

Alluvial Gully Systems Erosion Control & Rehabilitation Workshop

Collinsville 8-10 August 2016

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Project 2.1.10: The application and adaption of mine site rehabilitation approaches to alluvial gully rehabilitation in the Bowen Catchment

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SYNTHESIS STATEMENTS

The following synthesis statements represent the consensus view of the participants in a 3 day workshop about alluvial gully restoration held at Collinsville on August 8 – 10, 2016. The workshop participants included a diverse group of scientists and practitioners with diverse expertise in geomorphology, soil chemistry, soil biology, soil conservation, soil physics, landscape restoration, terrain analysis and reforming, and mine-site rehabilitation; employed in the university, government, private consulting and mining sectors.

- Large alluvial gully systems are a significant contributor to the sediment load of Great Barrier Reef (GBR) catchment rivers, and should be considered more as major point sources rather than diffuse sources that can be managed through catchment-wide land management programmes.
- Programmes aimed at significantly reducing sediment and nutrient loads to the GBR will need to focus rehabilitation efforts at these alluvial gully point sources if they are to meet stated sediment and nutrient export reduction targets.
- There was broad agreement that standard approaches to land management that involve the implementation of grazing BMPs and small scale, low cost, interventions will not be sufficient on their own to significantly reduce sediment and nutrient yields from large, active alluvial gully complexes. This is not to say that these approaches will not be part of the management solution mix, tailored to individual gully complexes.
- Many examples of gullies were observed in the field that had little or no overland flow entering the gully head. Therefore strategies that rely on modifying the rainfall:runoff ratio through grazing and pasture improvement will have little effect on the sediment yields of these gullies. Such gullies, some of which are migrating at rates of up to 2 m per year, are driven by the erosion of the exposed dispersive and/or slaking soils associated with direct rainfall impacting on the gully itself. Fluvial scour associated with flows concentrated within the gully itself also contributes significantly to secondary gully erosion processes and needs to be a major focus of management treatments. Where gullies also have an overland flow contribution, erosion rates are likely to be even higher than situations without an overland flow contribution, hence in these circumstances overland flow management will also need to be part of the management mix.
- It was agreed that the current rates of alluvial gully activity may not be directly related to current land management (be it good or poor). These large alluvial gullies are a legacy issue that may have been activated when cattle and other disturbance processes were first introduced into the landscape up to 150 years ago triggering the gully erosion.
- There was broad agreement that there is a huge diversity of alluvial gully types and processes - even within a fairly confined spatial area - and hence the management strategies employed to rehabilitate and stabilise these gullies will need to be carefully tailored to the individual site conditions and dominating processes.

- The diversity of alluvial gully form, function and activity is a function of a range of factors, including:
 - Soil/sediment heterogeneity
 - Local topography
 - Regional topography
 - Local hydrology, including piping/tunnelling
 - Regional hydrology – including the hydrological interaction with the mainstream channel into which the gully is draining.

There was broad agreement that more work is required to fully understand how these factors contribute to gully form, processes and rates of sediment and nutrient production; hence how this dictates the management strategy to be employed at each site.

- Given the diversity of gully forms an equally diverse array of management interventions will be required for their effective treatment.
- Some gullies will only be stabilised with high intensity, hard engineering intervention involving terrain reforming of the whole gully system, while others will require less interventionist measures. Yet others will require a combination of high intensity, hard engineering approaches for some parts of the gully complex and lower-key measures in other parts of the gully as part of an overall integrated gully complex management strategy.
- Given the scale of the alluvial gullies visited in the Bowen River catchment during the workshop, there was broad agreement that methods used in mined site rehabilitation and the scale of such activities, with some adaptation, are highly applicable to alluvial gully rehabilitation.
- Perhaps the key difference with mine rehabilitation is that mines often have a source of topsoil that is stripped from the site, directly placed on rehabilitation areas or stockpiled ahead of the mining operation. This is then available for re-application. In alluvial gully systems, however, much of the stable topsoil has been removed, so a stable soil surface needs to be reconstructed from the available stable or unstable sub-soil material, and organic material as a contributor for soil stability either manufactured on-site, or imported from elsewhere.
- Whilst seen to be a challenging problem, there was general agreement that the rehabilitation of large active alluvial gully systems is a tractable one, and that rehabilitation activities can be implemented cost-effectively within the scope of current budgets.
- Given the highly concentrated nature of alluvial gully sediment and nutrient sources, there was agreement that such sites could be treated at rates that are potentially cheaper (when measured in terms of \$/tonne of sediment export reduction) than any existing sediment mitigation strategies. Given that alluvial gullies are often deep, highly active and highly connected to the drainage network, significant investment in a single concentrated area can be justified because of the substantial sediment reductions that can be gained. At one of the sites visited during the workshop (Site 1 - which from

repeat LiDAR surveys is estimated to be producing ~ 25,000 t/yr of sediment) an investment of \$2m with an 80% effectiveness would deliver sediment reductions at a rate of \$100/tonne (based on a single year's yield reduction). This figure is at the lower end of available estimates for sediment reduction across the GBR catchments from any source. If the cost-effectiveness of the full life cycle of the gully is taken into account (i.e. where the gully may continue to erode at its current rate for 100 years or more, the cost-effectiveness equation could drop to \$10/tonne or less - allowing for continuing maintenance costs).

- There was general agreement that due to the complexity of alluvial gullies and their significance as major sources of sediment and nutrients to the GBR, that the rehabilitation of such sites should only occur in association with expert advice from a team of experienced practitioners.
- There was some discussion about the need to develop a training and accreditation process for those involved in alluvial gully rehabilitation design and implementation. In the meantime a number of general principles were agreed as requirements for the successful implementation of alluvial gully rehabilitation.
 - Assemble a team of experienced practitioners with a range of expertise to study the material characteristics of *each* site and recommend and oversee intervention design.
 - Site assessment must include the upstream and downstream controls at each site, and place the management interventions within this context.
 - Measure or estimate using verifiable techniques a pre-treatment gully sediment export rate, as this will determine value for money of any proposed intervention.
 - Determine the most cost effective and fit for purpose combination of hard and soft engineering to be used in each particular instance based on gully geometry and subsoil material characteristics.
 - Key principles of gully rehabilitation include:
 - Stock exclusion for the medium to long term
 - Development of short term erosion mitigation measures during the construction phase (e.g. sediment traps)
 - Where terrain reforming of vertical and near-vertical surfaces is being undertaken, it may be necessary to establish experimentally what is the appropriate stable slope batter for the given soils
 - Hardening of key slope components
 - Hydrological reconfiguration and associated drainage management needs to be undertaken, i.e. providing the means by which the gully network may drain without instigating further erosion. Drainage diversion should only be undertaken where flow can be safely diverted without creating a new erosion problem elsewhere.
 - Soil import or on-site soil building to provide material to cap unstable subsoils and provide a sustainable growth medium
 - Revegetation and ongoing maintenance (The need for ongoing maintenance was strongly emphasised by a number of experienced practitioners at the workshop. It was considered unlikely that a successful treatment could be implemented with a one off treatment.)

- Identify a source of soil ameliorants, particularly organic material but also gypsum and nitrogenous fertilisers, and plan for their appropriate transport to site and application. The volume of material required would appear to justify the establishment of green-waste collection services in the main population centres.
- Locate and transport to site the necessary engineering consumables (rock, geofabric, concrete, permeation grouts etc.) and have experienced installers available on site.
- There is an urgent need to undertake a first pass mapping and categorisation exercise to identify the most active gullies and describe the range of material characteristics encountered at these sites. Of particular concern is the proportion of very fine silt and clay (less than about 16µm), as this is the component that is transported to the most distant reefs, and the degree to which the subsoil undergoes dispersion and or slaking. Sodic subsoils will require expert assessment as structures (e.g. simple rock chutes) and approaches used elsewhere (e.g. battering back to a standard gradient, or applying gypsum to just the first 10 cm of exposed subsoil) will likely fail due to intense tunnelling.
- Despite the clear need for intervention of the sort described above, extensive applied research is urgently required to determine the precise cost-effectiveness of different combinations of treatment options across the range of gully types in large field trials. This research will need to include evaluation of:
 - *The best way to manage the risks associated with the first wet season following intervention.* Is it better to invest upfront in irrigation and fertiliser application to ensure a cover crop is well established before October, or might it be better to establish a type of storm insurance fund, where a proportion of all project budgets is diverted into a pool that is accessible by other projects in the event of destructive first rains.
 - *The best way to manage/rehabilitate the range of gully-channel connections, as distinct from the gully areas more generally.* This may involve numerical and physical modelling of the various options available for reconfiguring this crucial nexus (e.g. a hardened slot canyon compared with a large open swale that will alter the hydrodynamics of the trunk stream).
 - *Rules of thumb that relate material characteristics to likely success of treatment options.* Can we predict a stable slope angle based on assessment of soil characteristics and optimal selection of types of organic matter for topsoil design, or will a time-intensive (1 year plus) slope angle stability test be required in each and every case. Likewise, can we identify the effective depth of gypsum incorporation based on standard low cost soil tests?
 - *What is the best way to monitor current and future export rates?* How do the methods likely to be available and applied in a broader program compare to results obtained by more accurate and precise methods based on ground-based LiDAR measurements and intensive water quality monitoring at gully outlets?
 - *What is the best way to sample and assess the soil/sediment material physico-chemical and spatial variability to an acceptable confidence and rigor?* What statistical and modelling methods could be employed to do this?
 - *What is the best way to compare techniques in a scientifically rigorous manner requiring replication and controls?* How will inter-gully variability and seasonal variability be incorporated into any assessment of technique assessment?

- *Developing locally specific pioneer species for the effective gully restoration.*
- The current insistence on demarcating research funding from the much larger implementation funding pool will be a significant impediment to answering this last question. The amount of funds available to undertake research is simply not sufficient to cover the range and diversity of gullies and erosion processes, hence we must ensure that opportunistic science leveraged off the learnings from on-ground implementation is possible. At the very least, those involved in on-ground works need to be alert to the opportunities to undertake their intervention in such a way so as to make it possible to rigorously assess the effectiveness of the approaches adopted. In many cases this may take the form of simply documenting all approaches used and matching this information with monitoring data. Elsewhere it may be possible to configure the timing or spatial distribution of interventions into the form of a scientific experiment, taking advantage of any 'natural experiments' created by gully material and morphology diversity.
- Finally, we anticipate that there will be significant capacity constraints in terms of qualified and experienced personnel that need to be addressed. We should begin to plan for training of operators in the third year based on the outcomes of interventions undertaken in the first two, with the content of this training updated as each new year of empirical data becomes available.

Table 1: Workshop participants

Name	Title	Affiliation
Andrew Brooks	Senior Research Fellow	Griffith University GCCM
Robin Thwaites	Senior Scientist	Griffith University GCCM/ Geoscapes Australia
John Spencer	Senior Research Associate	Griffith University GCCM
Timothy Pietsch	Senior Research Fellow	Griffith University ARI
Adam Heap	Senior Environment & Community Advisor – Collinsville Coal Mine	Glencore
Trevor Spedding	Environment & Community Manager – Collinsville & Newlands Mine	Glencore
Damien Burrows	Director Tropwater	JCU
Hugh Pringle	Landscape Rehabilitation Specialist/Consultant	EMU Edith Cowen University & Namibian University of Science and Technology
Johannes Biala	Researcher/Contractor	Organic Force & QUT
Michael Goddard	Sustainable Industries Officer	CYNRM
Peter Zund	Senior Soil Scientist	DSITI
Rob Loch	Director/Principal Consultant	LandLoch
Ross Andrewartha	Director of Conservation North Queensland	Greening Australia
Steve Eccles	Soil Conservation Officer/consultant	Consultant -recently retired NSW Soil Con. / Hunter Local Land Services
Thomas Baumgartl	Principal Research Fellow	UQ Centre for Mined Land Rehabilitation
Will Higham	Principal programme manager	CYNRM
Andrew Freeman	GBR Programme Advisor	Agforce
Steve Lacey	Qld Grazing BMP Programme Manager	Agforce

Apologies: Bob Shepherd – QDAF; John Day - BMRG; George Bourne - DNRM, Jean Erbacher, QOGBR; Ami McGrath - DoE, Giles West DoE, Justin Claridge - AMECFW.



This communique summarises the workshop held in Collinsville, Queensland from 8 to 10 August 2016, with contributions from experts in soils, geomorphology, mine-site rehabilitation, soil rehabilitation and soil conservation, see Table 1.

Summary of Problem

Although estimates vary, depending on models used, there has been an approximate increase in sediment export to the Great Barrier Reef (GBR) of 5 to 10-fold following a change in land management from about the 1870s onwards. Degradation of the GBR environment has become evident in recent decades, with Crown of Thorns Starfish (COTS), nutrients and sediments (especially the very fine silt and clay fraction ($< 16 \mu\text{m}$) destabilising the coral reef habitat and ecology. This is also putting at risk large tourism-based and fishing industries

together valued at ~\$6 billion and employing over 60,000 people. Both the Federal Government and the Queensland State Government are now keen on adopting an interventionist approach to protect this asset, with a key objective of the 'Reef Plan' being to reduce sediment export to the GBR by up to 50% by 2025.

Bainbridge et al. (2014) have shown that the Burdekin River catchment is responsible for ~47% of the total fine sediment load delivered to the GBR Lagoon, with the Bowen-Bogie Rivers catchment, though occupying only 10% of the area of the Burdekin, delivering about 70% of the load. This comprises about 30% of the fine silt / clay load delivered to the entire GBR Lagoon. Therefore, whatever approach is adopted, reducing sediment production in the Bowen-Bogie Rivers catchment clearly plays a major part in achieving the sediment reduction targets set out in the Reef Plan.

Brooks and co-workers (2009; 2013; 2015; 2016) have recently drawn attention to the role played by large alluvial gully systems, which are particularly important sources of fine sediment owing to their particular sedimentology, location and scale. This finding has been supported by sediment tracing research in the main GBR contributory catchments (Olley et al., 2013; Wilkinson et al., 2013).

For the current purposes alluvial gullies are defined here as: *relatively young incisional features entrenched into alluvium not previously incised since initial deposition. Alluvial gully complexes (up to several km^2) are defined as actively eroding and expanding channel networks incised into and draining alluvial deposits. They often form a dense network of rills and small gullies nested hierarchically within larger macro-gully complexes. Alluvial gullies are variable in erosion process, form, landscape location, climate, relief, and texture of alluvium. However, they most often occur in vast deposits of alluvium along high stream-order main river channels or other large waterbodies such as lagoons or lakes. Thus they have high sediment delivery*

ratios and are highly connected sources of predominantly fine suspended sediment. They are often as wide as or wider than they are long, due to the lack of structural control on their lateral expansion. (Brooks et al., 2009).

Meeting the objectives of the Reef Plan will require a 3 Mt/yr reduction in sediment export, with high-intensity intervention for alluvial gully remediation/ stabilisation a necessary component of any strategy designed to achieve this. However, the methods by which this reduction in alluvial gully sediment production will be achieved are yet to be firmly articulated and agreed upon. Formulating an appropriate intervention plan will require input from a range of specialists in soil chemistry, physics and biology, geomorphology, and those experienced in large-scale terrain reforming such is typical of mined land rehabilitation.

WORKSHOP SUMMARY

Day 1 consisted of a series of introductory talks by workshop participants; Day 2 a field day to examine rehabilitated mine-sites and four different alluvial gully systems on Havilah Station. Day 3 provided the opportunity for group discussion of outcome-oriented themes expressed at the beginning of the workshop, informed by observations made, and discussions held, in the field on Day 2.

DAY 1: INTRODUCTORY TALKS (SEE ATTACHMENTS)

Damien Burrows introduced the purposes and aims of the NESP funding plan, and its role in the GBR research programs.

Andrew Brooks provided an overview of the workshop objectives in the context of recent research into the role of alluvial gullies as major sediment and nutrient sources in dry-tropics catchments.

Why the Bowen?

Burdekin estimated to contribute ~ 47% of the total fine sediment load to the GBR

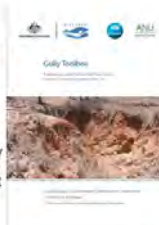
Burdekin Sediment Budget 2005-2009	load % breakdown by particle size			av loads (Mt/yr 2005-2009)			% of total at outlet
	clay	silt	sand	clay	silt	sand	
Burdekin R (below dam)	52%	43%	6%	1.32	1.05	0.13	30%
Bowen R (at Murrumbidgee)	27%	49%	24%	1.02	1.84	0.90	45%
Lower Bowen (Burdekin drainage area)	30%	38%	32%	0.79	0.83	0.55	24%
Lower Bowen (at Murrumbidgee)	37%	44%	19%	3.22	3.71	1.60	100%
Bowen + Jar Bowen R (at Murrumbidgee)	30%	43%	25%	1.80	2.62	1.45	70%

Note: Source: Burdekin R. (2010) Water Resources Research

Therefore Bowen ~ 30% of the total input to the GBR

Background

- Understanding of Reef WQ sources has undergone a major rethink in recent years
- The fact that we are now talking about gully erosion as a key source of sediment to the GBR is a major development!



Cost effectiveness?

- Multiple small gullies
= 12.8 t/yr @ \$1,500 = \$192/yr (assuming 100% effectiveness)
Time to achieve reduction ~ 3 people x 1 day per single gully treatment
- Fully gully regrade + soil treatment
= 10000/yr cost \$90,000 (assuming 10% effectiveness) = \$900/yr
Treatment time ~ 2 weeks (incl. maintenance)
Time taken to achieve equivalent result: 20 times longer using first approach @ 4.5 times the cost.



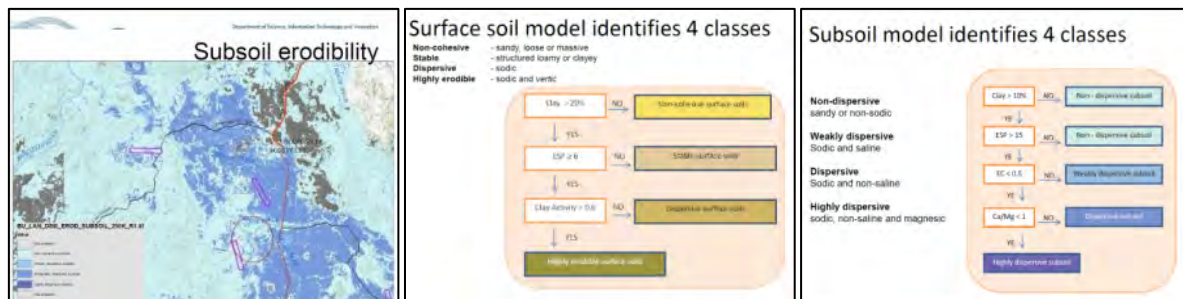

Hugh Pringle described the EMUtm approach (Ecosystem Management Understanding) as applied in Namibia and Western Australia. He focussed on the very great potential benefits, in terms of sediment export reduction and landscape rehydration of numerous low cost low tech interventions.



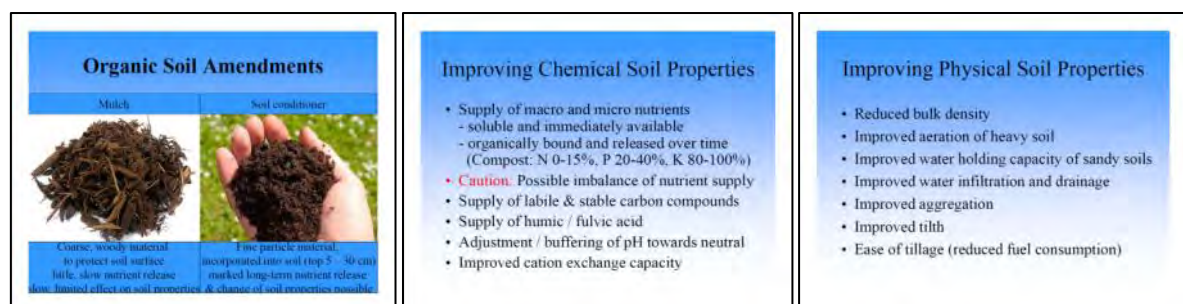
Steve Eccles described gully rehabilitation approaches as they have been implemented by the NSW Soil Conservation Service (and its descendent agencies).



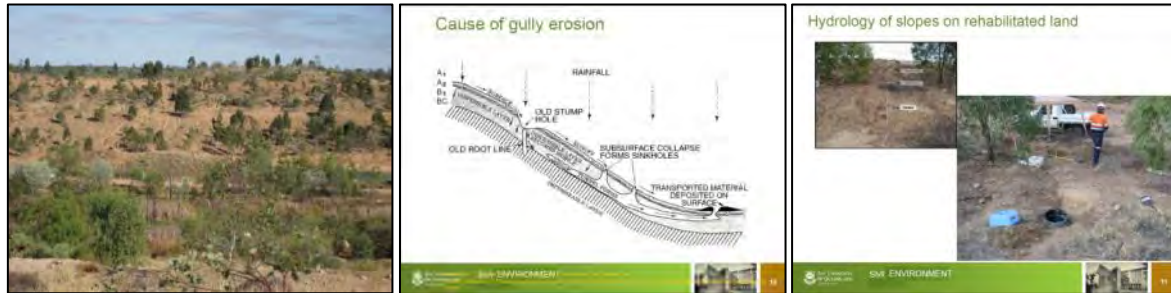
Peter Zund described the soil types of the area as detailed in soil surveys had undertaken in the region. Of primary interest is the domination of sodic subsoils of soils on Mesozoic sediments and thus the Quaternary alluvial sediments with a provenance from those substrates.



Johannes Biala described the production and application of organics to rehabilitated land in southern NSW. He also recommended that the population centres be approached to establish green waste collection services as a means to meet the forthcoming demand for organics in the service of gully rehabilitation.



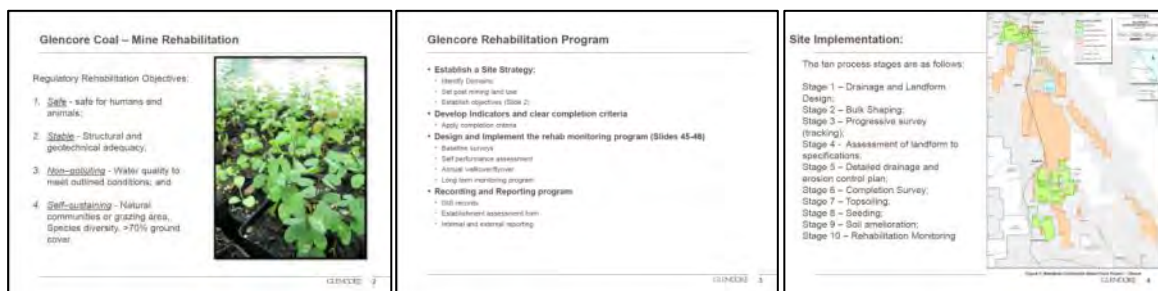
Thomas Baumgartl described the research undertaken at the University of Queensland into causes of Gully erosion. He showed how drones could be used to measure and monitor gully formation processes on treated spoil heaps.



Rob Loch provided examples from a very long career working in rehabilitated lands. He emphasised the availability in many instances of the necessary tools, but described a failure in general by others to apply these appropriately.



Trevor Spedding from Glencore described the approaches adopted in the mining industry to rehabilitate mining related disturbance. Included were examples of landform design and shaping, hard engineering, soil amelioration and the importance of 'topsoiling' and establishing an early vegetative cover for erosion prevention. He also described the utility in some instances of irrigating rehabilitated land.



DAY 2: FIELD EXCURSION TO FOUR SITES

Participants were taken to four differing alluvial gully system sites and introduced to the specific characteristics of each. A site of poorly planned and engineered rehabilitation on a pipeline gully crossing site was also inspected, commented upon, but not included in the gully system research plan. It served as a reminder on how not to go about gully / slope rehabilitation in these alluvial soils.

At each site participants, in four groups, were asked to jot down their responses to the issues/questions asked on the field sheets provided. This was to capture any valuable discussion and group thinking while traversing the gully systems, and inspirational thoughts.

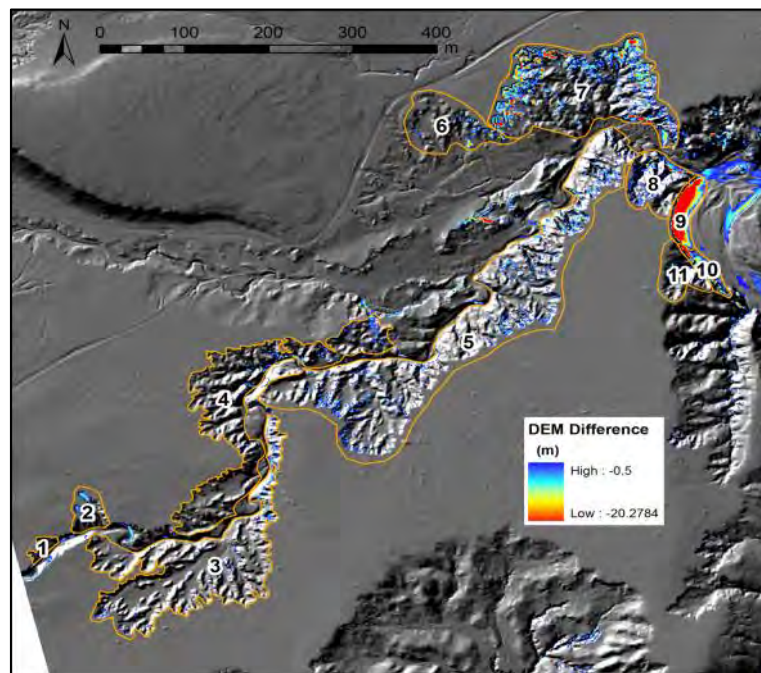


Figure 1: LiDAR-derived hillshade model of Gully System 1, with a first pass (coarse resolution) 'DEM of difference' indicated

Site 1



This site has clear sub-catchments, meaning it has potential to provide for separate trials. The gully is active throughout with a narrow and deep exit point - which in itself will create engineering challenges as it is not immediately clear how to make these canyons stable, for 'laying back the banks' will significantly alter the geometry of the channel. This site will benefit from intensive intervention involving large scale reshaping and multiple nested structures designed to control sediment export, though some research will be required to examine whether these are capable of capturing fine sediment (maybe not an issue for short term if they contribute to the long term stability of the gully).

Different sets of gully systems here in various stages of activity and development.

Bedrock at the base of the system (a rhyolite rock bar) and at exit to the system. Forms a good base for engineering rehabilitation methods / dams, weirs.

Soils are shallow overall (except for the cracking clay patches (back-swamp / slack-water deposits?). The vegetation is insufficient for preventing erosion.

There is still a large potential amount of sediment still to be removed.

Area 1A: The active, cathedral erosion zone:

At this site tunnelling does not seem to be an issue notwithstanding that the subsoils are highly erodible, (as evidenced by fluting). Issues for rehabilitation here include addressing questions of how to consolidate the slope toe, and is this even possible where shallow flows are undercutting very high walls; will concrete be necessary or will vegetation management be effective in some instances. The incorporation of low angle batters (1:10) as likely to be stipulated by any stability analysis, will be difficult as the slopes will then be too long (increased earthmoving costs, danger of cutting back over sub-catchment divide and capturing more flow or joining up other gullies).

Reshape and reform by engineering? Strip topsoil, batter back to over rim (?), gypsum and fertiliser amendments, introduce topsoil, organics, seeding and irrigation.

Area 1B: The broad bedrock-based flats and pillars zone:

This site is comparatively stabilised ('self-healing') suggesting no earthworks required in majority of gully area, conventional gully rehab options best employed include cattle exclusion and channel control. Encourage stabilisation by at least excluding cattle and protecting headwalls from run-on etc. Sediment traps down to main channel. Already showing signs of stabilisation. Need to maintain and enhance the ground cover. Batter back the isolated pillars? Possibly harvest soil in Area 1B to use in rehabilitating Area 1A?

Area 1C: The semi-stabilised linear gully system with active tributaries

This site is at a smaller scale, likely to require less intervention. Overland flow appears to a driver here, hence some clear water diversion may be appropriate. Channel has a rock and cobble bar which may be able to be keyed into with heavier (concrete) structures or drill rods.

Site 2



Very dendritic form with multiple subcatchments.

Complex site of active headwall erosion around rim with dominant tunnel erosion at lower level. Multiple surfaces with active headcutting and nick points. High head / large fall with no bedrock evident at base.

Exit is single narrow gorge channel. Highly efficient flushing?

Solution: re-channel dendritic channels to a few confluence points and control release in steps with sediment traps. Need supply of rock and geofabric.

Batter the headcuts. Exclude stock.

Site 3



This gully had low gradient short slopes, however the presence of severe cracking and obvious subsurface water flows extending from within 2 m of the rim suggests that this site will require significant soil amelioration in addition to modest reshaping. Growth medium will need to be manufactured with gypsum and organics added to the base material, with the spraying of soil stabilisers a likely candidate here. This site could benefit from a sediment dam (capable of retaining the 1 in 10/20 yr event) at the outlet, however significant questions remain as to how efficient this will be in trapping the finest sediment (again, this may not be an issue if long term stability of the gully is achieved) and stability of such a structure in the local soil type.

High risk site! Convex slopes in cracking clays with diffuse / ill-defined headcuts and rounded rim.

Groundwater pressure from behind red chromosol (relict sandier sediments) rim could lead to continued gullying and collapse at seepage/exit point. Cracking at surface leads to further tunnelling and gullying. Needs to be capped and/or reshaped.

Single exit with bedrock evident allows for potential of sediment control dam upstream of the exit (keyed how?) with a controlled spillway onto the bedrock sill.

Site 4



This site had two distinctive landforms, steep bare slopes and tunnelling cracking clays. The size and layout of the site made it suitable for trialling several intervention techniques (possibly 3 systems in 3 subcatchments along with 1 subcatchment left as control), whilst the presence of brigalow excludes the possibility of broadscale reshaping. A lower tech 'EMU' style intervention using temporary sediment and flow control structures is recommended, along with some targeted ripping and amelioration.

Spatially variable. Cracking clays and convex slopes with high, very active headcuts above in relict sandier sediments. Lots of sub-catchments allowing for several concurrent trials.

Use all timber on the site for sediment dam structures (?) which would last for the duration of the project, and track rolling.

Reduce the sub-catchments by lowering the middle relief and simplifying the dendritic channel form?

Batter and shape the upper, active zone of headcuts and gullies. Amend with gypsum and fertilise/organics.

Sediment structures in lower zone to reduce flows and trap sediments (fines trapped though?).

DAY THREE AND SUBSEQUENT COMMUNICATIONS

Research gaps identified include questions around how to identify and put in play trial or demonstration sites and how to incorporate some experimental design (replicates, controls, accounting for variability in gully forms and materials and responses) as well as taking into account visibility and other political or social factors. Furthermore, in the implementation phase we will need some means (and people) to undertake a mapping and classification exercise, along with a set of prioritisation criteria. To do this may require mapping sediment pathways and sinks, “Where does Burdekin sediment make reef-fall”...almost certainly not directly east of the Burdekin. Additionally, some thought will need to be given to the relative distribution of funds between initial program of stabilisation work and ongoing maintenance / management / monitoring.

To undertake the prioritisation there will need to be some sort of decision tree / hierarchical assessment process.

Step 1 will be the development of a priority areas map, based on our understanding of the most efficient (and voluminous) pathways from gully to reef.

Step 2 will be a rapid assessment of gullies in those priority areas, allowing a ranking of gullies in terms of their activity and scale. Of the top ranked gullies there will need to be a further culling based on detailed information obtained through historical measurement, soil material sampling (materials characterisation), and slope stability potential.

Finally, site logistics and potential as scientifically meaningful and politically powerful sites will be assessed. It will be necessary to monitor both research gullies and implementation gullies in order to measure impacts of interventions. Research gullies will need to be monitored to assess the effectiveness of different approaches while implementation gullies need to be monitored to assess how much sediment is being saved, as well as to provide a wider dataset than that available within the research program. Monitoring could involve precisely measuring morphological change as well as innovative tracing techniques that can focus on individual gullies, along with water quality (ssc) measurements in gully and in-stream. Note there is a very tight time-line to get monitoring programs in place as there will be minimal lead time.

Rapid Gully Assessment/Characterisation will require some desktop analysis including examining available LiDAR imagery (of which there is very little in the Bowen or Burdekin catchments), followed by field analysis which must capture upstream and downstream controls and include sampling for materials analysis based on a 3-dimensional stratification of the site. This should enable prioritisation of locations requiring treatment.

Glencore may be interested in sharing the costs of getting a LiDAR plane into the air, but however funded, as a foundational dataset the Bowen River should be flown repeatedly, with research sites, once established, examined repeatedly using ground-based LiDAR. Materials analysis have to assess the potential of topsoil to be created which provide not only a suitable medium for plant growth, but also a substrate with little susceptibility to surface erosion. This should include trials of soil ameliorants including gypsum, biosolids, alternative topsoils, manure and DAP fertilizer, but also possibly redirected waste streams of processed organic waste from Townsville or elsewhere. An important consideration will be the depth of mixing necessary to prevent tunnelling. Logistical considerations include the investigation of large scale sources of organics and their transport, which will by necessity include economic analysis

covering production, transport and application costs. Timing of operations will be critical, as first rains will be the most destructive. Therefore the potential of early irrigation to get cover crop established should be considered. Soil sampling will need to be done to depth (i.e. in region of battering) and include both structural and chemical tests and assessment of the application of ameliorants at different stages of the rehabilitation program. Will need to model backflow (slackwater) levels to incorporate into design.



Failed rock chute, undermined by collapsing dispersive soils.



Slot canyon entrance of gully to channel, note undercut wall on left.



Tunnelling defeating the effectiveness of protective groundcover.

Emails

Steve Eccles

In email correspondence, Steve Eccles sets out the information requirements he sees necessary for designing a gully rehabilitation program:

- Catchment size
- Soil tests to support earthworks and or revegetation
- Terrain map - existing contour map
- Aerial photograph enlargement

Steve describes the necessity of using appropriately sized machinery, fencing off rehabilitated sites and providing ongoing maintenance. He raises the need for capacity building, citing the importance of having experienced operators in the field in addition to an experienced design/investigative team who work closely with the implementation team. Steve poses questions around longevity of soil stabilising polymers and whether the current design manual for structures will be appropriate given the likely rain intensity. Steve goes on to propose a tripartite system of works, with different approaches for different gully components:

A. Slopes requiring battering

1. Undertake soil analysis in the cut and fill areas
2. Look at compaction options on fill or keep fill to a minimum.
3. Additives such as gypsum likely
4. Final slope stability, what can you get away with, this will need to be determined (soil tests will help decide). Maybe place rock at the toe and even place rock and then fill over the top.
5. Try and divert runoff water, even if they are small catchments. Providing it does not cause an issue elsewhere
6. Maybe a membrane on the slaking slopes may to add stability but I have not used it in slaking soils
7. Re vegetation: correct fertilisers a cover crop, plus balanced mixture of grasses and legumes (needs per annual grasses in the mixture.) May need follow up
8. A compost preferably, but at least a form of mulch; (could look at forestry by-products); it will need a form of cover protection and organic additives.
9. Maybe tree and or shrub seeds in the mixture to assist in stabilisation. Need to achieve 70% or more established ground cover.

B. Middle areas

1. Likely requirements would be rock shutters or flumes and rock sediment structures. This would need teams who know what they are doing.
2. Concrete or rock cutoffs and dissipaters. Geofabric needs to be used.
3. You can build banks in the tunnelling soils and some cases you will need to be this. Do not pond the water, build banks on cut, do not run water of fill unless compacted and soil treated. Try and spread the water in the channel and away from the constructed bank.

C. Bottom of the catchment

1. Fortunately these catchments are small and the bottom area is restricted, this provides area to place sediment traps and dissipaters mainly on relatively flat ground.
2. For longevity and stability rock and associated geofabric could be used but I think there are areas to experiment in this field

Rob Loch

Rob raised the need for capacity building, in that he saw it necessary that developing designs for each rehabilitation project would require small teams of very experienced soils/rehab people to ruminate upon the details of each individual site. Rob express his concern that it will take some time to develop a sufficiently comprehensive decision support system.

REFERENCES

- Bainbridge, Z. T., Lewis, S. E., Smithers, S. G., Kuhnert, P. M., Henderson, B. L., & Brodie, J. E. (2014). Fine-suspended sediment and water budgets for a large, seasonally dry tropical catchment: Burdekin River catchment, Queensland, Australia. *Water Resources Research*, 50(11), 9067-9087.
- Brooks, A.P., Shellberg, J.G., Knight, J., Spencer, J. (2009) Alluvial gully erosion across the Mitchell fluvial megafan, Queensland Australia. *Earth Surface Processes and Landforms*, 34, pp. 1951– 1969.
- Brooks, A.P., Spencer, J., Olley, J., Pietsch, T., Borombovits, D., Curwen, G., Shellberg, J., Howley, C., Gleeson, A., Simon, A., Bankhead, N., Klimetz, D., Eslami-Endargoli, L., Bourgeault, A., (2013) An Empirically-based Sediment Budget for the Normanby Basin: Sediment Sources, Sinks, and Drivers on the Cape York Savannah. Griffith University, 506pp. <https://www.researchgate.net/publication/258337838>
- Brooks, A.P., Curwen, G., Spencer, J., 2015. A Framework for Prioritising Gully Management in the Normanby Basin Cape York. A report to South Cape York Catchments for the Cape York Water Quality Improvement Plan by the Australian Rivers Institute, Griffith University, 28 pp. <http://maps.capeyorknrm.com.au/sites/default/files/downloads/Appendix%20%20Gully%20Prioritisation.pdf>
- Brooks, A., Spencer, J., Curwen, G., Shellberg, J., Garzon-Garcia, A., Burton, J. & Iwashita, F. (2016) Reducing sediment sources to the Reef: Managing alluvial gully erosion. Report to the National Environmental Science Programme. Reef and Rainforest Research Centre Limited, Cairns (375pp.).
- Olley, J., Brooks, A., Spencer, J., Pietsch, T. and Borombovits, D., 2013. Subsoil erosion dominates the supply of fine sediment to rivers draining into Princess Charlotte Bay, Australia. *Journal of Environmental Radioactivity*, 124(0): 121-129, <http://dx.doi.org/10.1016/j.jenvrad.2013.04.010>.
- Wilkinson, S.N., Hancock, G.J., Bartley, R., Hawdon, A.A. and Keen, R., 2013. Using sediment tracing to assess processes and spatial patterns of erosion in grazed rangelands, Burdekin River basin, Queensland, Australia. *Agriculture, Ecosystems and Environment*, 180: 90-102, DOI: 10.1016/j.agee.2012.02.002



National Environmental Science Programme

The challenge of managing gully sediment sources to significantly improve GBR water quality in the next 10 years



Why are we here?

- Share experience
- Reach a common understanding of the problem
- Devise approach to underpin a major gully sediment reduction programme in the Bowen catchment

Why the Bowen?

Burdekin estimated to contribute ~ 47% of the total fine sediment load to the GBR

Burdekin Sediment Budget 2005-2009	load % breakdown by particle size				av loads (Mt/yr: 2005-2009)				% of total at outlet
	clay	silt	sand	total	clay	silt	sand	total	
Burdekin R (below dam)	52%	41%	6%	100%	1.32	1.05	0.15	2.52	30%
Bowen R (@ Myuna)	27%	49%	24%	100%	1.02	1.84	0.90	3.76	45%
Lower Bowen/Burdekin ungauged tribs include: Oakly Ck, Pelican Ck, Lower Bowen R; Bogie R)	36%	38%	25%	100%	0.79	0.83	0.55	2.16	26%
Lower Burdekin @ Inkerman (catchment outlet)	37%	44%	19%	100%	3.12	3.71	1.60	8.44	100%
Bowen + Lwr Bowen & tribs +BogieR	30%	45%	25%	100%	1.80	2.67	1.45	5.92	70%
% of total at outlet					58%	72%	91%	70%	

Data source: Bainbridge et al., (2014) Water Resources Research

Therefore Bowen ~ 30% of the total input to the GBR

The challenge

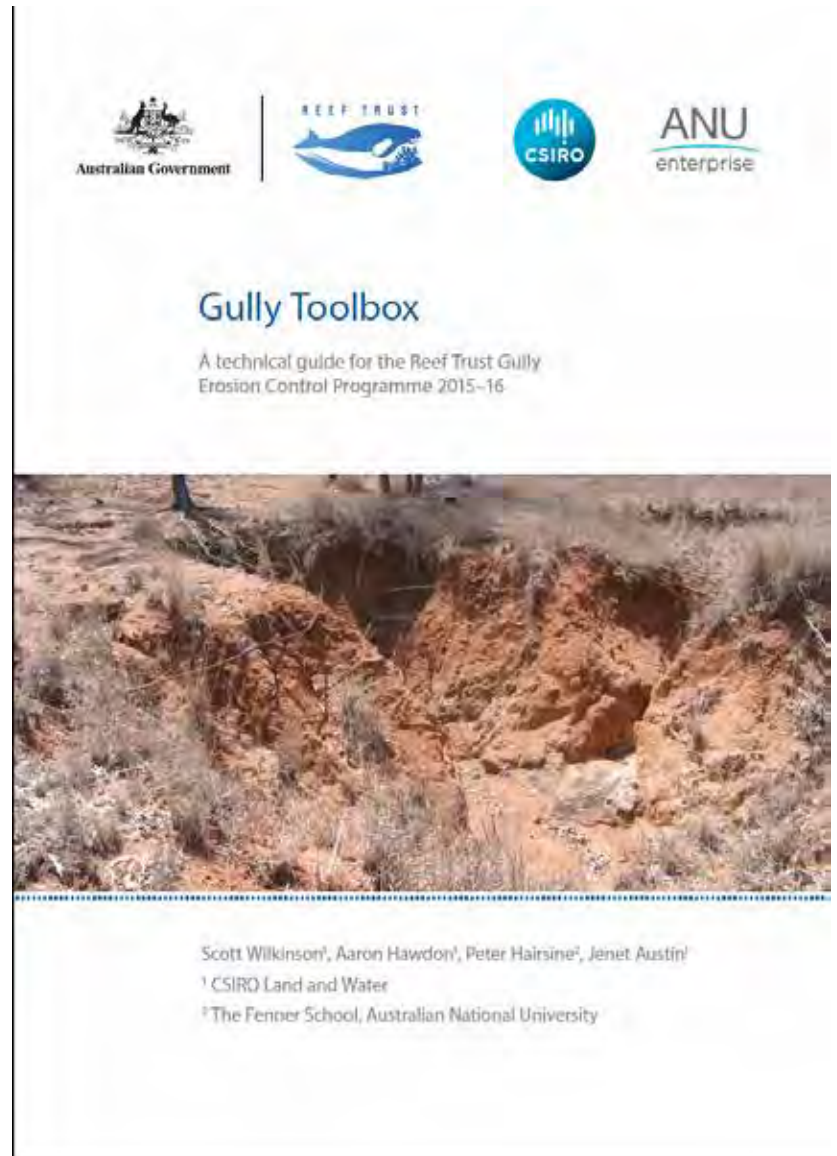
- Estimates are the current sediment load in the Bowen is “accelerated” somewhere between 5 – 10 fold above pre-European rates (doesn’t really matter)
- Key objective of Reef Plan to reduce sediment loads by ~~upto~~ 50% in next decade
- **Therefore we need to reduce total inputs by 3Mt/yr in the quickest and cheapest way possible**
- **THIS IS OUR CHALLENGE**

Key Workshop Outcomes

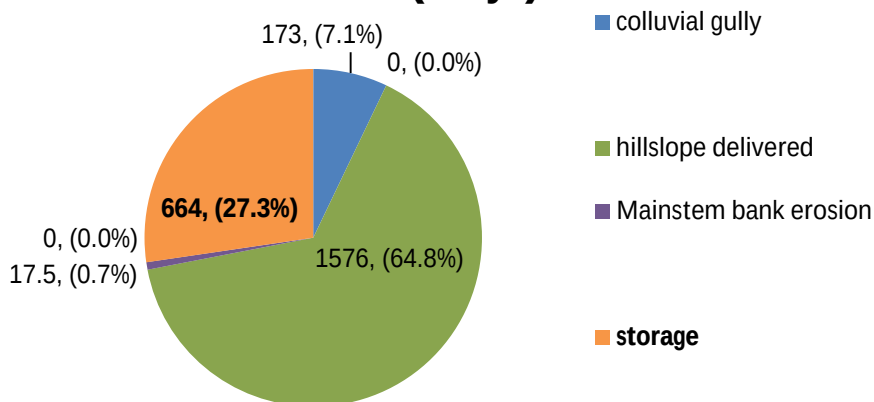
- Agreement on requirements to precede implementation of large-scale gully rehab programme – e.g.
 - High resolution gully mapping
 - Gully typology (form, rate of activity, sedimentological controls on gully form etc.)
 - Major Research gaps
 - Short list of appropriate gully rehab strategies for major gully types
 - Short list of demonstration trial treatments

Background

- Understanding of Reef WQ sources has undergone a major rethink in recent years
- The fact that we are now talking about gully erosion as a key source of sediment to the GBR is a major development!

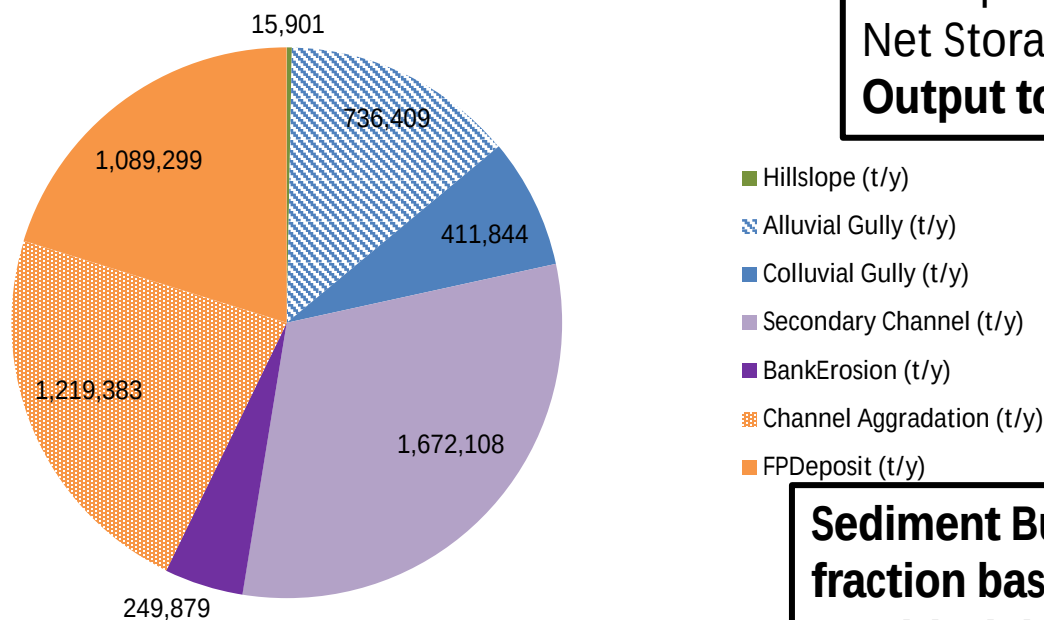


Previous Normanby SedNet Budget (Kt/yr)



Net input = 1767 Kt/yr
 Net Storage = 664 Kt/yr
Output to GBR = 1102 Kt/yr

GU Empirical Sediment Budget (2013)



Net input = 3086 Kt/yr
 Net Storage = 2308 Kt/yr
Output to GBR = 777 Kt/yr

Sediment Budget for <63um fraction based on extensive empirical data

Current thinking

CSIRO Gully Toolbox

- Rather than focusing investment on intensive management such as reshaping gullies at a few sites, a larger impact on catchment sediment loads can be achieved by investing in fencing to protect gullied and vulnerable areas from grazing at many sites, installing low cost porous check dams to assist vegetation recovery in the gully channel, and revegetating gullied areas. These are low-cost measures which can be applied across large areas. (gully toolbox p.7)

Reef Trust Gully Toolbox

Table 1. Relative effectiveness of gully erosion control activities at reducing sediment yield from the gully head, wall and channel, addressing the 3 principles in Figure 2. Greater effectiveness is indicated by more ticks. Individual treatments with relatively higher unit costs are indicated by more \$. Order 1 activities should be applied at all sites, Order 2 activities are applied only when relevant Order 1 activities are also applied. Any order 3 activities require relevant Order 1 and 2 activities. The control activities are described in detail in Section 3.

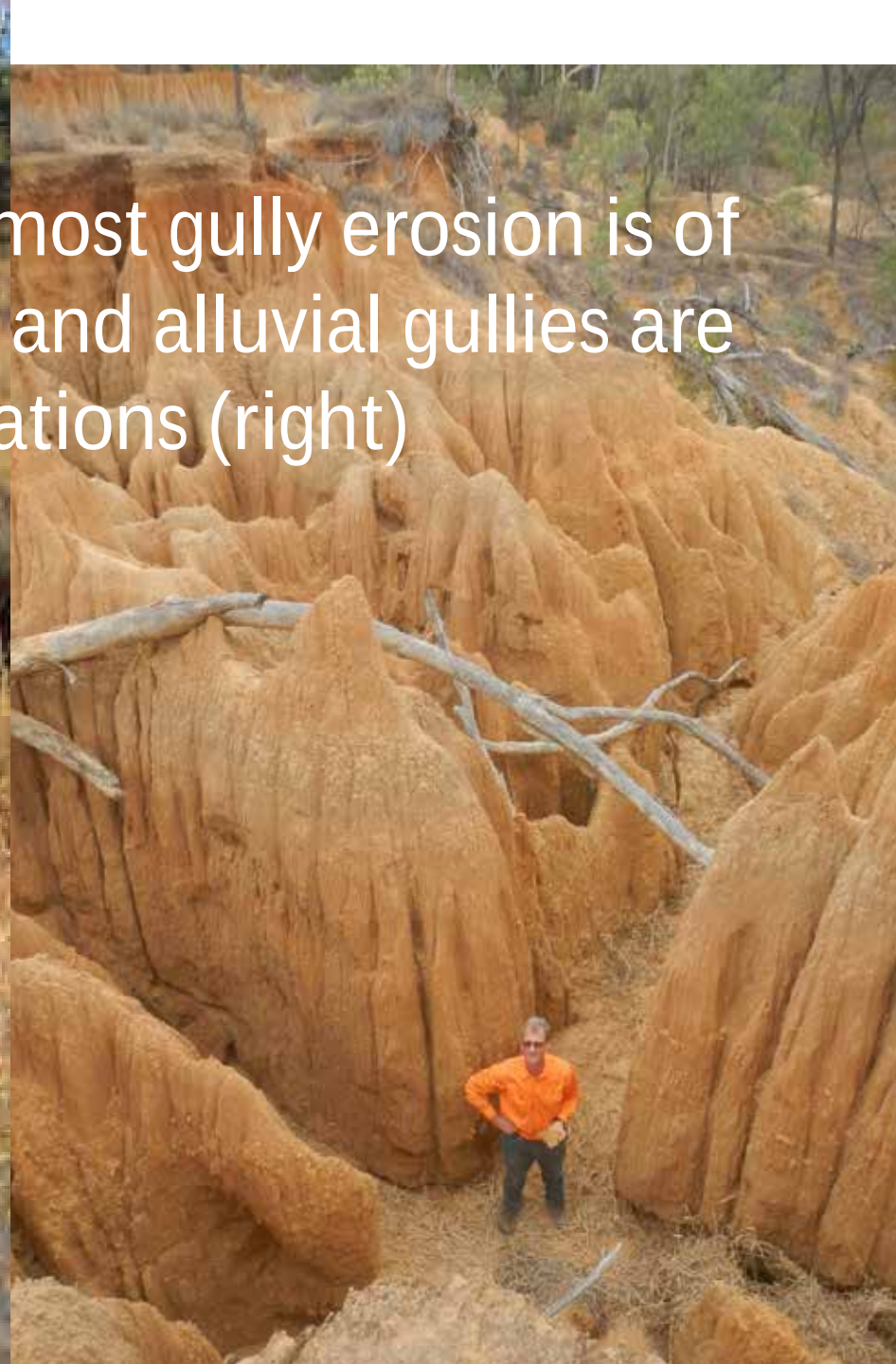
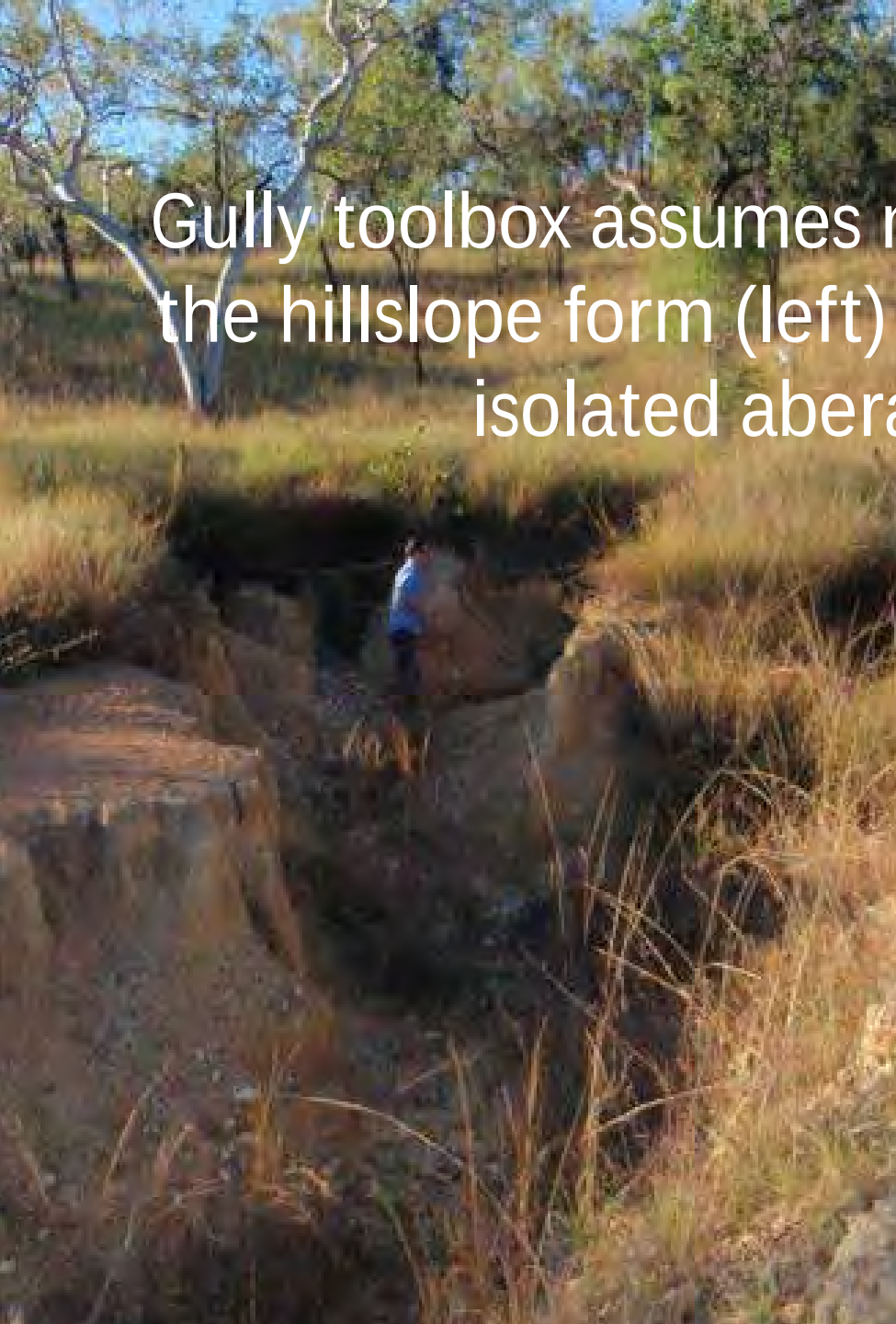
Control activity	Head	Wall	Channel	Cost	Order
Fence around gully and control stock access		✓	✓	\$	1
Porous check-dams and fence		✓	✓✓	\$\$	2
Revegetate gully and fence		✓✓	✓	\$\$	2
Engineered grade control structures and fence		✓	✓✓	\$\$\$\$	3
Low forage utilisation in gully catchment ^A	✓✓			n/a	1
Retain native woody vegetation in gully catchment	✓✓			n/a	1
Fire management to retain species composition ^A	✓			n/a	1
Off-stream water point to reduce grazing pressure at gully ^A	✓			\$\$\$	2
Manage road and fence line drainage and fence ^A	✓✓			\$\$\$	2
Runoff diversion bank or contour ripping and fence	✓✓			\$\$\$	2
Gully head drop structure	✓✓✓			\$\$\$\$	3
Reshape, revegetation	✓✓✓			\$\$\$\$	3

^A Cost assumes co-investment

Assumptions underpinning gully toolbox

- Treats gully erosion as a farm management problem
- Assumes it is a direct response to *current* grazing pressure and that reducing grazing pressure will reverse the problem
- Assumes lots of small scale treatments will add up to a large effect
- Assumes the bulk of sediment is delivered from multiple small gullies and not a smaller number of large gully complexes

Gully toolbox assumes most gully erosion is of the hillslope form (left) and alluvial gullies are isolated aberrations (right)



Gully Management to date in the GBR

- To date the focus in catchments like the Burdekin has been on small scale management of relatively inactive hillslope gullies
- To date the major problem associated with alluvial gullies has yet to be addressed



Researchers in the Burdekin implementing gully rehabilitation trials in a hillslope gully

Cost effectiveness?

1. Multiple small gullies

– (2.8 t/yr @ \$1,500 = \$540/t)

(assuming 100% effectiveness)

Time to achieve reduction - 3 people x 1 day per single gully treatment

2. Fully gully regrade + soil treatment

– 1000t/yr cost \$90,000

(assuming 75% effectiveness)

= \$120/t

Treatment time ~ 2 weeks (incl. maintenance)

Time taken to achieve equivalent result-
20 times longer using first approach @ 4.5
times the cost.



Way forward

- Need much greater focus on major point-source large gully complexes
- More akin to mine-site rehabilitation than a farm management problem
- Need to demonstrate how the rehabilitation of large active gullies can be achieved
- THIS IS WHY WE ARE HERE

- Current GBR-wide gully mapping totally inadequate for telling us what the relative contributions from different gullies are.
- Need to map and prioritise the gullies within the hotspot areas (such as the lower Bowen)

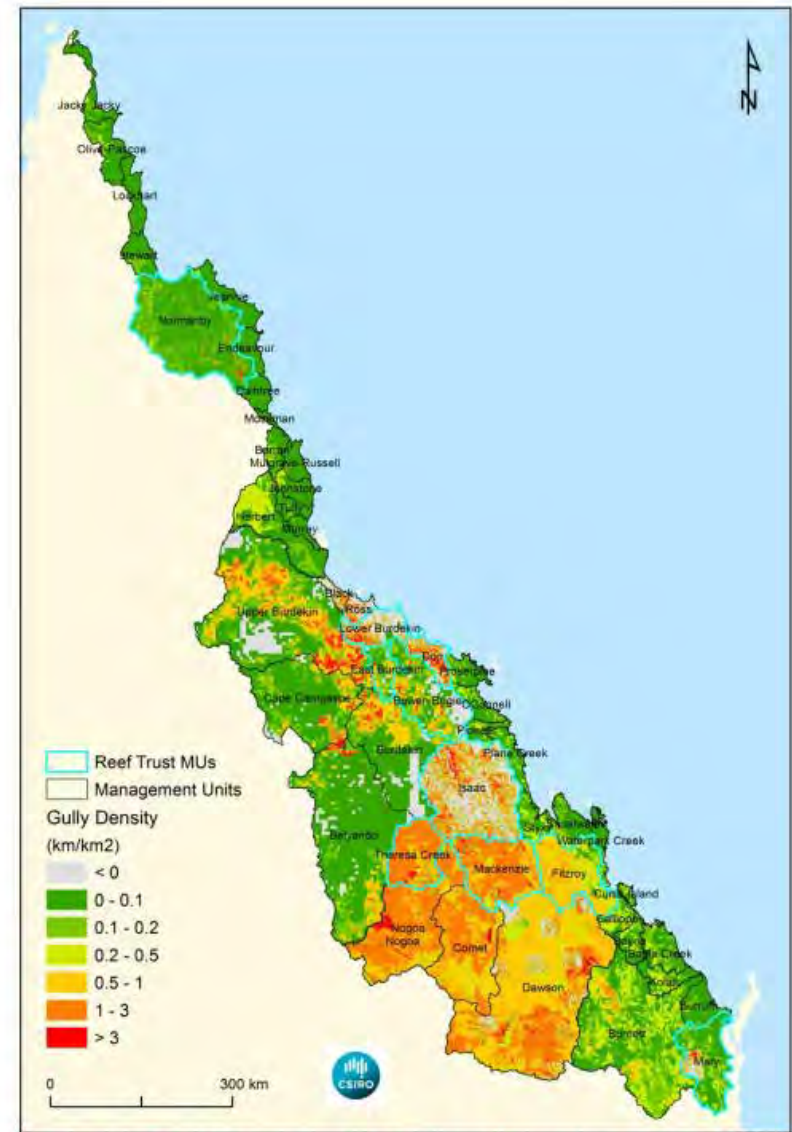
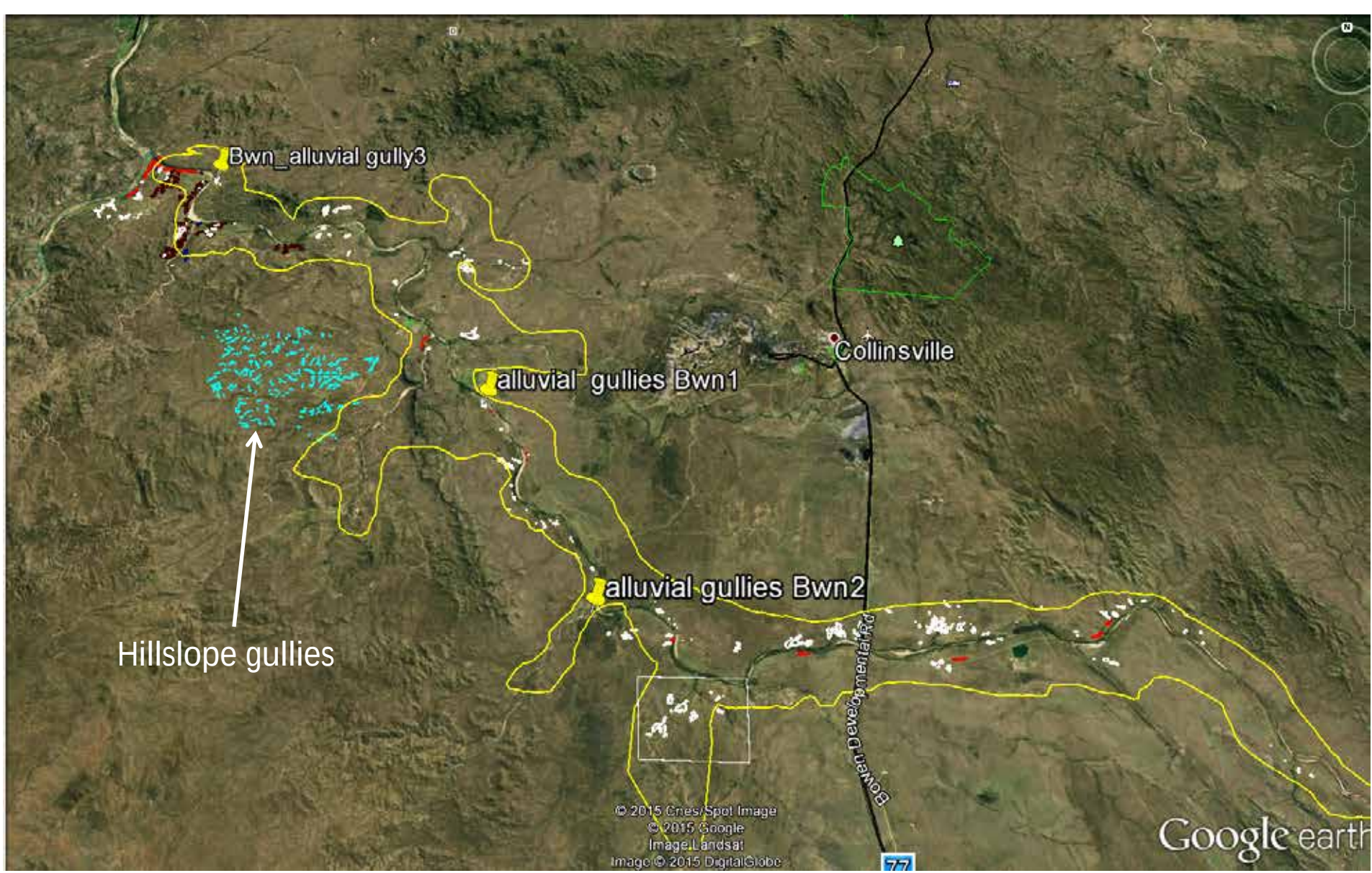
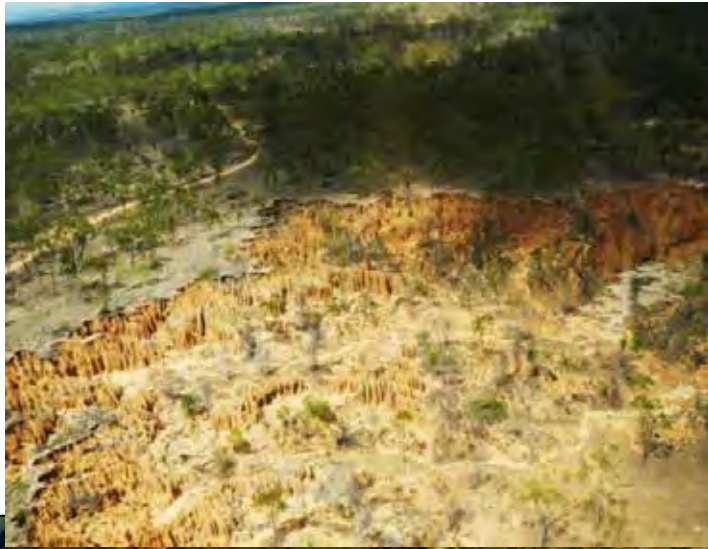


Figure 3 The density of gullies for catchments draining to the GBR lagoon. Catchment management units are labelled and outlined in black. The ten management units in the Reef Trust Gully Erosion Control Programme are outlined in blue. Variation is evident between management units in the methods for mapping gully density, and this mapping is not used to allocate funds between management units. The gully density data sources in each unit are: Normanby (Brooks *et al.*, 2013); Bowen/Bogie and East Burdekin (Tindall *et al.*, 2014) © Copyright The State of Queensland, Lower Burdekin, Don, Isaac and Mary (Darr *et al.*, © Copyright DNRN unpublished data), Theresa Creek, Mackenzie, Fitzroy (Trevithick *et al.*, 2009) © Copyright The State of Queensland, remaining units (Hughes *et al.*, 2001; NLWRA, 2001). In some management units data were converted from original mapping units to km/km² based on estimated gully widths. Please note: spatial data can be downloaded from the website.

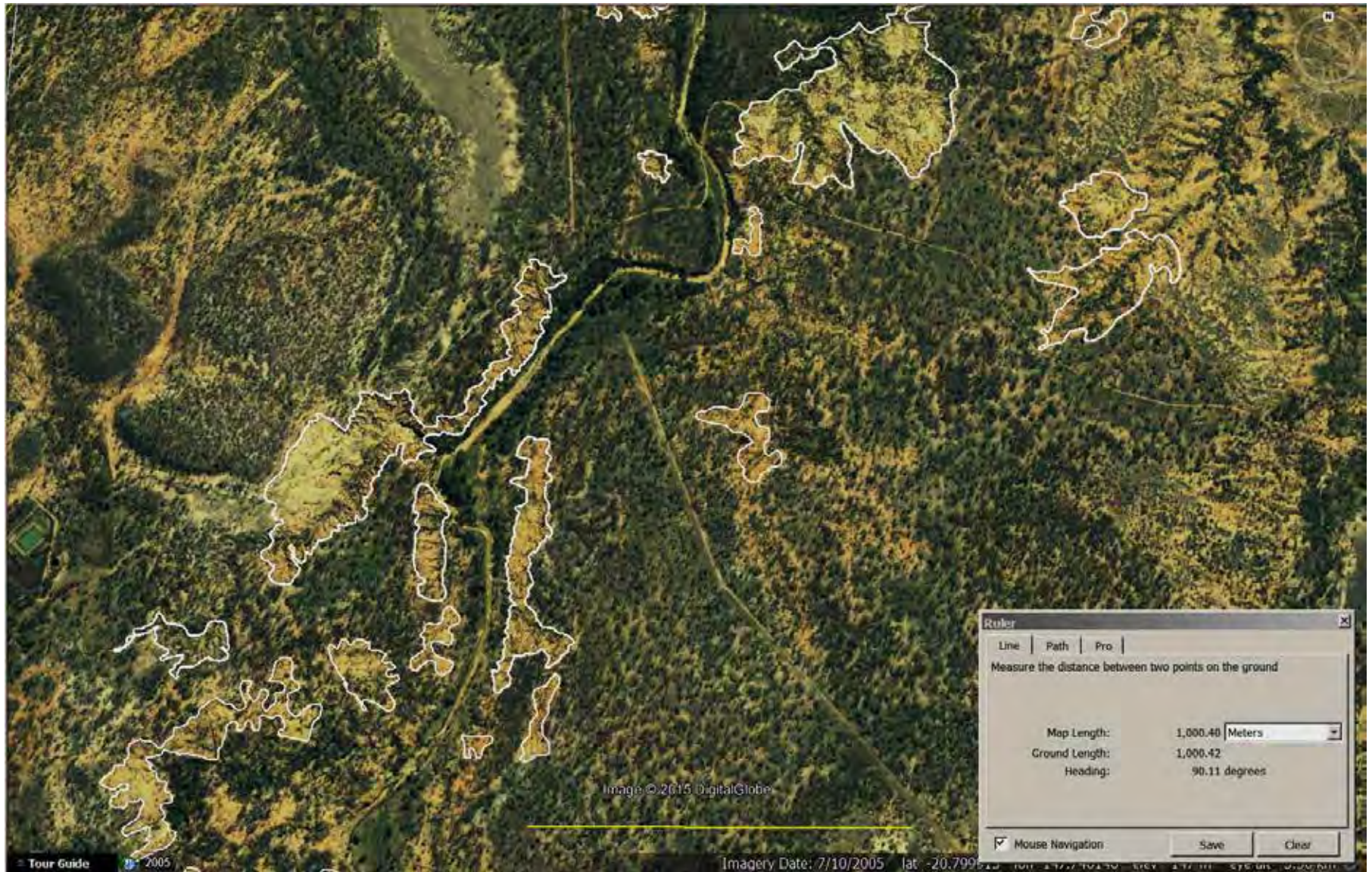
What are the sediment and nutrient contributions from alluvial gullies in the Bowen?



Alluvial Gullies in the Bowen R



Highly concentrated area of large alluvial gullies along Parrot Creek



Note yellow scale bar is 1km – mapped gullies in this image range in size from a ~1 to 30 ha

Highly Active Alluvial Gullies in the Bowen Catchment



Management of these
Sources more akin to
Mine rehab

Hence - working with
Mining companies in
Bowen



Normanby Intensive Active Gully Rehabilitation Trials

Before: Nov 2011

After: Dec 2011



Bushnell

11-30-2011 08:00:57



Bushnell

12-01-2011 15:28:38



Bushnell

12-20-2011 11:00:07



Bushnell

12-11-2011 11:00:02

7 Erosion Control Treatment Plots

(7m x 30m x 10% Slope)

1. No Treatment
2. Gypsum, Compost, Native Grass
3. Gypsum, Compost, Exotic Grass
4. Gypsum, Hydromulch, Exotic Grass
5. Gypsum Only
6. Compost, Native Grass
7. Straw, Exotic Grass

1) Reduce Water Runoff Into Gullies

2) Stabilize Gully Head

3) Reduce Slope of Gully Channel



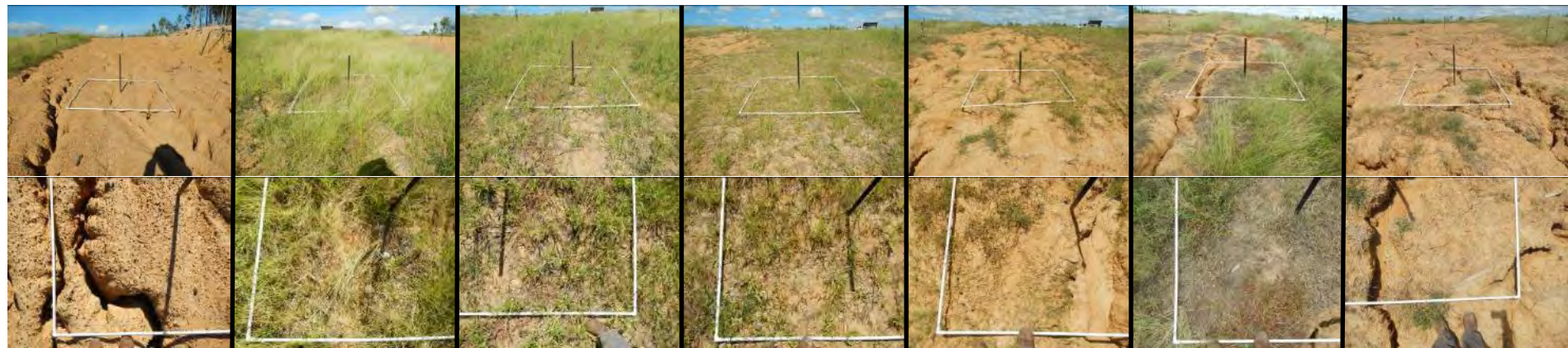
Vegetation Changes.....

After Two (2) Wet Seasons

1) Reduce Water Runoff Into Gullies

2) Stabilize Gully Head

3) Reduce Slope of Gully Channel



1
Control
No Treatment

2
Gypsum
Compost
Native Grass

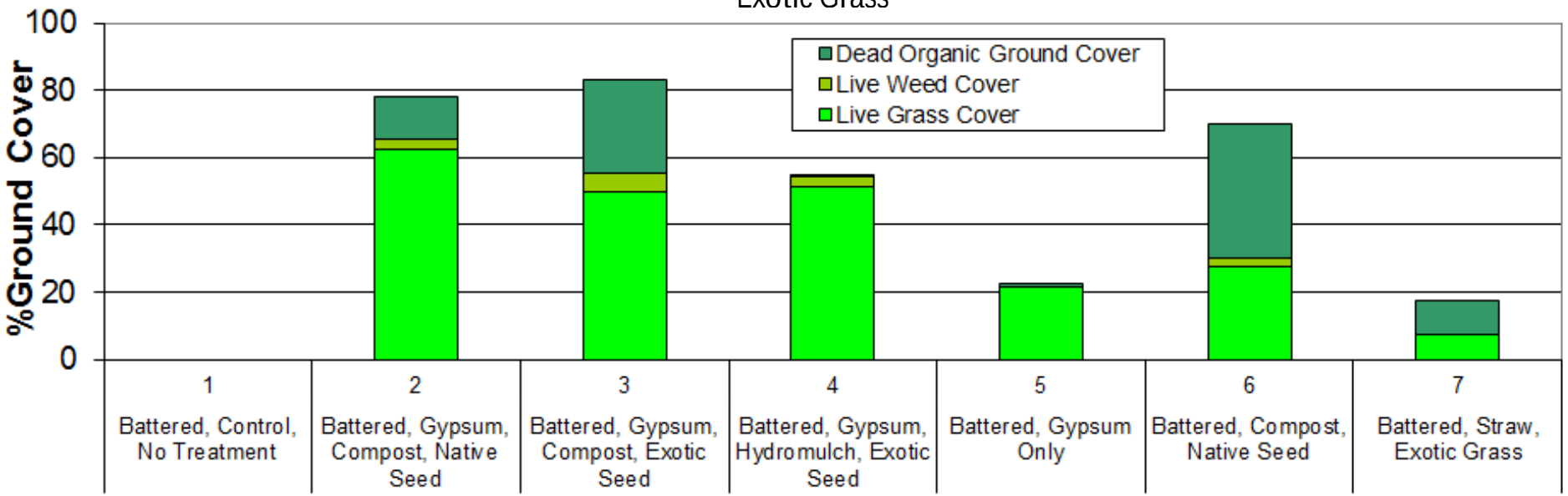
3
Gypsum
Compost
Exotic Grass

4
Gypsum
Hydromulch
Fertilizer
Exotic Grass

5
Gypsum
Only

6
Compost
Native Grass

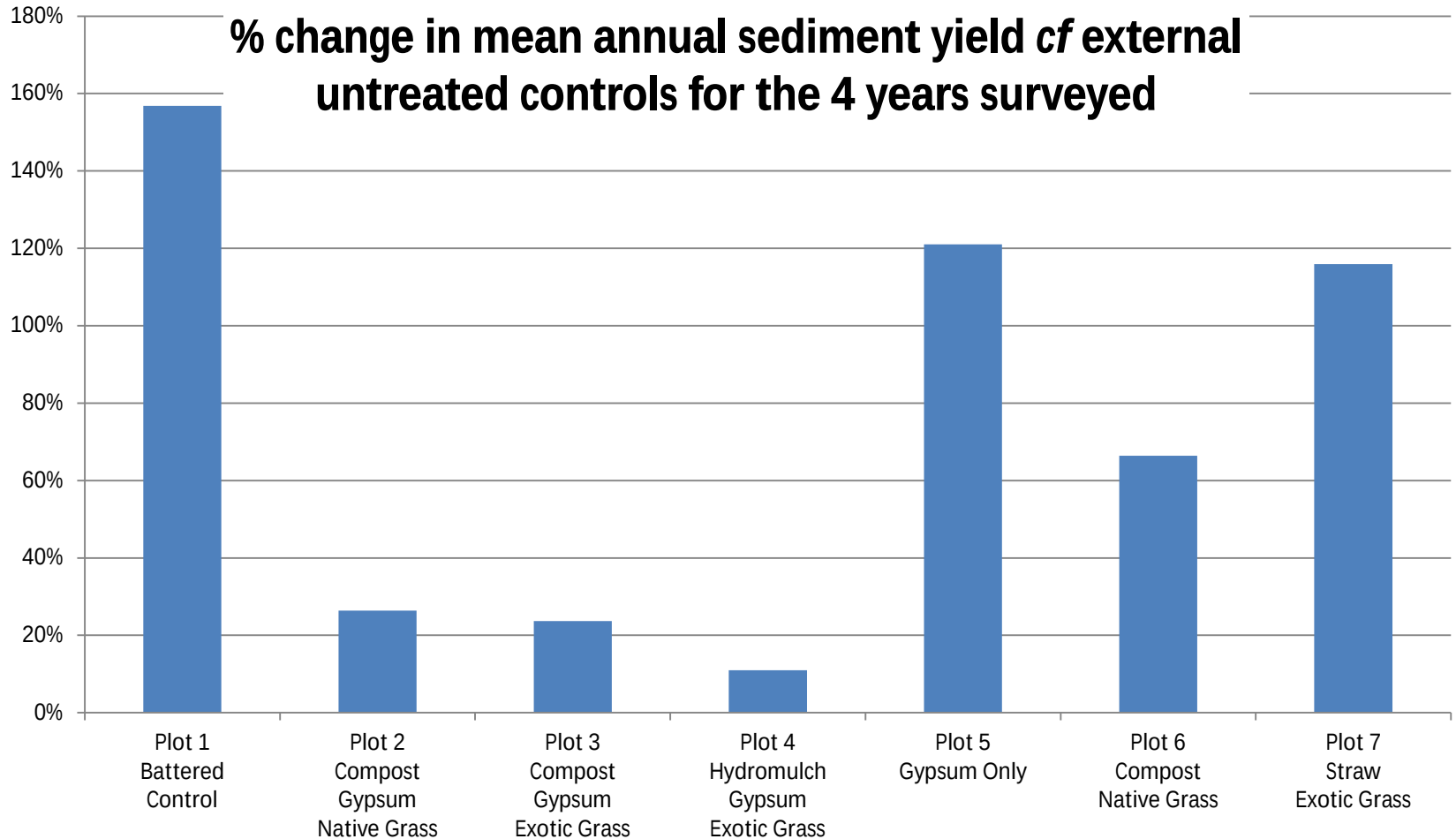
7
Straw
Exotic Grass



Crocodile Station Site April 2016



Summary of Sediment yields after 4 years



Gullies = major nutrient source as well as sediment source

Gully/land use	sediment (t/ha/y)	TN (kg/ha/y)	TP (kg/ha/y)
Granite Normanby	114.0	54.0	23.7
Laura - Crocodile station	29.2	10.5	0.3
Laura - Crocodile Gap	28.8	12.6	1.6
Sugar cane	1.2	22.2	2.7
Banana	1.8	25.3	3.1
Nature conservation	0.2	3.6	0.3

- Normanby has ~ 10,000 ha of gullies (could be > 1/3 of catchment N from 0.4% of catchment)

Programme overview

2.35 pm	Overview of NESP Programme		Prof Damien Burrows – TropWater JCU
2.45 pm	Bowen River Soils	Setting the scene of the soils in the region	Peter Zund, DSITI
3.10 pm	Introduction & experience with Mine rehab in Bowen area		Adam Heap/Trevor Spedding Glencore
3.30 pm	Lessons from mine site rehabilitation to gully and large scale degraded land rehabilitation		Thomas Baumgart CMLR - UQ
3.50 pm	Experience with rehabilitating degraded arid, semi-arid and savannah landscapes in Australia and Namibia		Hugh Pringle – EMU Edith Cowen Uni & Namibian University of Science and Technology
4.10 pm	Tea Break		
4.20 pm	Experience and approaches to managing sodic soils		Rob Loch - LandLoch
4.30pm	Experience and approaches to managing sodic soils in NSW		Steve Eccles ex NSW Soil Con
5.00 pm	The application of compost in degraded land restoration		Johannes Biala - QUT
5.20 pm	Don Catchment Gully rehab strategy		Ross Andrewartha Greening Australia
5.40 pm	Field trip overview for Tues	Field Trip details and plans	Robin Thwaites/Andrew Brooks/Tim Pietsch

• Tuesday - Field Trip August 9th 2016

07.15 am assemble at Morris Village

Wednesday 10 August 2016	Pit Pony Tavern		
Collinsville venue			
7.45 am – 8.00 am	Introduction to the day	Intentions and intended outcomes. Summary of Day 1 outcomes.	Andrew Brooks / Robin Thwaites
8.00 -8.55 am	Group discussion	Priority issues to form workshop topics for the day	Andrew Brooks, Robin Thwaites
9.00 – 10 am	Individual discussion and workshop groups	Butcher's Paper extravaganza	4 – 5 groups
10.00 – 10.15 am	Morning tea		
10.15 – 11.30 am	Group discussion	Butcher's Paper extravaganza The way forward. Solutions and methods.	Andrew Brooks, Robin Thwaites
11.30 am – 12.00 pm		Results and summary of groups work & summation	Andrew Brooks
12.00 – 12.30 close	Lunch		
Head back to TSV for 16:50 flights			



Australian Government



National
**Environmental
Science**
Programme

For more information please contact:

?????? ??????? ???????



Community empowered rehydration of arid and semi-arid drainage ecosystems in Australia and Namibia

Adjunct Prof. Dr Hugh Pringle

**Ecosystem Management Understanding
(EMU)TM**

**Namibian University of Science and
Technology**

Edith Cowan University



Gully Erosion Workshop, Colinsville Qld 8-10 August 2016

Acknowledgements

Please do not use or circulate any photographs in this presentation without Hugh Pringle's written permission.

You are welcome to use any diagrams as long as they are acknowledged clearly;

“Ken Tinley, EMU™”

Presentation structure

- Brief overview of Ecosystem Management

Understanding (EMU)TM

- Some examples from Namibia and Australia of
drainage ecosystem rehydration

The EMU™ Approach

- Ken Tinley DSc and Hugh Pringle PhD
- Holistic drainage ecosystem approach
- Capacity and redundancy building with stakeholders
- A hierarchy of salience

Re-covering the Red using local knowledge



E.M.U. *Ecosystem
Management
Understanding*

www.emuproject.org

1. Using local knowledge to solve local problems and seize local opportunities
2. Mixing local knowledge with scientific knowledge to produce a creative partnership
3. Focusing attention and resources on what really matters
4. Improving carrying capacity for livestock and wildlife together
5. Demonstrating ecological skill and environmental responsibility (+/- certification)

Key stages in Ecosystem Management Understanding (EMU)TM

*Ecosystem Management Understanding
(EMU)TM*

1: Initial meeting

Explore landholders key issues and goals, management history etc.
Reaffirm *complete confidentiality*

2: Overlay mapping exercise

Build the ecological baseline of the property using the landholders knowledge
Identify the key issue areas and most important interactions and drivers of change

3: Aerial survey of key issues and areas mapped

An aerial traverse route is planned together based on assessment of the landholders mapped knowledge
Digital photos are taken of key issues during the flight

4: Flight debrief and plan ground inspections

What did we see, map the key issues we saw and consider them in context of the initial mapping...what do we think is going on? Use photos from flight on a TV
Visit key areas on the ground to check interpretations and assessments

5: Major review: Reassess and identify (map) management priority areas

i) Where is the most important country in need of some strategic intervention? Identify them on an overlay with simple dot points to capture just what really matters and what we think needs to be done
ii) Consider if additional expertise is needed to build a few key projects based on mapped priority areas
iii) Is existing monitoring telling you what you really want to know where you want to know it? Make a plan to fill the gaps of what you really want to do

A: Build priority project proposals

Seek external funding if required

B: Implement project(s)

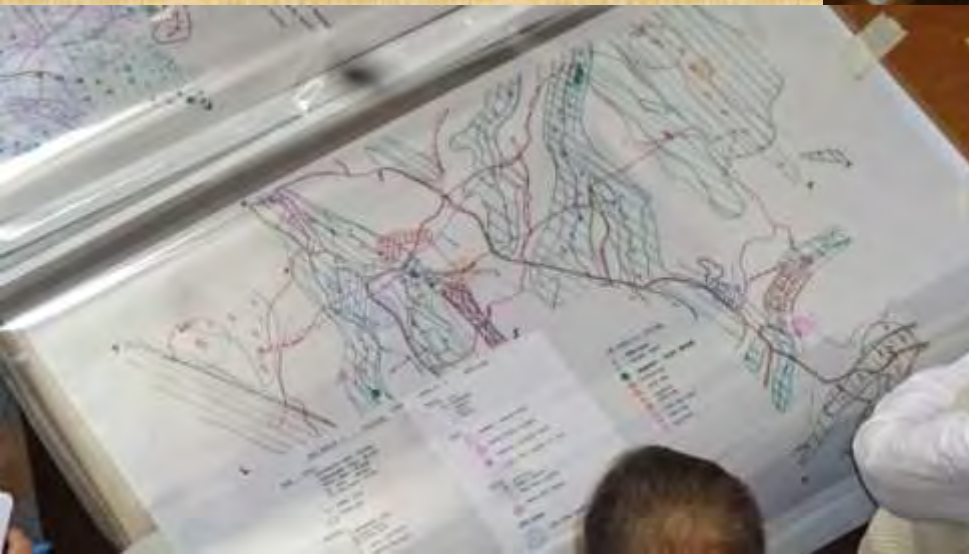
Establish baseline monitoring BEFORE starting works that will assess if it "worked"

6: Install property-wide monitoring system

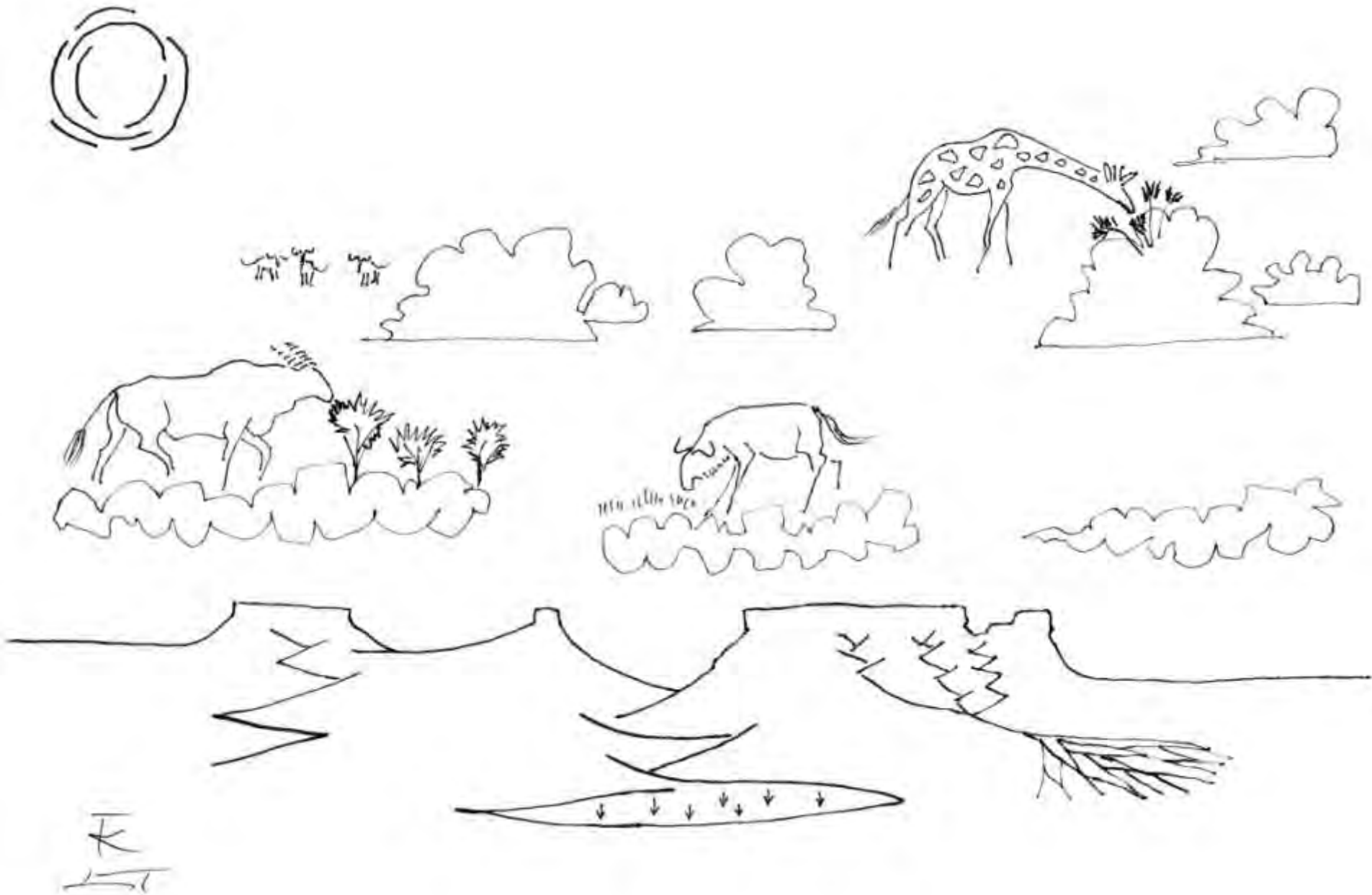
Your "intelligence" system of what matters and where based on mapped management priorities. YOUR "finger on the pulse" system of feedback information.

REVIEW, REVISE and REFINE

Ongoing learning by doing
Map major observations and revelations on a new overlay left out on a small table for this purpose
Revisit the visual "plan" at least annually to assess room for improvement or the need for changes



Geomorphic and edaphic form, function and trend ignored



Stepped longitudinal river profile (eg. Murchison River):
rock bars with rapids (riffle & pool sequences) - secondary base levels.

ideal graded longitudinal river profile of equilibrium

sea level (primary base level)

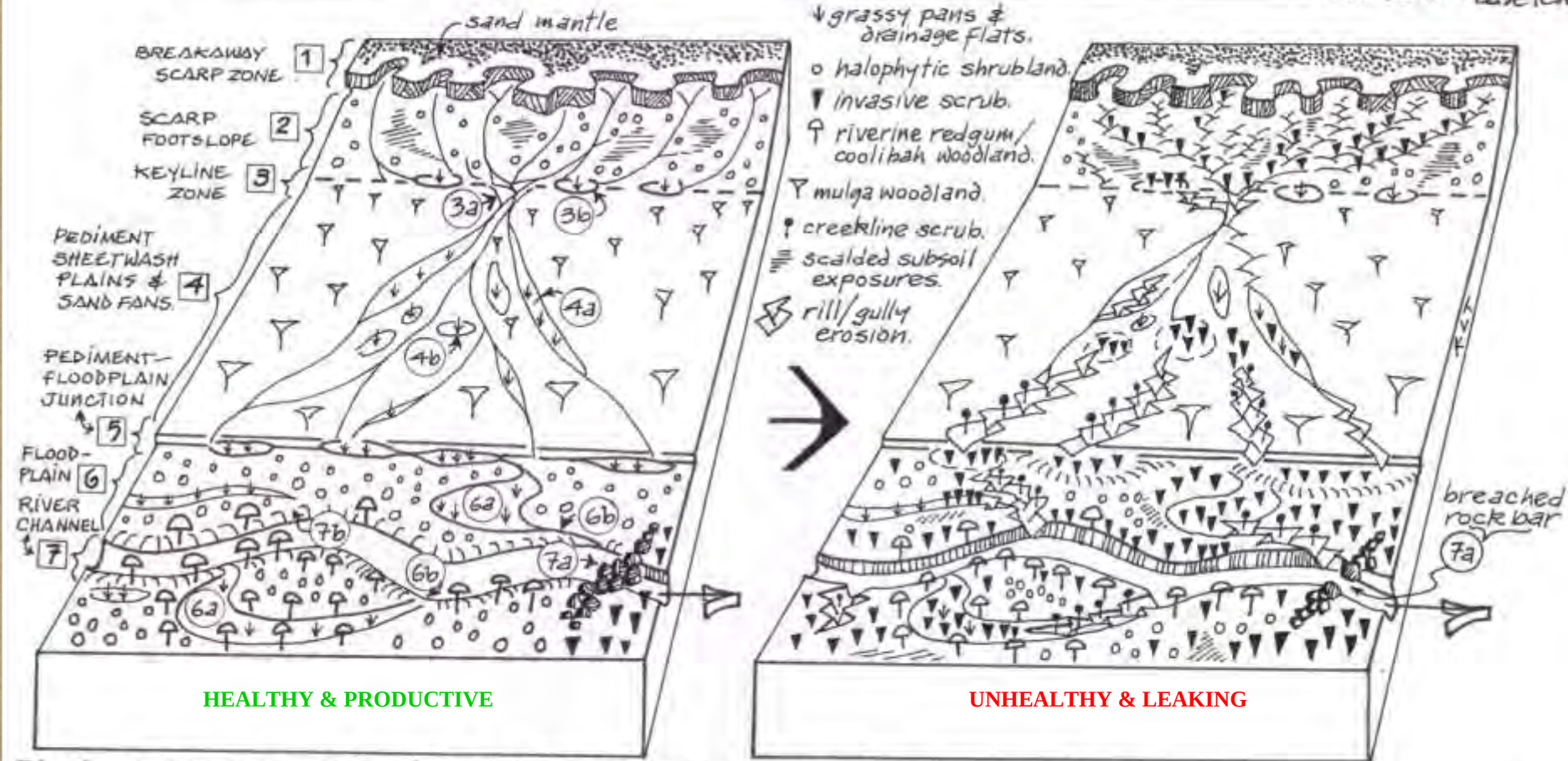


Fig 1. SEGMENT OF MAJOR RIVER & ITS FLOODPLAIN WITH ADJOINING VALLEY-SIDE CATCHMENT.

① landscape in dynamic equilibrium (minimal erosion).

② same landscape in active, erosion driven transformation.

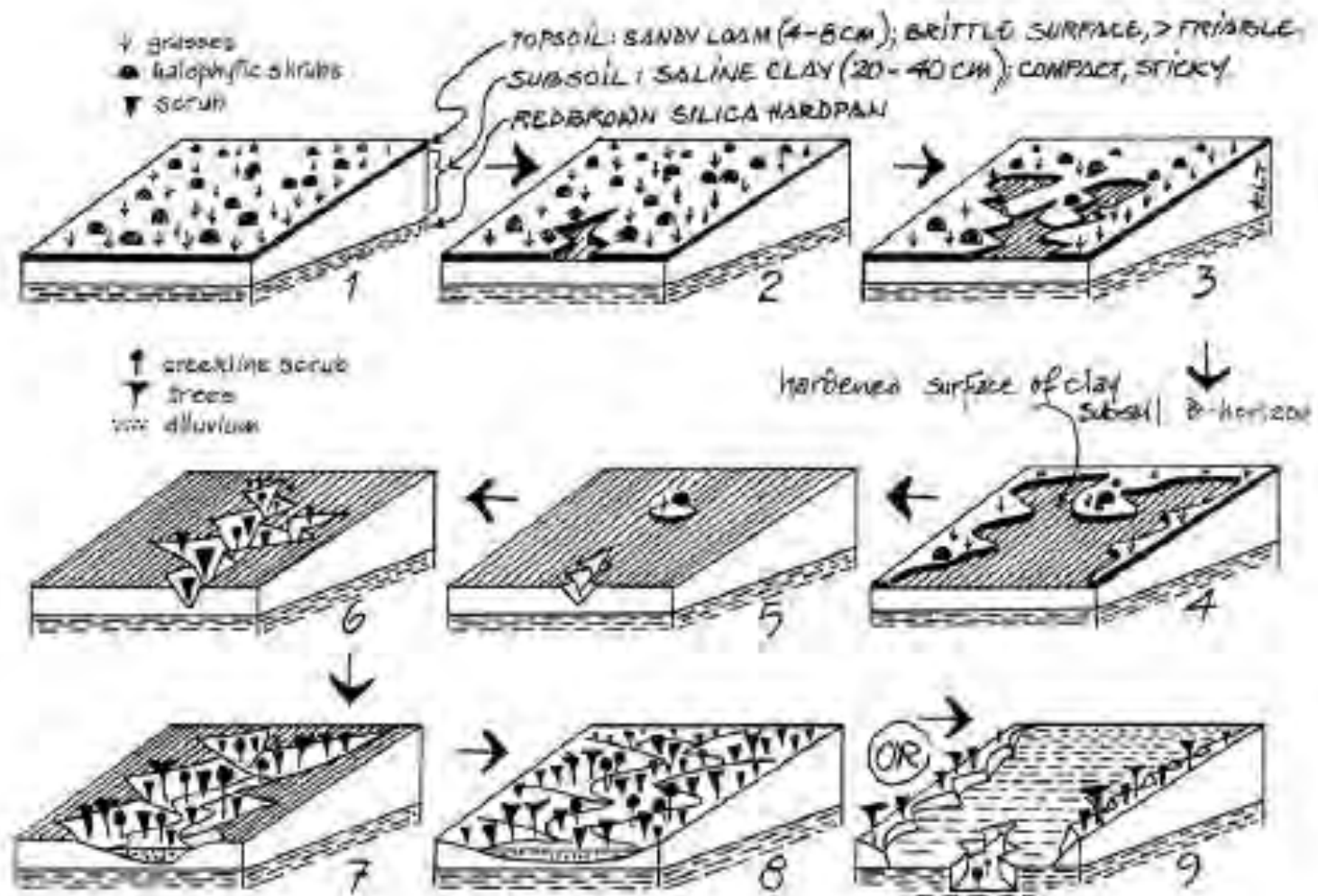
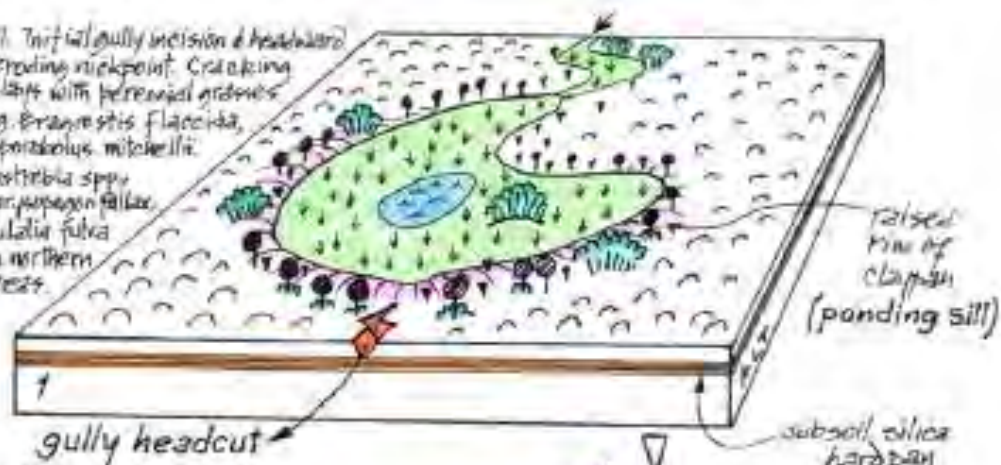


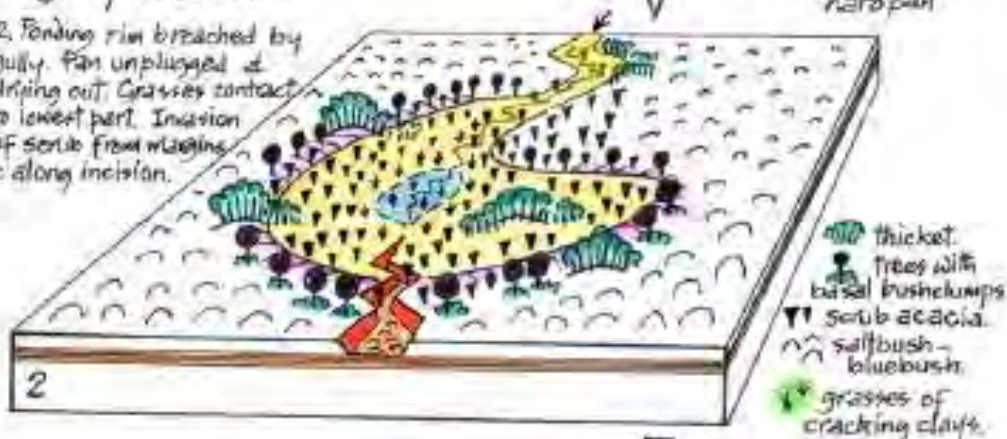
Figure 13: Fragmentation and Coalrescence Succession.

Example of a soil-vegetation replacement sequence. Overgrazing with topsoils stripped by erosion resulting in the demise of a chenopod shrubland. Coalrescence of the burnt clay subsoil areas becomes the new land surface colonized by scrub. If unchecked, erosion will continue, with variations, down to the hardpan.

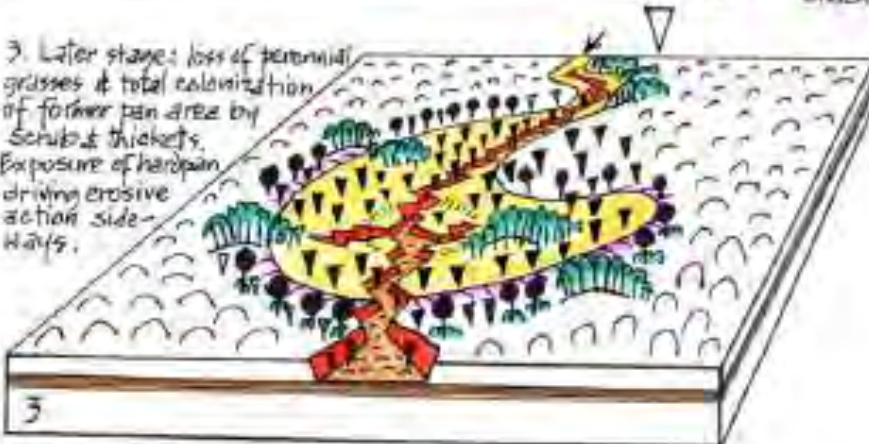
1. Initial gully incision & headward
eroding nickpoint. Cracking
clays with perennial grasses
eg. *Brachystis flaccida*,
Sporobolus mitchellii,
Artibeia spp.,
Oenopogon fallax,
Eulalia fulva
in northern
area.



2. Ponding rim breached by
gully. Pan unplugged &
driving out. Grasses contract
to lowest part. Invasion
of scrub from margins
& along incision.



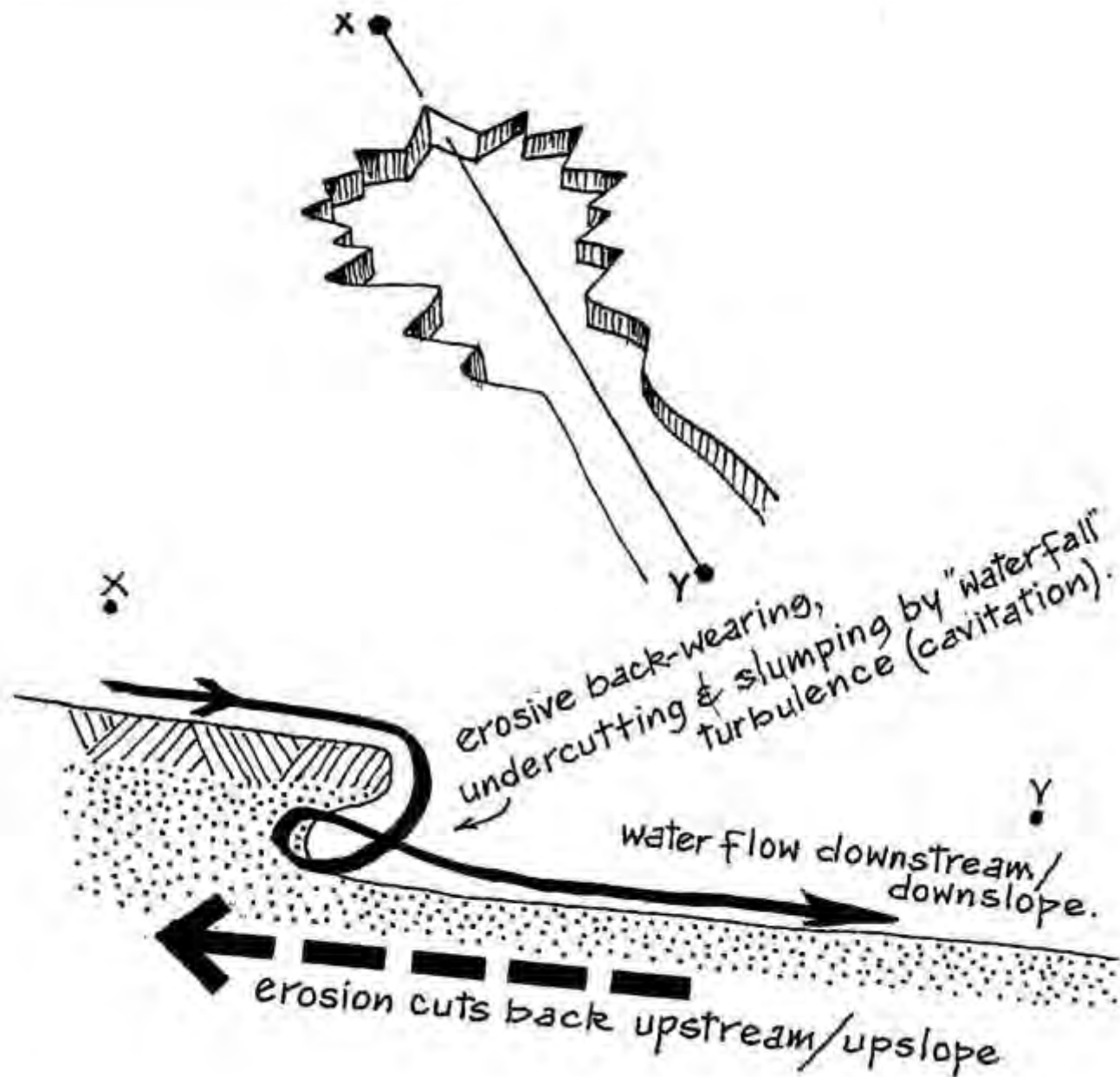
3. Later stage: loss of perennial
grasses & total colonization
of former pan area by
scrub & thickets.
Exposure of hardpan
driving erosive
action side-
ways.

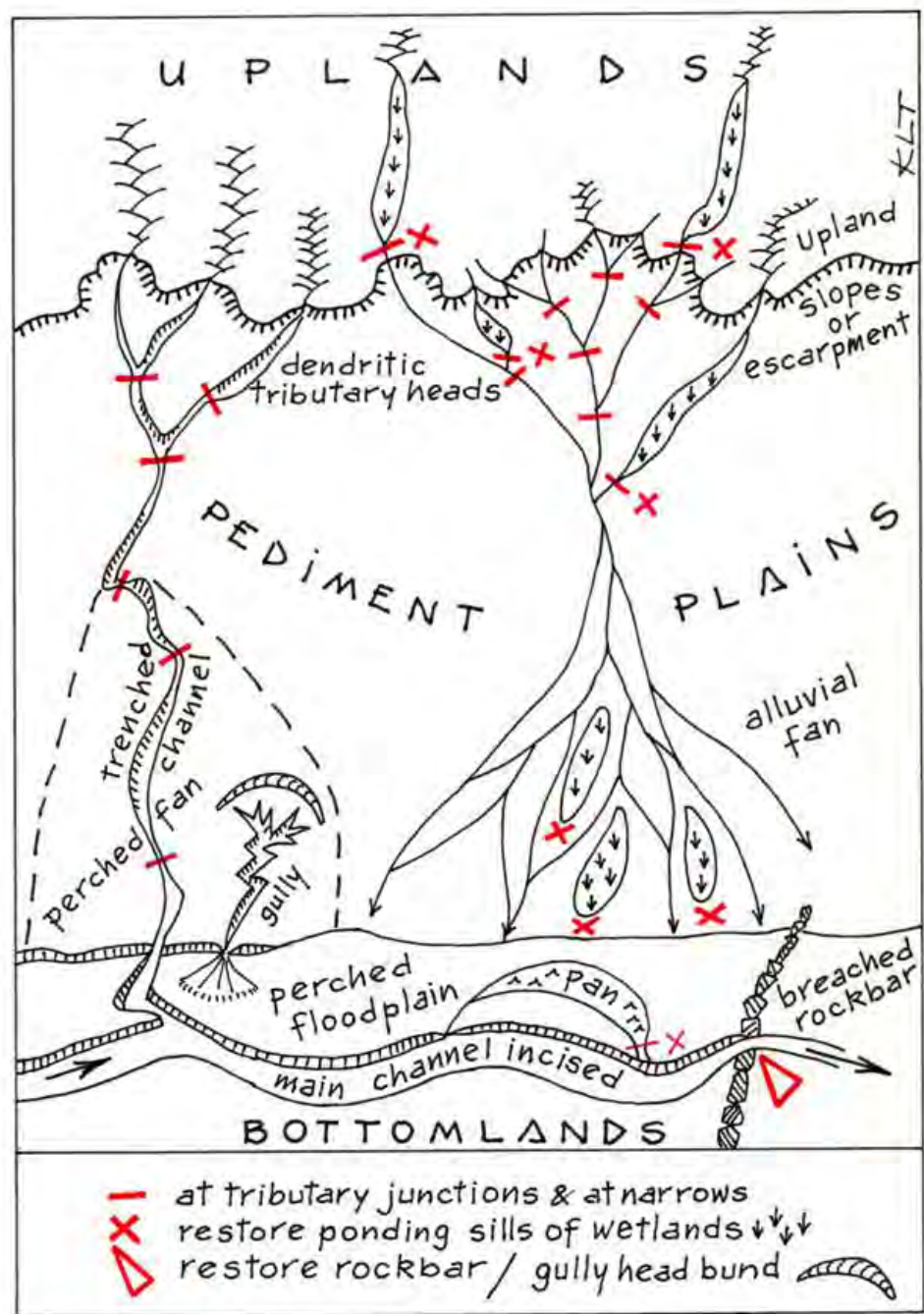


raised
rim of
clay pan
(ponding sill)

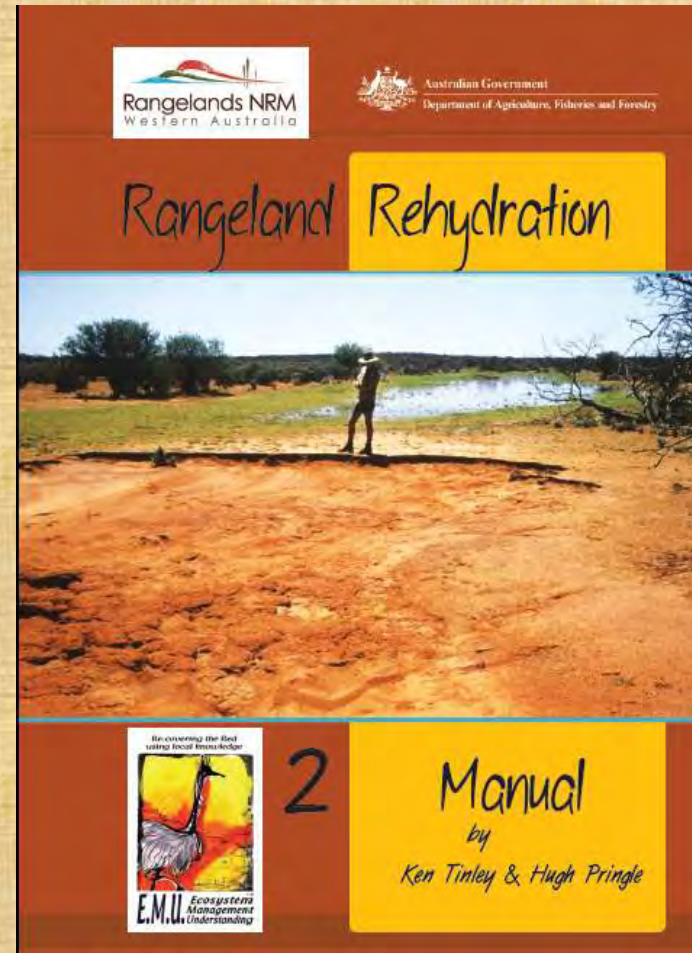
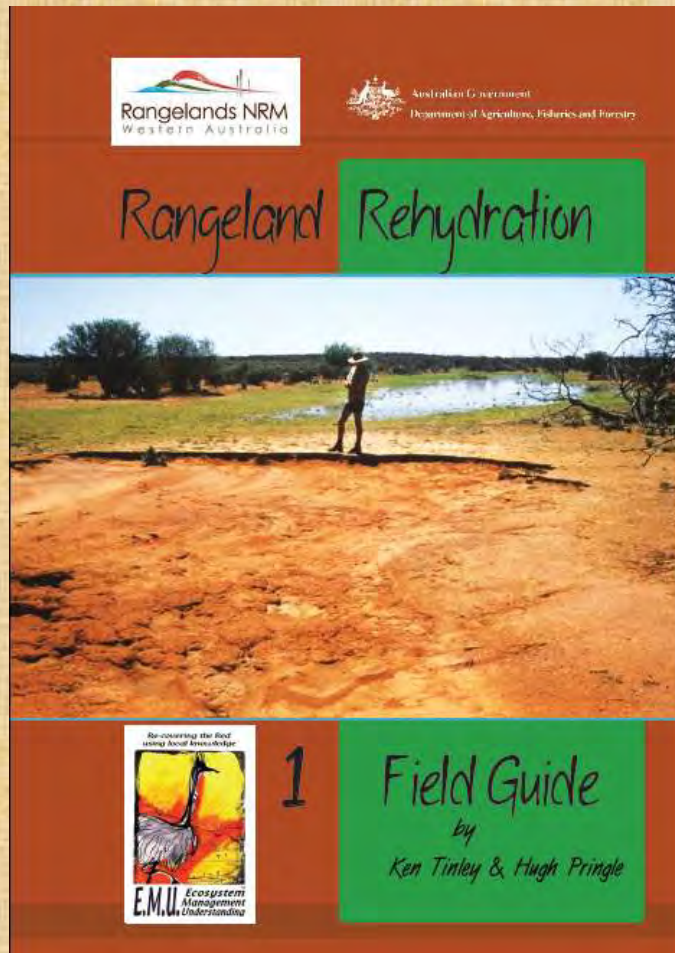
subsoil silica
hardpan

thicket.
trees with
basal bushclumps
scrub acacia.
saltbush-
bluebush.
grasses of
cracking clays.





The Rangeland Rehydration Manuals



EMU areas of activity

- Gascoyne-Murchison Region (WA) 2000-
- Goldfields Nullarbor Region (WA) 2003-2006
- Central Australia (CLMA; NT & SA) 2008-
- SAAL Region (SA) 2009-
- APY Lands (SA) 2012-2015
- Gulf of Carpentaria (CLCAC) 2013/4)
- Western Lands (NSW) 2016-
- Namibia (2013-)
- Ethiopia (Ben Norton, 2014-)
- Tajikistan (Ben Norton, 2015-)

Erora Community, Kunene, NW Namibia



Image © 2011 GeoEye
© 2011 Cnes/Spot Image

©2010 Google

Community members pointing out issues first



“Where do you want us to start?”
“Start above Central Bore, we need to restore
groundwater”





Image © 2011 GeoEye
© 2011 Cnes/Spot Image

©2010 Google

Community are heavily involved in detailed planning, the young are included



Marking points together on a satellite image





We used available local resources



Some techniques



Cattle knocking down a gully head



Diversion filters even in the crop fields!!!



Is it working on the ground?



Slowing water flow and ponding





Before



Just after rain



Dried
out



Before rain → During rain

↙
After water
infiltrated

A “diversion” filter to spread water away



Before



After



Three Rivers example of a “bleeding” floodplain

The Forsyth family









“Rakes” across rock bars higher in
the catchment

The old Shearing Shed road, now a
creek diverting floodout water







Higher again, Jaminda Rake









Then down to stabilise the gully
heads eating floodplain









**Some other techniques without
their drainage ecosystem/synergy
planning context**

Wooleen, Murchison

David Pollock



Todmorden, Oodnadatta

Douglas Lillecrapp







Yakabindie, NE Goldfields

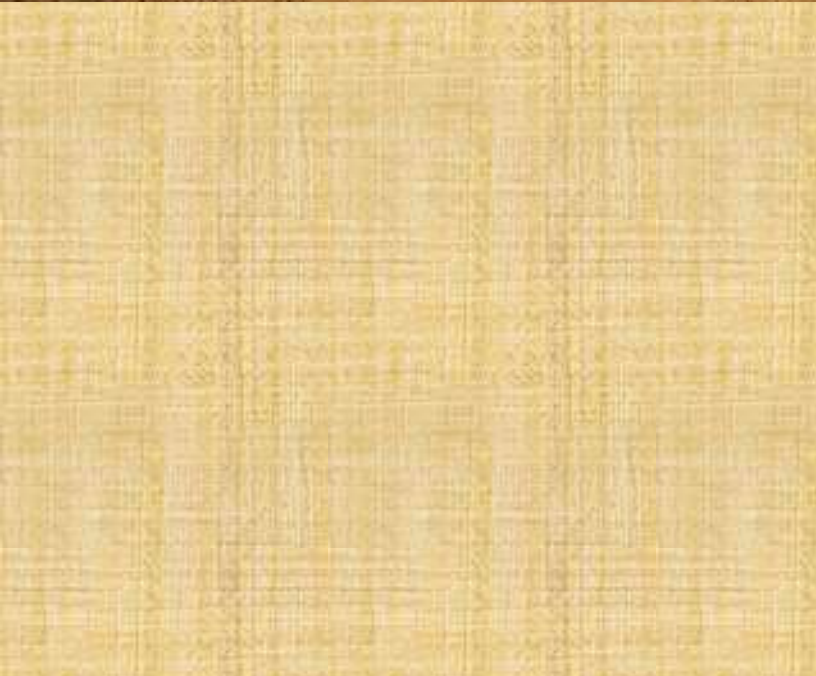
Doug and Lucy Brownlie





Wirrealpa, North Flinders

Warren and Barb Fargher



Summary

1. Work out what is going wrong and where natural flows need to be restored
2. Work out what needs to be fixed where and why (critical control points)
3. Work out how to achieve this with local ingenuity and creativity...and available resources

**NONE OF THIS IS WORTH STARTING WITHOUT
GOOD GRAZING, INFRASTRUCTURE etc MGT**



Re-covering the Red
using local knowledge



E.M.U. Ecosystem
Management
Understanding

Highly Erodible Soils

Sodic and Solodic Soils

- 31 years experience in Soil Conservation-NRM, Salinity
- Team Leader, District Coordinator, District Soil Conservationist
- Salinity Management, Land Management, Native Vegetation, Incentive Schemes
- Innovative soil works and rehabilitation programs
- Project Management Soil Conservation Projects, Section 10 Projects, Soil, Salinity and NRM Incentive Schemes.
- Consultancies, Urban Investigations, Mining Rehabilitation

Steve Eccles

steve.eccles59@hotmail.com

- Working with Sodic and Solodic soils in Queanbeyan, Upper Hunter (Scone, Muswellbrook and Singleton Areas.)
- Soil Conservationist Queanbeyan-Googong and Burra Projects preventing of Lake Burley Griffin 1985-1987.
- Soil Conservationist Scone 1987-1989.
- District Soil Conservationist Muswellbrook 1990-1995.
- Upper Hunter Catchment Manager 1996 – 2001
- DIPNR Project Officer 2001-2004
- HCRCMA Catchment Officer 2005-2010
- Team Leader/ District Coordinator 2011-2016

Sodic soils present Canberra and Upper Hunter Areas

- Establish the Objectives for the Project
- Project Plan
- Build a Team
- Catchment Investigations
- Community and Stakeholder Engagement
- Review of Natural Resources
- Catchment Planning and Property Planning
- Earthworks and Land Management Design
- Costing of the Program
- Funding – Partnerships
- Implementation Team
- Implementation, Earth works, Engineering Works, Land Management – Changes and Implementation
- Rehabilitation
- Risk Management
- Monitoring and Maintenance

Steps in the project



Characteristics Sodic Soils



Susceptible to Gully Erosion



Susceptible to Rill Erosion



Susceptible to Tunnel erosion



Active Head Cut



Lack of Topsoil



Hard Setting Soil Layers



High Runoff, Highly Dispersible



Often Saline or Saline Profiles

- pH-often acid
- pH- can be alkaline
- Low in Calcium
- High in Sodium
- Can be high in Magnesium
- Sodicity – Ca and Na Balance issue
- Low phosphorus
- Maybe high aluminium
- Low carbon, Low organic matter, Low microbial activity

Mineral balances



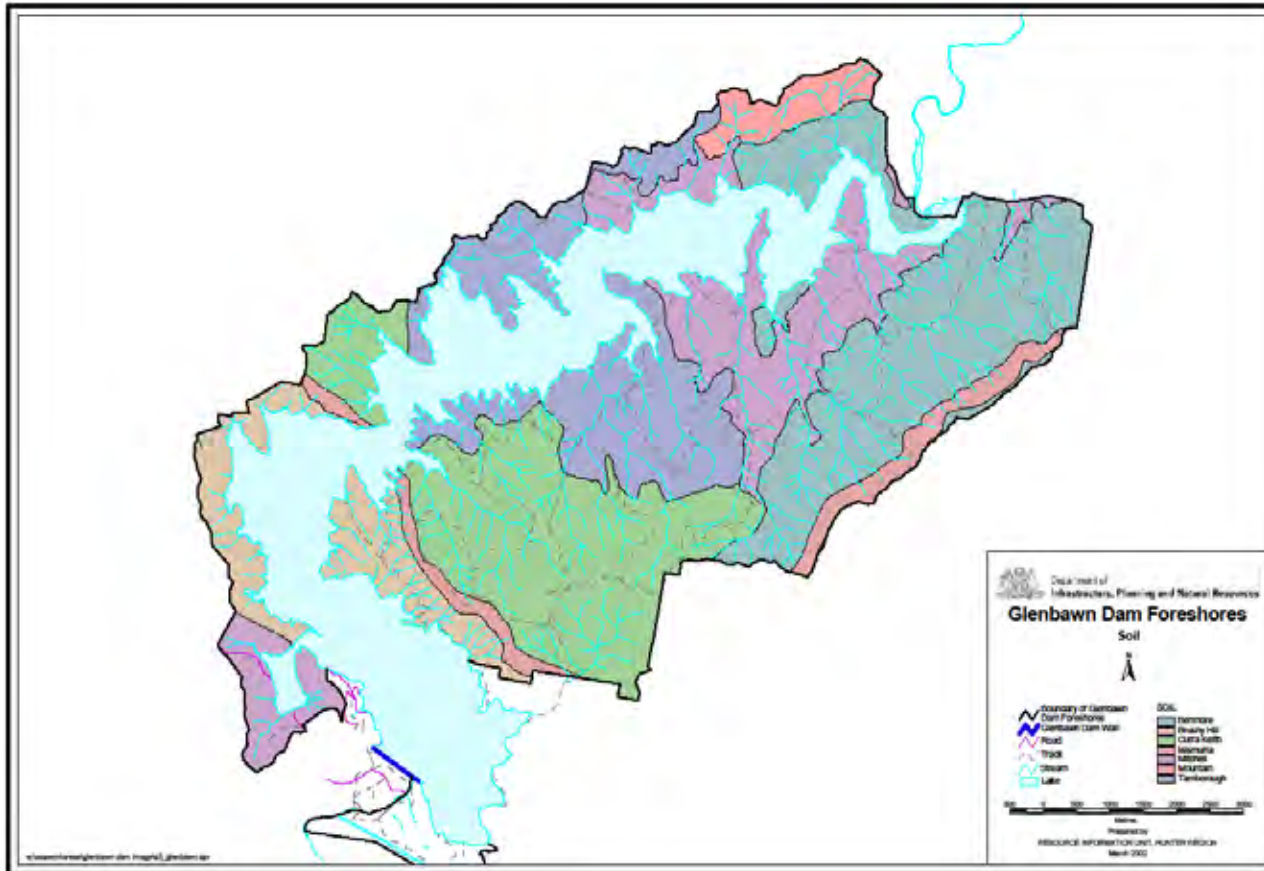
How to treat



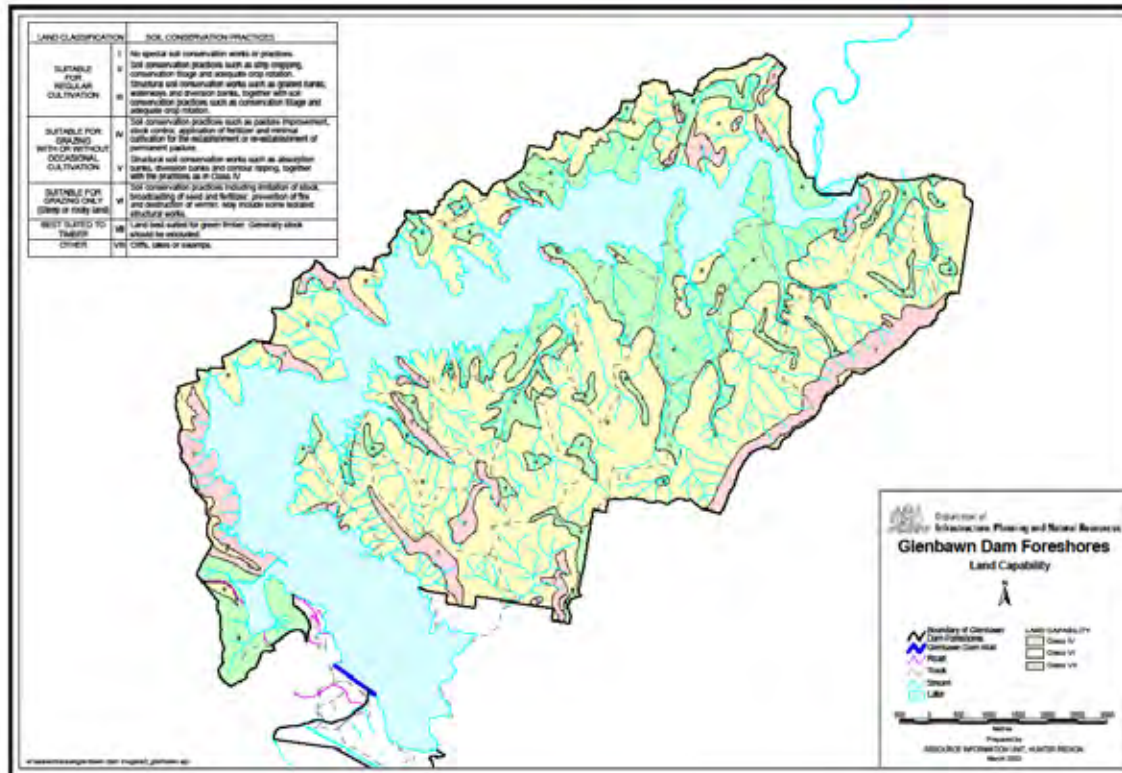
Engage Community and Stakeholders



Undertake investigations



Assess Data and Natural Resource Information



Land Capability

Gully Control Structures



Diversion banks



Clearwater diversions

Tree Establishment



Grazing Changes



**Land Management Changes in the
Catchments**

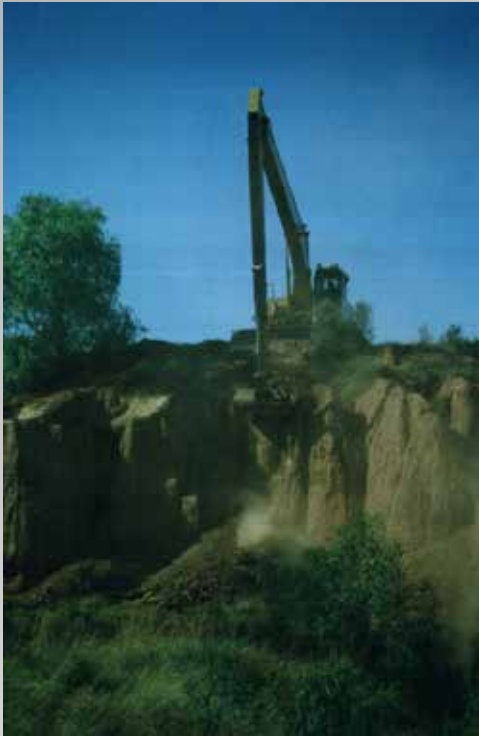


Treatments of Large Gully's



Rock Flume

Battering to 3:1



Gully Fill with Rock Bed Controls



**Rock bed controls firstly used in
Ogilivy Hill Section 10 Project**



Same Gully Revegetated

**Geofabric, Cut-off
Trenches, Gypsum**



**Rock Placed on
Geofabric**



Rock Flume Construction

**Geofabric, Gypsum,
cut-off trenches**



**Rock Placed on
Geofabric**



Rock Flume Construction

Gully Heads



Gully Metres Deep



Phashett Jerrys Plains



**Gully Fill with Diversion GCS
Above the Erosion**

- Soil Ameliorants, Gypsum or Lime depending on pH.
- Compaction at correct moisture content
Use of sheep's foot rollers and water carts.
- Use of Geofabric or plastic liners.
- Use of appropriate fertiliser and cover crop and pasture seed.
- Use of organic matter.

Earthworks and Disturbed Areas

**Delivered to Site between
25mm to 32mm deep**



**Loading Compost to
Belt Spreader**



Green Waste Compost



Doughboy Hollow Singleton

Belt Spreader



Compost Spread



Compost Spreading on Treated Area



**Resilience - Ground Cover
Established**

- Vermin control, domestic animal exclusion
- Ensure the land is managed to its capability
- Look at the entire catchment not just the eroded area, reduce peak discharge and increase the time of concentration
- Domestic stock managed, excluded from areas and controlled grazing in others
- Monitoring and maintenance, very difficult soils there will be failures, in some areas allow for 10 % of costs for maintenance
- Design all structures at least 1 in 20 years suggest look at 1 in 50 years storm intensity
- Look at resilience in the revegetation ensure the revegetation area is not over grazed

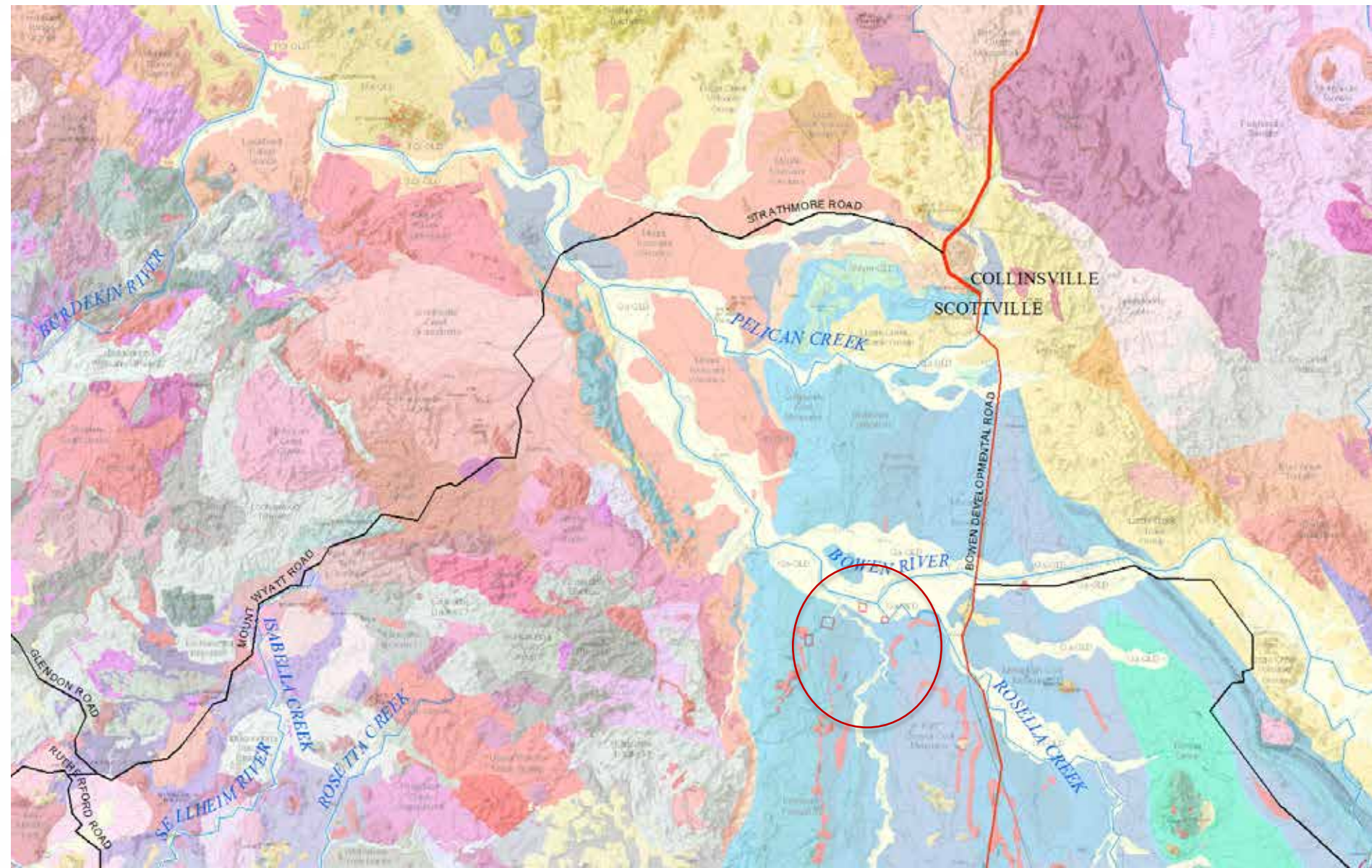
Important items to consider

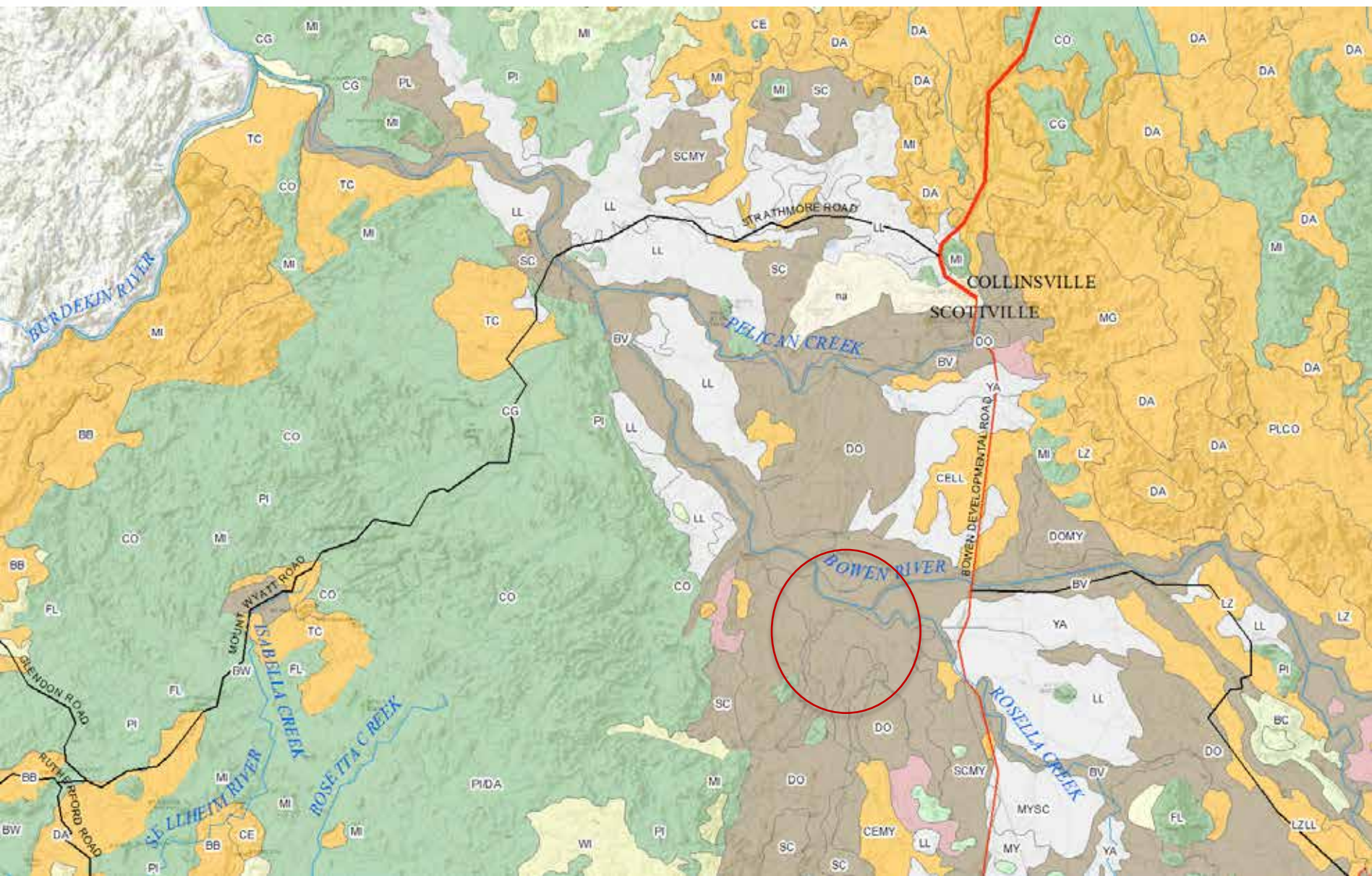
Alluvial Gully Erosion Workshop – Collinsville

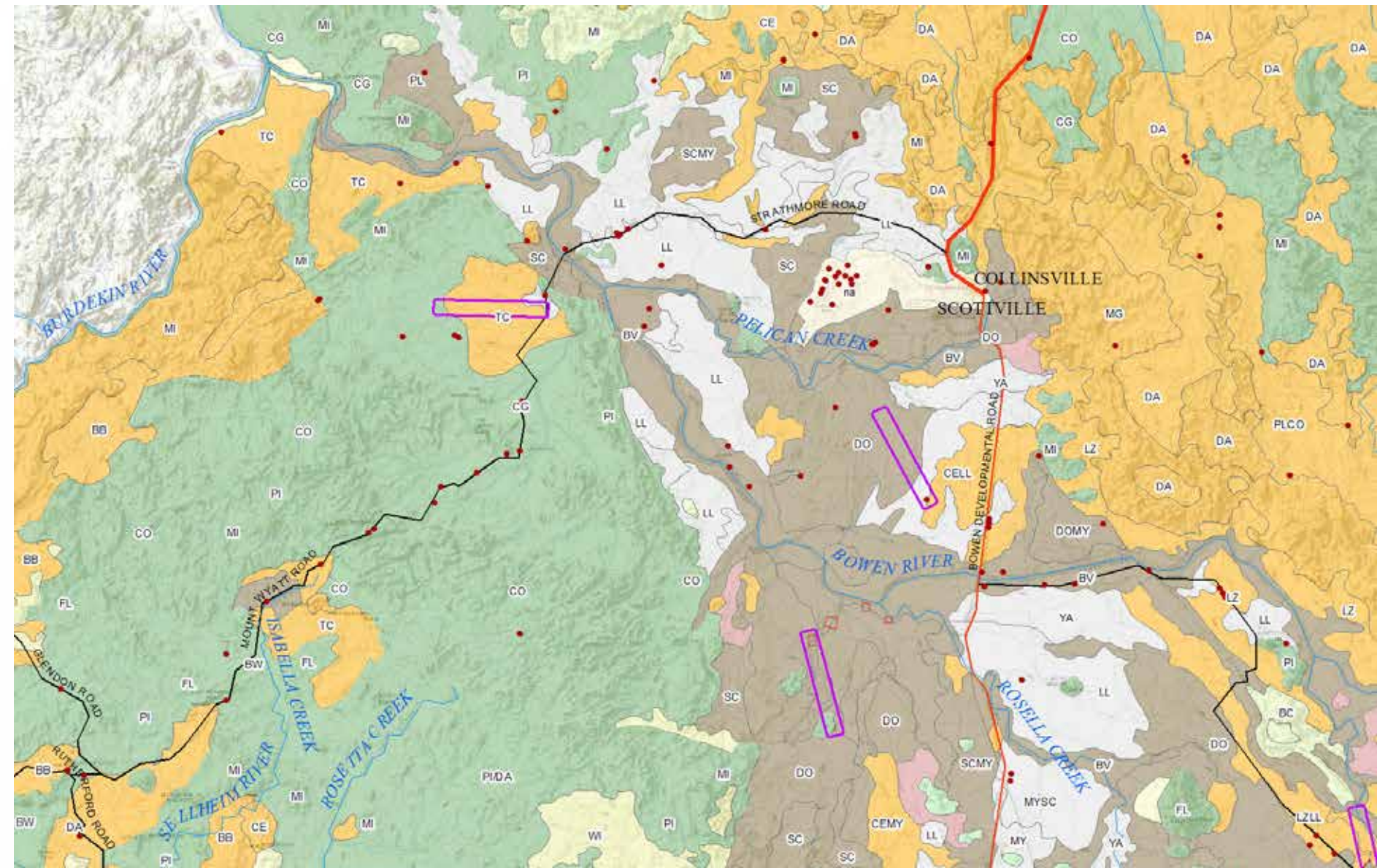
8-10 August 2016

Peter Zund

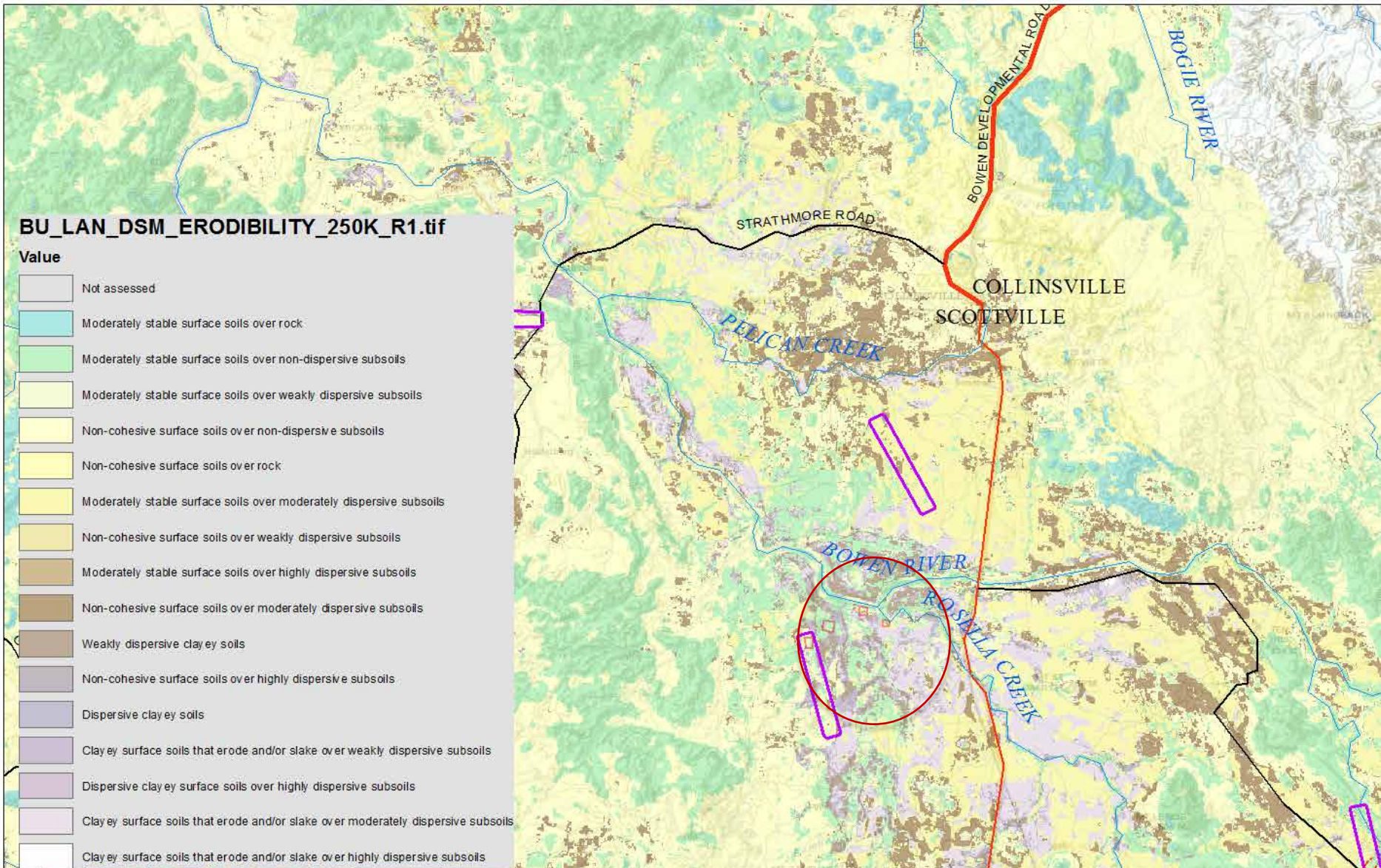
Geology



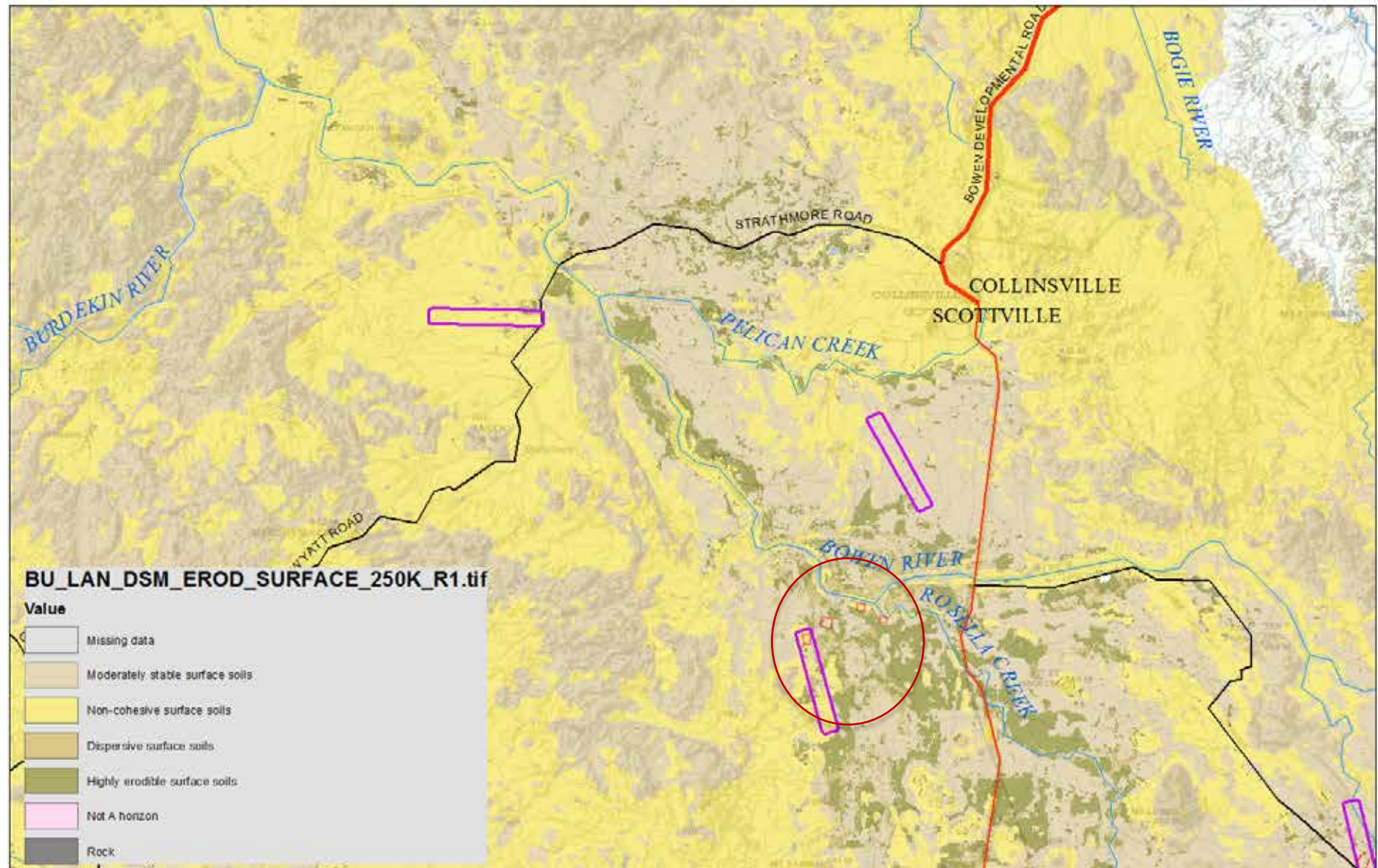




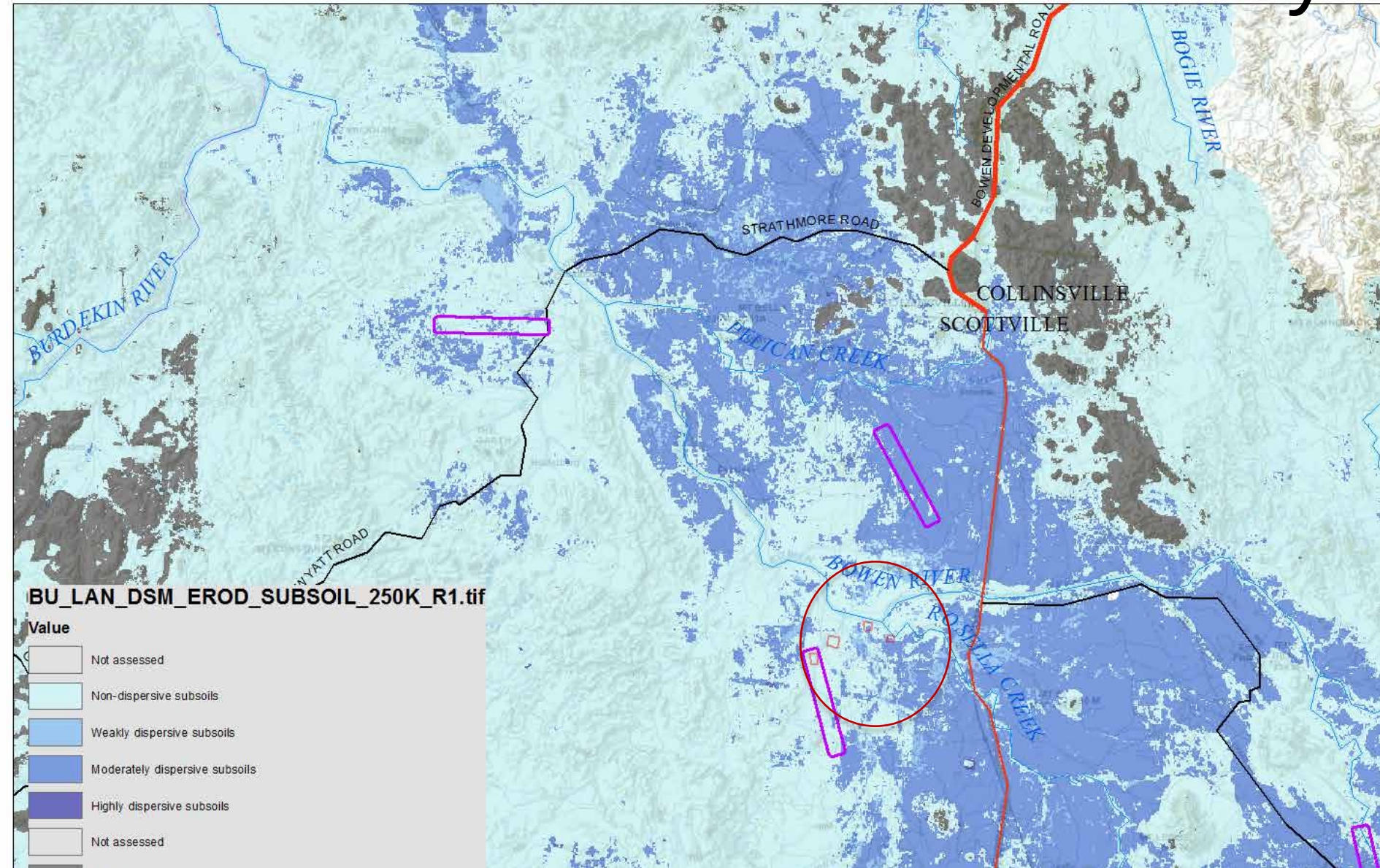
Soil erodibility



Surface soil erodibility



Subsoil erodibility



Surface soil model identifies 4 classes

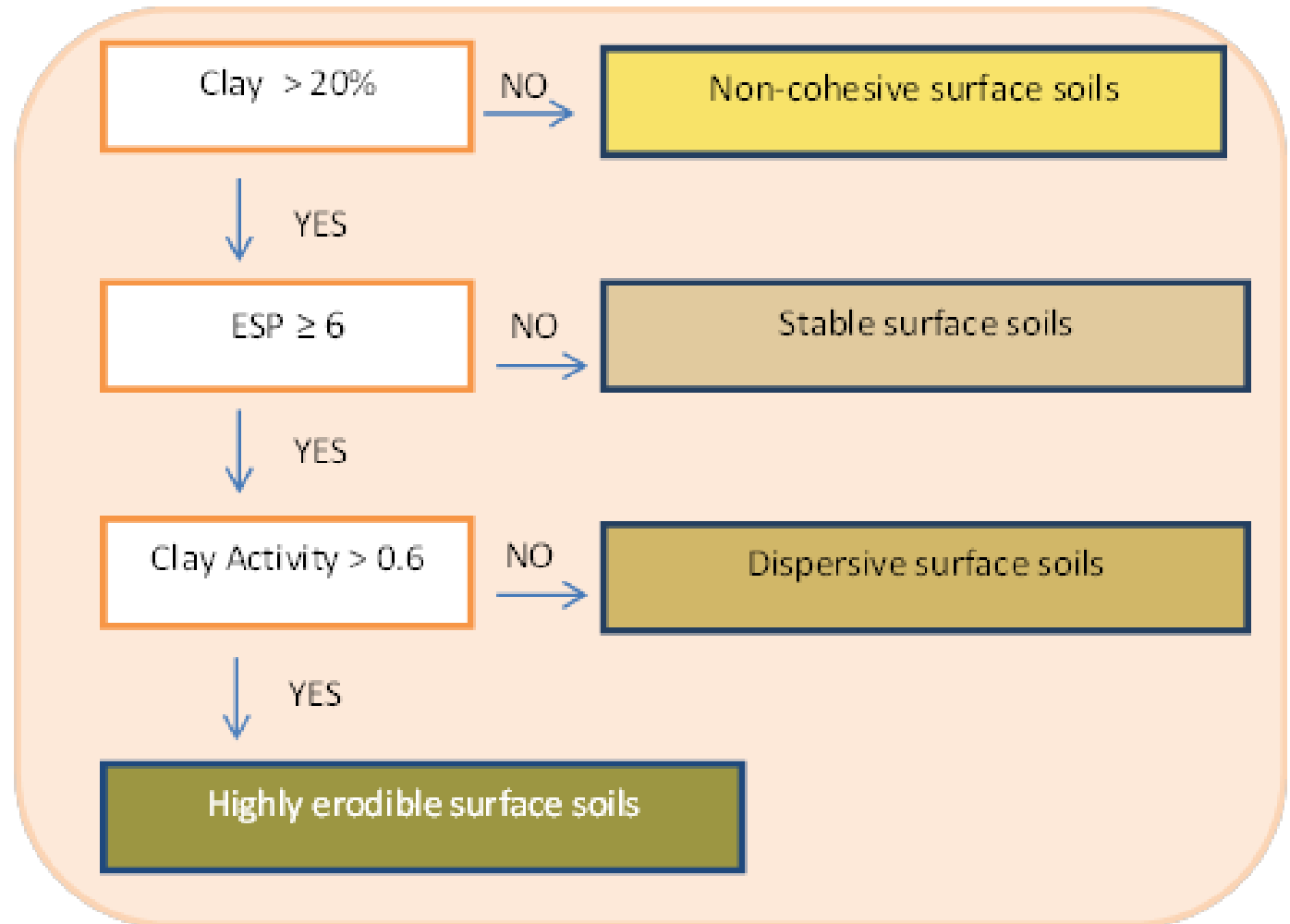
Non-cohesive

Stable

Dispersive

Highly erodible

- sandy, loose or massive
- structured loamy or clayey
- sodic
- sodic and *vertic*



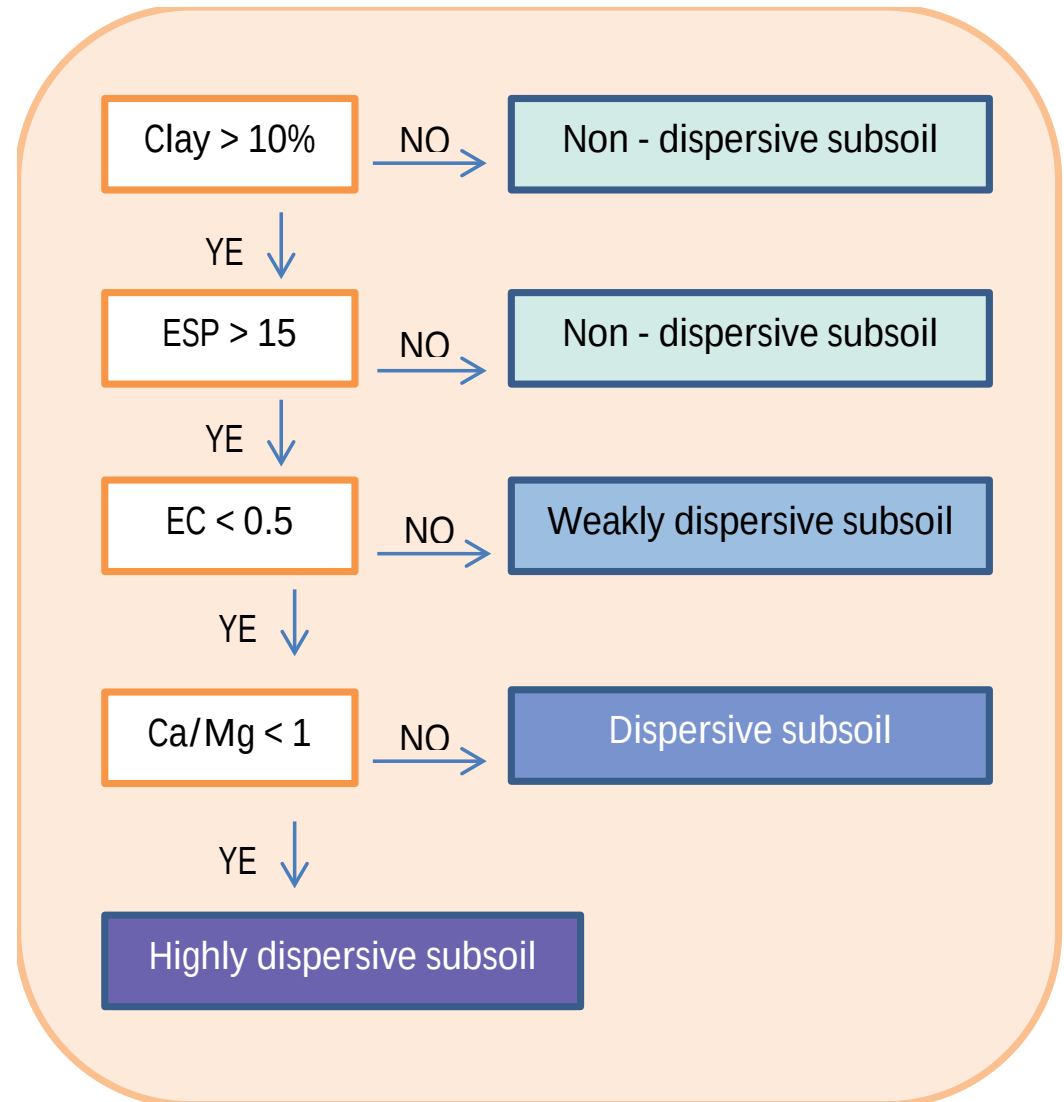
Subsoil model identifies 4 classes

Non-dispersive
sandy or non-sodic

Weakly dispersive
Sodic and saline

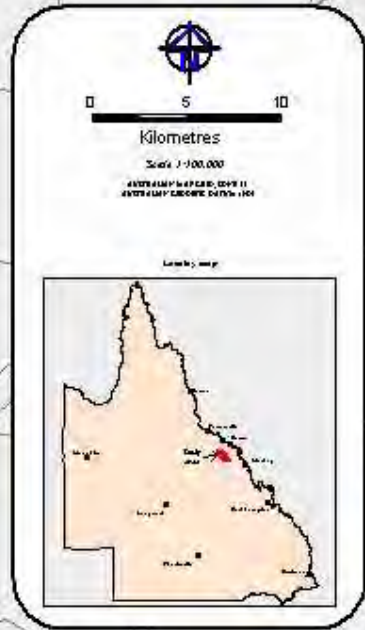
Dispersive
Sodic and non-saline

Highly dispersive
sodic, non-saline and magnesian



Overall soil erodibility

		Surface soil characteristics			
		Moderately stable surface soils (1)	Non-cohesive surface soils (2)	Dispersive surface soils (3)	Highly erodible surface soils (4)
Subsoil characteristics	Sediment (C or D) or Rock (R) (9)	Loamy to clayey surface soil over sediment or rock (RU, TE) (1)	Sandy massive surface soil over sediment or rock (RU) (5)	Weakly dispersive clay soil (TE, VE, HY, DE) (11)	Highly erodible clay soil over rock (TE) (8)
	Non-dispersive subsoils (1)	Loamy to clayey surface soil over non-dispersive subsoil (VE, CH, FE, DE, KA) (2)	Sandy massive surface soil over non-dispersive subsoil (CH, KA, TE) (4)		Highly erodible clay surface soil over weakly dispersive subsoil (VE) (14)
	Weakly dispersive subsoils (2)	Loamy to clayey surface soil over weakly dispersive clay subsoil (VE, HY, KU, CA, DE) (3)	Sandy massive surface soil over weakly dispersive subsoil (HY, KU) (7)		
	Moderately dispersive subsoils (3)	Loamy to clayey surface soil over moderately dispersive clay subsoil (VE, HY, SO, DE) (6)	Sandy massive surface soil over moderately dispersive subsoil (HY, SO) (10)	Moderately dispersive clay soil (VE, DE) (13)	Highly erodible clay soil over moderately dispersive subsoil (VE) (16)
	Highly dispersive subsoils (4)	Loamy to clayey soil over a highly dispersive clay subsoil (VE, HY, SO) (9)	Sandy massive surface soil over highly dispersive subsoil (SO) (12)	Dispersive loamy or clay surface soil over highly dispersive clay subsoil (VE, HY, DE) (15)	Highly erodible clay soil over highly dispersive clay subsoil (VE) (17)

[illegible]

Collinsville Irrigation Survey

1:100,000 scale mapping

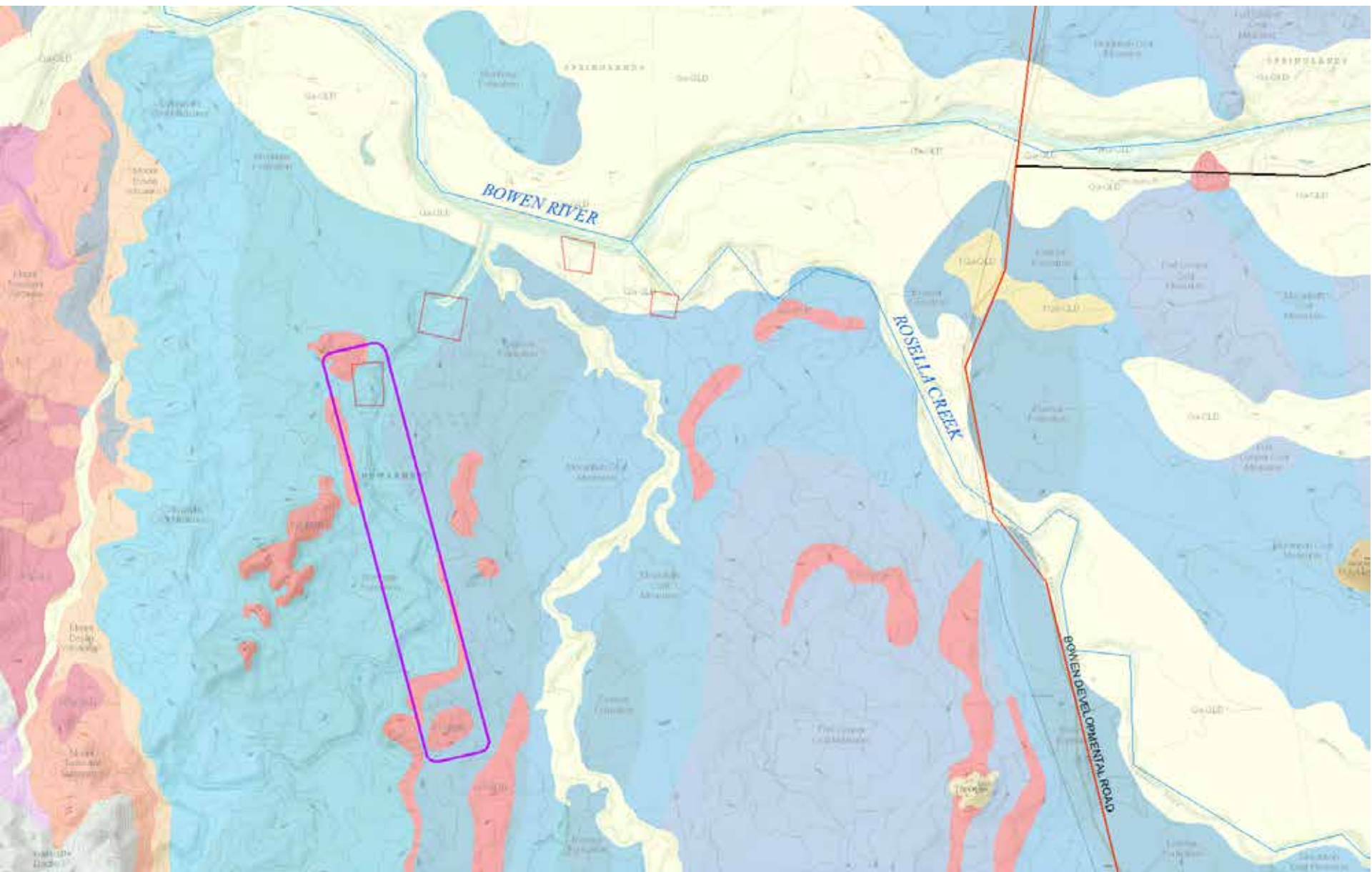


Site CIA 4 – from Hyder Env.

Depth interval (cm)	Horizon	Colour	Texture	pH	Salinity (EC – dS/m)	ESP (%)	Ca/Mg ratio
0-5	A1	Grey	Sandy loam	5.7	0.02	1.9	1.4
5-12	A2e	Bleached	Sandy clay loam	6.5	0.03	4.1	1.4
12-35	B21	Brown	Light medium clay	8.1	0.37	31.6	1.2
35-55	B22	Brown	Light medium clay	9.2	0.82	44.1	0.9
55-75	B23	Brown	Fine sandy light clay	9.5	0.67	41.3	1.0
75-125	D1	Brown	Sandy light clay	9.7	0.52	38.5	0.9
125-150	D2	Brown	Course sandy clay loam	9.1	0.33	31.5	0.8

Soil erodibility classification – Non-cohesive surface over dispersive subsoil – Class 10/17

Havilah – Field visit



SMI ENVIRONMENT



Experience from mine rehabilitation in the Bowen Basin

Thomas Baumgartl
Regional Water and Land Resources Program









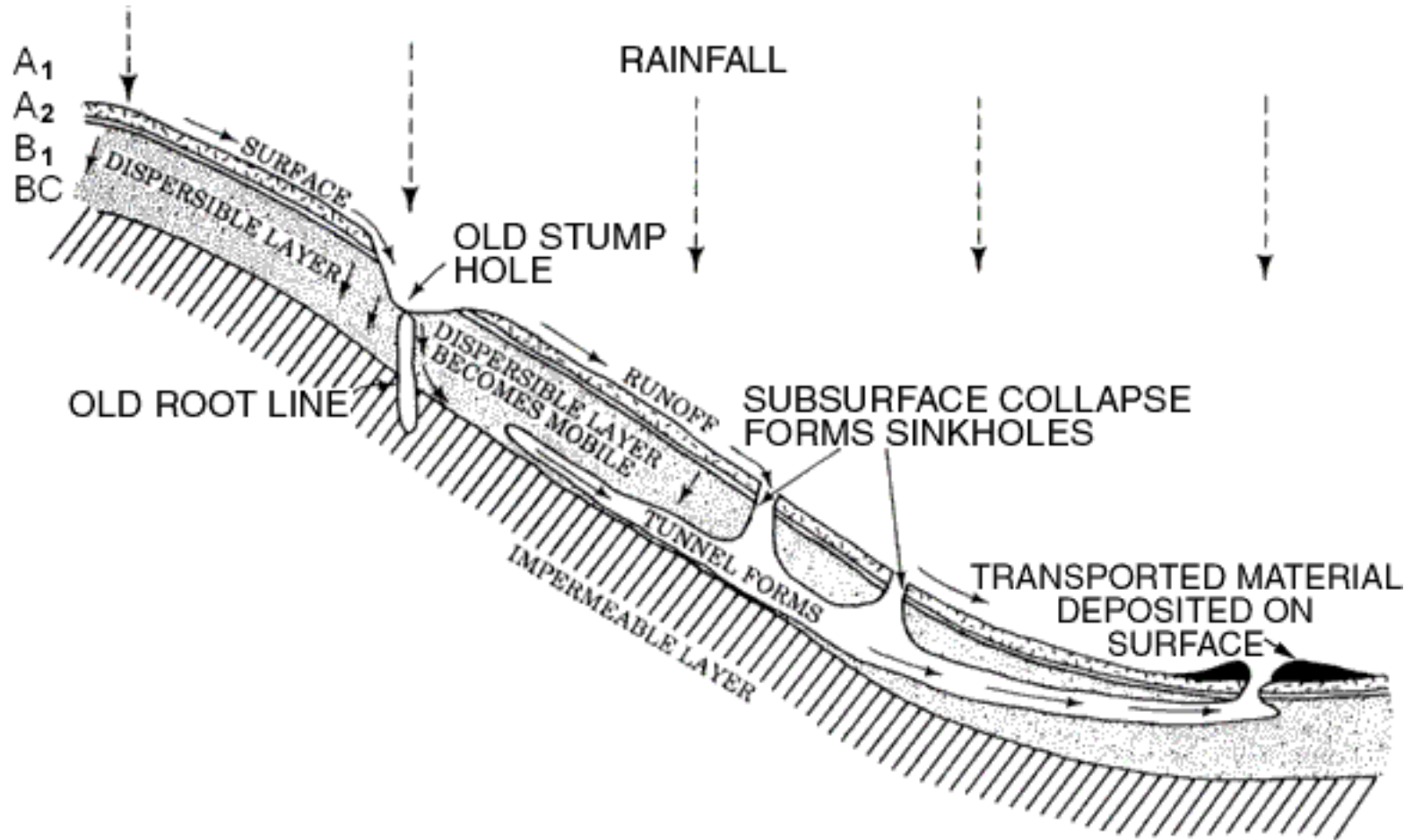


Tunnel/gully erosion





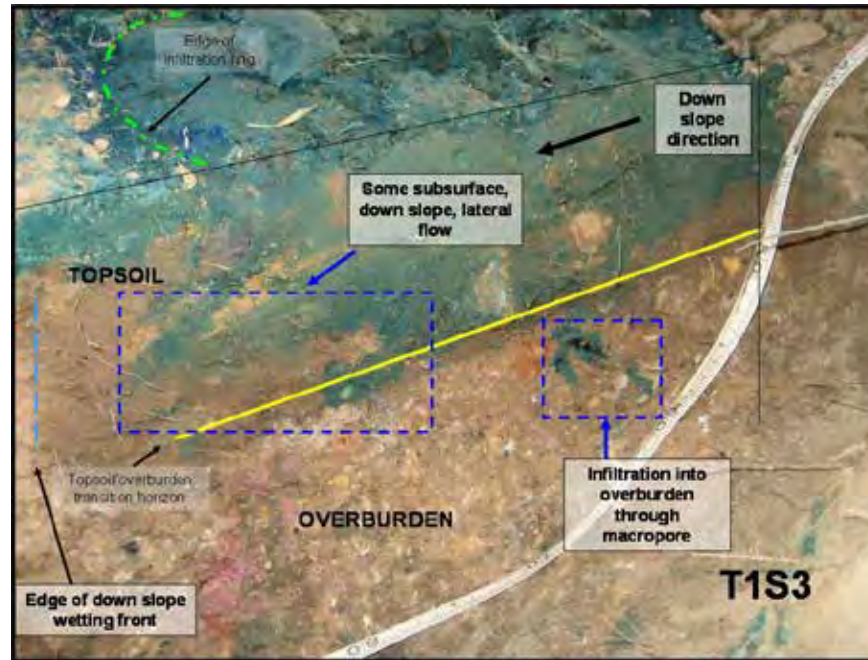
Cause of gully erosion



Hydrology of slopes on rehabilitated land



Lateral flow tests



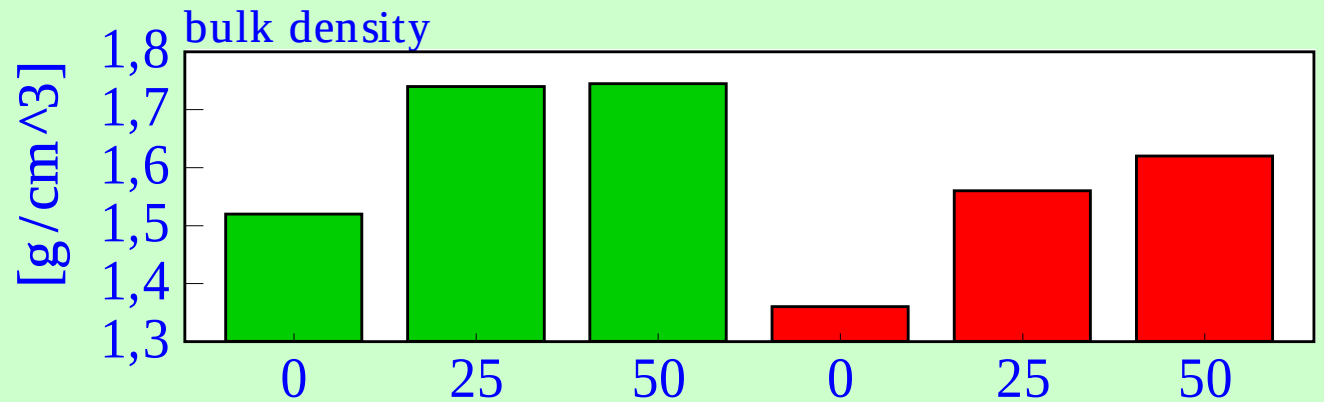
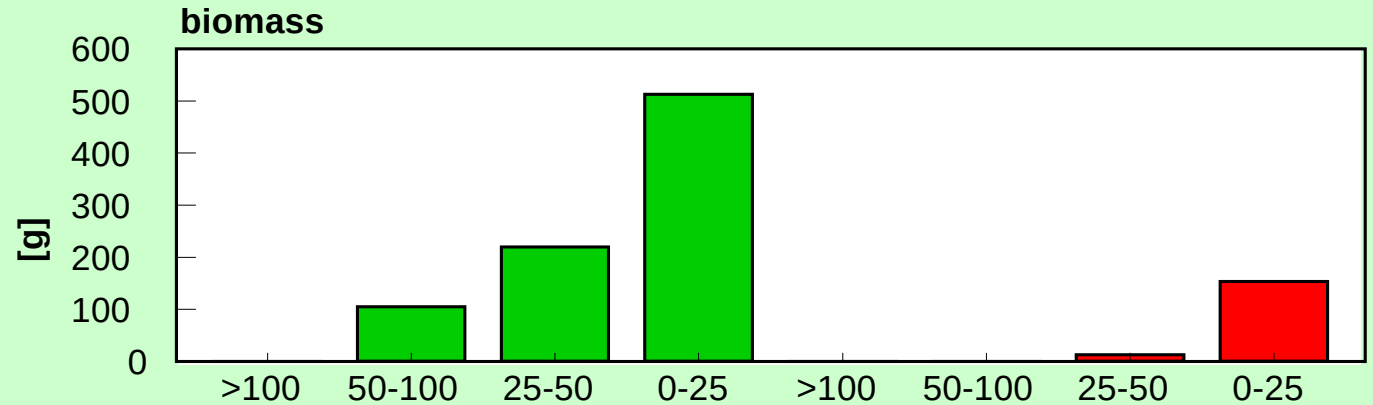
- Water infiltrates to the topsoil/overburden interface.
- Infiltration rate is reduced, with subsurface lateral flow initiated or flow into the overburden through macropores.

Stability controlling parameters



soil

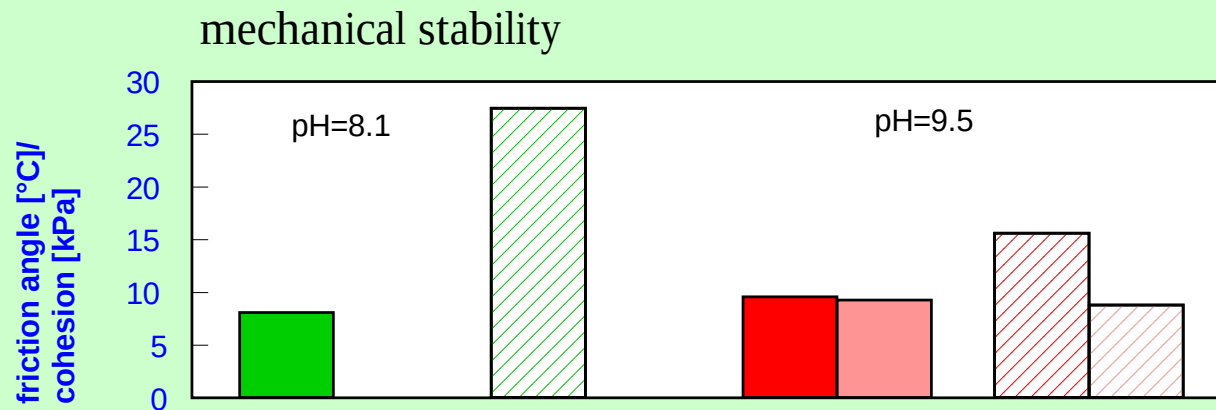
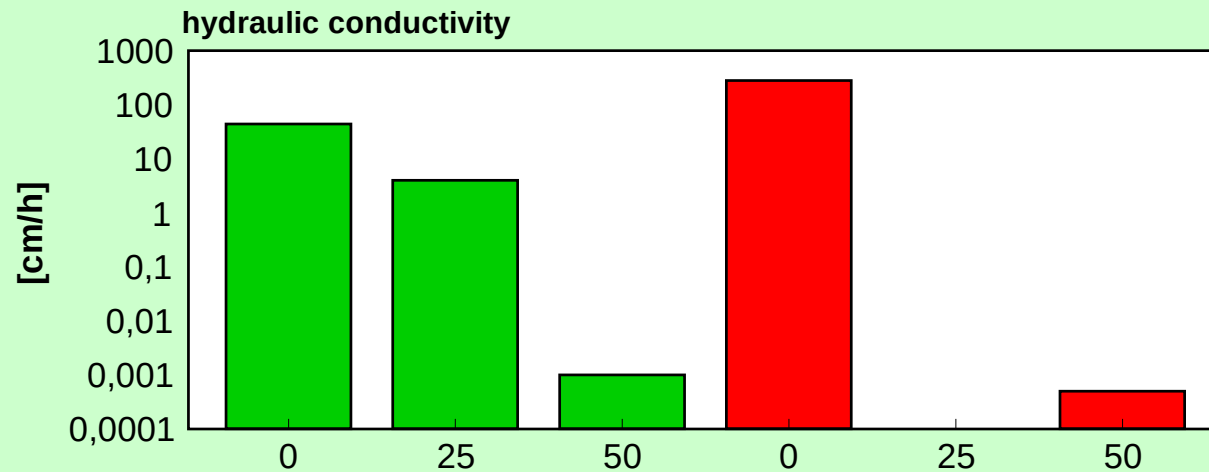
spoil



Stability controlling parameters

soil

spoil

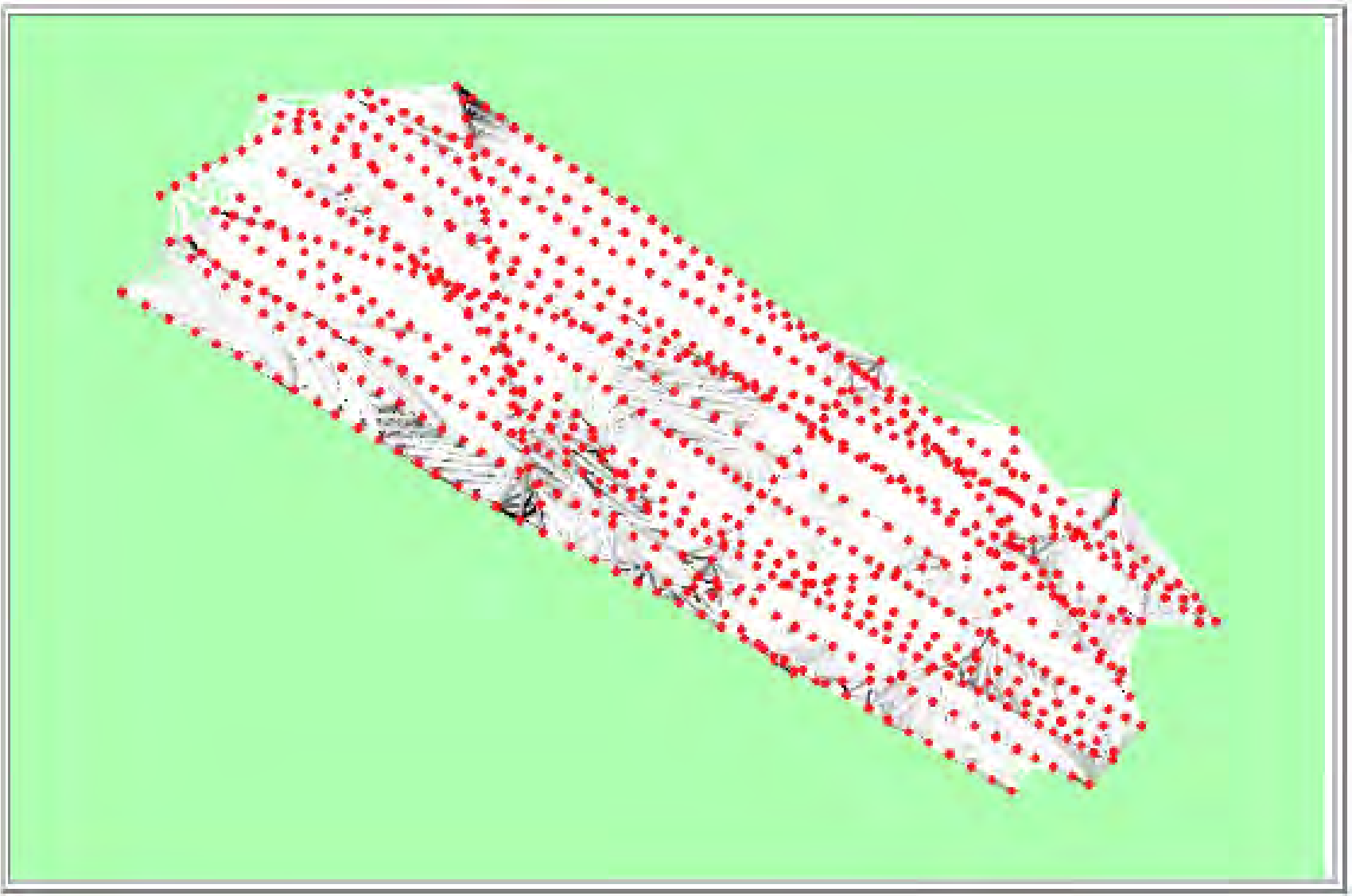


UAV as a tool to identify and quantify erosion



Generate an ortho-mosaic

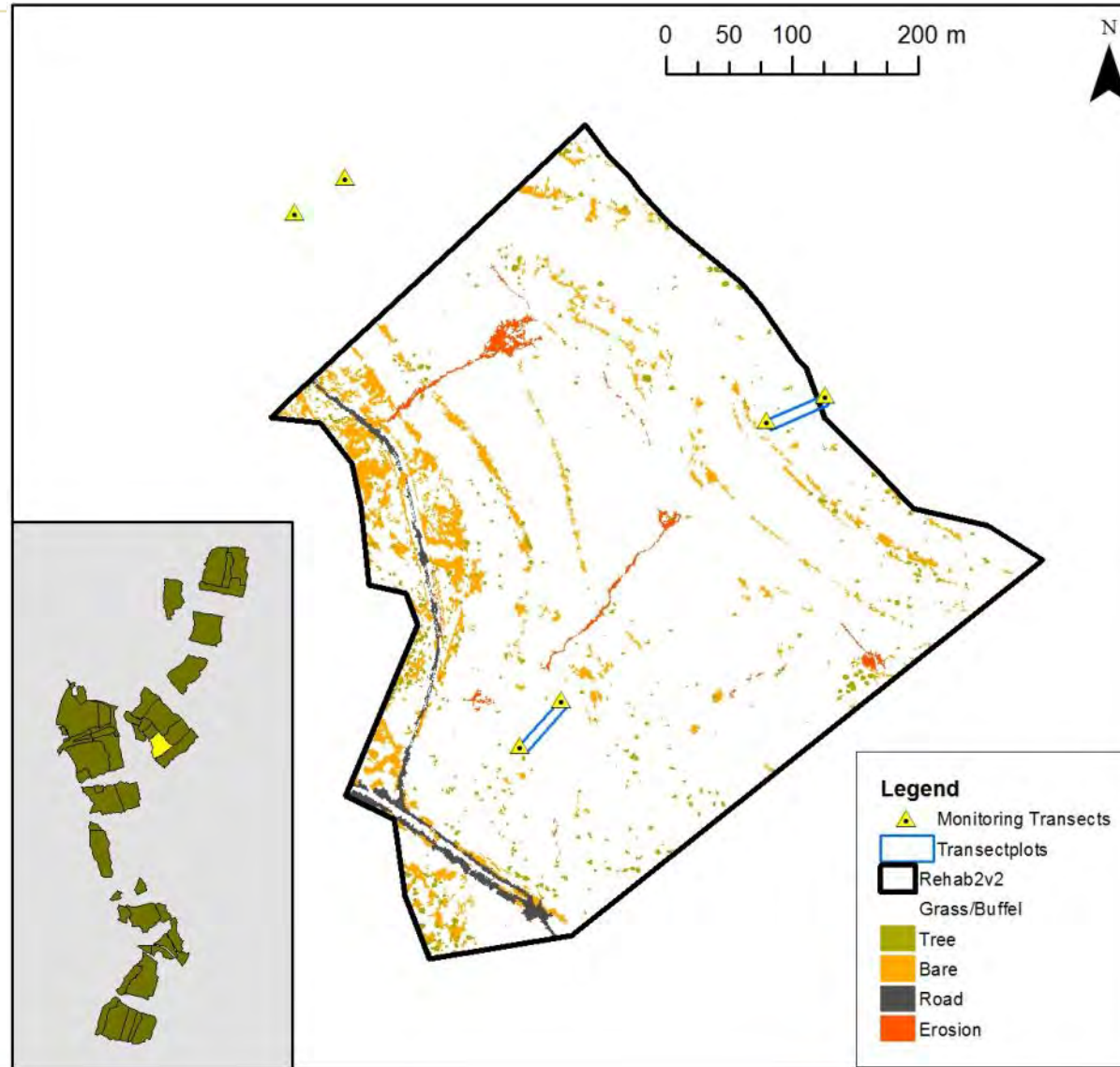




Create a digital elevation model

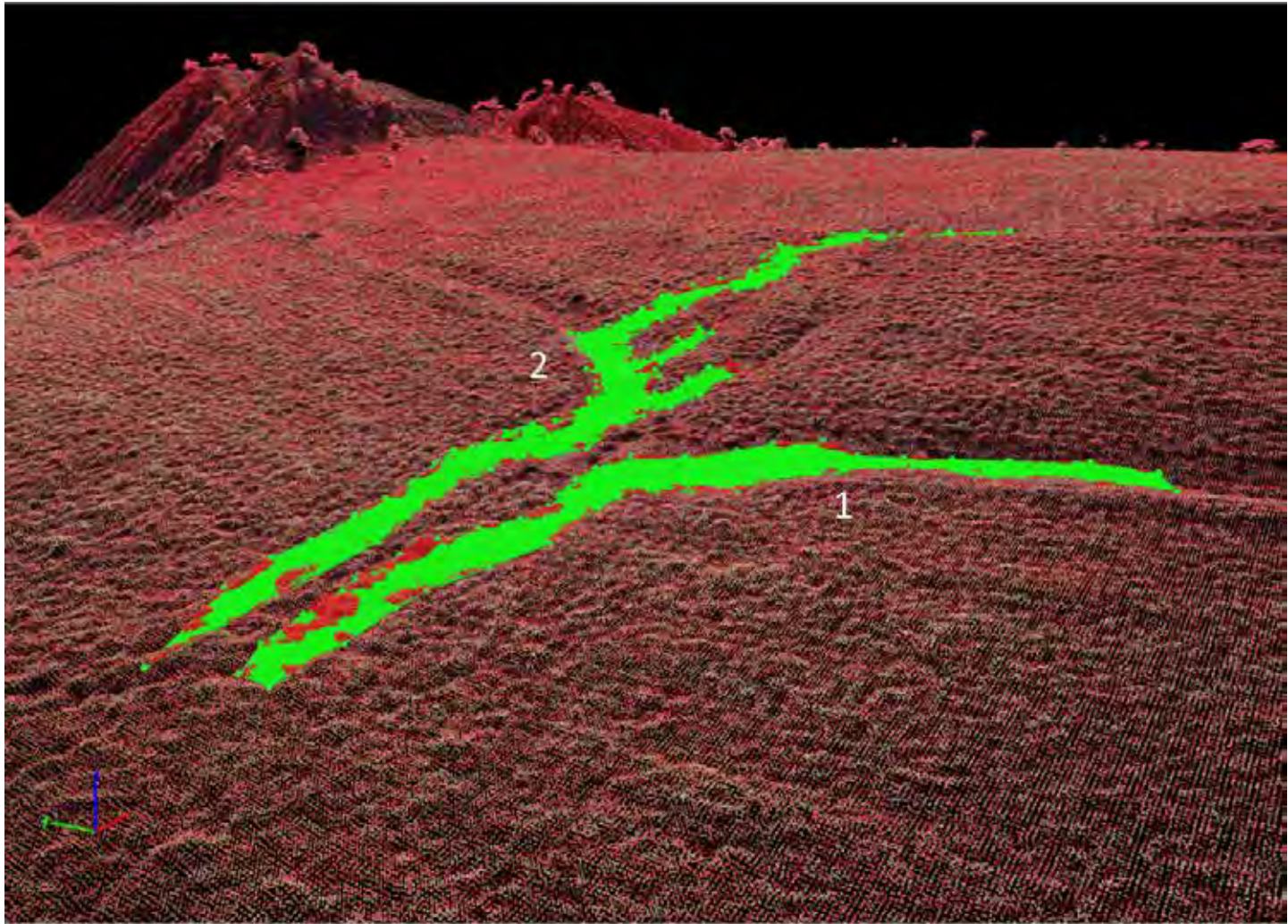


Resolution and coverage



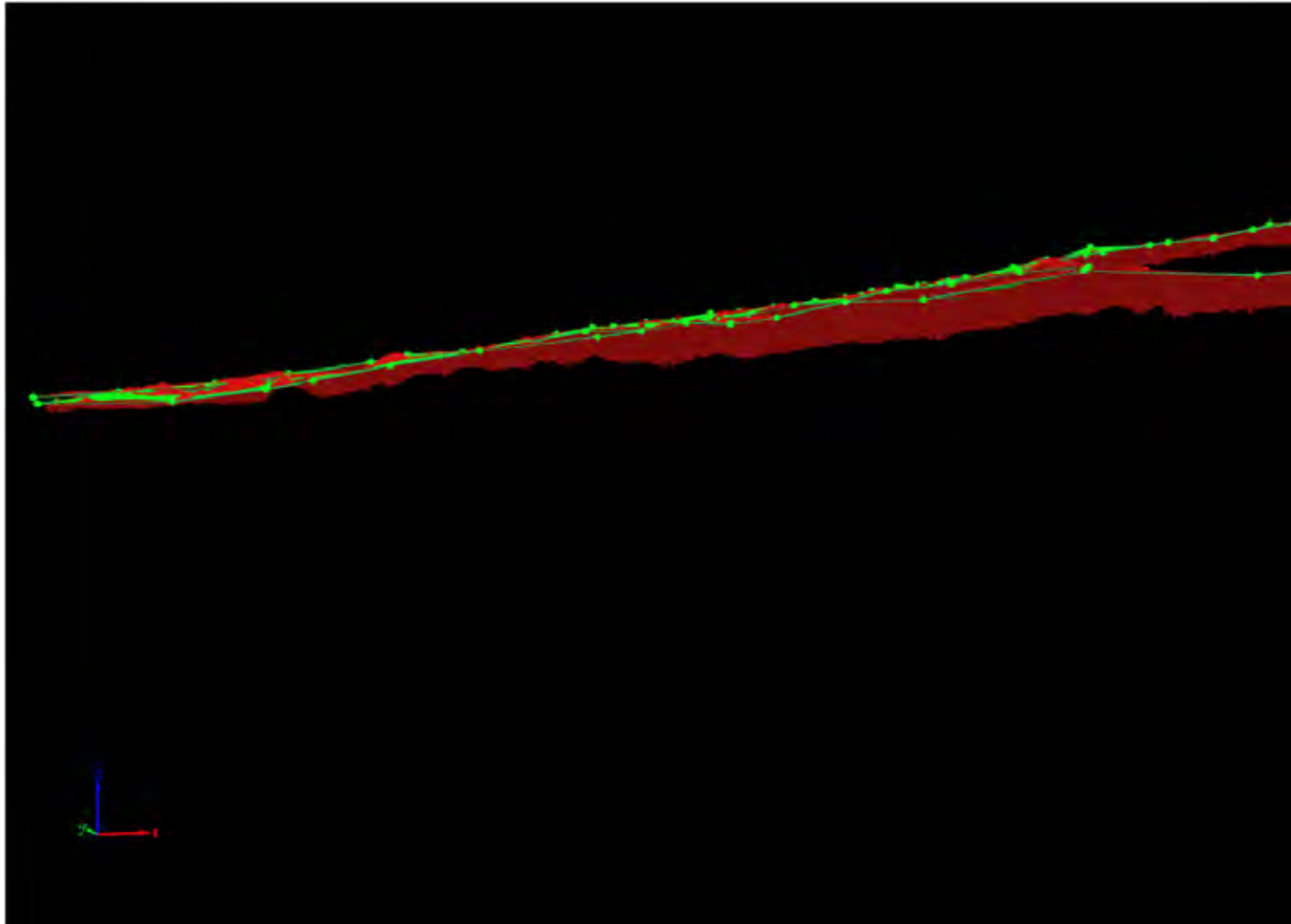
Quantifying erosion caused by flow concentration





Geospatial Element	Gully 1	Gully 2
Projected 2D Length (m)	146.311	288.499
Terrain 3D Length (m)	147.163	291.899
Projected 2D area (m2)	335.949	563.214
Enclosed 3D Area (m2)	338.858	572.08
Terrain 3D Area (m2)	547.716	987.493
Fill Volume (m3)	-140.8±27.3	-244.5±46.0
Cut Volume (m3)	3.3±4.2	5.0±6.6
Total Volume (m3)	-137.4±31.4	-239.5±52.6





Rehabilitation of rehabilitated land



Conclusions

Factors to be controlled to minimise risk of erosion:

- Topography – slope

Steepness of terrain

Annual erosion rates of 0.7, 3.1 and 48t/ha for 10, 20 and 30% slopes respectively



- **Vegetation**

- a) In general, measured erosion loss declines significantly above around 50% cover.
- b) In some instances, significant erosion loss can still occur despite very high levels of cover (in the region of 100%).
- c) Soil movement appears to increase with slope angle, with some very high rates of loss recorded above around 12% slope.

V. plays a very important role in stabilisation of soil, but it cannot control erosion alone



- Protection of surfaces

Surface cover with more than 30%v rock showed little erosion

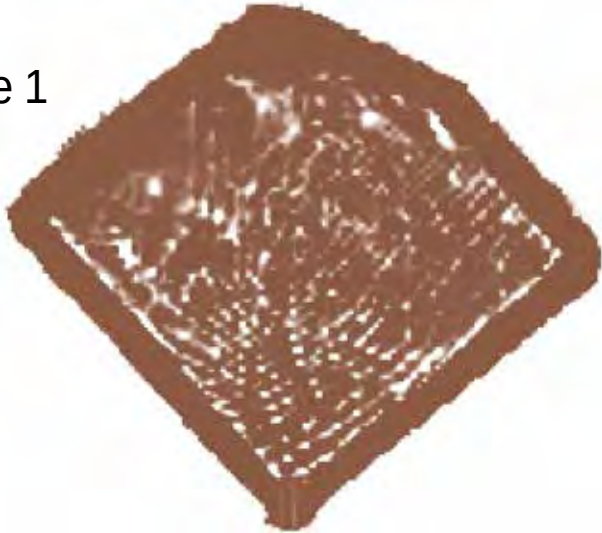
- Erosion models do not allow prediction of gully erosion

- Gully erosion: stabilisation of non-consolidated and developed landform; inclusion of ecosystem functions

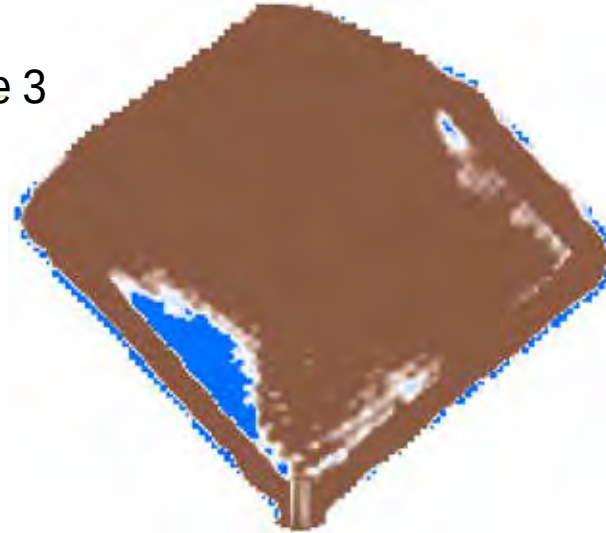




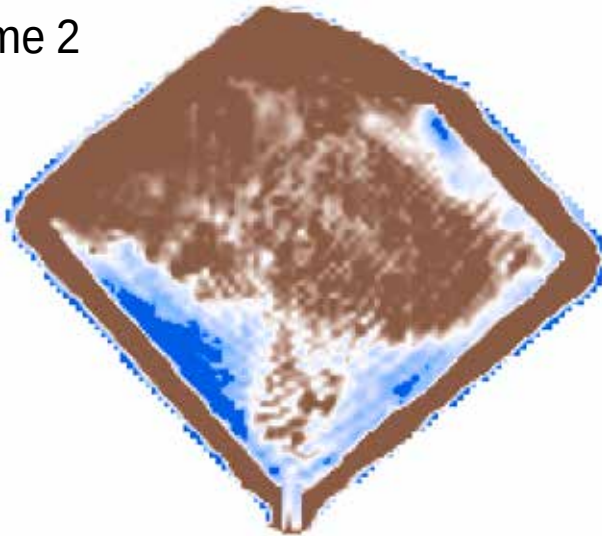
Time 1



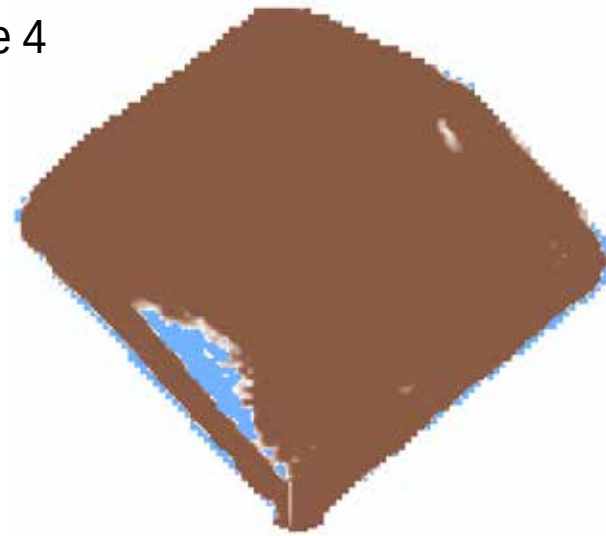
Time 3



Time 2



Time 4



SM





Gullies in dispersive soils

Rob Loch



My experience

Research: 1972 - 1996

- Soil management
- Soil erosion

Consulting: 1996 – present

- Site stabilisation and remediation
- Erosion control
- Soil assessment

Farming: ~1950's to present

- Crops
- Fertilisers
- Planting operations



Gully experience?



Gullies and can we manage them?

- Occur widely
- Sign of dysfunctional landscapes
- Often linked to unstable subsoils
- Control is generally “possible”
- Control may be costly



Sodic dispersive subsoils

A higher proportion of sodic subsoils in Australia than anywhere else in the world



Research needs?

Nil



Education and training needs are high

Most gully control efforts are

- technically narrow
- lacking practical experience with equipment and works
- lacking knowledge of rehabilitation options



Three key issues for gully stabilisation

- Flow paths/patterns
- Soil and vegetation management
- Surface stabilisation (short and long-term)

All three need to be addressed



Focussing on soils

We know (and have known for a long time):

- 🌱 You can't stabilise dispersive soils without treatment
- 🌱 You can't revegetate soils if they're infertile
- 🌱 And you do need to consider salinity if revegetating subsoils.

These are as certain as death, taxes, and another TV reality show

Example #1: Research for QRail



Control

LA-30
31-01-01

Gypsum, fertiliser, irrigation



LA-09
31-01-01

Drain - Brisbane



Dispersive creek diversion, Brisbane



Common issues for dispersive soils

- ✍ Soil analysis lacking
- ✍ Gypsum insufficient
- ✍ Gypsum not well applied
- ✍ Insufficient rainfall and time
- ✍ Inadequate fertilisation
- ✍ Need for on-going maintenance
- ✍ Inappropriate vegetation
- ✍ High initial instability (soil, site, flow paths)

Personal perspective

- We do have sufficient information to manage gullies
- We do, however, need to find a way to ensure that future gully remediation planning and works apply the full range of available knowledge.
- Demonstration projects will be site-specific, but could contribute to developing some form of decision support tool.
- Remediation of some gullies will be costly, but the old Welsh adage “buy cheap, buy twice”, strongly applies.

GLENCORE



Glencore Coal Alluvial Gully Erosion and Rehabilitation Workshop

8th August 2016
Collinsville

Glencore Coal – Mine Rehabilitation

Regulatory Rehabilitation Objectives:

1. Safe - safe for humans and animals;
2. Stable - Structural and geotechnical adequacy;
3. Non-polluting - Water quality to meet outlined conditions; and
4. Self-sustaining - Natural communities or grazing area, Species diversity, >70% ground cover.



Glencore Rehabilitation Program

- **Establish a Site Strategy:**
 - Identify Domains
 - Set post mining land use
 - Establish objectives (Slide 2)
- **Develop Indicators and clear completion criteria**
 - Apply completion criteria
- **Design and Implement the rehab monitoring program (Slides 45-46)**
 - Baseline surveys
 - Self performance assessment
 - Annual walkover/flyover
 - Long term monitoring program
- **Recording and Reporting program**
 - GIS records
 - Establishment assessment form
 - Internal and external reporting

Site Implementation:

The ten process stages are as follows:

- Stage 1 – Drainage and Landform Design;
- Stage 2 – Bulk Shaping;
- Stage 3 – Progressive survey (tracking);
- Stage 4 - Assessment of landform to specifications;
- Stage 5 – Detailed drainage and erosion control plan;
- Stage 6 – Completion Survey;
- Stage 7 – Topsoiling;
- Stage 8 – Seeding;
- Stage 9 – Soil amelioration;
- Stage 10 – Rehabilitation Monitoring

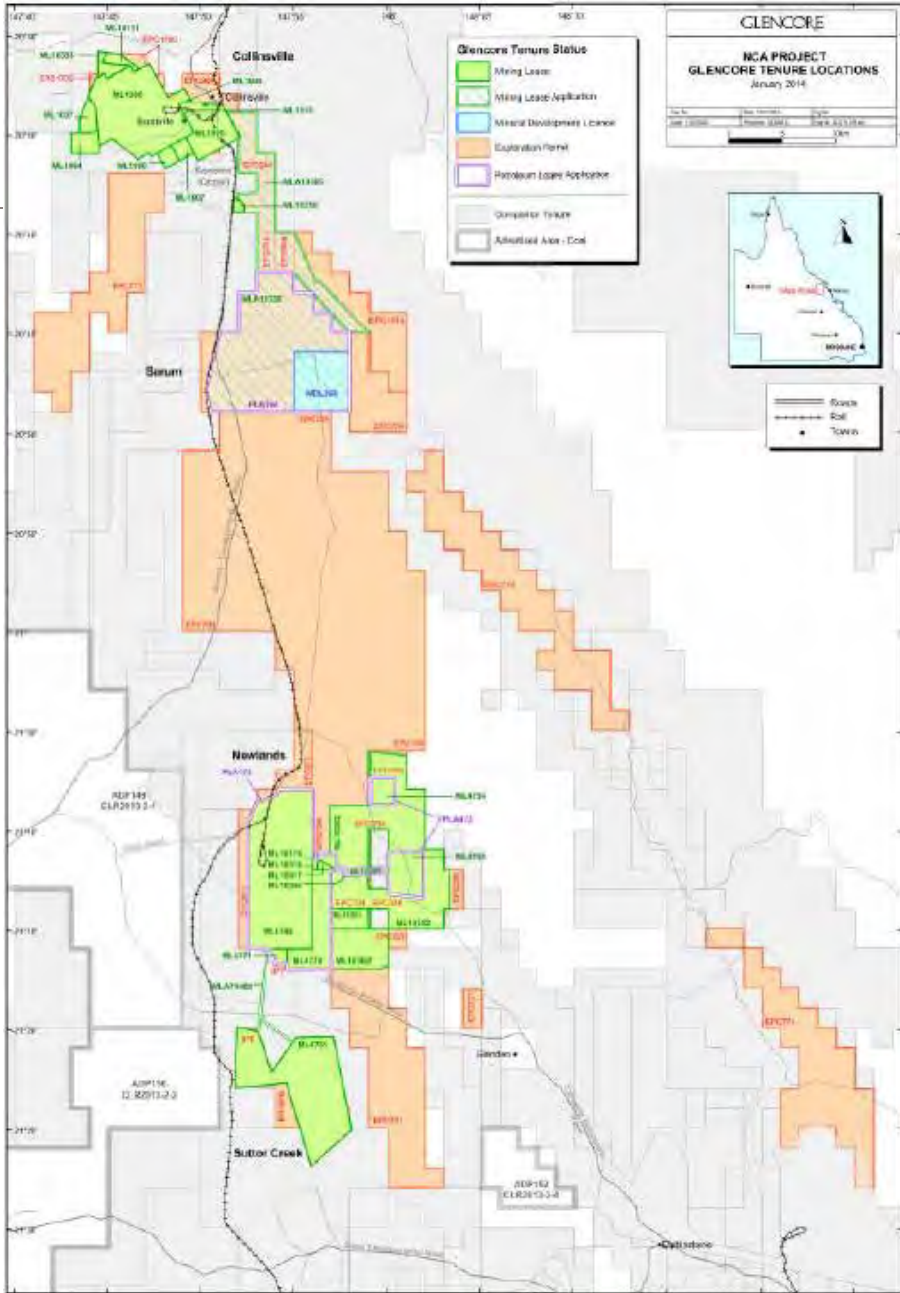
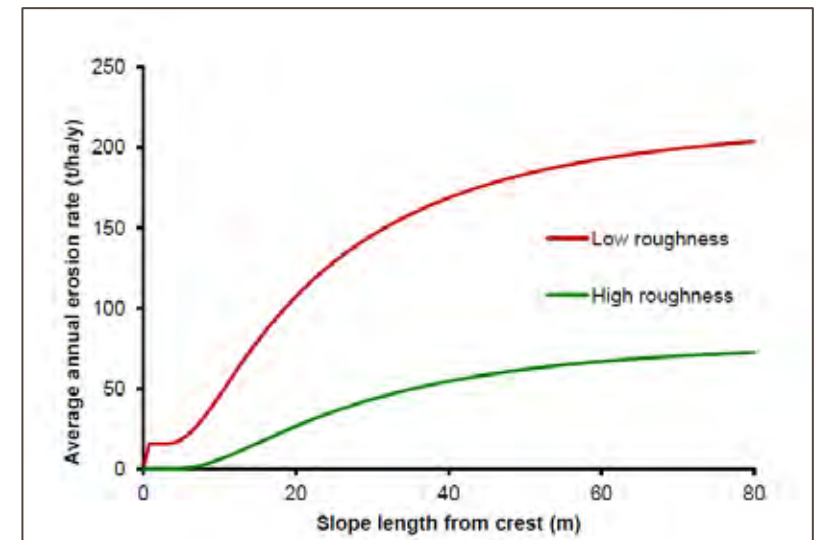
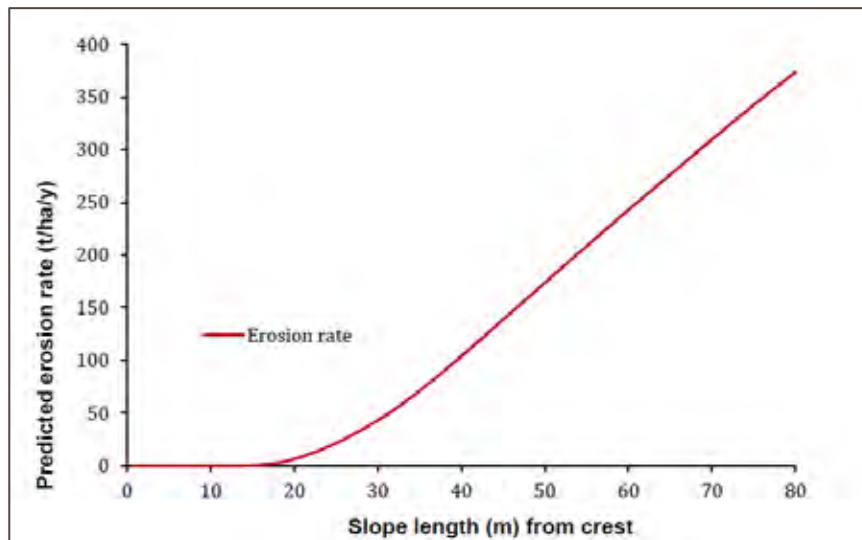
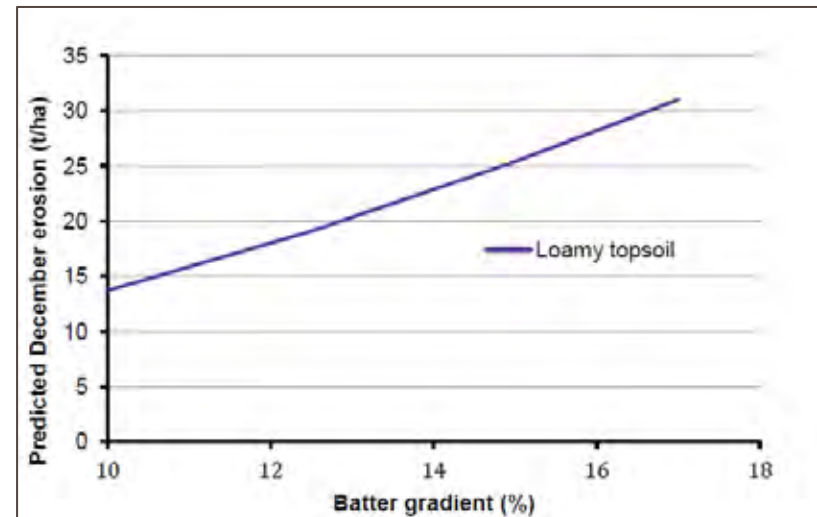
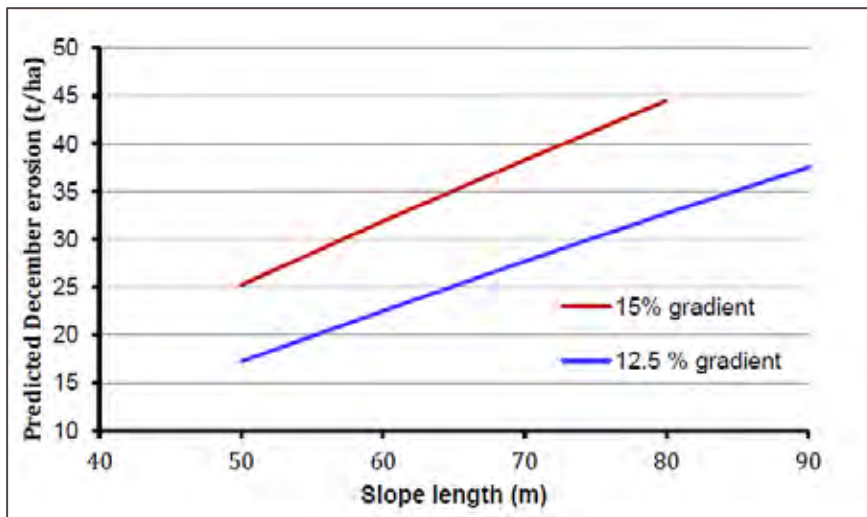


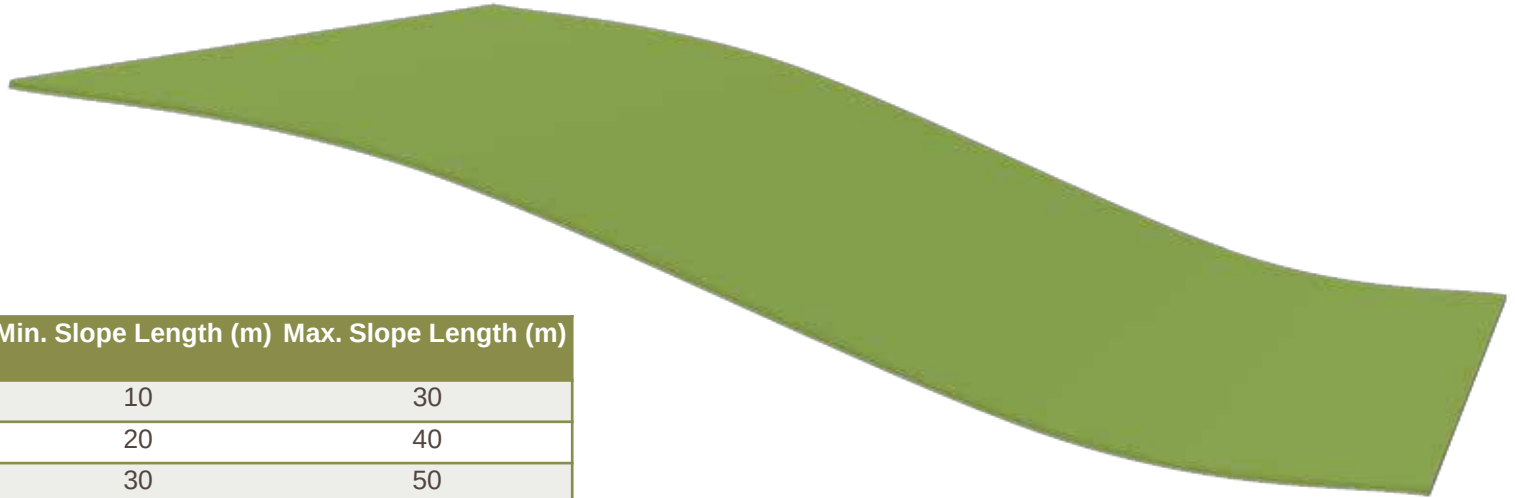
Figure 1: Newlands Collinsville Abbot Point Project – Tenure

Slope length & Slope Gradient vs Erosion rates

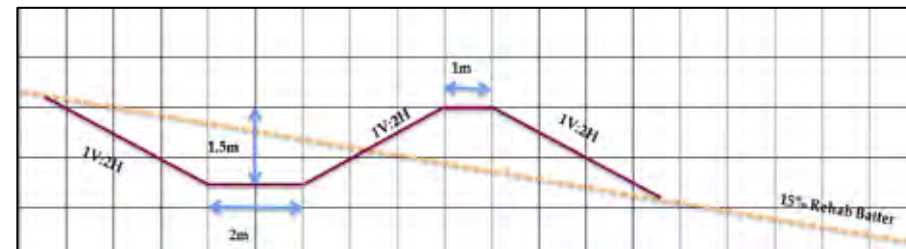
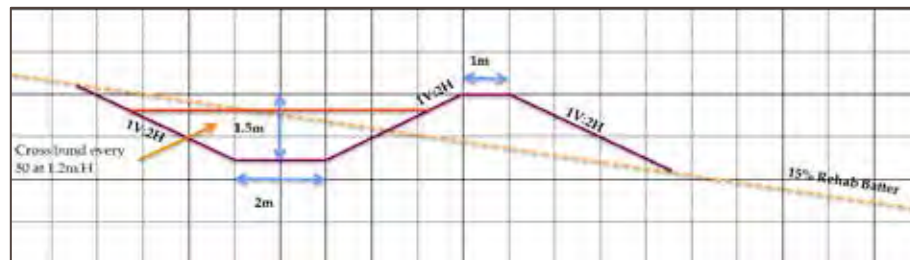


Rehabilitation Batter Profiles

'Concave - Convex' batter



Max. Slope Grade (%)	Min. Slope Length (m)	Max. Slope Length (m)
>30	10	30
25	20	40
20	30	50
15	40	80
10	80	120
5	120	180
2	180	250



Newlands Coal - Rehabilitation

Capping –

Required to provide a stable non-polluting layer above high risk materials e.g. Tails, Reject, dispersive or geo-chemically unstable (AMD) spoil, etc..

Topsoiling –

Growth medium for establishing vegetative cover.



Newlands Coal Rehabilitation

2009 Wollombi rehabilitation – approximately 3 months after seeding



Newlands Coal - Rehabilitation

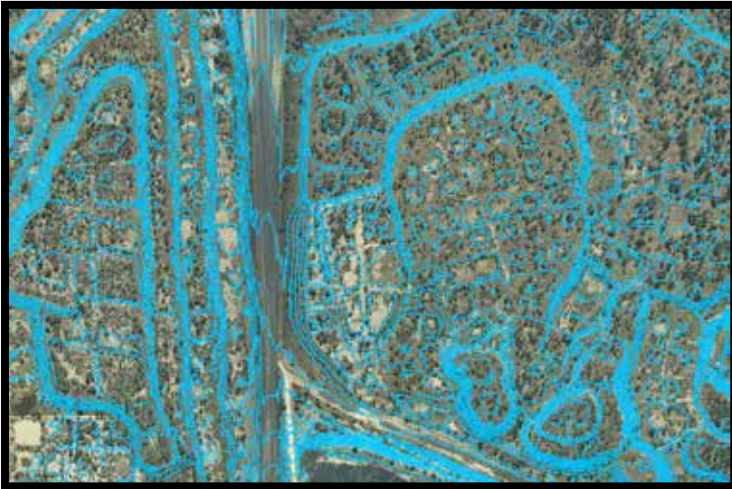
Topsoil spread onto re-contoured spoil



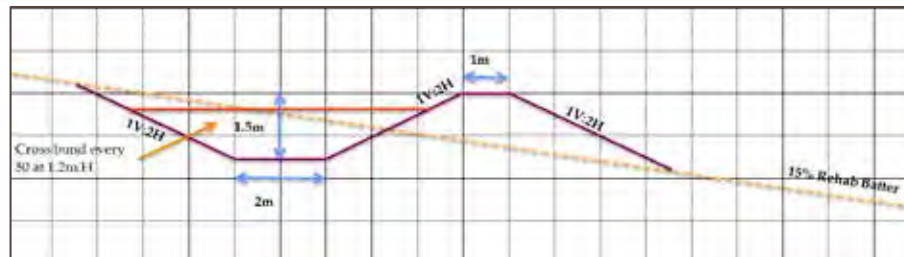
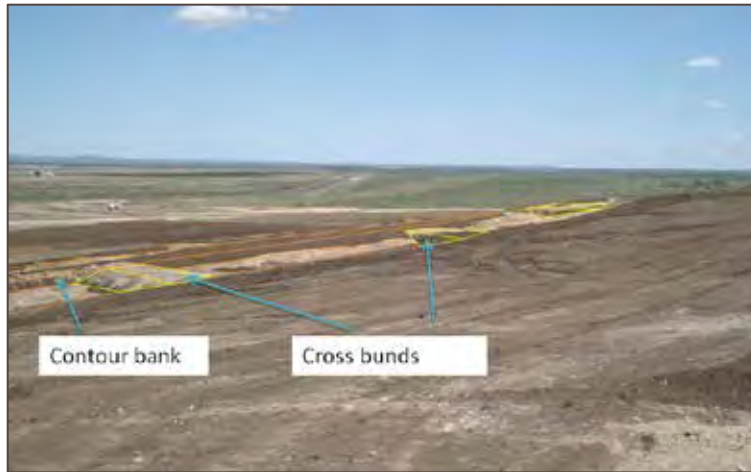
Newlands Coal - Rehabilitation - Drainage Internally Draining Rehab (IDR)

Historical IDR Design Criteria

External bunds (requirement dependant on slope of adjacent landform)	Volume equal to or exceeding planimetric catchment surface area (m^2) multiplied by 333 mm.
Cross bunds	Construct in channel of external bunds and contour banks at 50 m intervals.
Cell dimension	Any shape but not exceeding 150 m in dimension. If slope of base exceeds 4%, length perpendicular to contour must not exceed 50 m.
Cell volume	Minimum planimetric catchment surface area (m^2) multiplied by 333 mm.



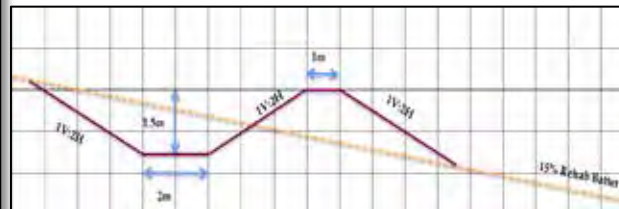
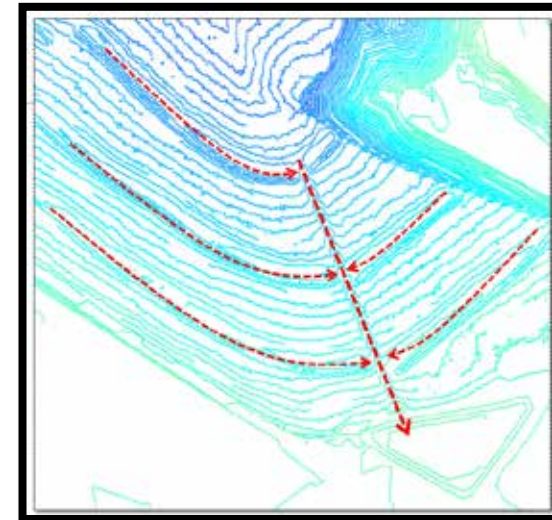
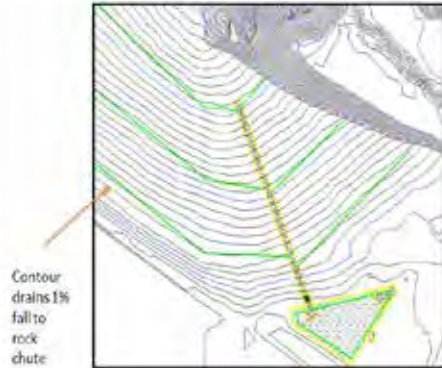
Newlands Coal – Rehabilitation - Limited Free Draining



Newlands Coal - Rehabilitation - Fully Free Draining

Environmental
Ramp 20 Rock Chute A

Feature ID	Feature Name
Click to add desc.	Click to add desc.



Newlands Coal Rehabilitation

Re-shaped mine spoil/waste dumps



Newlands Coal Rehabilitation - Enhancement

Tree trash placement



Newlands Coal Rehabilitation

Ripping and Seeding with native grasses and tree seed



Newlands Coal - Rehabilitation

Native and naturalised grasses



Seed Mix

BOTANICAL NAME	COMMON NAME
Cover Crop	
<i>Echinochloa esculenta</i>	Jap Millet
Grass Species	
Target volume (kg/ha) =	
<i>Bothriochloa ewartiana</i>	Desert blue grass
<i>Bothriochloa pertusa</i>	Dawson indian couch
	Bisset creeping blue grass
<i>Bothriochloa insculpta</i>	Bermuda grass (speedie couch)
<i>Cynadon dactylon</i>	Curly mitchell grass
<i>Astrebila lappacea</i>	Queensland bluegrass
<i>Dicanthium sericeum</i>	Floren Blue Grass
<i>Dicanthium aristatum</i>	Blue dawn
<i>Paspalum nicorae</i>	katambora rhodes
<i>Chloris gayana</i>	Forest Blue Grass
<i>Bothriochloa bladhi</i>	
Legume Species	
<i>Stylosanthes scabra</i>	Siran stylo
<i>Stylosanthes hamata</i>	Verano stylo
<i>Clitoria ternatea</i>	Butterfly pea
<i>Macroptilium bracteatum</i>	Burgundy bean
Shrub Species	
<i>Acacia podalyrifolia</i>	Qld Silver
<i>Acacia decora</i>	West silver
<i>Acacia harpophylla</i>	Brigalow
<i>Acacia victoriae</i>	Prickly wattle
<i>Atalaya hemiglauc</i>	Whitewood
<i>Atriplex nummularia dehulled</i>	Old man saltbush
	Leichardt Bean
<i>Carissa ovata</i>	Currant Bush
<i>Enchylaena tomentosa</i>	Ruby Saltbush
<i>Lysiphylum hookeri</i>	White bauhinia
<i>Senna notabilis</i>	Cockroach bush
Tree Species	
<i>Brachychiton populneus</i>	Kurrajong
<i>Brachychiton rupestris</i>	narrow leaf bottle tree
<i>Corymbia erythrophloia</i>	Gum-topped bloodwood
<i>Corymbia clarksoniana</i>	Clarksons bloodwood
<i>Eucalyptus cambageana</i>	Dawson Gum
<i>Eucalyptus camaldulensis</i>	River Red gum
<i>Eucalyptus citriodora</i>	Lemon scented
<i>Eucalyptus crebra</i>	Ironbark
<i>Eucalyptus tereticornis</i>	Blue gum/River red gum
<i>Eucalyptus tessellaris</i>	Moreton bay ash
<i>Eucalyptus fibrosa</i>	Red Iron Bark
<i>Eucalyptus melanophloia</i>	Silver leaf Ironbark
<i>Eucalyptus orgadophila</i>	Mountain Coolibah

Collinsville Coal Mine Rehabilitation

Before - Garrick East August 2015



Collinsville Coal Mine Rehabilitation

During - Garrick East Rehabilitation



During - September 2015



During - December 2015

Collinsville Coal Mine Rehabilitation

After - Garrick East Rehabilitation Finalised in March 2016



Bellmore Deposit 2001

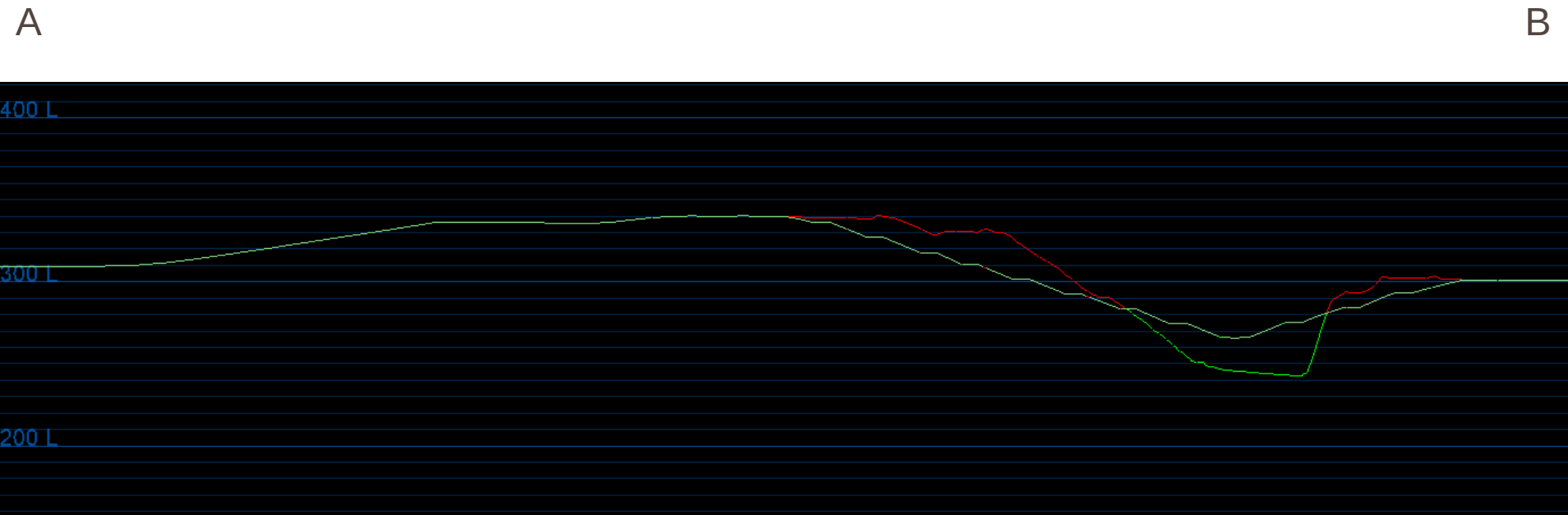


Bellmore Deposit 2012



Cross section 4

Ramp 20



Newlands Coal 2016



Newlands Coal February 2016



Newlands Coal April 2016

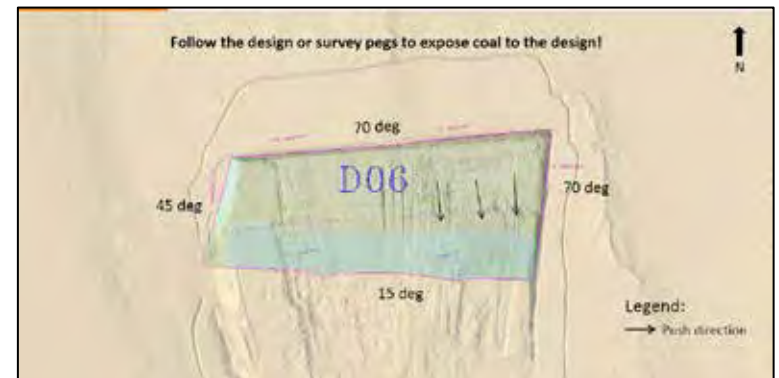


Newlands Coal April 2016



Ramp 12 North Rehabilitation





Newlands Coal - Rehabilitation

Aerial Fertiliser and Gypsum Application



Seed & Amelioration Application

Seed Type	Application Rates
Cover Crop (Jap Millet/Sorghum)	2kg/ha
Grass & Legume (coated and uncoated)	10-15kg/ha
Tree & Shrub Seed	2-5kg/ha

What	Application Rate
DAP Fertiliser	100-200kg/ha
Gypsum (Sodic/dispersive soils only)	4-8t/ha

Newlands Coal Rehabilitation

Hay mulching trial at Eastern Creek



Costs

Expense	Cost
Seed	\$250 - 2000/ha depending on species & volumes Eucalyptus seed ~\$20-\$300/kg Grass \$8 - \$60/kg coated & uncoated
Seed spreading via tractor	\$200/ha
DAP Fert	~\$1000/t = \$100 - \$200/ha
Gypsum	\$150/t = \$750 - \$1500/ha
Biosoils (delivered)	\$120/t @ 100t/ha = \$12,000/ha
Aerial ameliorant spreading	\$300/ha
NB - economics of scale apply	

Rehab Gully Erosion - Before



Rehab Gully Erosion - During

Rock chute construction



Rehabilitation Gully Erosion - During

Rock chute construction



Rehabilitation Gully Erosion - After



Diversion Bank Erosion



Diversion Bank Erosion



Travelling Irrigators – Under Utilised??



Fines Dam 09



Fines Dam 09



Newlands Coal – Monitoring Transects

Rehabilitation Monitoring Sites



Ramp 7

Suttor Creek ROM

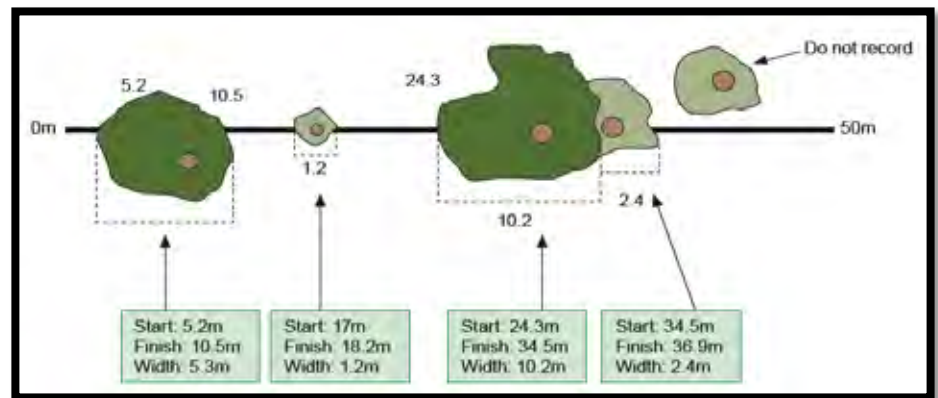


Newlands Coal – Rehab Monitoring Program

Rehabilitation Monitoring

Aim

- To track, document and report the success and performance of rehab against mine closure objectives;
- Assess data overtime to determine trajectory (positive or negative);
- Use of control/analogue sites to assess and compare performance and goals (e.g. grazed open woodland, Brigalow, riparian sites);
- Aspects monitored include soil surface assessment (stability, infiltration, and nutrient cycling);
- Vegetation dynamics (groundcover assessment, woody plant density and richness, canopy cover, grass plant density);
- Habitat complexity;
- Disturbance monitoring;
- Soil sampling;
- Pasture productivity assessment;
- Photographic monitoring



Newlands Coal - Rehabilitation

- Time series Photos – Ramp 7 - 1997



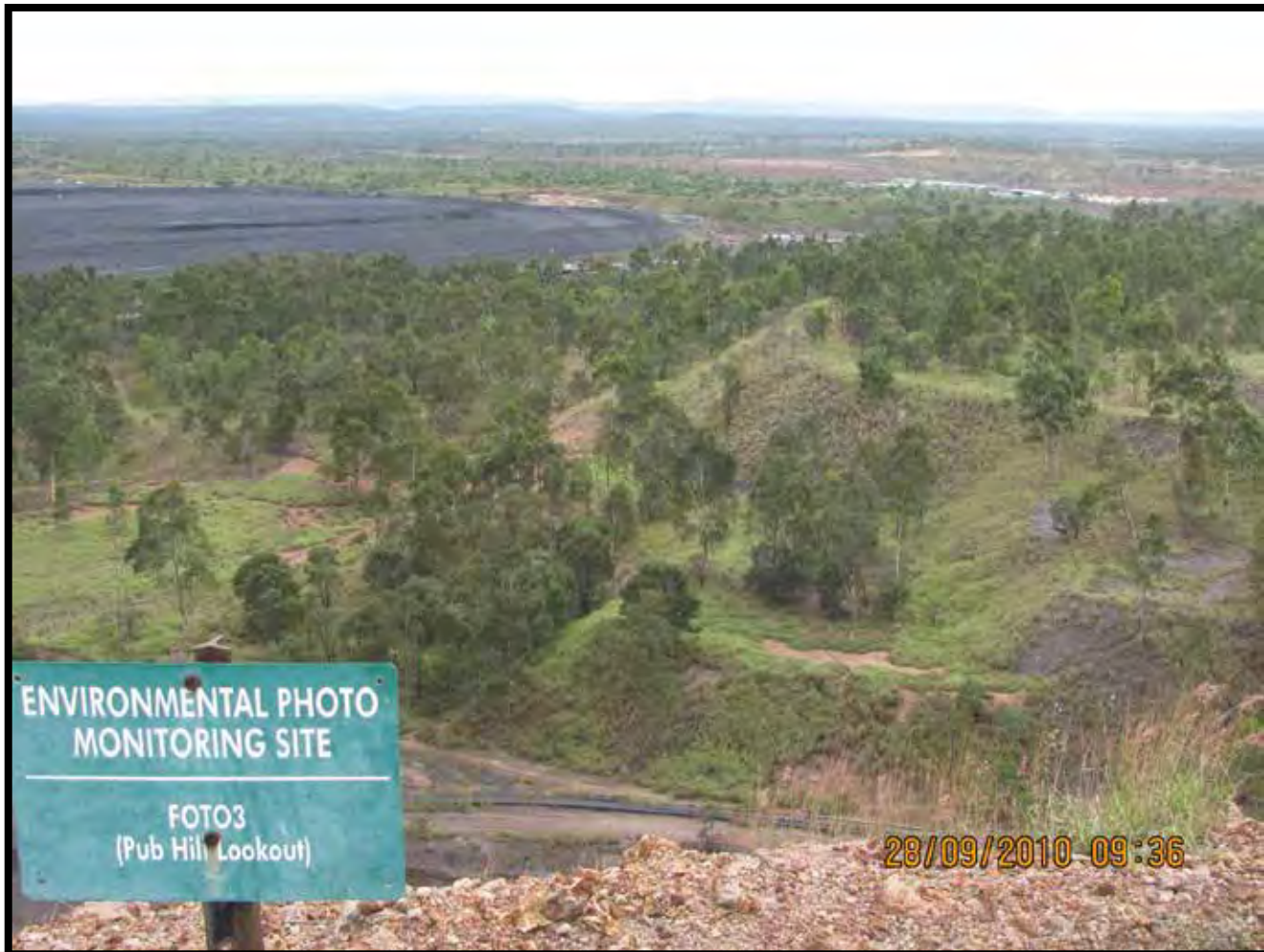
Newlands Coal - Rehabilitation

- Time series Photos – Ramp 7 - 1999



Newlands Coal - Rehabilitation

- Time series Photos – Ramp 7 - 2010



Newlands Coal - Rehabilitation

Rehabilitated external slope at Wollombi Pit (2009 & 2010) & Wollombi Brigalow Conservation Area



Newlands Coal - Rehabilitation

Rehabilitated external slope at Wollombi Pit (2010) & Wollombi Brigalow Conservation Area



Suttor Ck Div. 1B - 2006



Suttor Ck Div. 1B - 2008



Suttor Ck Div. 1B - 2010



Suttor Creek Diversion 2C



Rehab or Background?

1



Questions?



Don River Sediment Reduction Project



Don River Sediment Reduction Project

Funded under Reef Trust II

Overview

- **Joint project with Don River Improvement Trust and Bowen-Collinsville Landcare**
- **Don River catchment characteristics**
 - **Compact catchment (3356 km²)**
 - **Ranked #16/20 in CSIRO report (published Feb 15)**
 - **Sediment contributions**
 - **Tonnes/ha/yr = 0.23 (#5/20)**
 - **Per km of gully: 82t/km/yr (#4/20)**
- **Built on engagement with GBRMPA & other on-ground investigations**
- **Project timeframe Feb 2016-June 2018.**
- **Focussed on 2 properties approx. 30 km inland from Bowen**
 - **500 ha treatment area**
 - **Control & treatment gullies identified**

Site Selection Process



- In association with Don River Improvement Trust & Bowen & Collinsville LandCare
- Representative of grazing properties within the mid-reaches of Don River.
- GBRMPA receiving waters analysis / input
- 2 properties representative of grazing activities along mid-reaches of Don River
 - Site 1: Nyoola
 - Site 2: Minnie Vale

Nyoola property details



• Nyoola

- 3000 ha beef grazing enterprise
- Steve, Wendy Holmes & sons

- 2 project sites

Nyoola North

- 122 ha
- Black cracking clays
- Minor weed infestation
- Woodland riparian zones adjacent to cleared pastures

Nyoola South

- 139 ha
- Duplex chromosols
- *Allocasuarina* woodlands adjacent to cleared pastures.

Erosion examples at Nyoola sites

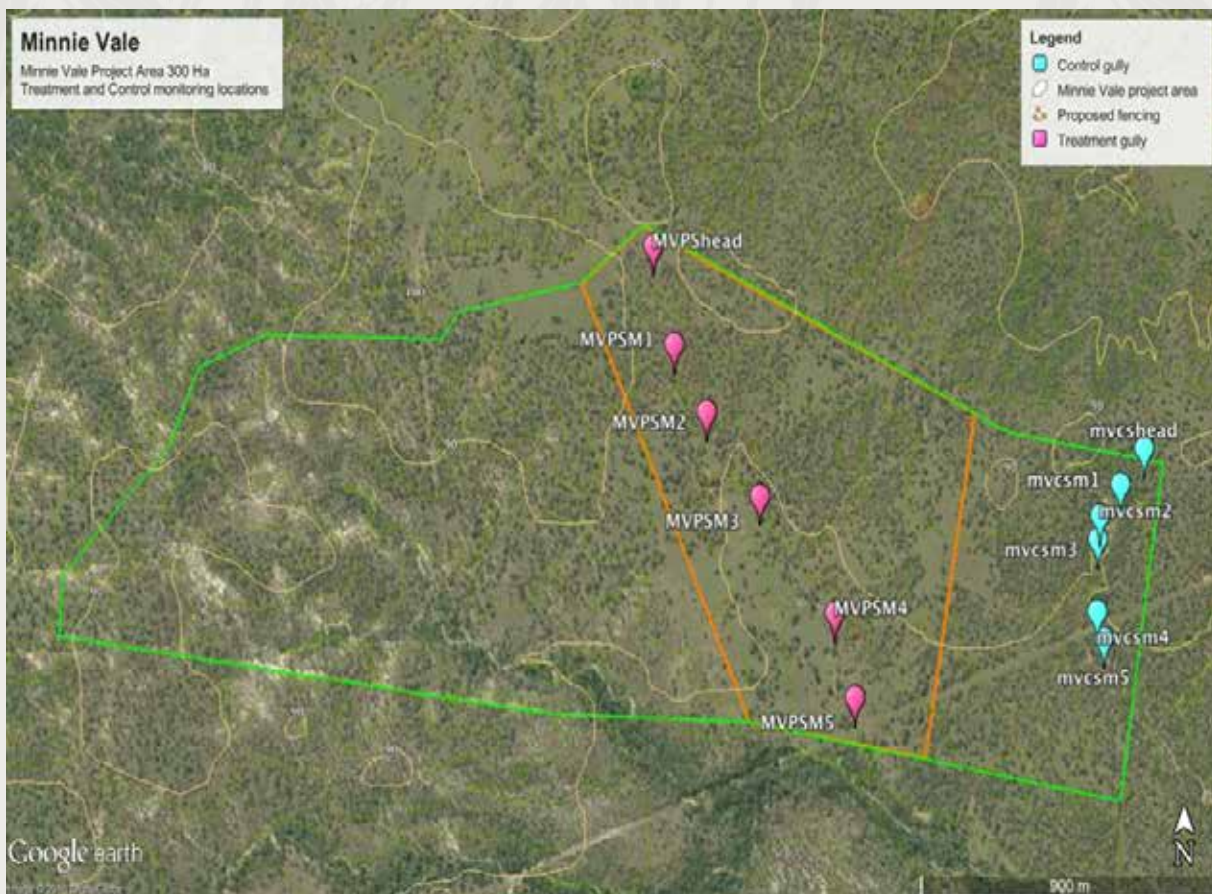


Nyoola North



Nyoola South

Minnie Vale property details



• Minnie Vale

- 3500 ha beef grazing enterprise
- Barney & Juanita Gordon & family
- 1 project site flowing SSE into Mary Creek/Don River

Project site details

- 300 ha
- Loamy duplex red chromosols
- Incised gully systems (0.5-2.5 m deep)
- Vegetation open eucalypt woodlands including endangered regional ecosystem [*Eremphilla mitchellii* low open woodland (11.3.33)].

Erosion examples at Minnie Vale



Planned interventions

- 1. Completion of site design & monitoring program (done)**
 - **Photo monitoring points established in control & treatment gullies**
 - **Gully condition assessment**
- 2. Site-specific restoration plans in accordance with Gully Toolbox guidelines**
 - **Exclusion fencing**
 - **Ground cover & riparian zone restoration**
 - **Installation of porous check dams**
 - **Majority of works during 'dry season'**
- 3. Monitoring (pre & post season) pasture/soil/restoration conditions**
- 4. Extension /field days**