Rehydrating Landscapes in Central Australia

Mulloon Institute
For environment, farming and society.

The Mulloon Institute

The Mulloon Institute (TMI) is a not-for-profit research, education, and advocacy organisation. It is recognised globally as a demonstrator of sustainable agriculture and environmental regeneration through landscape rehydration and restoration.

TMI demonstrates innovative land management approaches that create healthier landscapes with more resilience to climatic extremes. By supporting transformational change in the way landscapes are managed, TMIs work benefits Australia's farmers and communities and ultimately our planet.

The mission of the Mulloon Institute is to actively demonstrate, validate and share landscape rehydration, restoration and regenerative practices in order to create sustainable, profitable and resilient agricultural and environmental systems now and into the future. As part of this goal, we seek to build the capacity of landholders to read their landscape and the ecological processes it supports, to use this knowledge to plan effective landscape rehydration interventions and continue to work toward improving the resilience and productivity of their land.

Rehydrating Landscapes in Central Australia

This document provides land managers an understanding of landscape rehydration theory and practical guidance for implementing techniques and solutions in the arid zones of Australia. It has been prepared by the Mulloon Institute as part of the landscape rehydration demonstration project for Central Australia, Centralian, jointly funded through the Australian Government's Future Drought Fund and the Northen WA and Northern Territory Drought Hub.

Mulloon Consulting acknowledges Traditional Owners of Country throughout Australia and recognises the continuing connection to lands, waters and communities. We pay our respect to Aboriginal and Torres Strait Islander cultures; and to Elders past and present.

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Australian Government
Department of Agriculture, Fisheries and Forestry
Future Drought Fund
Northern Hub

This program/project is supported by the Northern Hub, through funding from the Australian Government's Future Drought Fund.

The Centralian Landscape Rehydration Project

The Centralian Landscape Rehydration project consists of scaling landscape rehydration and regenerative management practices to restore landscape function in the central Australian rangeland region. The project will plan and construct working demonstrations of landscape rehydration to illustrate drought resilience at scale on pastoral properties in central Australia. The demonstration sites consist of Aileron Station, Ahakeye Aboriginal Land Trust, Narwietooma Station and Glen Helen Station.

The project aims to restore the natural water movement in the landscape, increasing soil moisture so that healthy soils can be maintained (or established where they have been eroded or degraded). This will support the building of soil carbon and microbiology, which then supports nutrient cycling and vegetation (pasture) growth. Pre and post rehydration landscape studies will demonstrate landscape changes as a result of works, including monitoring sites for long term evaluation of the project. A fifth station – Woodgreen, which has had a long history of landscape rehydration work is being sampled to identify the changes in hydrology and soil health attributed to the landscape rehydration work.

Figure 1. Landscape Planners Lance Mudgway and Erin Healy from the Mulloon Institute setting up survey equipment at Narwietooma Station prior to setting out works.

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Figure 2. Constructing earth banks in Central Australia

1 Introducing Landscape Rehydration

Landscape rehydration is a key priority in agricultural areas around Australia, focussing on:

- *hydrology* – the movement and distribution of water above and below ground and in the atmosphere
- *landscape function* – the patterns and processes by which a landscape retains and uses its vital resources, especially water, as a biophysical system.

Landscape rehydration aims to reinstate natural processes that optimise the movement, storage and cycling of water within the landscape to support a diverse range of plants, animals and human enterprises. Strategies employed rebuild soil fertility, fix more carbon in the landscape, restore lost biodiversity, improve water quality and availability and moderate climatic extremes. This results in increased agricultural productivity, production of high-quality nutrient dense food, improved human health and community cohesion.

Figure 3. Incised creekline and bare, dehydrated floodplain after historic long-term over-grazing by cattle.

These objectives are achieved through physical on-ground interventions where improved management cannot repair the landscape on its own. Typically, this is where waterways have become incised or the landscape is severely degraded, which reduces the residence time of water on the landscape (Figure 3). In-stream structures raise the level of the bed of the watercourse, slow and filter water flows, and reinstate the water movement between streams, floodplains and local shallow groundwater. They function the same way fallen trees, organic debris and instream vegetation once did when landscapes were well vegetated prior to European settlement. Contour banks assist to redistribute runoff on floodplains and prevent further erosion of gullies and flowlines. These interventions assist the landscape to store more water in wet times, like a sponge, and slowly release it during drier times, hydrating the wider landscape and making water available for plants and downstream areas.

Introducing Landscape Rehydration

Along with physical interventions, appropriate land management is critical to achieve landscape repair. This includes grazing management and protection of vulnerable and hydrologically significant areas. Effective grazing management can build soil health and influence plant vigour, leading to enhanced production, the moderation of temperature extremes and the efficient cycling of water at the soil surface and underground. Changes to infrastructure such as fencing and water points is often needed to enable improved grazing management.

Plants have a vital role to play in landscape rehydration. Plants in the right place are very effective and inexpensive landscape healers. Maintaining a diversity of plants ensures a landscape is accumulating rather than losing vital resources, has a healthy daily water cycle and is in general more resilient to the impact of pests, drought, flood events and other negative impacts.

Complex natural ecosystems that supported indigenous production systems for millennia have been degraded through the imposition of inappropriate production systems to the landscape. Restoring landscape function and the water cycle provides the conditions necessary to restore a healthy and biodiverse ecosystem. This in turn allows natural functions to support a more sustainable production model, with reduced artificial inputs and providing more nutrient dense, high-quality food.

In a drying and more variable climate resulting from climate change and global warming, rehydrating landscapes is more important now than ever to make landscapes more resilient to drought and flood.

1.1 Understanding energy in the landscape

The sun is the primary source of energy on our planet. Energy from the sun is essential to all life on Earth, and it has a major role in many of the systems and processes that influence our landscape. Weather and climate patterns, photosynthesis in plants, chemical reactions and oxidation, ocean currents and of particular relevance to landscape rehydration, the water cycle all require energy from the sun.

A large amount of energy reaches the Earth’s surface from the sun (Figure 4), which must be absorbed and dissipated through the biosphere, mostly through the interaction of plants and water. The transformation of water from liquid to vapour absorbs significant amounts of energy, and in combination with weather patterns (also driven by the sun’s energy), helps to disperse the energy through the atmosphere, as well as moderate temperatures over a daily cycle. It also drives the water cycle.

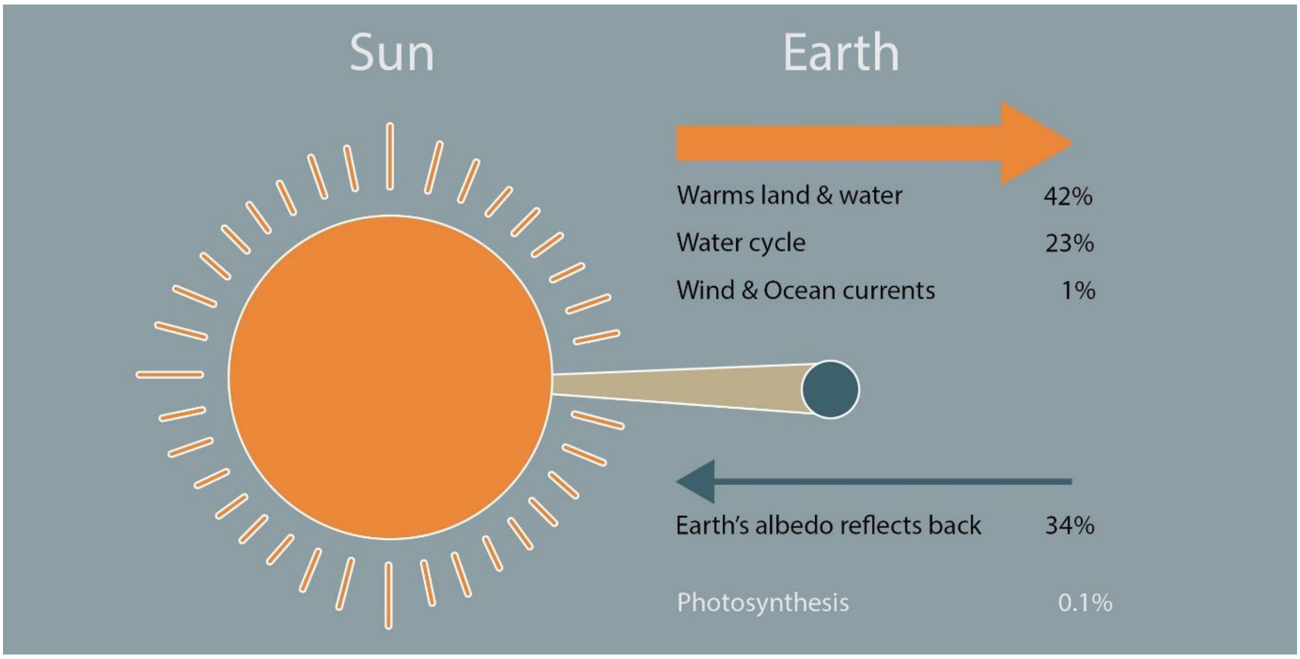


Figure 4. Flow of energy from the sun to Earth.

When water interacts with solar energy and gravity alone, it is the most erosive force on the planet. Furthermore, a sunlit but waterless environment results in dramatic temperature fluctuations between night and day (Figure 5). It is plants that make our planet hospitable to life. When the water cycle is integrated into the operation of biodiverse ecosystems, we see energy being captured, dissipated and effectively moderated at the planet's surface and within the atmosphere. The functional coupling of the water cycle and the biological cycle builds soil fertility and moderates our climate.

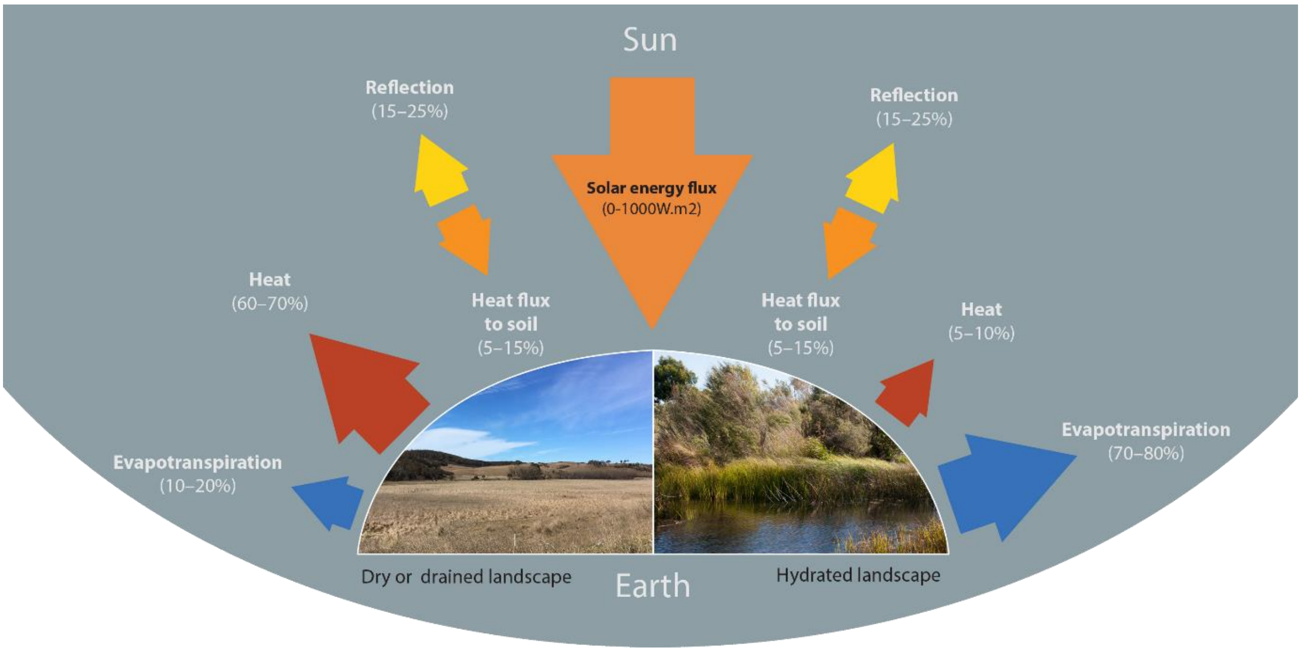


Figure 5. The difference in energy conversion between dry and hydrated landscapes (adapted from Pokorný et al. 2010).

1.2 Understanding water in the landscape

Water is a powerful dynamic substance able to absorb, transfer and release vast amounts of solar energy. It dissipates and distributes the energy from the sun and gravitational forces. The interaction of sunlight, gravity and water form foundational processes of the water cycle (Figure 6). The water cycle has two major components – the large water cycle over the oceans and the small water cycle over land. Only around 12% of all water on earth moves between the large and small water cycles.

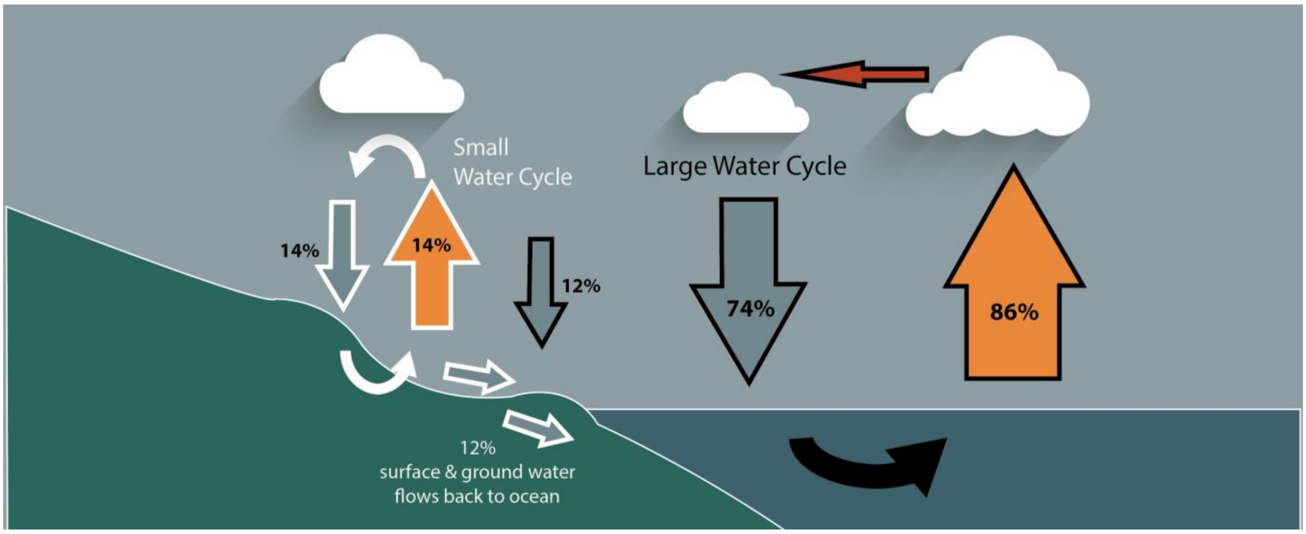


Figure 6. The relative contribution of evaporation to rainfall over both the oceans and the continents (adapted from Pokorný et al. 2010).

1.3 Understanding the role of plants in the landscape

Plants are a vital part of the small water cycle. Evapotranspiration is the process that occurs in every plant when water is transported from the soil and out of the leaves, at which point it evaporates. Plants only keep a tiny fraction of this water to support photosynthesis, metabolism and growth, releasing around 97% into the atmosphere as vapour. Mature trees can transpire hundreds of litres of water per day.

When liquid water turns into vapour, it takes energy (from the sun), cooling the air temperature around the plant. So not only do plants provide shade for the soil and animals, they change the temperature of the air around them. Conversely, the transformation of vapour back into liquid (condensation) at night releases energy, keeping night time temperatures warmer and reducing frosts.

Landscape Rehydration focuses on restoring the small water cycle, as this cycle is a key driver of biology and ecological function in our terrestrial landscapes.

Not only do plants provide climate moderation through evapotranspiration, condensation and shading the ground, they also protect the soil by their physical presence – roots in the ground and stems and green material above it, as well as dropping dead leaves and material to create a mulch layer over the ground surface. The shading and mulch act as a protective blanket over the soil to moderate temperature and protect the biological life within the soil, in addition to feeding it. Moreover, the vegetation and mulch dissipate the energy of raindrops and increase the ability of the soil to absorb water, reducing erosion and runoff. Root exudates from plants along with gradual incorporation of the litter into the soil bind the soil, stabilising landscapes and feeding microbial communities that in turn create a spongy soil structure that can absorb and hold more water.

Increasing plant diversity in a landscape creates more resilience to climate fluctuations, the impacts of different kinds of management and the influx of diseases and pests. This resilience reduces the potential for erosion, supporting restoration activities.

1.4 Changes in landscape post-European settlement

Since European colonisation of Australia, there has been significant ecological impacts on the landscape. Indigenous peoples have been living and managing the landscape for over 65,000 years, co-evolving alongside biodiverse and highly functional ecosystems across the continent. The colonising peoples brought an agricultural system, livestock and crops that were suited to the cold climates of Europe and disregarded the farming practices and native foods that had been the staples of Indigenous agricultural systems.

The changes in land management practices and introduction of new organisms have had widespread impacts across the continent. Biodiversity in Australia’s ecosystems has declined dramatically, bushfires have increased in scale, intensity and frequency and soil has been degraded or lost.

Under natural systems, surface water together with vegetation and debris creates contours over the landscape that store and slow water flow (Figure 7 to Figure 9). Where runoff concentrates in valleys, debris accumulates at various points creating natural weirs, or “steps”. These steps create pools, with riffles in between – the “chain of ponds”.

Figure 7. Natural spinifex contours, West MacDonnell Ranges.

Removal of vegetation through direct clearing, inappropriate grazing pressure and more frequent intense wildfire has removed the materials nature used to create steps in the landscape as well as exposing the soil to erosion. This has resulted in the natural steps being eroded away and ultimately waterways becoming incised, breaking the connection between surface water and shallow groundwater in the floodplain.

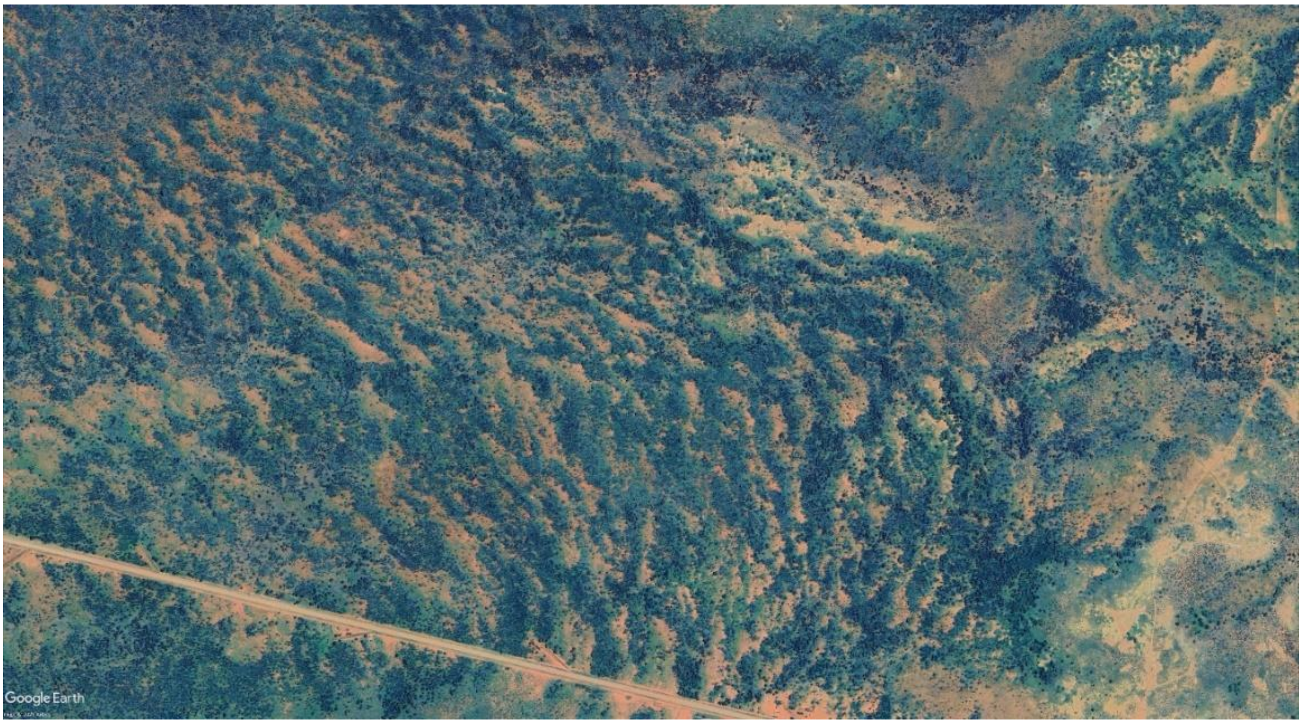


Figure 8. Natural mulga contours on the floodplain (Google Earth, imagery 2/2023).

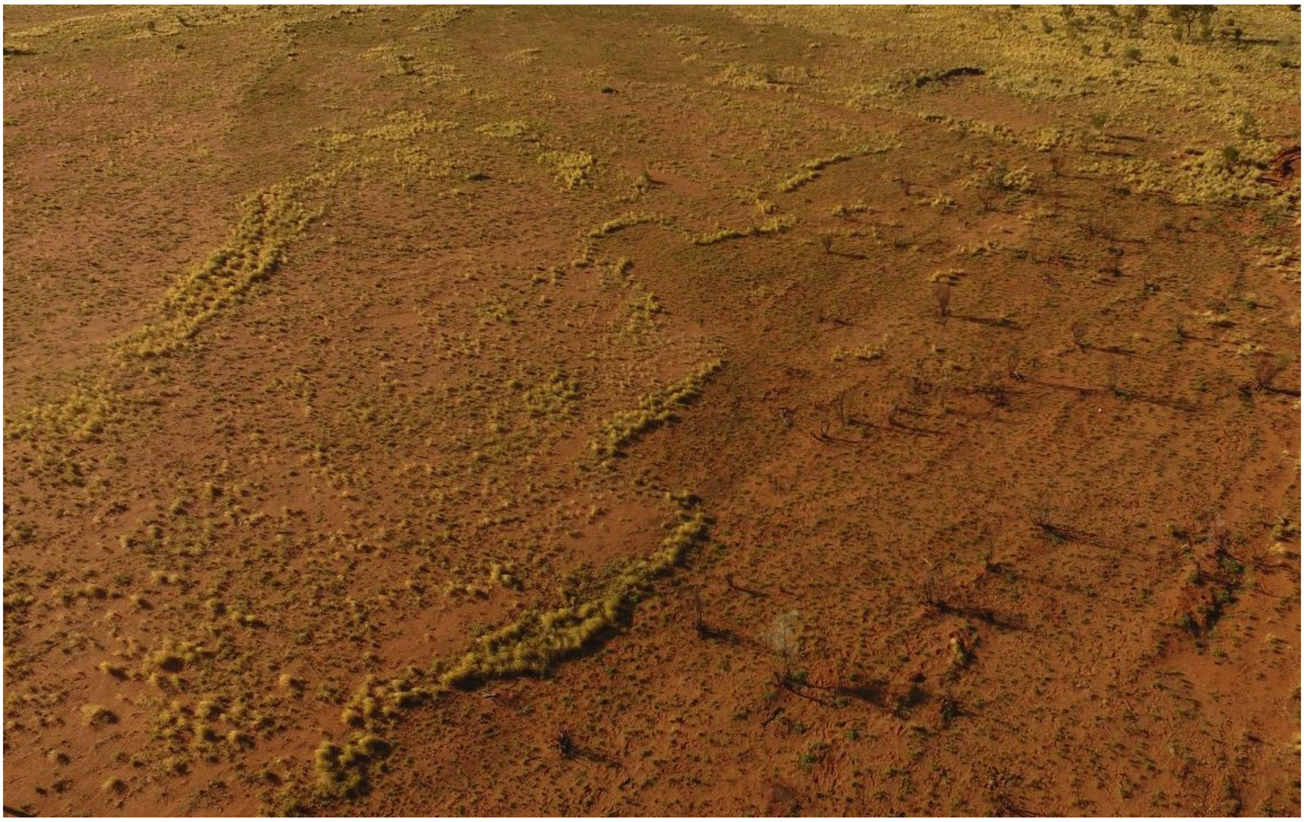


Figure 9. Grass contours on a floodplain.

1.5 Water – the landscape shaper

The water cycle under the influence of gravity, powered by and carrying all that solar energy, is the most erosive force in nature and shapes our planet. That force is put to work against the binding forces of soil and rock, resulting in erosion.

The erosion of landscapes by water is influenced by and large by velocity of flow as the energy of flowing water is proportional to the square of the velocity. Therefore, doubling the velocity of flow will increase the energy by four times. The velocity of flow, and therefore the energy is related to three factors (Figure 10):

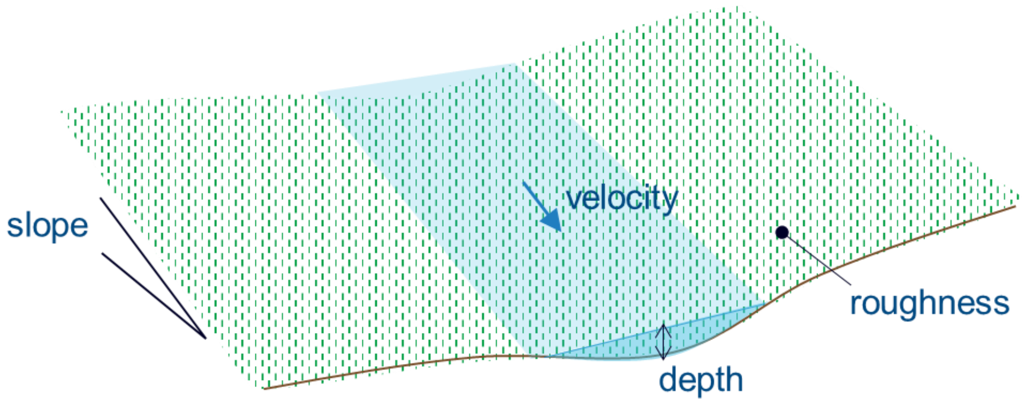


Figure 10. Factors affecting flow velocity and energy.

Slope Velocity is proportional to the square root of the slope over which the water is flowing (therefore energy is proportional to the slope). Slope can be reduced by increasing the total flow length between two points (adding meanders).

Volume Flow energy is proportional to the depth of flow; increasing the volume of flow will increase the depth and therefore the energy. Volume is largely determined by rainfall, and catchment size and composition – for instance a steep rocky catchment will generate more runoff than a forested catchment with deep soils. Volume can be reduced by increasing infiltration in the catchment (by improving soils and adding vegetation) and increasing storage in the catchment.

Roughness Velocity is proportional to the inverse of surface roughness expressed as a decimal number (0–1) with smaller numbers representing a smoother surface. Doubling the surface roughness will halve the velocity. Surface roughness can be effectively increased by spreading flow over a wider area – reducing the depth. Surface roughness can be increased directly by plant growth or adding soil cover like mulch, logs or rocks.

Head-cuts

Head-cuts are a process by which erosion moves upslope, cutting through the natural steps and dehydrating landscapes (Figure 11 and Figure 12). Head-cuts are often formed where a road or cattle track creates a drop in a concentrated flow path. The falling water over the drop undercuts the soil, which collapses (Figure 13). Head-cuts can migrate several hundred metres in a single event.

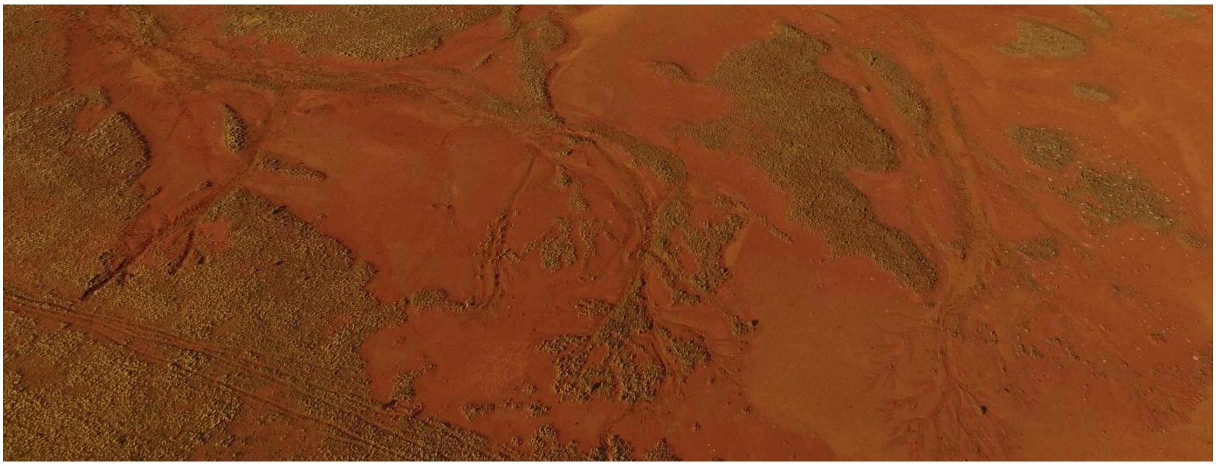


Figure 11. Head-cuts on an overgrazed floodplain.

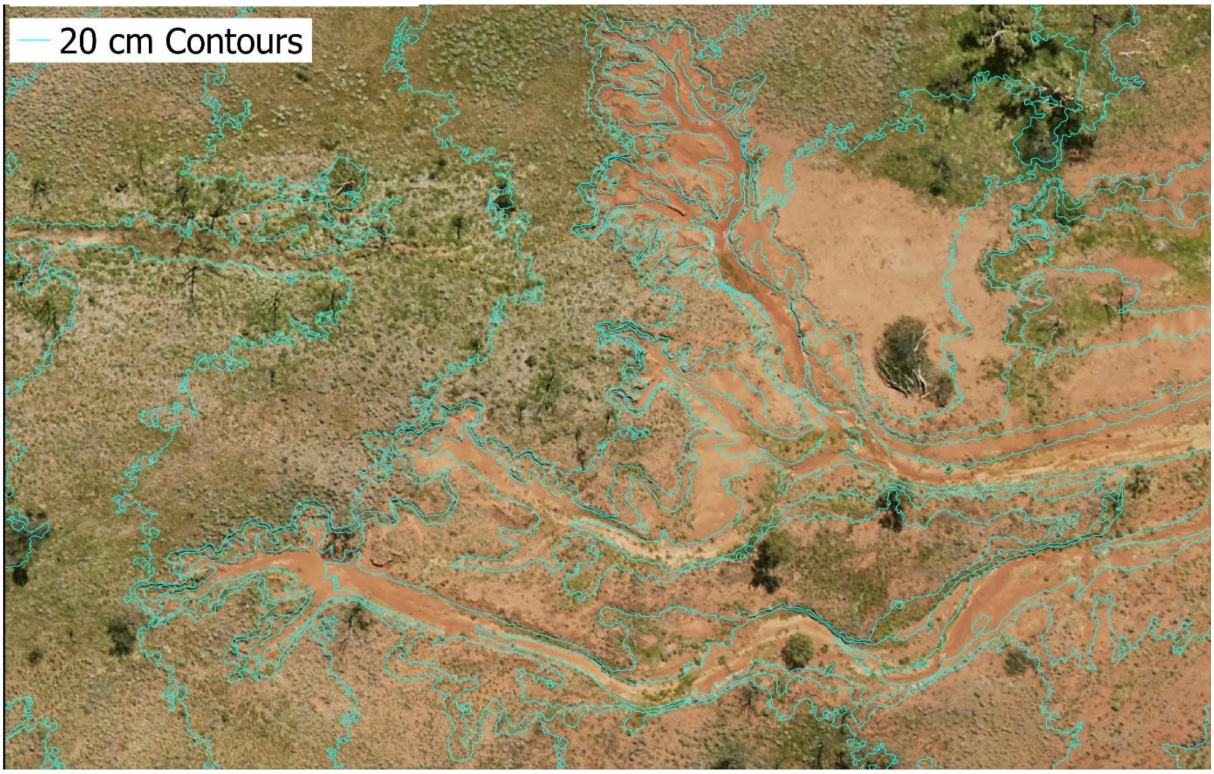


Figure 12. Head-cuts on a tributary to an incised waterway (height of head-cuts up to 0.5 m).

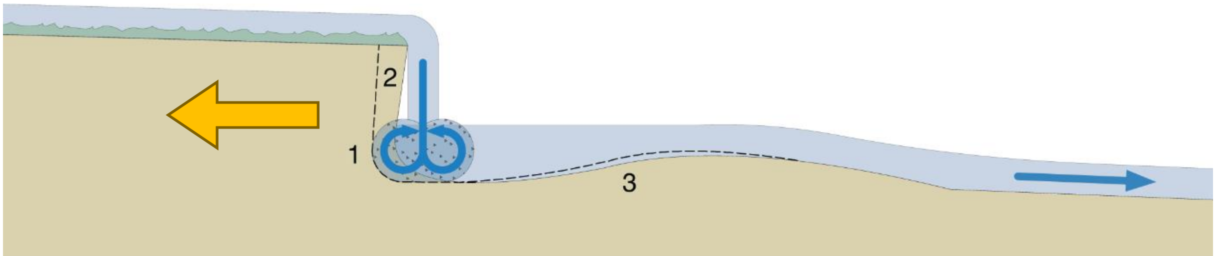


Figure 13. Process of head-cut migration: 1) water flows over a drop, scouring the toe of the face of the head-cut; 2) when the toe is undermined, the head-cut collapses; 3) the collapsed material is transported downstream by the flow.

2 Understanding the landscape

A catchment is the area of land which contributes runoff to a point in a watercourse. The catchment is defined by the highest hills and ridgelines around it.

One of the first steps in landscape rehydration is to understand the landscape and catchment. It is important to note that the catchment may extend well beyond the area of land that requires restoration.

Understanding the landscape cannot begin without some form of aerial imagery of the area. Detailed imagery can be acquired from the NT Government Land Information System (https://www.ntlis.nt.gov.au/imfPublic/airPhotoimf.jsp), however in most instances satellite imagery available in any online web mapping service should be adequate. Google Earth enables imagery at different times to be viewed, which can be an advantage to see changes over time.

2.1 Catchment Function Analysis

A Catchment Function Analysis is a process of looking at a landscape as a functional system in order to determine where interventions will have the most impact. Tim Wiley (2017) explains that "by analysing a catchment as a functioning system it can be determined 1) how the landscape should function, 2) where key processes have been disrupted and 3) what needs to be done to restore natural catchment function."

Using Google Earth, you can identify and map catchments and other areas of interest from a bird's eye view. It can also be used to quickly calculate areas and distances and other measurements as well as identify landscape features such as ridge lines, scalded soils, vegetation cover, erosion, incised gullies, steep slopes and constriction points in a watercourse. Understanding where these features are located and how they impact the function of the catchment enables you to determine where intervention is needed most.

Having an understanding of the catchment size is also useful for conceptualizing volumes of water that may move through the system. This is important for determining the type and scale of landscape rehydration interventions you may wish to employ.

2.2 Land systems mapping

In the mid-20th century CSIRO conducted a series of land research surveys across Australia including many arid zone areas in the Northern Territory, Western Australia and Queensland. General reports have been created for individual regions detailing the classified land system and component land units for a particular region.

Each individual land system and units describe the specific climate, geology, mineral deposits, water sources, geomorphology, soils, vegetation (including distribution and type of plant communities), natural pastures and present and potential land uses of the mapped area. These land systems can provide a thorough conceptual understanding of the conditions within a catchment area and can also act as a reference of the land condition in the mid-20th century. An example for Harts Range, present on Narwietooma and Glen Helen Stations, is shown in Figure 14.

(1) HARTS LAND SYSTEM (4500 SQ. MILES)

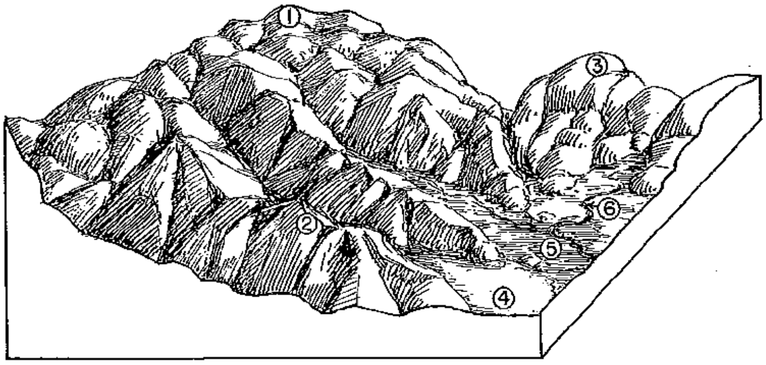
Rugged mountain ranges trending east–west through the centre of the area.

Geology.—Gneiss and schist, some massive granite and basic intrusives. Pre-Cambrian age, Arunta block, MacDonnell–Harts Ranges and Mt. Doreen–Reynolds Range.

Geomorphology.—Erosional weathered land surface: mountains with relief about 1000 ft; dense, vigorously-dissecting drainage.

Water Resources.—Small supplies of good to moderate-quality water from some fracture zones and small alluvial pockets.

Climate.—Nearest comparable climatic station is Alice Springs.



Unit	Area	Land Form	Soil*	Plant Community
1	Large	Uplands: rounded, locally bevelled crests, and rectilinear rocky slopes attaining 60%; narrow, winding valleys	Outcrop with pockets of shallow, gritty and stony soils	*A. kempeana* (witchetty bush)–*Cassia* spp. or sparse shrubs and low trees over sparse forbs and grasses or *Triodia clelandii* (spinifex). Minor bare rock
2	Large	Mountain ridges: narrow crests with structural benches and escarpments; rocky slopes, attaining 60%; closely spaced valleys as in unit 1		
3	Medium	Granite domes and tors: bare rock summits and rectilinear, boulder-strewn slopes, 40–60%; narrow, joint-controlled valleys with steep amphitheatral heads, locally opening into small upland basins		Sparse shrubs and low trees, or minor *A. aneura* (mulga) over *Triodia pungens* (soft spinifex), *T. spicata* (spinifex), or minor sparse forbs and grasses
4	Small	Erosional slopes at the foot of units 1, 2, and 3; some rock outcrops	Shallow soils—gritty red clayey sands (3*a*), red earths (4*a*), and calcareous earths (6*a*)	Sparse low trees, or minor *A. aneura* (mulga) over short grasses and forbs
5	Small	Drainage floors and tributary fans: narrow and discontinuous	Coarse-textured alluvial soils (1*a*, 1*h*)	Sparse low trees over short grasses and forbs
6	Very small	Shallow channels	——	*E. camaldulensis* (red gum)–*A. estrophiolata* (ironwood) over *Chloris acicularis* (curly windmill grass)

* The numbers in parentheses in this column refer to soil groupings in Part VIII.

Figure 14 Example of a Land System Report (from Perry, 2010).

CSIRO's general reports of land system maps can be accessed from CSIRO Land Research Survey website (https://www.publish.csiro.au/CR/issue/5812). The mapping is available from the NT data hub: https://data.nt.gov.au/, and search for Land systems under Environment, Parks and Water Security.

2.3 Ecosystem Management Understanding

Ecosystem Management Understanding (EMU) is another landscape assessment and management approach that has been designed for arid climate zones and managing pastoral stations. "The approach is an interpretive process to visually recognise landscape patterns and processes, and to identify indicators of change" (Tinley and Pringle, 2014a).

The EMU system is focused on increasing the capacity of land managers to monitor their landscape and identify the issues that are leading to declining productivity and ecological function. By reading the landscape and understanding the interactions between livestock and the physical (drainage, soils and geology) and living components (plants and wildlife) of an ecosystem, land managers can develop solutions that harness natural processes to repair their landscape. The Rangeland Rehydration Field Guide and Manual (Tinley and Pringle, 2014a & b) are an excellent resource for understanding and applying this approach.

2.4 Reading the landscape

Visual observation of the landscape is very important to an understanding of landscape function and what may be necessary to heal it. Ideally, observation should be undertaken by walking the areas as this allows time to observe details. Flying a drone and taking images from overhead can add a different perspective. The following describes features to be looking for when observing.

Geography and landscape

Take note of the slope of an area. Is it steep, moderate or flat?

Are you on an alluvial area (finer soils deposited by water), such as a floodplain or alluvial fan? Alluvial fans typically occur at break of slope between a shedding (erosive) landscape and a flatter (depositional) landscape, where a confined watercourse discharges on to the flatter area (Figure 15). Floodplains are generally flat areas adjacent to a watercourse and can be narrow (a few meters) to very wide (kilometres) in width.

Is bedrock visible? Bedrock features will define landscape and water movement.

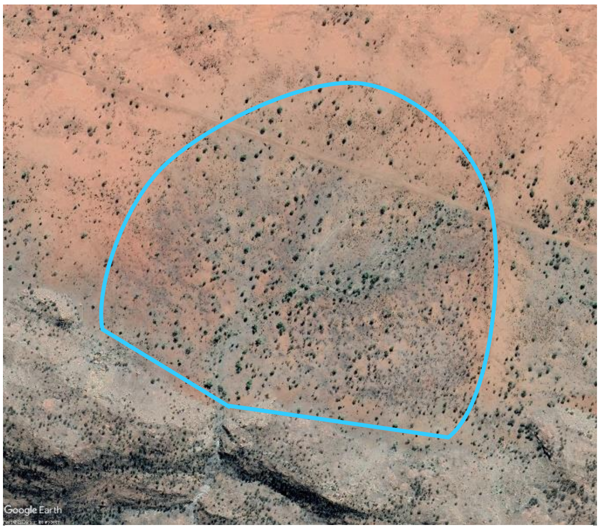


Figure 15 An alluvial fan.

Understanding the landscape

Soil

Soil condition indicates overall condition of an area. Things to look for are:

- Is the soil surface hard-packed or friable?
- Is the soil below the surface heavy (clay) or sandy or loamy – a clay soil near the surface may indicate that the topsoil has been eroded away.
- Are there gullies, rills or head-cuts indicating erosion?
- Is the soil bare or covered by organic material or vegetation?
- Are there animal tracks and do they appear to be from one species or a range of different animals/birds/lizards?
- Are there stock tracks, what direction do they go and do they appear to be from long-term use – cattle tracks can result in significant erosion?

Figure 16 Bare, hard-packed soil – little subsoil left, note erosion rills; ground surface difference between bare areas and where there is remnant vegetation can indicate amount of soil loss (inset).

Vegetation

Taking note of the vegetation type (e.g. grasses, chenopods[1], shrubs and trees), species and distribution will provide significant clues as to the condition and history of a location (see Figure 17 to Figure 19). Things to look for are:

- Is there a tree canopy and how open is it?
- What species are they and what condition do they appear to be in?
- Are there shrubs and bushes and what condition do they appear to be in?
- Is there a ground cover and is it dominated by grasses, chenopods or small shrubs (grasses would indicate a healthier ground cover layer than woody shrubs)?
- What percentage of the soil is covered by the ground cover layer of vegetation?

[1] Chenopod – drought tolerant hardy low shrubland of sclerolaena, atriplex (saltbush), maireana (bluebush), Chenopodium (samphire) and rhagodia genera – colonisers of degraded areas

Figure 17 Vegetation types – L chenopod, R buffell grassland (with open tree canopy).

Figure 18 Mixed species grassland with low forbs/shrubs and open mulga/sheoak woodland in background.

Different species will indicate presence or lack of water, for instance rushes will indicate a permanent or near permanent water body, while some eucalyptus species will indicate presence of water in the subsoil. If these are not healthy, this may indicate that the landscape is becoming dehydrated.

Figure 19 Grassland in foreground grading through shrubland then woodland in background reflecting soil type and conditions.

Stream morphology

The shape and size of a waterway tells us many things about the behaviour of water. Things to look for are:

- Are the stream banks steep and undercut (Figure 20), steep at the top with a slope at the bottom (indicating eroded, but stabilising - Figure 3), or flat and stable?
- How deep is the streambed below the banks? Is there any vegetation on the stream banks; after a flow event, is it bent down flat or still upright?
- Does the stream bed appear scoured with a hard surface or is there deposition material (Figure 21)?
- Is the deposition material large, such as rocks, indicating flow velocity is still quite high or fine, such as fine sand or silt, indicating that the flow velocity is slow?
- Is there debris caught in vegetation? This indicates the height of flood water and size of material indicates flow energy (and the availability of material for nature to rebuild steps), see Figure 22.

Identifying the steps that created the original ponds in the “chain of ponds” can be useful. Even where they have been eroded away and the waterway incised, they can be indicated by surrounding features such as rock, remnant vegetation, darker organic matter in the sediment in the banks, or where a waterway transforms from a wide or multiple small channel(s) to a narrow channel.

Figure 20 Unstable undercut channel bank indicating active erosion.

Figure 21 A creekline that has inscised, then refilled with sediment – note sediment is coarse sand and pebbles indicating velocity is still relatively high.

Figure 22 Debris caught in trees in the creek floor – flood flows reach at least 1 m above the bank here.

Other features

Other features to be noted are infrastructure such as water points, roads/tracks, firebreaks and fence lines. These can often have an influence on water flow and can sometimes be a catalyst where erosion can start, especially roads where they have been graded to below the ground surface level. Distribution and density of water points will influence grazing pressure, with higher grazing pressure closer to water and greater likelihood of permanent footpads forming, which can also be a catalyst for erosion.

3 Planning for Landscape Rehydration

3.1 Planning principles

Slow the flow

A key ethos of landscape rehydration is to "slow the flow". This can be achieved by altering any or all of the factors influencing flow energy – volume/depth, slope and roughness. Recreating the natural "chain of ponds" that dominated waterway systems in Australia prior to European settlement is a principle methodology employed in landscape rehydration. Steps are rebuilt to raise water levels and ultimately the waterway bed through sedimentation. This in effect reduces the slope (Figure 23).

A second principle used is "water on water" to de-energise the flow. Where water must flow over steeper slopes, a layer of still water is used against the waterway bed and bank or soil surface to dissipate the energy of water (Figure 23).

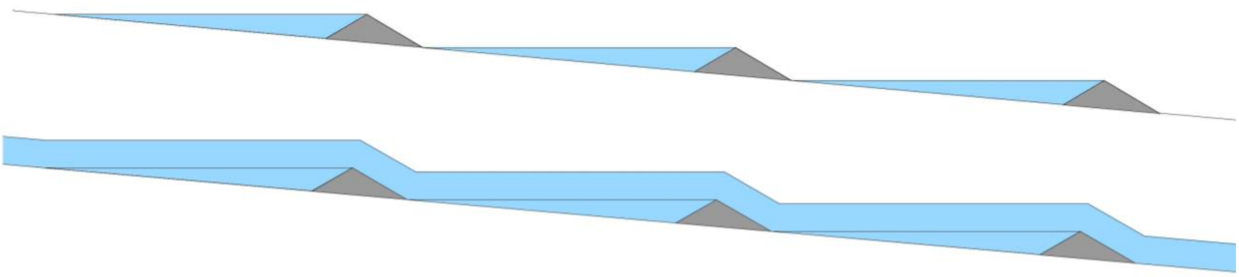


Figure 23 A series of weirs or steps where the downstream step creates a pool up to the toe of the next upstream step.

Halt active erosion

Erosion is the main process through which dehydration occurs, so it is important to stop any active erosion. The major process of erosion that dehydrates landscapes is through the migration of head-cuts up slope and cutting through the natural steps or "chain of ponds". Head-cuts can be stopped by:

- creating a pool of still water at the toe of the head-cut
- battering or ramping the head-cuts to change the slope and providing protection or armouring with brush or rocks
- reducing the flow over the head-cut by dispersing or storing water above
- a combination of these.

Protect and expand water storing features

Existing intact and well-stabilised areas should be preserved and protected. This is much more effective and less costly than trying to recover them once degraded. Often, this protection requires the halting of migration of active head-cuts downslope.

Grow more plants

Ultimately, the aim of all activity is to grow more plants. The above-ground parts of plants provide:

- protection and cover to the soil (increased roughness to slow the flow)
- organic matter to feed biological organisms in the soil
- surfaces on which dew can form to harvest water vapour from the atmosphere
- climate moderation
- shade and shelter for stock (larger plants).

The below ground components of plants (roots) provide:

- stabilisation and binding of the soil
- exudates to feed biological organisms in the soil
- transfer of moisture and nutrients to lower in the soil profile where it is protected from evaporation.

These functions together with the soil biology help to improve soil structure and soil moisture holding capacity. Plants and the soil biology also help to buffer against soil issues such as acidity and salinity. Encouraging more plant growth sometimes requires addition of water to catalyse the initial building of the system, especially in those areas that have been dehydrated through erosion.

3.2 Planning to restore your landscape

It is vital that the desired outcome is compatible with the *vision of the property* and area to be treated. The approach needs to be appropriately matched to the location and tools, resources and skills available. Time for observation and reflection will need to be included in the plan. An iterative approach is suggested, taking small, achievable steps and adapting as you go to ensure that your project is fit-for-purpose.

It is important to identify those issues and processes that will have the greatest impact and list these in order of priority. Take time to justify why they are in that order.

It is useful to lay out on a map the type of works that could be done. This can be done on Google Earth or on paper. Detailed contour information, if available, is very useful to help identify placement of interventions. The following section outlines some key concepts for preparing a plan, and chapter 4 describes a range of interventions.

3.3 Key concepts in planning

What to do and where?

In an incised waterway with a dehydrated floodplain, the usual solution is to install in-stream structures to provide grade control in the waterway, raise water levels to allow water to spill back out onto the floodplain, and ultimately raise the bed profile. Contour banks can also be used to redistribute water further out onto the floodplain.

On erosion gullies that are draining sections of the floodplain, plugging the gullies with instream structures is a typical response, to slow flow and trap sediment to rebuild and reflood the floodplain.

Head-cuts can be treated by drowning them from below by in-stream structures, direct treatment by ramping and protecting with brush or rock, or diverting flow away upslope using contour banks, or a combination of these. Usually, in-stream structures downstream are employed to rebuild the gullies as well.

Where water is already flooding out over a floodplain or alluvial fan (i.e. there are no gullies), but overgrazing has degraded soil and vegetation cover is reduced, reducing surface roughness, the surface roughness and infiltration capacity of the soil can be reinstated using rip-line contours or fence contours to encourage deposition of sediment, organic matter and seed.

The choice of structure type will often depend on availability of materials. In-stream structures will often be earth, due to the lack of other materials. However, where transported rocks are present in stream, flow-over rock armoured in-stream structures may be better suited, especially in woody or steeper terrain where there is greater risk of tyre puncture on a loader. Alternatively, where there is a supply of logs and brush, log and brush type structures can be used. If there is little larger material, stakes can be used to hold smaller brush.

Where to start and end?

When looking at installing in-stream structures to provide grade control and rebuild incised waterways or gullies, it is important to recognize that a single in-stream structure will have limited effectiveness. To attain a good outcome a sequence of carefully designed structures that work in unison is required. The backwater ponds from the lower structures in the sequence cushion the flow that will spill over the upper structure, preventing scouring or erosion of the toe. Over the long term, a sequence of structures can bring about cumulative benefits for the stream, riparian zone and floodplain of a large area.

At the downstream end, a natural sill, or where the waterway broadens out into a very wide and shallow depression will be the point to start works (Figure 24). Water levels are then stepped up along the waterway until the upper head-cuts are reached (see Figure 23). A laser level is useful to determine the level of the natural sill (and therefore the water level and where it reaches upstream in the bed of the waterway).

Safe re-entry

It is critical that wherever flow is diverted out of a waterway channel, that where it re-enters the channel, it does so safely. The most effective way to do this is to ensure there is still water onto which the re-entry flow will discharge, created for example by an in-stream structure or natural step downstream. If this cannot occur, the second principle is to ensure that the flow is broad and shallow, and on as flat a slope as possible. This will reduce depth, increase relative roughness and reduce slope. Re-entry zones should be kept undisturbed to maintain any vegetation growth present.

Location of the diversion intervention is also important – try to place it adjacent to a natural feature that will direct flow away from the channel or move it in a broad shallow flow. An example may be a sub-branch of the waterway or a floodplain depression (Figure 25).

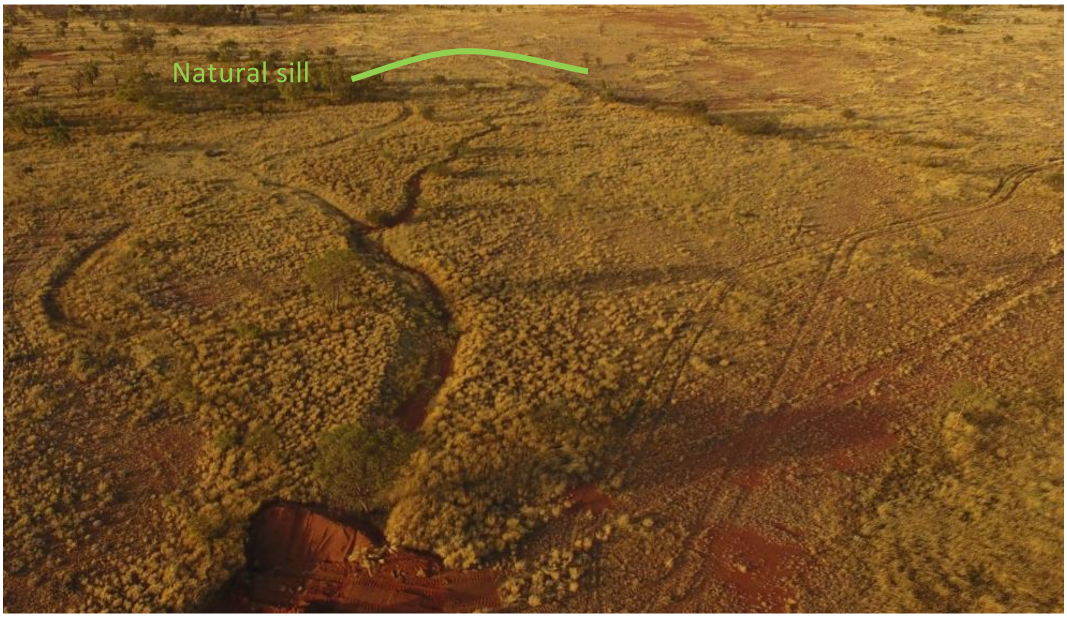


Figure 24 Natural sill in waterway banks water up to first in-stream structure.

Figure 25 A shallow "V" drain connects the overflow from an in-stream structure to a natural deppresion on the floodplain – re-entry occurs 3 km downstream via dam and secondary broad shallow channel; high over-flows re-enter the channel (with reduced volume) onto a pool created by another in-stream structure downstream.

4 Rehydration interventions – in-stream structures

4.1 Earth – flow around

Earthen 'flow around' structures are used as gully plugs and in-stream structures to raise water levels in the waterway where materials such as rock and logs are not available for construction. 'Flow around' refers to the fact that water will flow around the ends of the structure, rather than over the top. Not being armoured, water must not be allowed to flow over the top of the structure, which will compromise its structural integrity. Vegetation is the primary protection for the structure to stabilise it and create a buffer of still water against the structure.

As 'flow around' structures must be constructed with the top above the expected peak flood level on the adjacent floodplain, these structures are ideal to lift water to re-flood the floodplain. In conjunction with contour banks, they can be used to rehydrate large areas.

Being earth, 'flow around' structures will store water for periods of time on the upstream side, creating pools. Sediment, organic matter and seeds will be deposited, rebuilding incised waterways and supporting vegetation to stabilise banks of the waterway. In addition, the pooled water will recharge sub-surface water. These structures are not compacted, so water will slowly seep through them, and the ponds will be temporary.

Figure 26 `An earth flow around structure at Glen Helen Station. Note the vegetation establishing on the earth bank which will strengthen and protect the structure.

4.2 Flow Over Structures

These structures are designed to slow the passage of water within a stream channel. They create temporary pools of still water upstream, allowing sediment and organic matter to settle to rebuild the stream bed over time. By slowing the velocity of stream flow, this kind of structure also reduces the risk of stream bank erosion and enables aquatic and riparian plants to re-establish.

The sequence of backwater ponds produced behind each structure causes water to be retained in that part of the watercourse for longer, which allows shallow groundwater systems beneath the stream bed to be recharged. As water builds up behind the structure, the water level of the channel is also raised. This allows water to more frequently spill onto adjacent floodplains. The structures are designed so that when the water reaches a certain point it 'flows over' the structure itself and carries on its downstream journey.

Flow over structures are constructed from natural materials such as rock and/or logs, often with an earthen base, and they can be quite permeable. The establishment of vegetation in and around the structure is essential to stabilise, strengthen and eventually 'naturalise' the structure over the long term. It is important that any rocks or logs used are keyed into the bed and banks of the channel and are adequate to brace the structure. Because they are designed for water to flow over them, it is important that the stream banks adjacent to the structure are battered to the correct gradient and armoured with suitable material to protect them from being scoured by high energy flows. The materials most likely to be used in Central Australia are rock armoured earth, which is described in this section.

Flow over structures are often used to provide bed (or grade) control in a waterway, recreating the "chain of ponds" and slowing flow to reduce erosion. They may be used between flow around structures which are placed to spill water out onto the floodplain on steeper waterways where it is not feasible to use flow around structures, and there is suitable material available. Flow over structures are sometimes called "leaky weirs".

Figure 27 A 'flow over' structure constructed on Mulloon Creek.

4.3 Flow through structures

Flow through structures are relatively permeable structures designed to increase surface roughness, slow the flow of water and capture mobilised sediment in overland flow down gullies and in-stream flows. They are often called "leaky weirs" and are constructed from branches, logs and brush which are wedged into the gully against existing features such as trees, bushes or rocks (“brush packs”, Figure 28), woven through wooden pins (called a “pin weir”) or braced against the upstream side of stakes (“stake and brush weir”, Figure 29).

Figure 28 Example of a brush pack in-stream structure anchored against a tree.

These are low-cost and low-risk structures that are quick to install. They are useful for raising the bed of minor incised gullies, reducing flow velocities in major waterways and providing immediate ground cover on scalded and/or eroded sites.

By slowing overland or in-stream flow, water can infiltrate the soil and provide ideal conditions for seed germination. Wind-blown seed from other species will also collect in the structures and germinate. The resulting establishment of vegetation will drive the long-term repair process. ‘Flow through’ structures are very suitable for sites that have limited ground cover and exposed soil, where sediment and organic matter is on the move.

Figure 29 Example of a stake and brush weir in-stream structure with brush placed on the upstream side. Sediment and organic material will become trapped and continue to accumulate.

5 Rehydration interventions – contour banks

Contour banks are earthen channels with a spoil bank on the downhill side, on a contour, that allow surface runoff to collect, spread across the floodplain or slope and soak into the ground. They are often connected to an in-stream structure to divert water away from the incised channel back onto the floodplain or into old floodplain channels (Figure 30). They can also be used to divert runoff away from eroded waterways or head-cuts (Figure 31). There are three main components to the contour bank: the channel, the spoil bank and the overflow sill(s).

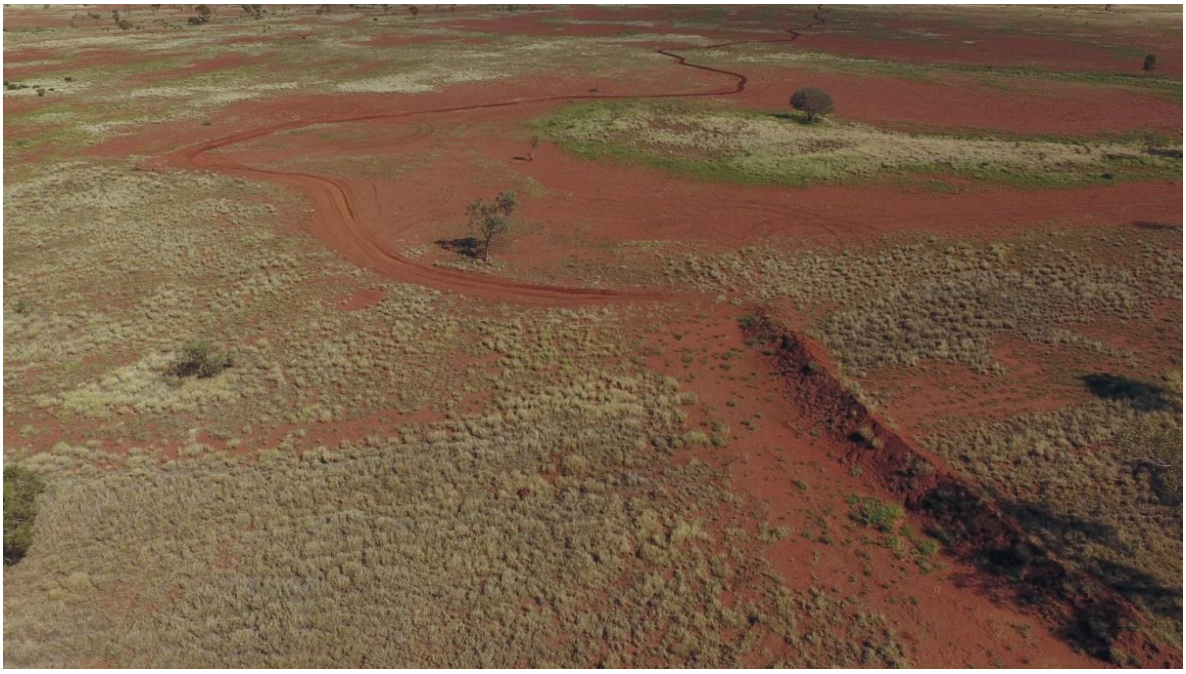


Figure 30 A contour bank extending off a flow around in-stream structure.

Figure 31 A contour bank protecting a series of headcuts on gullies below.

Rehydration interventions – contour banks

Contour banks are located on a line of equal elevation (contour), encompassing at least one flow path and extending out to a ridge on one or both sides. Contour banks are placed where infiltration from the channel and overflow from the primary sills can be of most benefit – often at the head of a floodplain. Overflow sills are needed to allow excess water from the contour to overflow the contour channel safely (Figure 32). They are areas where there is no spoil bank downslope and the downslope area is left as undisturbed as possible. Contour banks will have a "primary" sill on the ridges to spill excess water such that the overflow disperses and spreads out. Where a significant waterway or flowline is crossed, or at the start of a contour where it is linked to an in-stream structure, the contour bank should also have a "Secondary" sill to allow large runoff events to pass directly downslope to protect the contour channel from high flows.

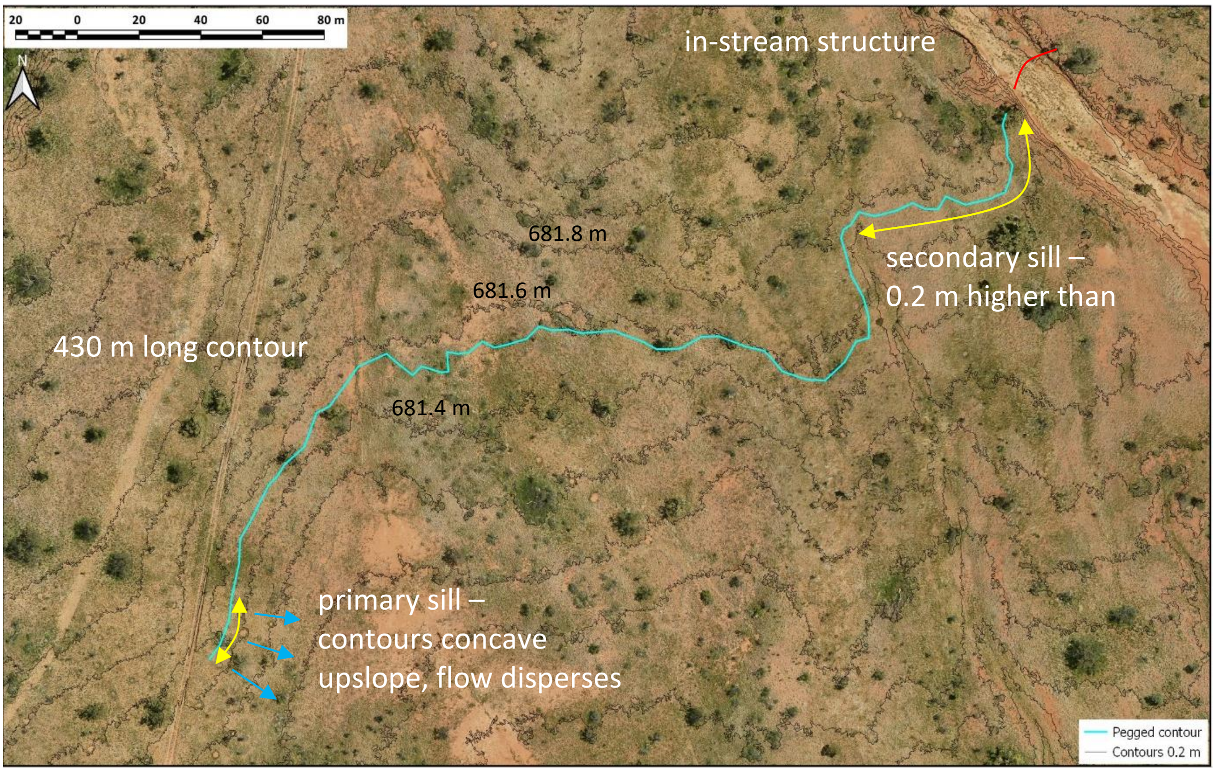


Figure 32 Contour bank on Aileron Station showing location and overflow sills.

Figure 33 First pass of constructing a contour bank (note blade is pushing spoil downslope).

6 Other Landscape Rehydration Interventions

Any barrier to the flow of water that is constructed along the contour will help to slow the flow of water across the landscape, reducing its erosive energy and increasing infiltration into the soil.

6.1 Rip-line contour

A rip-line contour is a low impact and simple intervention that is suitable in bare or scalded areas where runoff is already dispersed. Rip-lines add roughness to the soil surface into which seed and organic material can deposit during a rainfall event, re-starting the process for natural regeneration of vegetation (Figure 34). In addition, the rip-lines increase infiltration into the soil. This will begin to restore the water cycle at a small scale and reduce further erosion, thereby increasing soil health and productivity in the landscape

Figure 34 Rip-lines on the contour across what was a bare, scalded area have accumulated seed and other organic matter, in only one summer, promoting growth of vegetation even beyond the rip-lines themselves.

6.2 Fence contour

Constructing a fence along a contour can act as a trap for debris and organic matter during high rainfall events, which will increase roughness, slowing the flow of water and encouraging sediment to settle, building soil. Fences constructed on contour, when complemented with regenerative grazing management practices, can also play a role in slowing the flow of water over the landscape. The vegetation growing in paddocks or cells that have not been recently grazed act as a barrier that will slow the flow of water.

6.3 Brush wall/contour

A brush wall is similar to a fence contour, except brush and woody material is laid on the contour to create a low permeable bund. It is cheaper and quicker than a fence contour provided material is available nearby. Brush contours are liable to be washed away in high flows so are limited to areas with small catchments or dispersed flow.

6.4 Head-cut management

There are two approaches to managing head-cuts. In more severe cases, the drop is flattened off and brush or rock used to armour the surface. This is more suited to confined or very deep head-cuts. Smaller or extensive head-cuts can be packed with brush, anchored with stakes (Figure 35) or wire (Figure 36). Knocking down the drop lip can also be done with feet, hand tools or a skid-steer loader.

Figure 35 Brush packing extensive head-cuts, anchored with posts (from Tinley & Pringle 2014a).

Figure 36 Brush packing extensive head-cuts, anchored with wire mesh (from Tinley & Pringle 2014a).

6.5 Mulching

Anywhere bare soil is observed, placement of mulch can be used to increase surface roughness to slow flow and deposit sediment, organic matter and seed. In high flow areas the mulch may need to be secured by rocks or stakes or mesh. Any material can be used – old hay, grass or brush cut from nearby bush or pasture.

7 Monitoring Landscape Rehydration interventions

Monitoring involves observing and recording changes over time. It is an essential aspect of any enterprise that involves ongoing management and should provide useful information about the change, or lack of, that is occurring. Apart from records of production (stock carrying capacity, quality and production, pasture yield and quality), a number of simple monitoring methods can be employed to track the changes occurring. These methods are:

- photo points (visual record of many aspects)
- aerial imagery (visual record).
- satellite imagery
- vegetation cover
- soil pH and depth.

Ideally, baseline data (collected prior to any changes in management, or before works are constructed) or a control site (an area that isn't impacted by the changes in management or construction works being monitored) should be established to provide a reference point to compare changes to.

7.1 Photo point monitoring

Photo point monitoring is a quick and relatively easy method of analysing changes in the landscape. It involves taking a series of photos taken from a fixed location of the same view at specified time intervals (generally before, during and after project completion). The photos should illustrate change in landscape condition following the implementation of infrastructure or new management approaches.

Photopoints are simple to set up, being just two pickets with one marking the camera location and the other marking the camera direction, approximately 10 m away. The angle of the posts should be considered to minimise obscuring shadows or sun glare.

The same camera orientation (portrait or landscape) should always be used. Ideally bright but cloudy conditions are best to take photos to eliminate shadows and provide even light, but photos should be taken at roughly the same time of day each time. A label at the sighter post or tag on the image should be used (and GPS tagging employed if available).

Figure 37 Before and after photos illustrate change over time – in this case after only a few weeks, vegetation has started to colonise the structure and overflow sill.

7.2 Aerial imagery (drone)

Using drones or accessing other aerial imagery is a great way to monitor changes in landscape over time. This can be a better option than ground photopoints for monitoring change over large areas or accessing difficult, dangerous, or fragile terrain. Depending on the image data you have access to, you may be able to use non-visible energy frequencies such as infra-red and ultraviolet to analyse changes to your project site.

Drones come in a range of sizes and capabilities (correlated to cost) but are relatively cheap compared to other aerial and satellite imagery options, especially if monitoring is done regularly or there are many monitoring sites.

Similar to photopoint monitoring, it is important that the images and other data you capture is from a consistent location over time. Ensure that height, angle, weather conditions and time of day are consistent also. Combining aerial imagery with ground photopoints provides different perspectives of the same monitoring location and extends the opportunity to analyse change.

Drone imagery can be oblique (general view of a feature, from an angle) or directly down. In the latter case, multiple images can be stitched together to create a mosaic. This can be useful to visualise the change in areas over time, such as bared off soil or the extent of erosion gullies.

7.3 Satellite imagery

Satellite imagery with different spectral bands and derived indices can be a powerful tool for monitoring a wide range of parameters such as available feed, pasture cover, biomass and soil carbon. There are a number of service providers in this space (e.g., Cibo Labs – see Figure 38). An advantage of this data is that retrospective data can be obtained, providing a baseline to measure changes against.

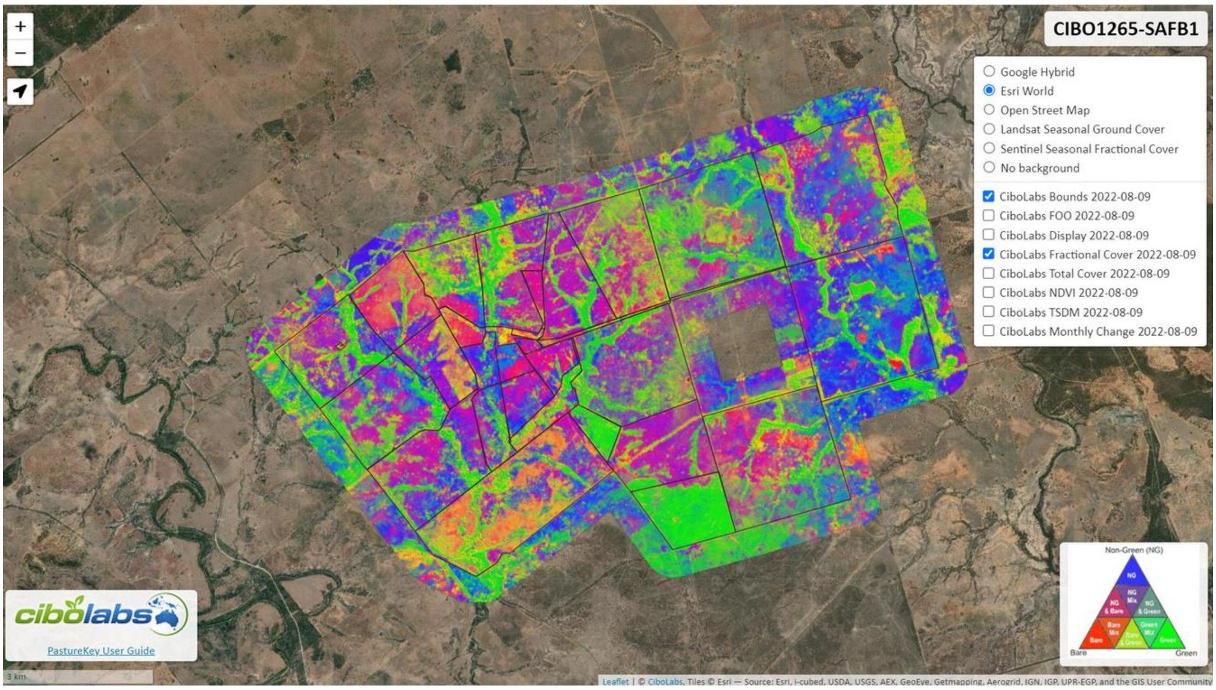


Figure 38 Example of Cibo-Lab's product "my Pasture Key" as a tool for measuring ground cover at the paddock scale.

7.4 Soil depth

Measuring soil depth is as simple as digging a hole 0.5 to 1 metre deep and then measuring the changes in soil colour and how deep plant roots grow (Figure 39). The darker soil at the top of the profile contains the nutrients and biology that plants need to thrive and acts as a sponge for holding onto soil moisture. Repeating this process over time should show an increasing depth of darker soil and root penetration as soil conditions improve.

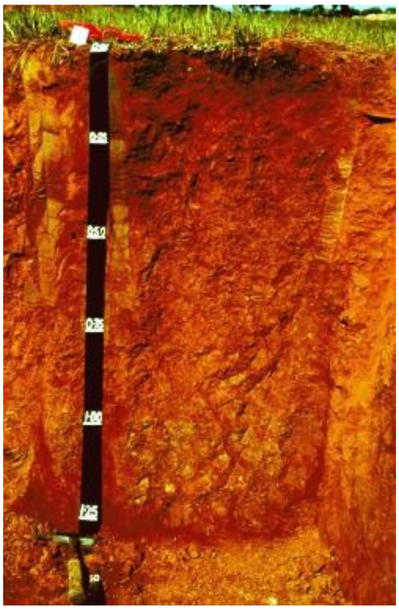


Figure 39 Monitoring changes in the soil profile is a simple way to observe improvements in the landscape.

7.5 Ground cover measurement

Ground cover is estimated on a transect with 8 to 10 points per transect in relatively uniform areas and up to 15 where there is high variability. Ground cover estimation is usually done when it is lowest – i.e. late autumn before rain.

Cut a 30 x 30 cm square hole in a piece of cardboard or make a 30 x 30 cm square from wire to create a quadrat marker. Along the transect, place the quadrat on the ground at random and visually assess the ground cover in the quadrat, comparing it to the standard images (Figure 40).

7.6 Pasture Biomass Measurement and Composition

Biomass can be measured by cutting all material from a set area, weighing, drying and reweighing to obtain the kg of dry matter per unit area. A number of samples are taken from each site and the results averaged. A more detailed assessment can be obtained by separating the types of material (eg. Into grass and chenopod) before weighing and drying.

Composition can be quickly assessed by identifying species located at the end of a randomly thrown stick (or on the tow of your boot) along a transect – at least 50 points on the transect should be sampled. Another method is to visually estimate the proportion of different species in a fixed quadrat (this can be the area between your feet spread approximately 50 cm apart).

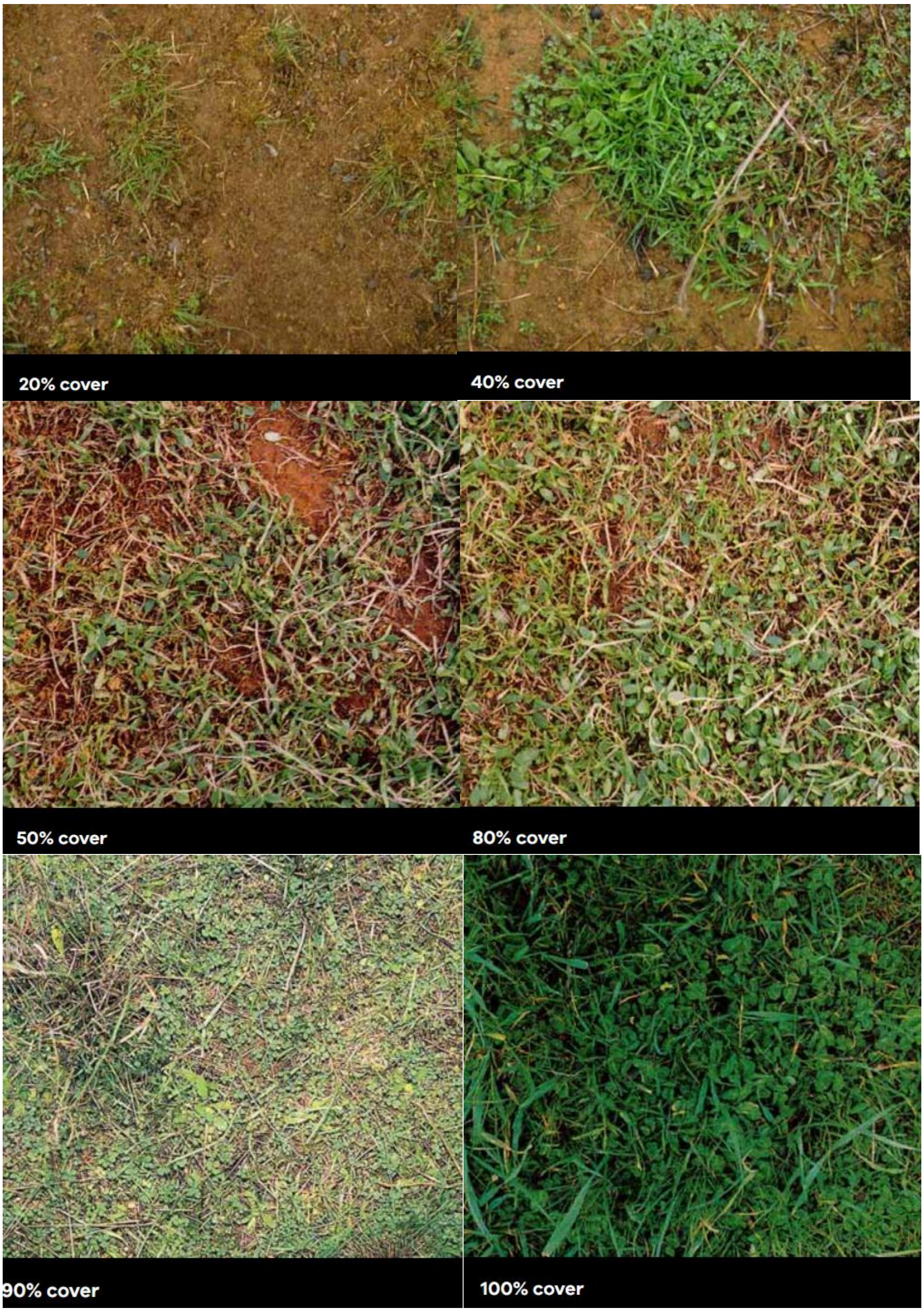


Figure 40 Standard images of ground cover for comparison to quadrat (from Agriculture Victoria).

8 Central Australian Landscape Rehydration Case studies

8.1 Ti-Tree Station, Ahakeye Aboriginal Lands Trust.

This site comprises a broad alluvial slope, intersected by the road to Adelaide Bore. Many small gullies have been eroded up the slope almost to the low rocky ridge which forms the catchment boundary. Historic grading of the road means that it is up to 0.5 m below the ground surface, creating drops from which head-cuts have eroded upslope and redirected runoff into concentrated points on the downslope side, which have also eroded (Figure 41). An old track and cattle pads have also redirected and concentrated runoff, causing erosion. The objective of this demonstration is to halt erosion and rebuild the waterways and restore the natural water movement in the landscape. At the lower end where slopes are less, this has already started occurring naturally, with historically incised channels now refilled with sediment (Figure 21).

A mix of earth flow around and brush flow through in-stream structures have been planned for this site, with the earth flow around structures in the larger waterways and the flow though structures in steeper sections and smaller gullies (Figure 42 and Figure 43). Some brush packs were employed between earth flow around structures in the larger waterways where there was no suitable spill or re-entry points over the banks of the waterway. An example of a series of flow around earth structures is shown in Figure 44.

Of the flow through structures, stake and brush (Figure 29 and Figure 45) and brush pack (Figure 46) structures were employed. Initially, stakes alone were driven, however insufficient material collected on these, so brush was added at a later date. The aim of the flow through structures is to slow flow in the stream to reduce energy and therefore erosion of the bed and banks and enhance the depositional processes occurring at the site to speed up the natural recovery.

Figure 41 Aerial view of the Ahakeye site from the east.

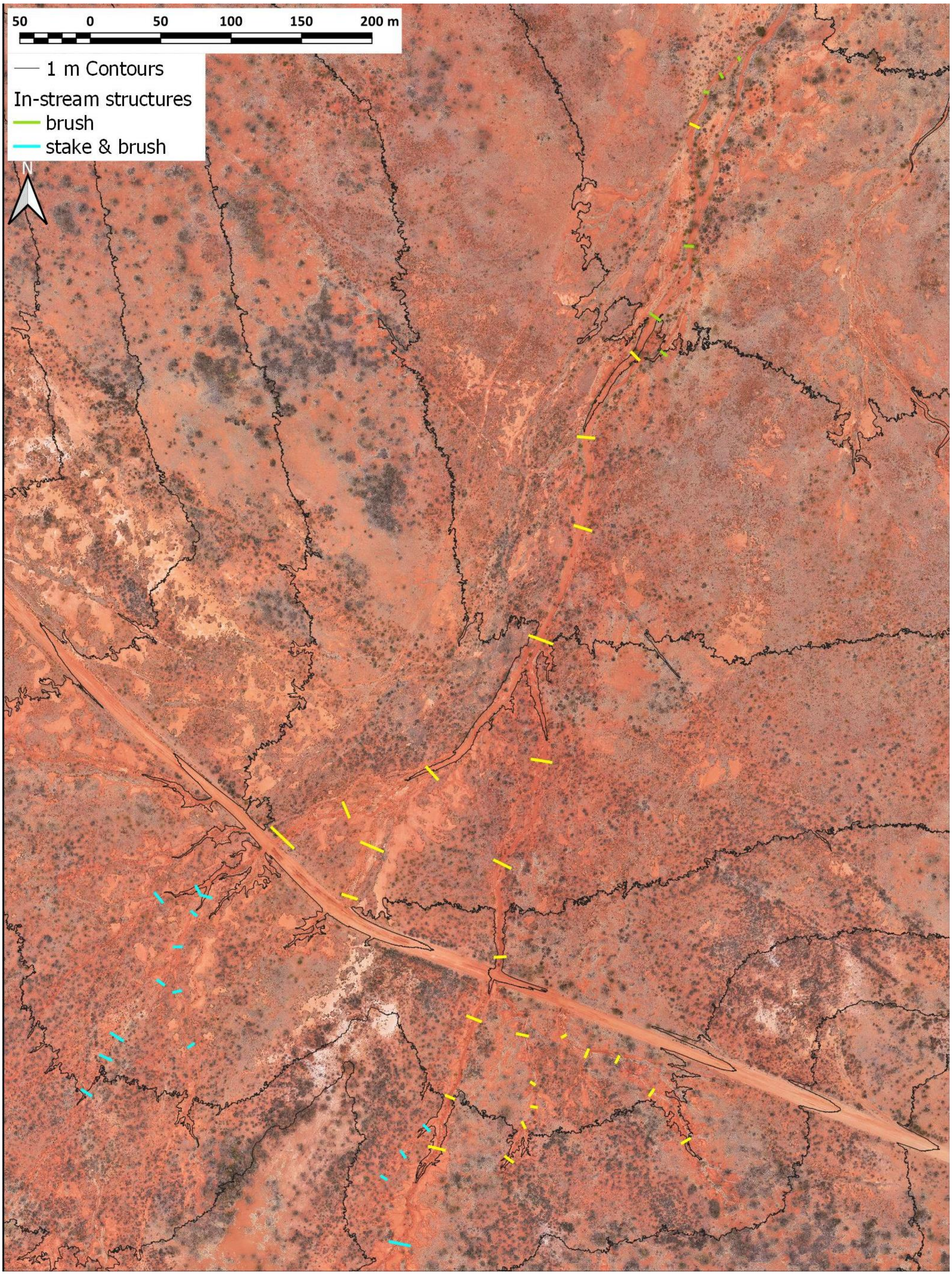


Figure 42 Plan of Ahakeye demonstration site western side structures.

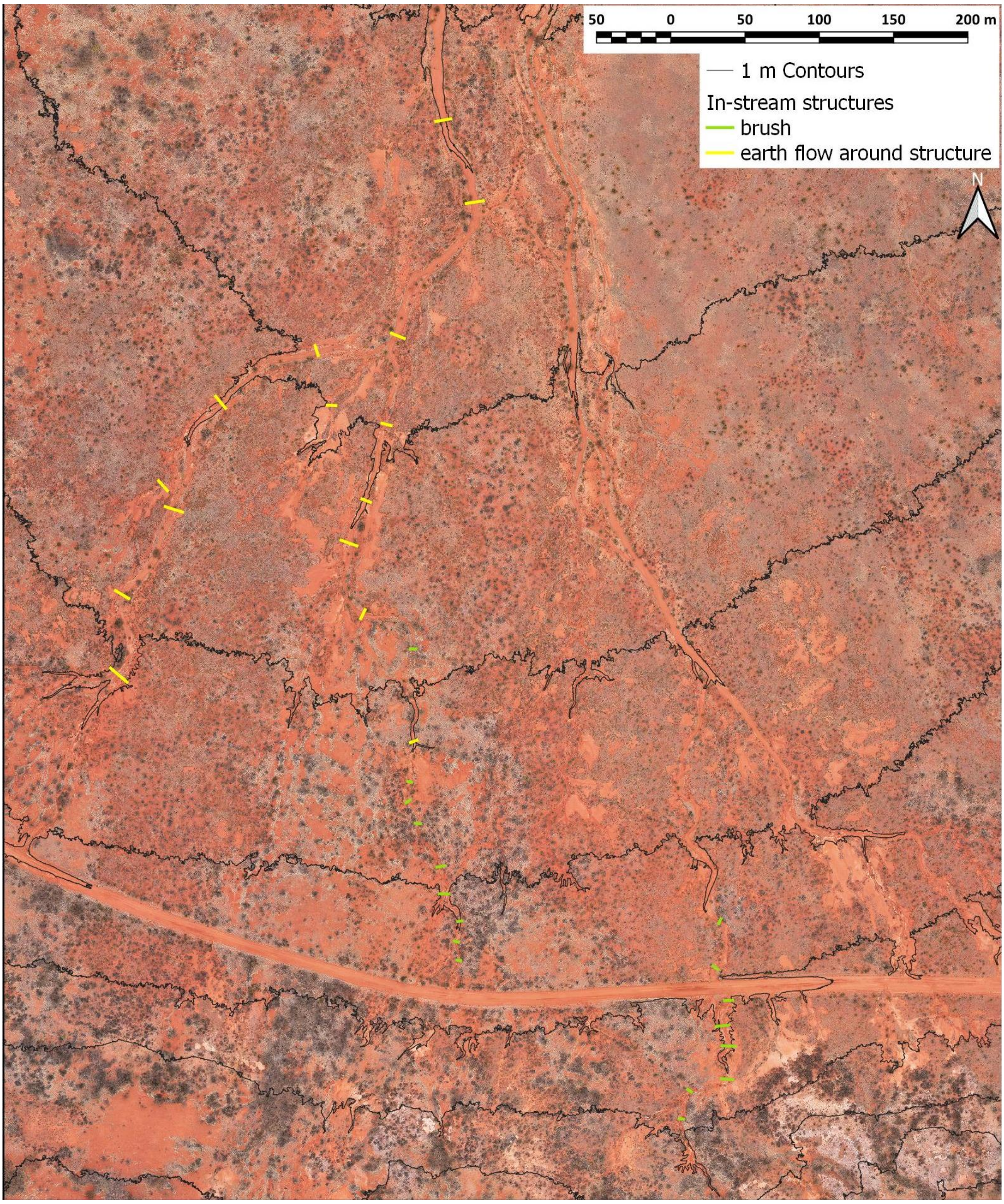


Figure 43 Plan of Ahakeye demonstration site eastern side structures.

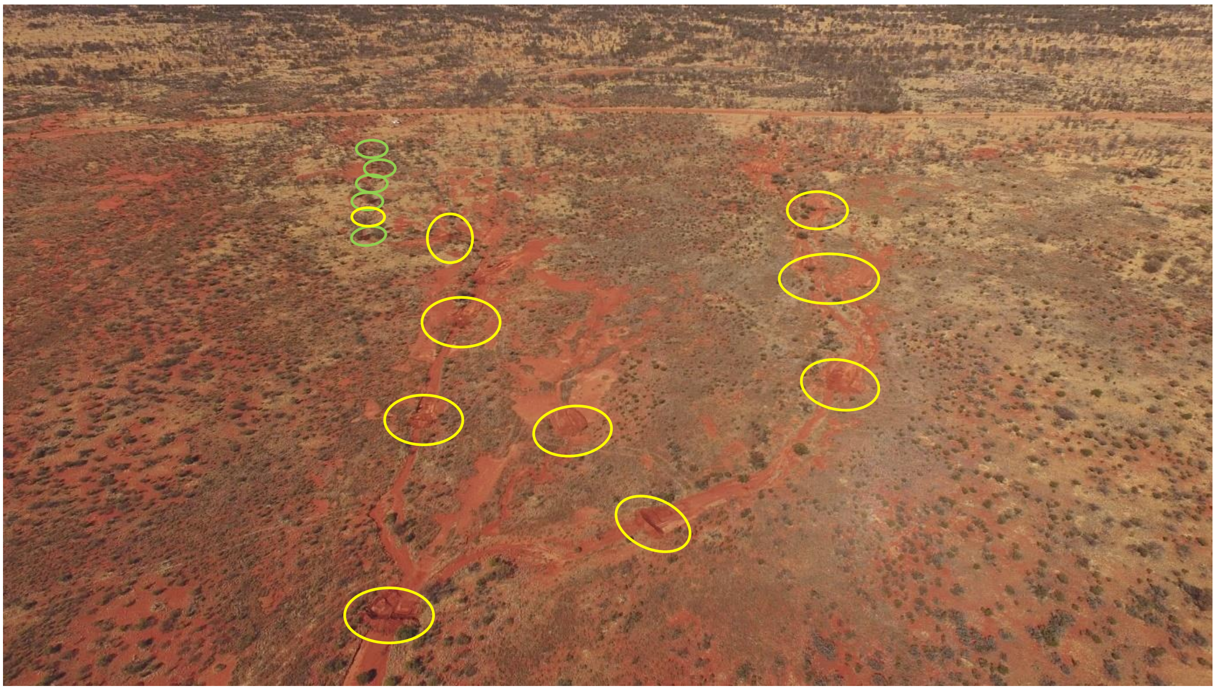


Figure 44 Aerial view of Ahakeye site with earth flow around structures visible along the larger eroded watercourse (yellow) and brush packs further upstream in the smaller gullies (green).

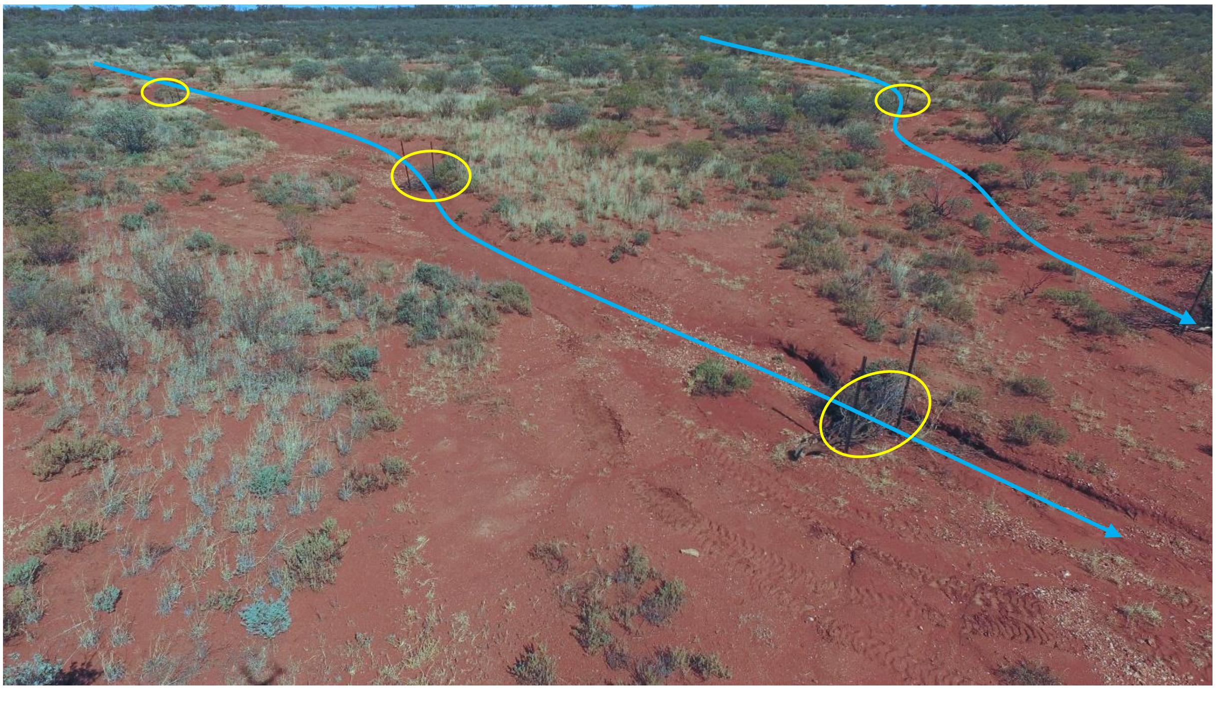


Figure 45 A series of small stake and brush weirs on multiple gullies above the road.

Figure 46 A series of larger brush pack weirs on either side of the road.

Figure 47 low brush pack weirs downstream of a flow around earth structure at the lower end of the site.

8.2 Narwietooma Station, Hewitt Cattle Co.

This site comprises a broad floodplain incised by a waterway on the eastern side (Figure 48). The waterway is divided into several parallel channels. As a result of the erosion and incision of the waterway, the floodplain has become dehydrated and disconnected from the smaller flood flows.

Figure 48 Narwietooma floodplain looking downstream (north) with the incised creeklines on the right.

LiDAR (Light detecting and ranging) was flown over the Narwietooma Station demonstration site, providing detailed topographical data as a digital terrain model (DTM). This enabled desk-top planning of landscape rehydration interventions and made parameters to design sill lengths easy to calculate, which reduced the time to set-out works on the ground. Contours were planned on Narwietooma to redistribute water back onto the floodplain from incised waterway channels in conjunction with in-stream structures (Figure 49).

Figure 30 and Figure 50 to Figure 52 show a number of the completed contour banks at Narwietooma.

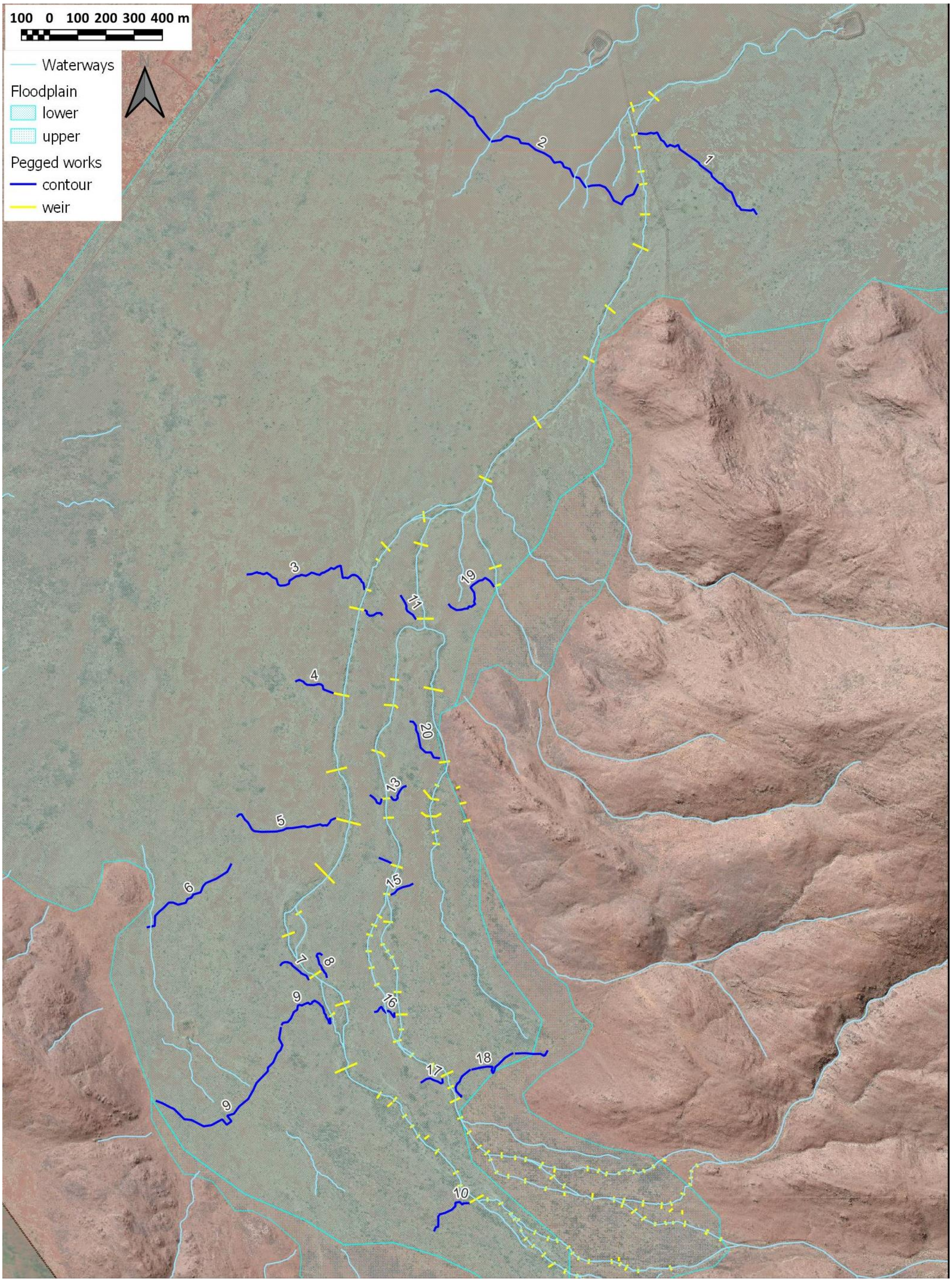


Figure 49 Plan of Narwietooma contour banks to redistribute concentrated flows in incised waterways back onto the floodplain (LiDAR DTM hillshade and orthophotos background).

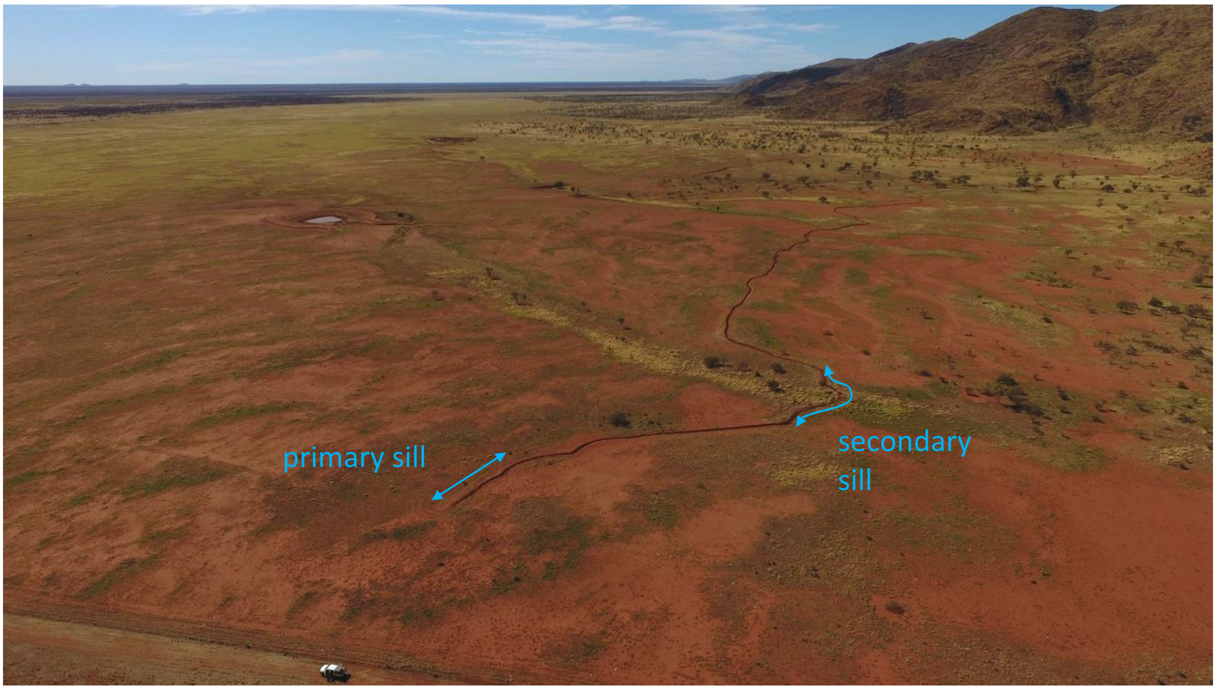


Figure 50 Overhead view of contour 2 at Narwietooma.

Figure 51 Completing the primary sill on contour 3 at Narwietooma.

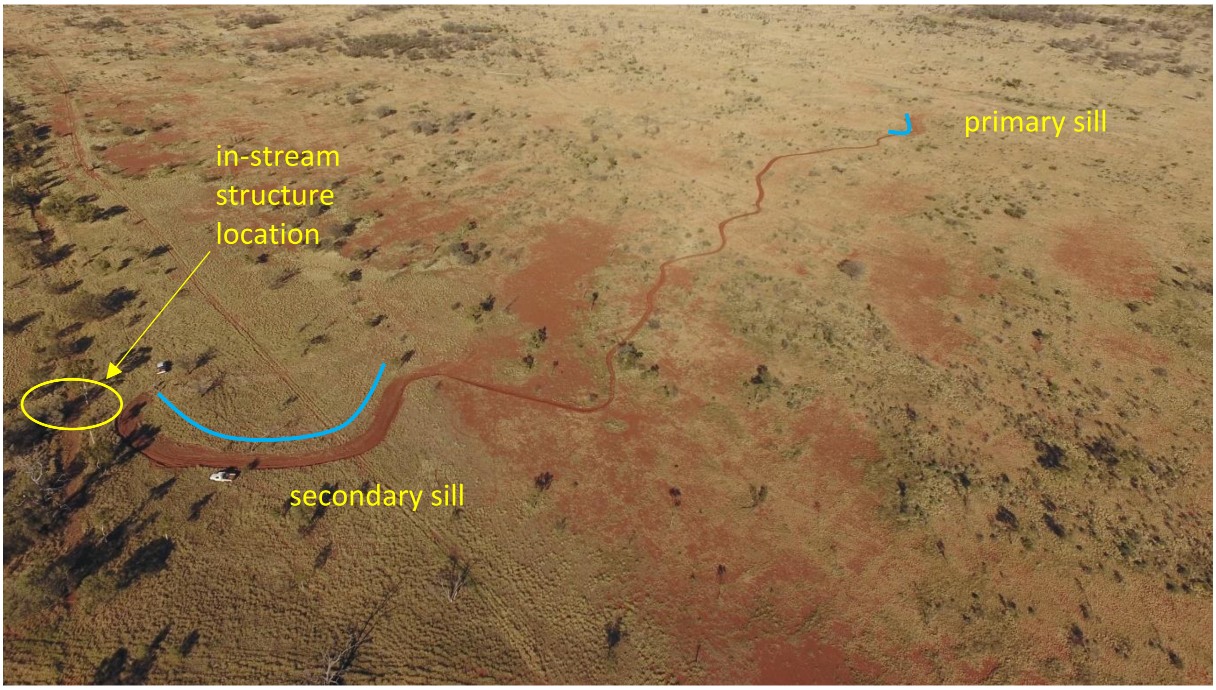


Figure 52 Narwietooma contour 3.

8.3 Glen Helen Station, Crossing Bore paddock, Hewitt Cattle Co.

This site comprises a series of floodplain areas that have been eroded at the lower end by head-cuts and resulting incised gullies (Figure 53). The floodplains have also been subject to heavy grazing pressure, there being only one water point in a very large paddock (this site is near the water point). The objective of the works is to restore the plug at the bottom of the gully and to increase roughness of the floodplain to encourage overland flow to drop sediment, organic matter and seed where it is needed.

Figure 53 Aerial view of the Glen Helen lower floodplain site before intervention.

The interventions employed are series of ‘flow around’ earth in-stream structures in the gully to recreate a chain of pools, rebuild the waterway and reflood the lower flood plain, and some rip-line contours to increase roughness and increase infiltration (Figure 54). See Figure 55 and Figure 56 which show the most downstream structure while Figure 57 shows how the upper structures are holding up water after rainfall. Figure 34 shows the rip-line contour 6 months after ripping with grasses already establishing some distance away from the contour.

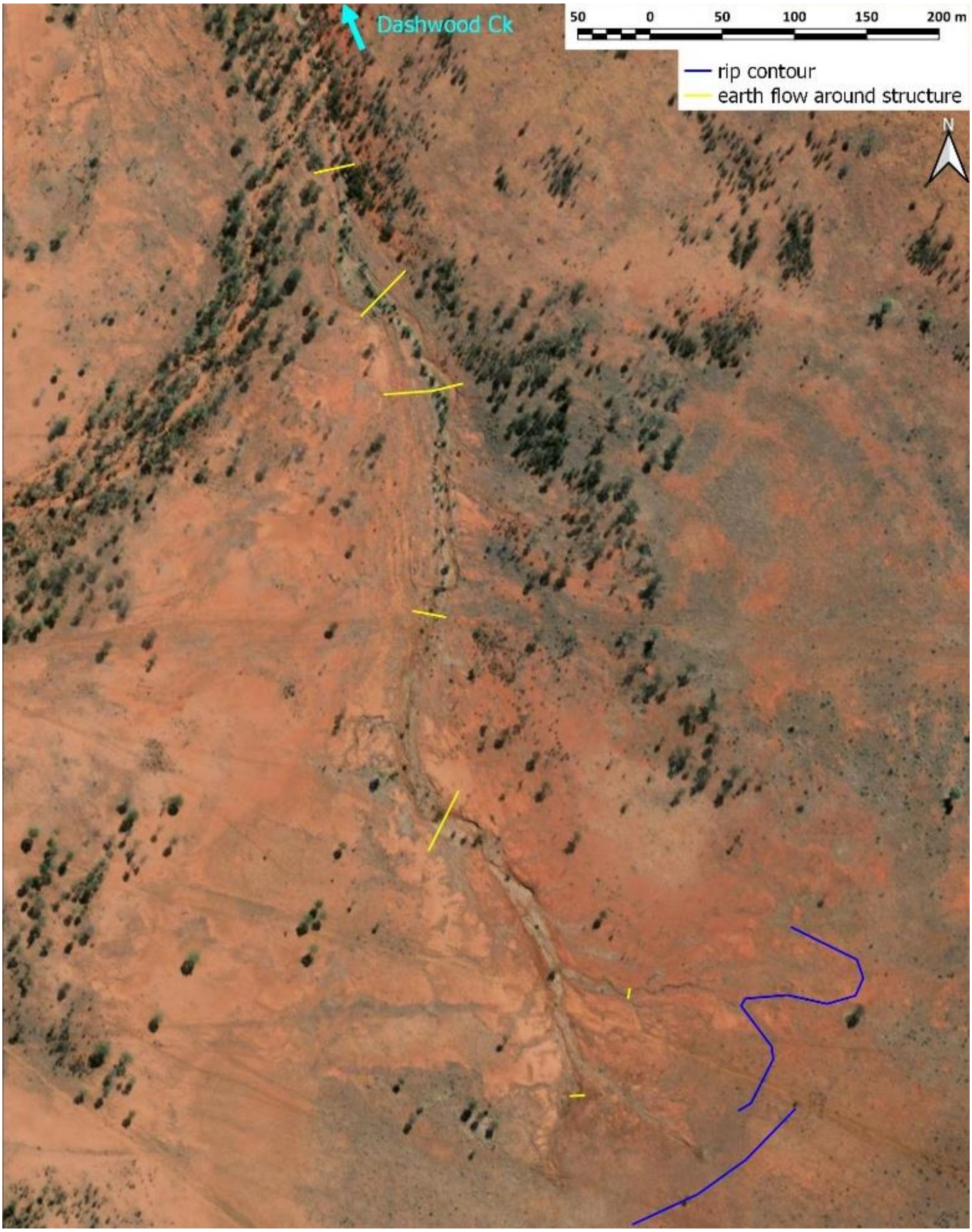


Figure 54 Plan of Glen Helen lower floodplain structures.

Figure 55 Earth flow around in-stream structure at Glen Helen lower floodplain just after construction (November 2022). Note near end toe anchored against tree and curvature of structure (flow direction right to left).

Figure 56 The same earth flow around in-stream structure at Glen Helen lower floodplain shown in Figure 55 after rainfall in January 2023. Note establishment of vegetation on structure.

Figure 57 Overview of earth flow around in-stream structures on Glen Helen lower floodplain immediately after rainfall in June 2023.

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