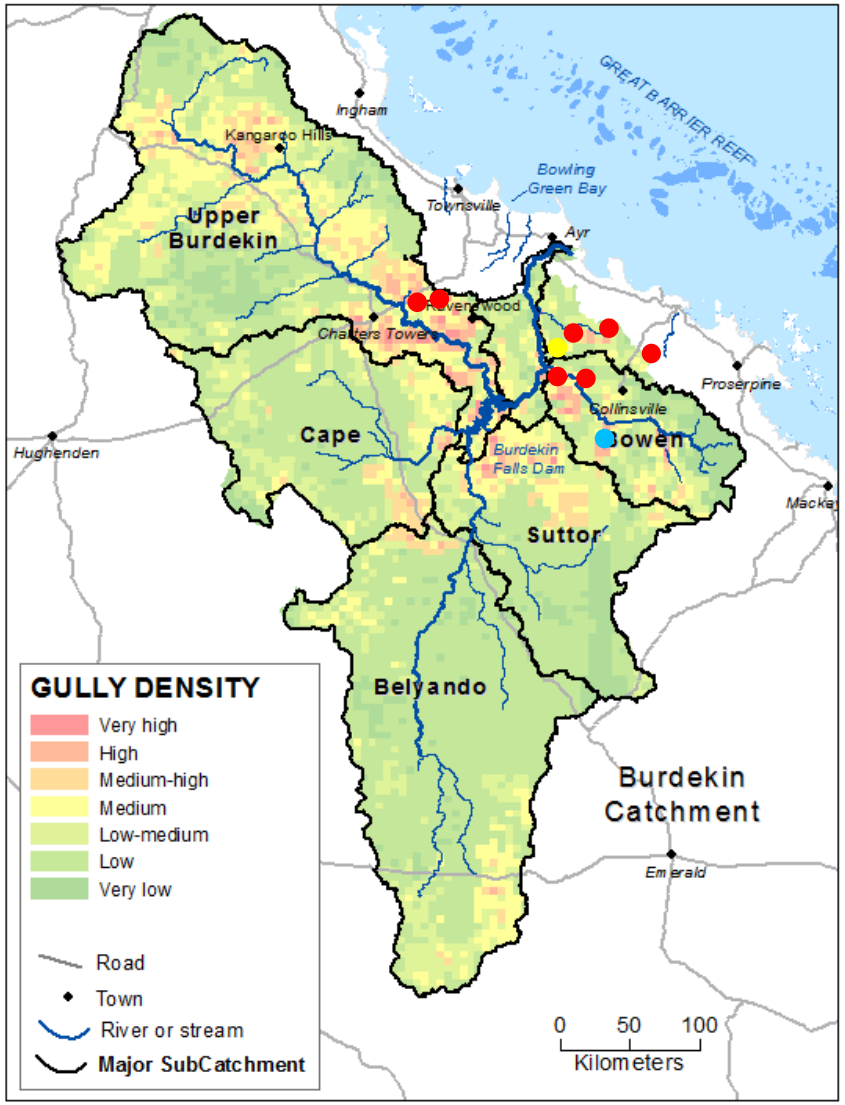


Why the Burdekin? and where in the Burdekin catchment?









Trialling a range of erosion control techniques

Cheaper $.....$$……$$$$.....to more expensive.







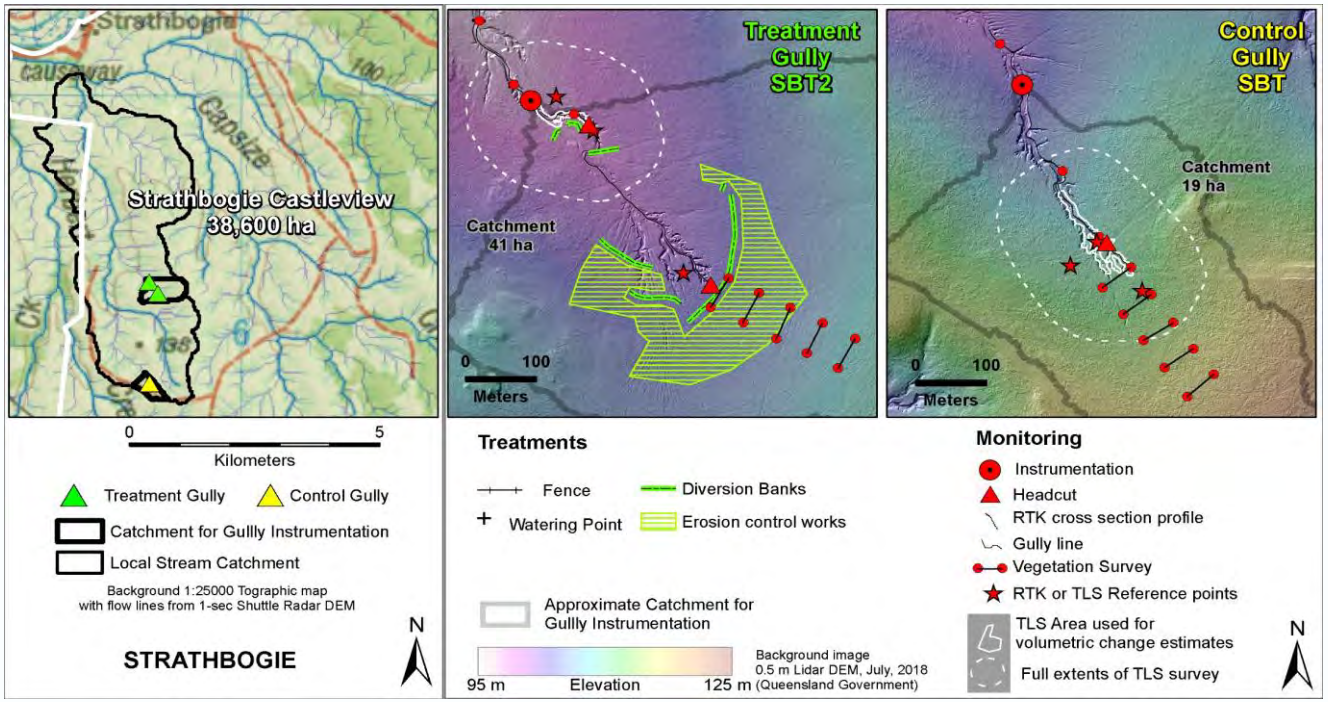








Indicators of change



Vegetation and land condition

↓

Terrain

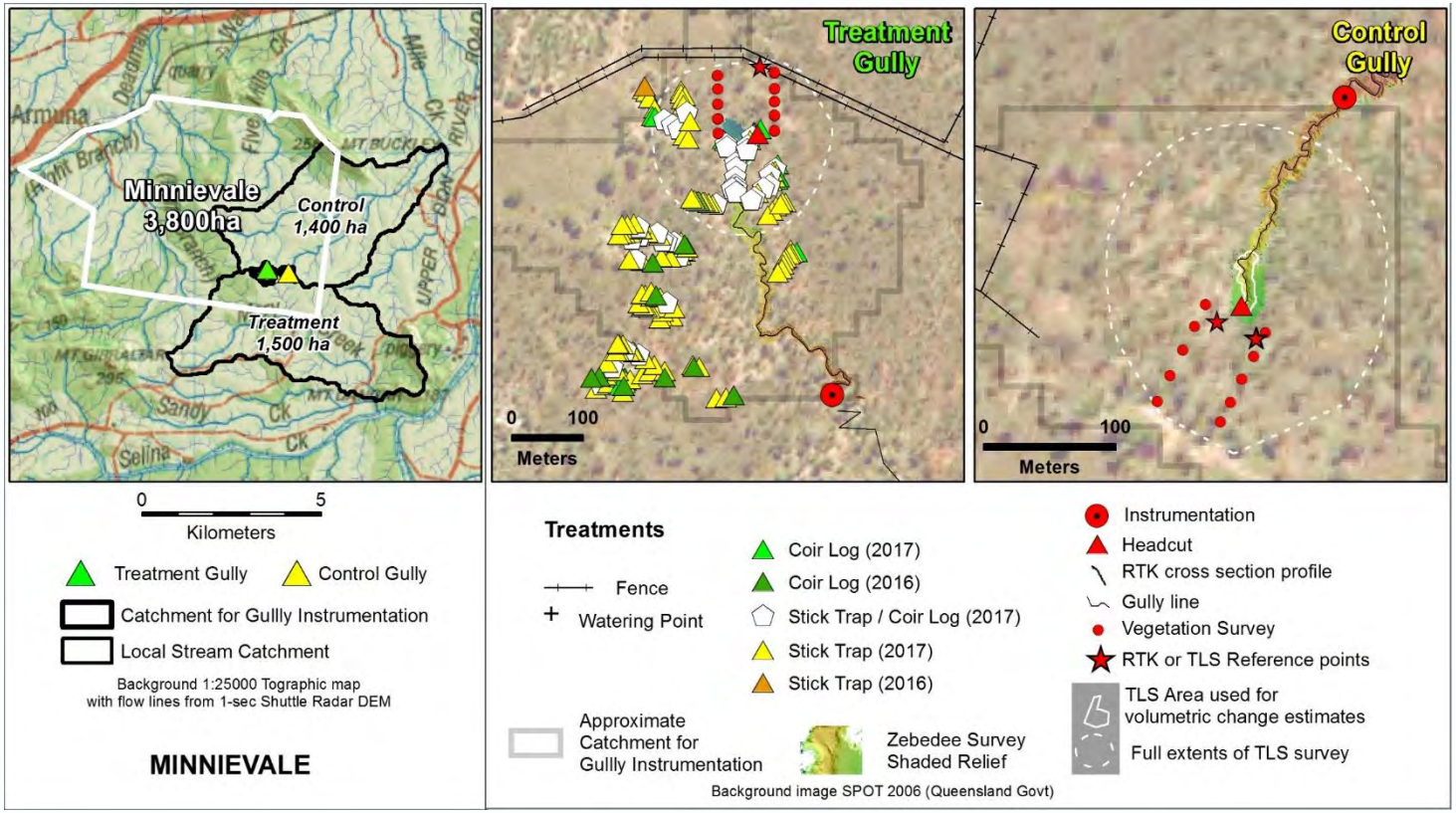
↓

Water Quality and Hydrology

↓

Sediment loads

Treatment and control - monitoring

















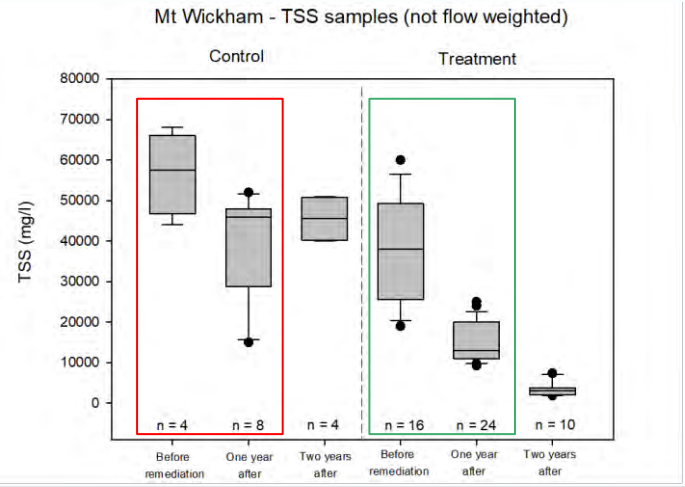


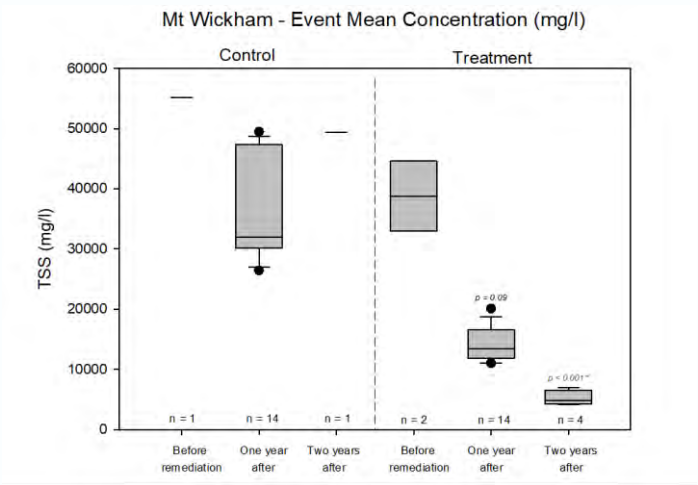
Methods and approach

To detect an improvement in water quality you need:

- Control sites paired with treatment sites.
- Before data or baseline data (at least 1-2 years of baseline data) at both control and treatment sites.
- Demonstrate that there is a statistically significant difference in sediment concentrations (between sites and years; two way ANOVA)
- $Treatment\ effectiveness = \frac{SYC - SYT}{SYC} \times 100$

Where SYC and SYT is the sediment yield in t/ha following treatment for a given year or wet season for the Control (C) and Treatment (T) sites, respectively.





Synthesis of the treatment history and monitoring results for all sites.

		Virginia Park	Meadowvale	Strathbogie	Minnievale	Mt Wickham	Glen Bowen	Mt Pleasant
	Burdekin basin	Upper Burdekin	Upper Burdekin	Bogie	Don	Bowen	Bowen	Bogie
	Managing organisation	CSIRO	CSIRO	NQDT	Greening Aust.	NQDT (Verterra)	NQDT (Neilly Group)	NQDT (Mulloon Institute)
	Gully type	Linear hillslope gullies and scalds	Linear hillslope gullies and scalds	Linear hillslope gullies	Linear hillslope gullies and scalds	Scalds and major alluvial gullies	Scalds and major alluvial gullies	Linear hillslope gullies and scalds
	Average annual long-term rainfall (mm) from nearest BOM site	~ 660 mm	~ 680 mm	~ 750 mm	~ 880 mm	~600 mm	~ 725 mm	~ 690 mm
	Soil type	Red **Chromosol**	Red **Chromosol**	Black **Vertosol**	Sodic Hypocalcic Red **Dermosol**	Hypernatric Brown **Sodosol**	Brown or Yellow **Sodosols**	Black and Brown **Chromosols** and Brown **Sodosols**.
	Catchment area (ha) above monitoring station at treatment site	1.3 ha	5.0 ha	41 ha	25 ha	14 ha	2.7 ha	259 ha
	Primary treatment	Disc plough above the treatment gully Fenced off gully (electric fence) Porous check dams installed in the gully (n=6)	Four strand cattle exclusion fence around the gully ~30% of the gully catchment has long term cattle exclusion	Five hillslope flow diversion banks with two drains Fencing Small rock revetment near headcut	Hillslope ripped, and seeded (creeping blue grass, V8 stylo, R.Rhodes etc) Fencing Total of 200 timber porous check dams installed	Major earth works, soil treatment, rock chute structures Fencing Significant re-veg using mixed exotic species	Major earth works, soil treatment, rock chute structures + earth bund, water points Fencing pending Significant re-veg using mixed exotic species	Landscape rehydration Four v-notch log rock sill structures and an earth bank to divert flows Fencing (pending) and trough
	Grazing management in treatment paddock	Historically this site has undertaken wet season spelling and forage budgeting.	No grazing management outside of exclosure areas.	No grazing management.	Grazing Mgt Plan. Reduced stock numbers in treatment paddock.	Cattle have been excluded since works began, but future grazing proposed.	Cattle excluded during rehab. Low stock numbers and short duration graze proposed.	Exclusion for limited periods and then rotational grazing.
	No. years treatment in place	10	3	1	4	2.5	1	1
	No. years of control/treatment monitoring	3-4	3-4	4	4	3	1	1
	Total cost ($) of on-ground works	$3.5k	$3.8k	~$44k	~$27k	$595k	~$840k	$95k
Measured improvement at treatment site compared to control.	Land condition	Improved	Improved	Declined	Improved	Improved	No significant effect	No significant effect
	Vegetation (hillslope + gully)	Improved	Improved	No significant effect	Improved	Improved	Improved	Improved
	Erosion rate (headcut)	Improved	Improved	Improved*	Improved	NA	NA	NA
	Sediment concentrations	Improved	No significant effect	Improved	Improved	Improved	Improved*	No significant effect
	Sediment loads	No significant effect	No significant effect	Improved	No significant effect	Improved	NA	No significant effect
	Treatment effectiveness value			0.95		0.85		

Some interesting results to discuss – Mt Wickham

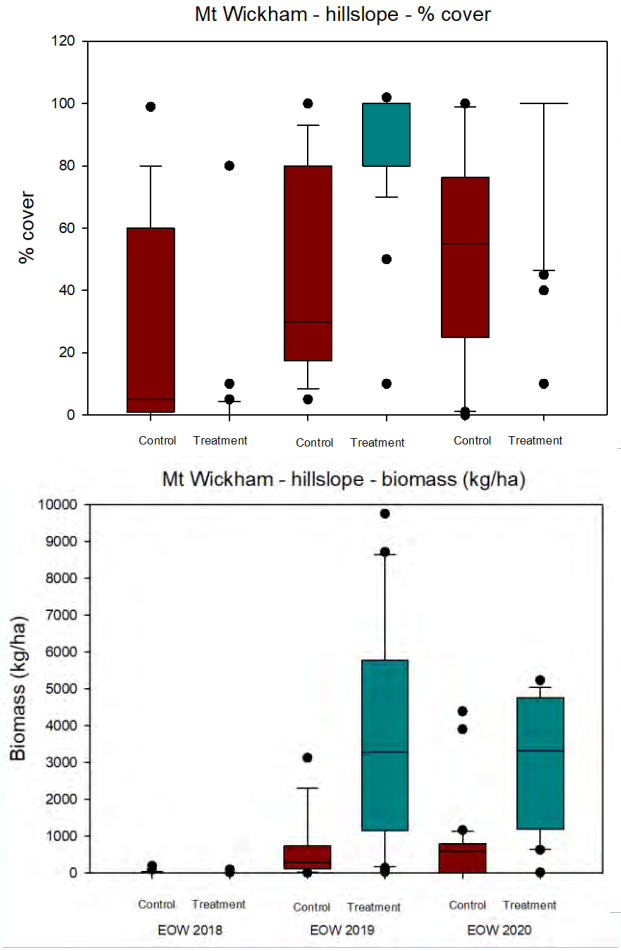


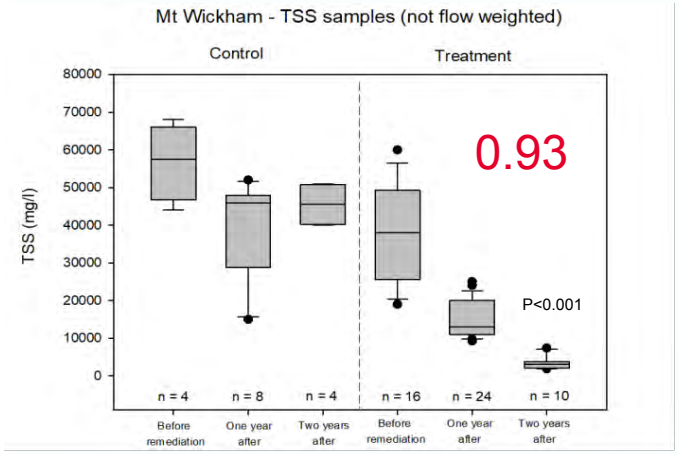


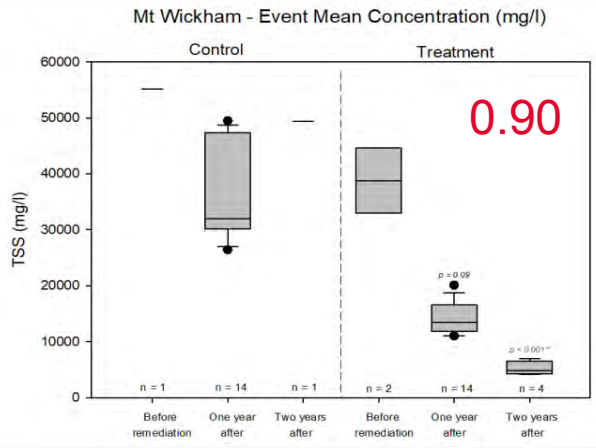


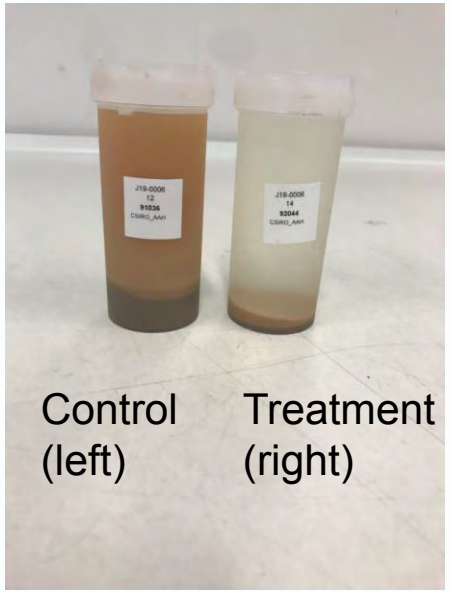


Some interesting results to discuss – Mt Wickham (>0.85)

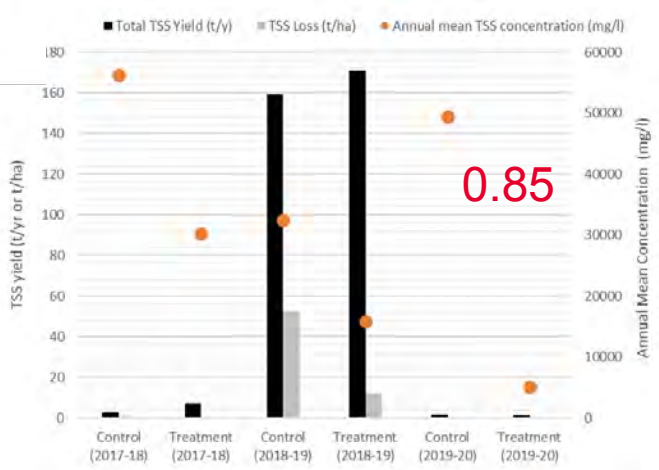










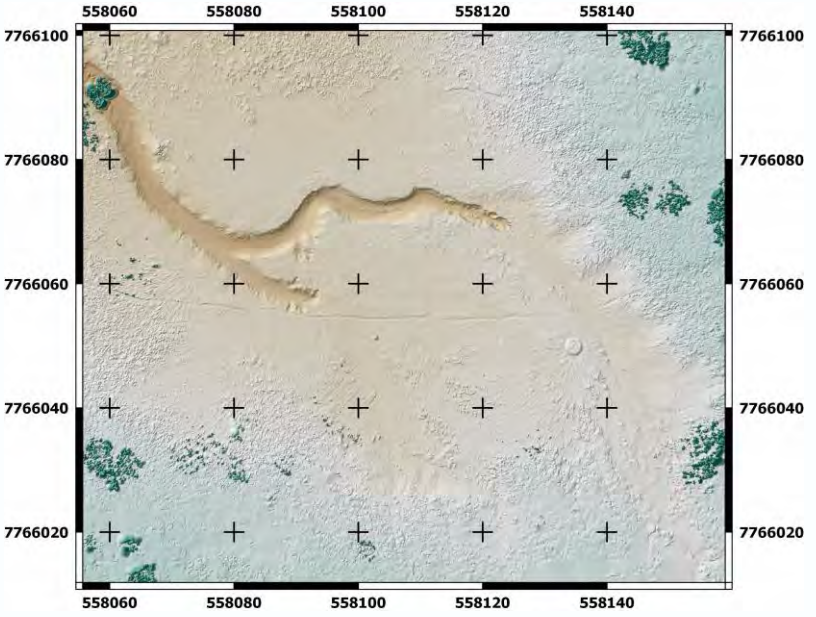


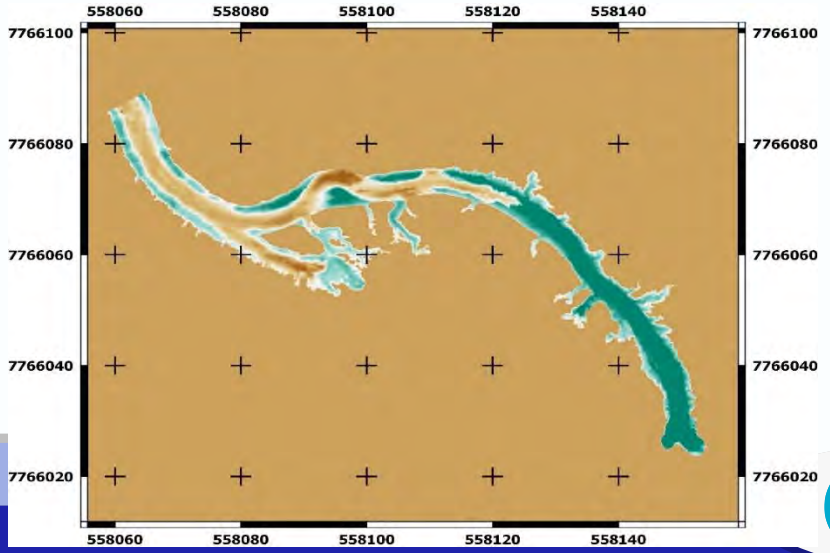
Some interesting results to discuss – Strathbogie

- ~54 m in three wet seasons (<5 µm sediment)









Some interesting results to discuss – Strathbogie

- **~54 m in three wet seasons (<5 µm sediment)**









Control site peak event in 2018/19



Treatment site peak event in 2018/19

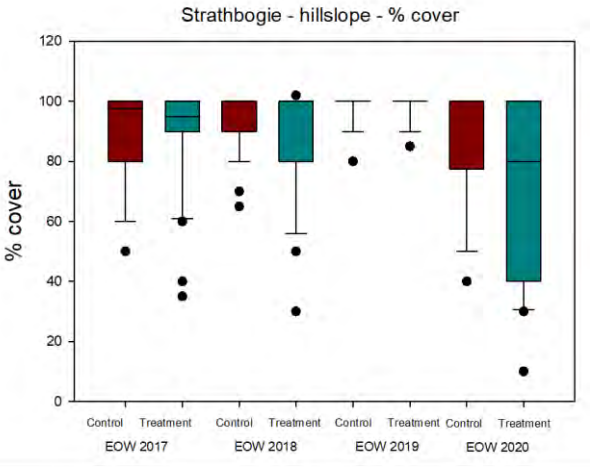


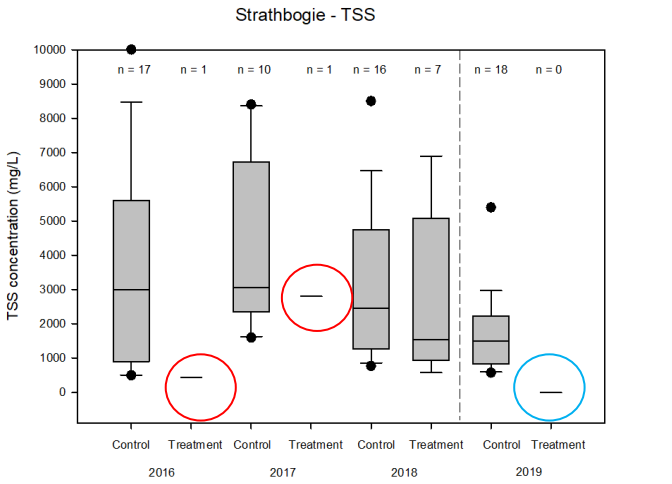
Control site peak event in 2019/20

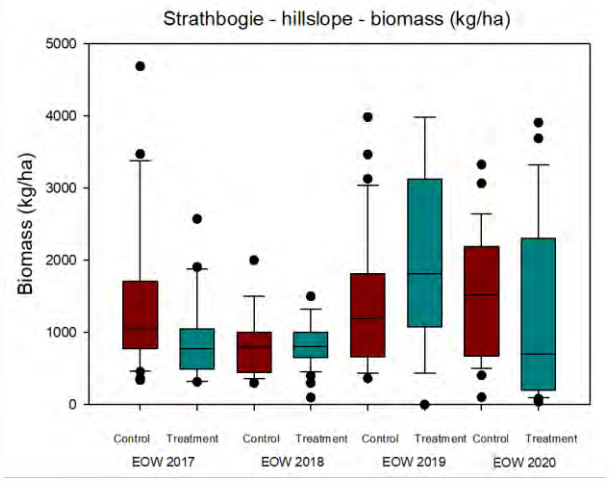


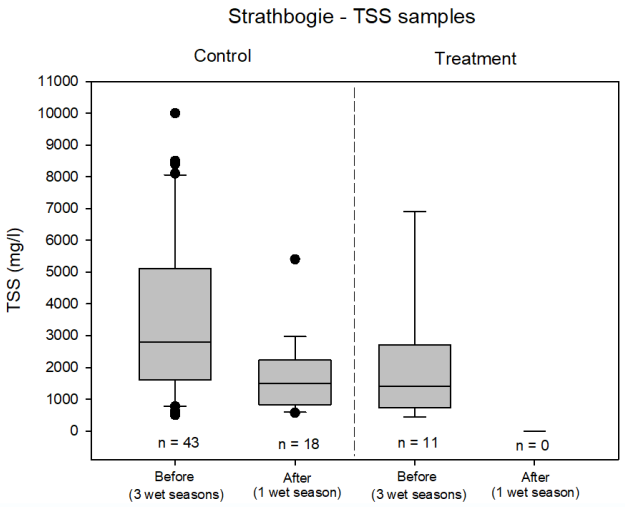
Treatment site peak event in 2019/20

Some interesting results to discuss – Strathbogie (0.95)















However, the control site is giving statistically different TSS concentrations in the 'before' and 'after' period, even without intervention ($p = 0.002$).

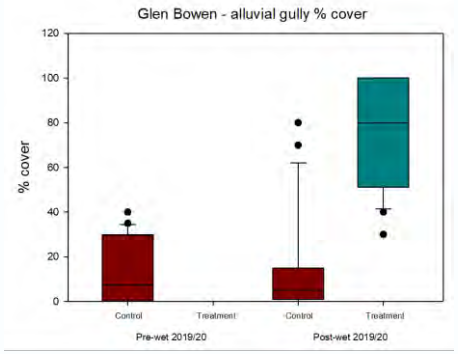
Some interesting results to discuss – Glen Bowen

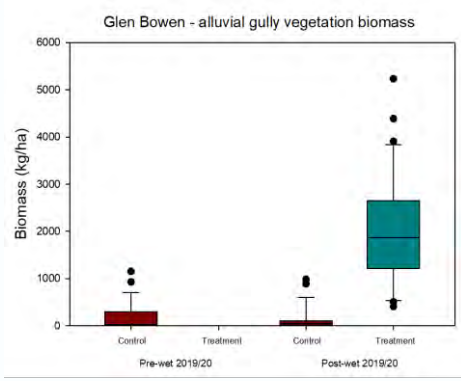


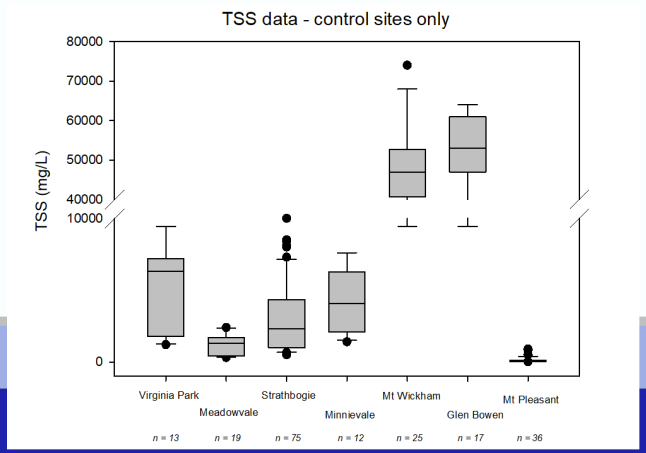


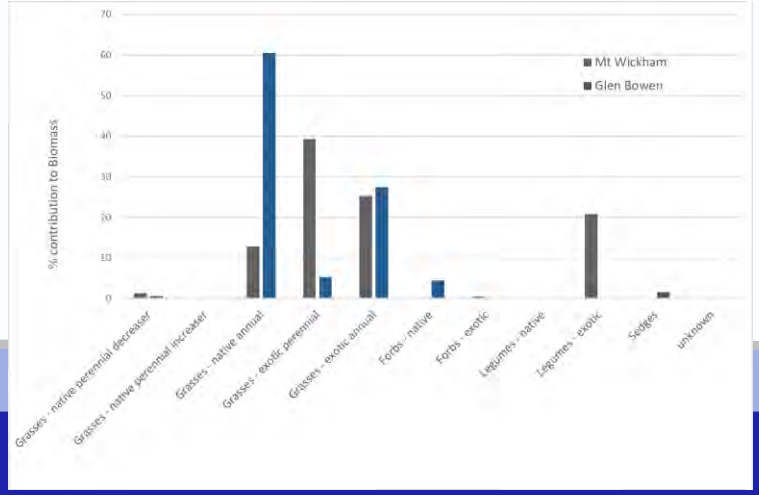








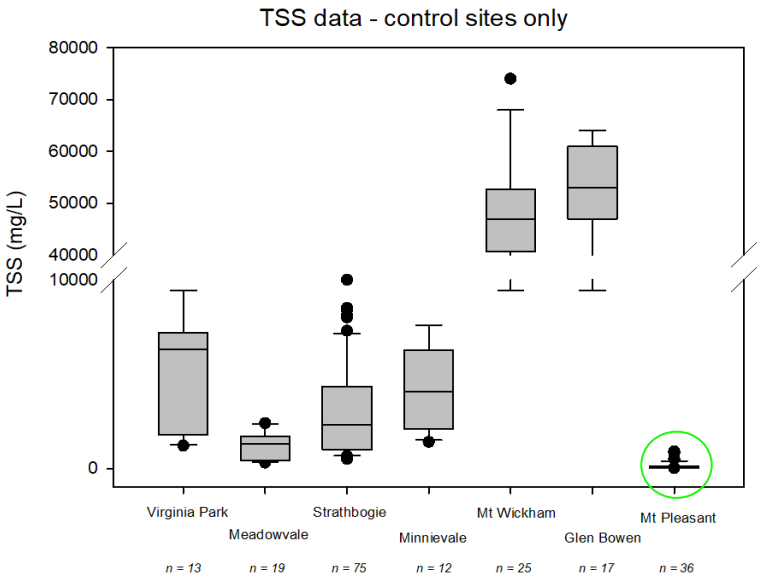


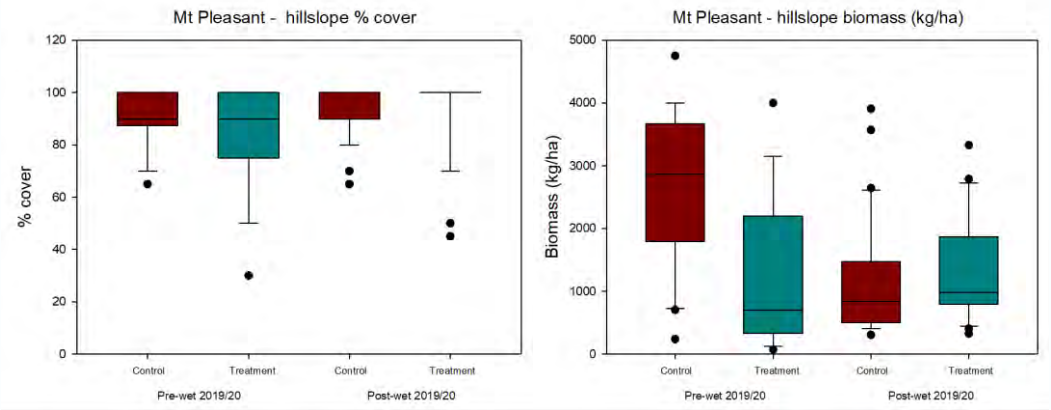


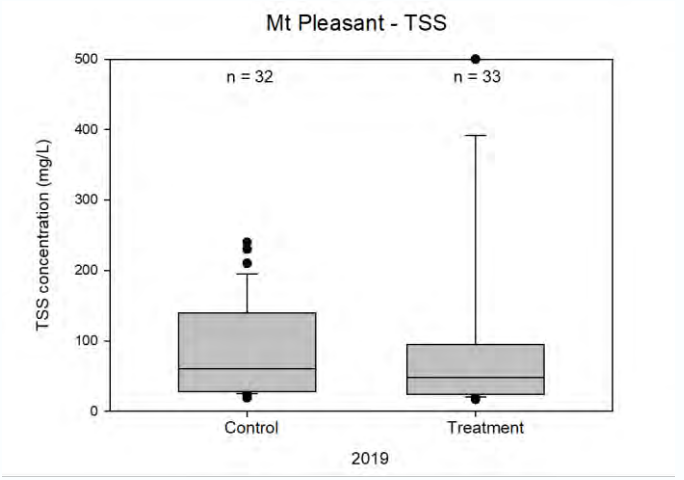
Some interesting results to discuss – Mt Pleasant











Key messages – grazing management and gullies

- For linear gullies, annual average soil loss is strongly dependent on the drainage area.
- At the sites where the head-cuts have been fenced off for between 3-9 years, the annual gully head-cut retreat rates have declined.
- Stock exclusion can double the amount of sediment trapped in the gully floor due to vegetation.
- Most sites have shown some improvement in % cover or biomass following treatment.
- However, gully catchment land condition remains in C or D class for most sites (exotics or annuals with lower biomass and lower infiltration).
- Stock access needs to be carefully managed
- Cost-effectiveness for gullies >$1500/t





Key messages – porous check dams

- Sites with fencing and porous check dams are showing improvements in the vegetation metrics in the gully floor/channel and gully walls.
- This increased cover, in conjunction with the sediment check dam structures has resulted in high (>90%) sediment trapping.
- However, the material that is being trapped is predominantly coarse (>63 µm) sediment.
  - *Koci, J., Wilkinson, S., Henderson, A., Hawdon, A., Bartley, R. and Goodwin, N., Accepted. Rehabilitation effects on gully sediment yields and vegetation in a savanna rangeland. Earth Surface Processes and Landforms (Special Issue on Gully Erosion).*
- Cost-effectiveness > $1500/t as the baseline sediment yields aren't very high
  - May be an option for landholders interested in cheaper long term options + carbon capture?





Key messages – hillslope interventions

- Strathbogie focused on hillslope runoff diversion banks (and ripping) which have effectively ‘starved’ the active gully.
- This first year was relatively dry, and the test will be whether the diversion banks concentrate surface runoff and cause gully initiation elsewhere.
- The land condition is still relatively poor and should be the focus for the long-term resilience of this site.
- Cost-effectiveness ~$70/t
  - There may be landholder benefits to this approach



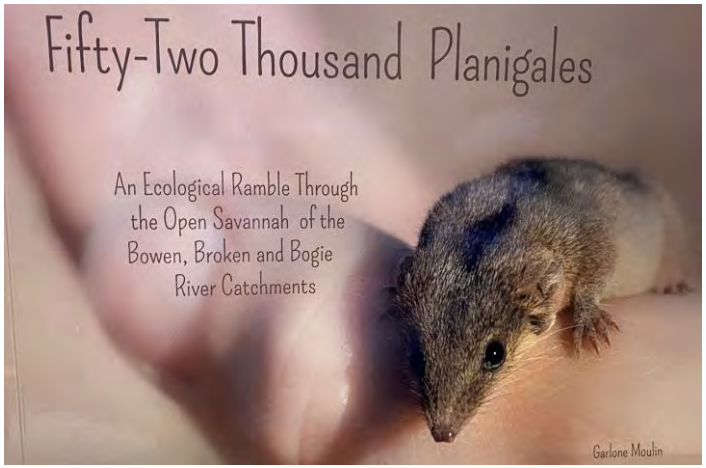




Key messages – landscape rehydration

- Mt Pleasant implemented a landscape rehydration project.
- The property was already in relatively good condition compared to other sites.
- Gully rehabilitation is not worth doing for water quality benefits alone.
- We have not yet factored in multiple benefits
- Cost-effectiveness unknown







Key messages – large scale rehabilitation

- The larger scale rehabilitation works (e.g. Mt Wickham) have resulted in statistically improved vegetation metrics, TSS and sediment loads relative to the un-treated control.
- Vegetation will need to be carefully managed at the treatment site due to the low rainfall during the establishment phase.
- Cost-effectiveness $300 - $600/t (Mt Wickham)





Key outcomes and Project linkages

- Provides data for P2R models and cost-effectiveness calculations
- Steve Lewis and Zoe Bainbridge (JCU) – geochem and particle size in river and marine systems
- Alex Garzon-Garcia and Jo Burton (QDES), samples have been supplied for nutrient bio-availability analysis.
- NESP synthesis projects and presentations





Challenges and remaining questions

- How long do we monitor for?
- Do we need to continue to measure water quality and discharge response at these sites (it is expensive)?
  - Water quality measurement allow us to measure TSS, TN, TP, particle size
  - Discharge allows us to see if runoff and % runoff is changed due to remediation
  - Lidar (aerial and ground based) is challenging when there is high cover (post-treatment)
  - Annual measurements are highly variable
  - Will the vegetation and structures survive?
  - Multiple lines of evidence allow for variable climate, instrumentation errors etc
  - Cost-effectiveness varies with the data!







Publications from this project

Publications attributed to the NESP listed below. Orange = large NESP funding contribution, Blue = minor NESP funding contribution. NESP project 2.1.4 and 5.9 team members noted in **bold**. Papers available as open access in italics.

1. *Jarihani, B., Sidle, R.C., **Bartley, R.**, Roth, C.H. and **Wilkinson, S.N.**, 2017. Characterisation of Hydrological Response to Rainfall at Multi Spatio-Temporal Scales in Savannas of Semi-Arid Australia. Water, 9(7), 10.3390/w9070540.*

2. Koci, J., Leon, J., Jarihani, B., Sidle, R., **Wilkinson, S**. and **Bartley, R**., 2017. Assessment of UAV and ground-based Structure from Motion with Multi-View Stereo photogrammetry in a gullied savanna catchment. International Journal of Geo-Information., 6(328), doi:10.3390/ijgi6110328.

3. Kuhnert, P.M., Pagendam, D.E., **Bartley, R**., Gladish, D.W., Lewis, S.E. and Bainbridge, Z.T., 2018. Making management decisions in the face of uncertainty: a case study using the Burdekin catchment in the Great Barrier Reef. Marine and Freshwater Research, https://doi.org/10.1071/MF17237.

4. **Wilkinson, S.N**., **Kinsey-Henderson, A.E., Hawdon, A.A**., Hairsine, P.B., **Bartley, R.** and **Baker, B**., 2018. Grazing impacts on gully dynamics indicate approaches for gully erosion control in northeast Australia. Earth Surface Processes and Landforms, 10.1002/esp.4339.

5. Bainbridge, Z., Lewis, S., **Bartley, R**., Fabricius, K., Collier, C., Waterhouse, J., Garzon-Garcia, A., Robson, B., Burton, J., Wenger, A. and Brodie, J., 2018. Fine sediment and particulate organic matter: A review and case study on ridge-to-reef transport, transformations, fates, and impacts on marine ecosystems. Marine Pollution Bulletin, 135: p1205-1220, 10.1016/j.marpolbul.2018.08.002.

6. *Judy, J.D., Kirby, J.K., Farrell, M., McLaughlin, M.J., **Wilkinson, S.N., Bartley, R**. and Bertsch, P.M., 2018. Colloidal nitrogen is an important and highly-mobile form of nitrogen discharging into the Great Barrier Reef lagoon. Scientific Reports, 8 (Article number 12854), 10.1038/s41598-018-31115-z.*

7. Koci, J., Sidle, R.C., **Kinsey-Henderson, A.E., Bartley, R., Wilkinson, S.N., Hawdon, A.A.,** Jarihani, B., Roth, C.H. and Hogarth, L., 2020. Effect of reduced grazing pressure on sediment and nutrient yields in savanna rangeland streams draining to the Great Barrier Reef. Journal of Hydrology, 582: 124520, https://doi.org/10.1016/j.jhydrol.2019.124520.

8. Walker, S.J., **Wilkinson, S.N**., van Dijk, A.I.J.M. and Hairsine, P.B., 2020. A multi-resolution method to map and identify locations of future gully and channel incision. Geomorphology, 358: 107115, https://doi.org/10.1016/j.geomorph.2020.107115.

9. ***Bartley, R**., Poesen, J., **Wilkinson, S**. and Vanmaercke, M., 2020. A review of the magnitude and response times for sediment yield reductions following the rehabilitation of gullied landscapes. Earth Surface Processes and Landforms, 10.1002/esp.4963.*

10. *Koci, J., **Wilkinson, S., Henderson, A., Hawdon, A., Bartley, R. and Goodwin, N**., In Press. Rehabilitation effects on gully sediment yields and vegetation in a savanna rangeland. Earth Surface Processes and Landforms (Special Issue on Gully Erosion).*

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More information – see NESP (Bartley)
https://nesptropical.edu.au/index.php/round-2-projects/project-2-1-4/
https://nesptropical.edu.au/index.php/round-5-projects/project-5-9/

Thank you

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Tropical Water Quality Hub
National Environmental Science Programme

Queensland Government

LANDHOLDERS DRIVING CHANGE
BURDEKIN MAJOR INTEGRATED PROJECT

NQ DRY TROPICS

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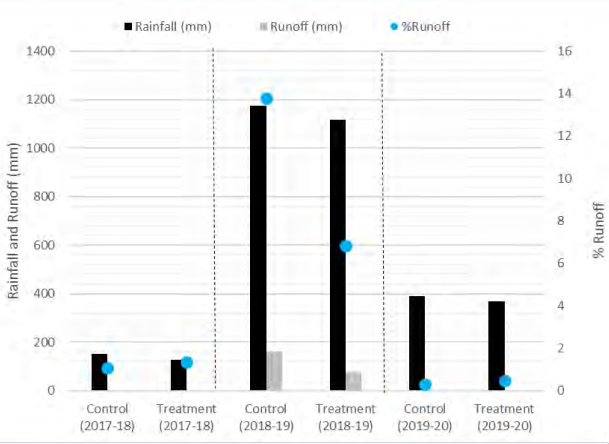
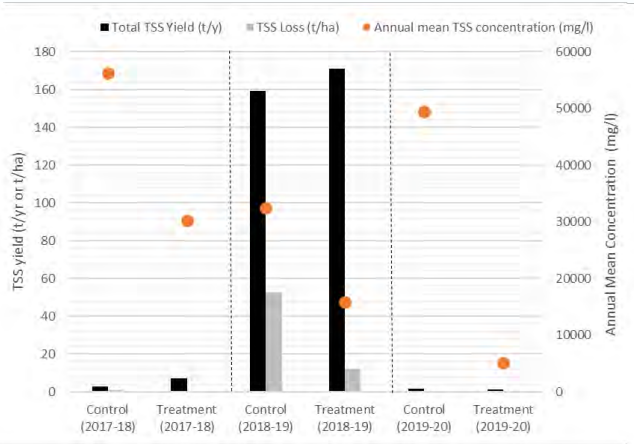
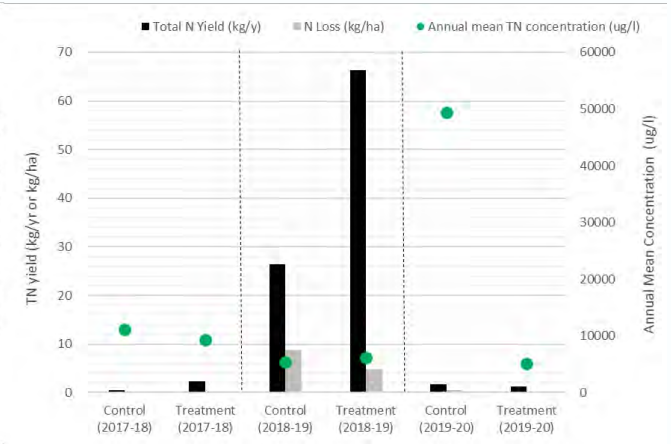
Concentration vs Loads

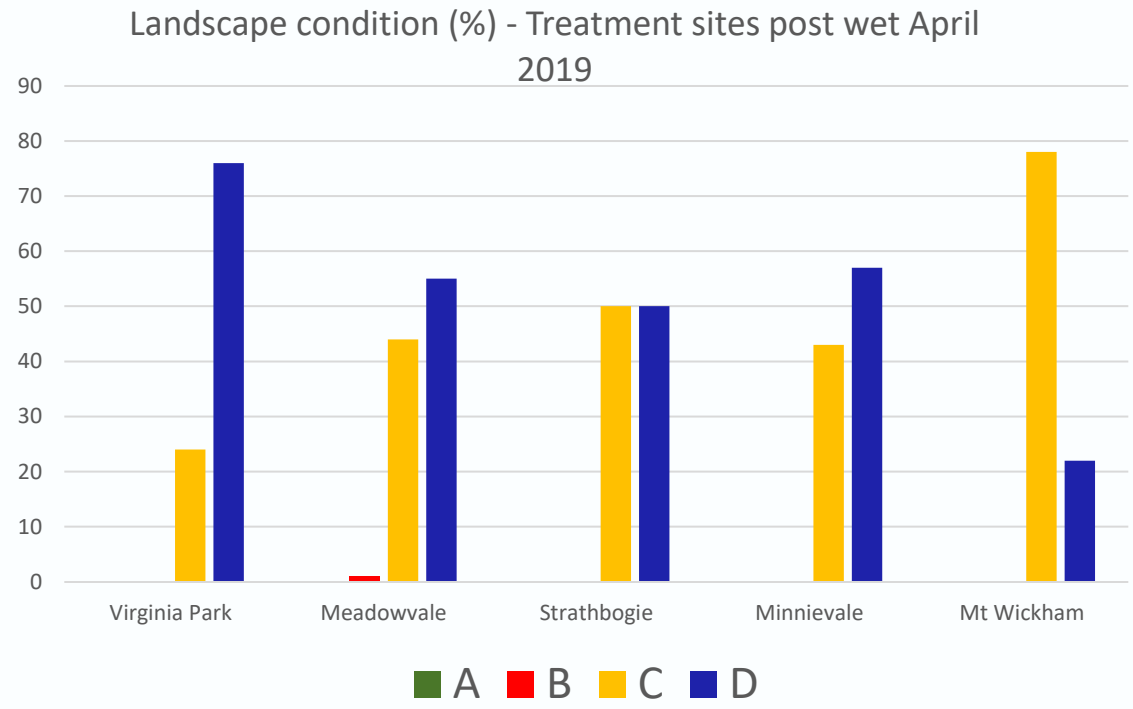
- Concentrations can reflect high erosion, they can also reflect low rainfall

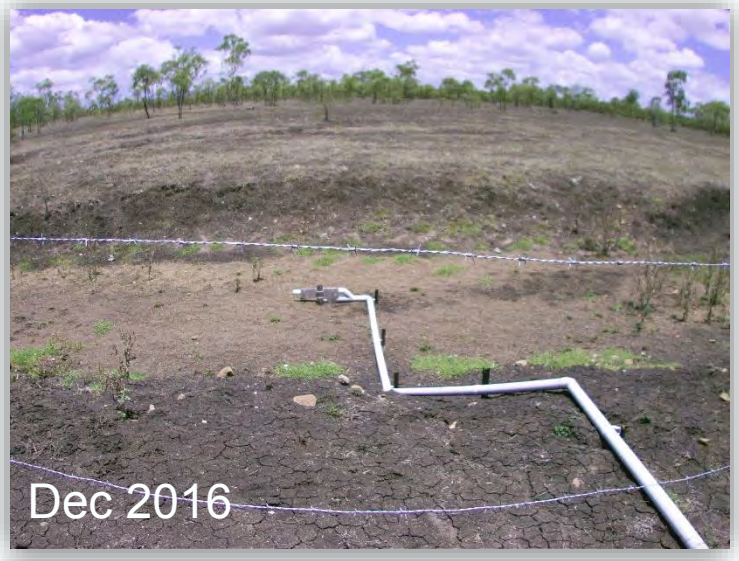






Results – hillslope cover and land condition

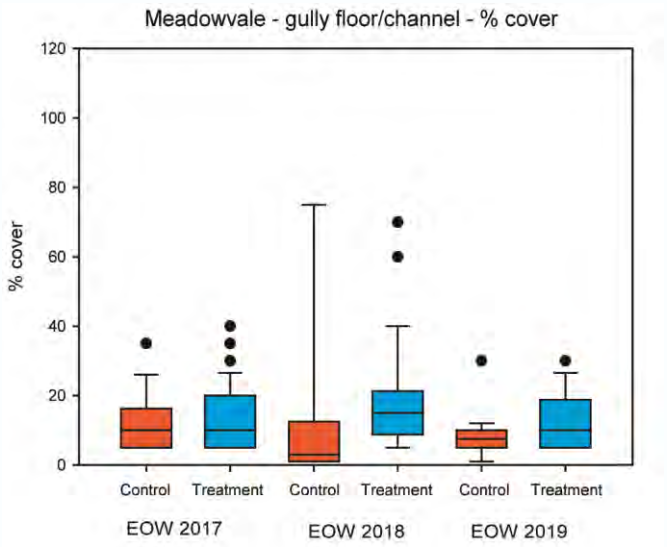


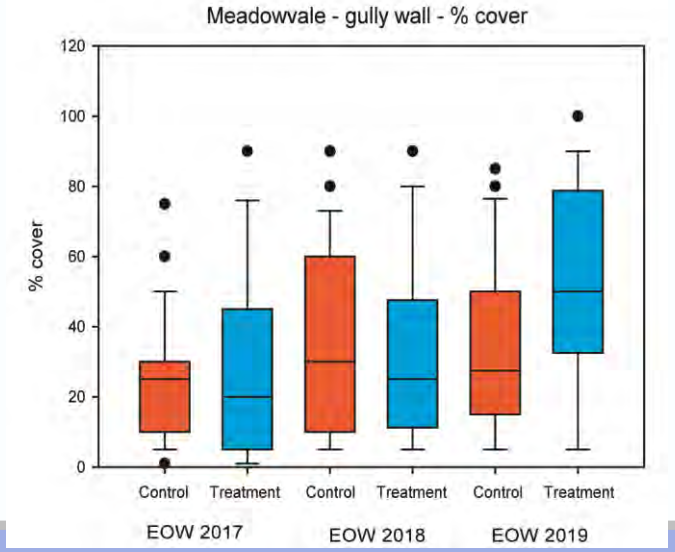




- Improving hillslope condition is important, but the hydrology and water quality benefits will take longer
- Under long-term livestock exclusion gully sediment yields were 77% lower than those of grazed gullies (Wilkinson et al., 2018, ESPL paper)

Results – gully cover and biomass (Meadowvale)











Event time series – Mt Wickham 2018-19

