Landscape Rehydration in Western Australia: A Review

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Mulloon Institute

GOVERNMENT OF WESTERN AUSTRALIA

natural resource management program

Literature Review

Acknowledgements

This project is supported by funding from the Western Australian Government's State NRM Program. The review aims to document available literature relevant to, and case studies of, Landscape Rehydration in Western Australia. This report is part of the Mulloon Institute's WA Community Stewardship Grant: Landscape Rehydration Trial and Demonstration in the Wheatbelt of WA.

Abstract

This literature review consolidates the impacts of Landscape Rehydration on stream and floodplain dynamics, mitigating existing land degradation, farm productivity and landholder profitability in Western Australia (WA). Available research and documented case studies showed that Landscape Rehydration works play an important role in stabilising erosion, reducing stream sediment pollution, increasing water and nutrient availability across the landscape, ameliorating waterlogging, and facilitating extensive native revegetation. There is no independent, quantitative evidence that Landscape Rehydration will alleviate dryland salinity by increasing freshwater recharge, however, emerging case studies in WA indicate that Landscape Rehydration works can drive a surge in native vegetation, which provides a beneficial role in mitigating dryland salinity. Research also shows Landscape Rehydration works, complemented by managed grazing regimes, can substantially improve pastoral productivity. While the positive profitability outcomes of available Landscape Rehydration case studies are unclear, an opportunity exists for the efficacy and economic viability of Landscape Rehydration to improve as available knowledge, resources and support services become available.

Statement on Research Methodology

Searches were conducted in May 2022 using the Scopus database and the Google Scholar advanced search function. Search terms included 'Landscape Rehydration', 'In-stream Structure', 'Leaky-weir', 'Contour', 'Rangeland Rehydration' and 'Natural Sequence Farming'. The review search returned 18 relevant papers, comprising both published literature and case studies predominantly within Western Australia, but also in relevant areas across Qld and NSW.

Photos front page:

Top: Landscape Rehydration works (contours) implemented on Paraway-Koolpinia in 2022.
Bottom: Landscape Rehydration works (pin weirs) implemented on Paraway-Koolpinia in 2022.

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1 Introduction

It is well recognised that European colonisation and the subsequent clearing of vegetation and introduction of domestic livestock has led to severe environmental degradation across Australia (Hurditch, 2015; Streeton et al., 2013). In Western Australia, modern agricultural grazing and cultivation practices are thought to be responsible for increased vegetation degradation, soil compaction, soil erosion resulting in stream channel incision and widening, bed and bank erosion and general floodplain degradation (Hurditch, 2015).

Today, the challenges of increasingly variable weather patterns and environmental degradation have been masked by technological advances in irrigation, available fertilisers, crop and livestock genetics, and pest and disease management. However, in Western Australia erosion, soil salinity and soil infertility are major forms of land degradation that affect millions of hectares of arable land (DPIRD, 2022a). A 20% reduction in winter rainfall across southwest Western Australia has also occurred since the mid-1970's, contributing to the growing range of climate variables impacting landholders (Guthrie, 2022).

Current landholder actions targeting dryland salinity and biodiversity loss are considered vastly insufficient to halt the degradation process (Pannell et al., 2006). However, several emerging case studies in Western Australia have demonstrated that landholders are engaging in new land management approaches, such as Landscape Rehydration, which aims to re-establish biophysical landscape functions to restore ecosystem services and agricultural productivity.

Landscape Rehydration was coined by the Mulloon Institute to describe the process of returning the small water cycle from a compromised to natural state. Landscape Rehydration involves physical works (infrastructure) that are designed to restore the natural flow of water through the landscape via the implementation of in-stream structures, hillslope earthworks such as contours and revegetation. Landscape Rehydration is associated with various benefits including increased soil hydration, stability and health, vegetation, drought resilience, flood control and agricultural productivity (the Mulloon Institute, 2020).

Landscape Rehydration theory is inspired by various system thinkers and educators such as Michal Kravčík and Jan Pokorný, authors of 'Water for the Recovery of the Climate – A New Water Paradigm', Professor of Limnology Wilhelm Dipl, E.M.U. founder Hugh Pringle, Global 500 recipient Ron Watkins and well-recognised microbiologists Walter Jehne, Nicole Masters, and Christine Jones.

Landscape Rehydration works are also inspired by practices such as Keyline Design developed by P. A. Yeomans and Natural Sequence Farming (NSF) developed by Peter Andrews OAM and the Holistic Management works of Allan Savory. While holistic management and Yeoman's keyline design have been adapted to case studies across the world, NSF and Landscape Rehydration practices have predominately been conducted across the Australian East Coast. Implementation of Landscape Rehydration practices in an environment with high salinity and waterlogging issues such as WA, raises concerns at the concept of rewetting the landscape.

This literature review aims to corroborate the impacts of Landscape Rehydration on stream and floodplain dynamics, mitigating existing land degradation, farm productivity and landholder profitability in Western Australia.

2 Discussion

2.1 Landscape Rehydration Works

2.1.1 In-stream Structures

Landscape Rehydration works include in-stream structures such as leaky weirs and rock baffles. Leaky weirs implemented at The Wood's farm, Geraldton, were constructed to plug an old drain in the valley floor of the property which blocked the flow of water and transformed the valley into a "chain of ponds" which was shown to slow water and capture organic matter (Wiley and O'Bree, 2020). WA's Rangeland NRM's field guide highlights how chains of wetlands and floodplains are responsible for recharging moisture in the landscape, allowing for persistence of productive perennial pasture and preventing the encroachment of less palatable woody shrubs onto alluvial grasslands (Tinely and Pringle, 2014).

The “chain of ponds” or wetlands system also provides a flood impact buffer, slowing stream velocities and reducing the sediment transport capacity of run-off and stream flows. This can be seen in case studies within the semiarid landscape of Central West NSW, where observations over a period of five years revealed that the instillation of leaky weirs within incised stream channels slowed flow velocities and promoted sediment aggradation and the infilling of incised streams (Streeton et al., 2013). An expert panel from CSIRO concluded similar findings at Bylong Valley, NSW, supporting the ability of in-stream structures to slow stream flows and increase sedimentation (CSIRO, 2002).

The aggradation of sediment is necessary to aid the formation of earth banks or benches within the stream channel, which should be placed where there are natural steps in the landscape and are considered the most important geomorphic process in channel re-constriction (Wiley, 2017b; Bush, 2010). Quantitative research conducted at Widden Brook, NSW, also showed that sedimentary aggradation associated with in-stream structures allows the lateral connectivity of groundwater and stream flows via sedimentary channel deposits (Keene et al., 2007). This connectivity is important as alluvial groundwater has been found to be important in maintaining base flow conditions within streams (Keene et al., 2007), and the erosion of stream deposits leads to the disconnection between groundwater and stream channel flows.

A study in the Central West NSW Rangelands concluded that while in-stream structures promote sediment retention, the maintenance and enhancement of ground cover vegetation is crucial in protecting the stream bed from high stream flow events and securing the longevity of the structures (Streeton et al., 2013). Western Australian Landscape Planner and Hydrologist, Lance Mudgway stated during a phone interview conducted on 14 June 2022, that vegetation has an essential role to play in stabilising in-stream structures by commencing the process of ‘quickly’ rebuilding fertility and encouraging the natural recolonization of the stream by native vegetation.

2.1.2 Contour Banks

Contour banks are used to slow and spread the flow of water across the landscape and away from erosion features, and to run water out of creeks and ponding areas across the floodplains and wetlands during high rainfall events to promote natural biophysical landscape functions (McCosker and Landsberg, 2021; Silcock and Hall, 2014). In Western Australia, case studies have used contour banks to help pool water at the bottom of wetlands or ponds and disperse water out of creeks during high rainfall events such as floods (Wiley, 2017a; Wiley and O'Bree, 2020; Wiley, 2017b). In Western Australian and Queensland rangelands, the use of contour banks is recommended over weirs on very flat or degraded land that is prone to soil erosion to prevent water erosion and promote soil water infiltration (Silcock and Hall, 2014).

Agronomic analysis of contours in broad-acre cropping operations highlighted the potential of landscape rehydration earthworks to present inefficiencies in GIS guided Controlled Traffic Farming (CTF) and modern no-till systems in addition to upfront earthworks costs (Callow and Bell, 2021). Case studies in Southwest Queensland highlight contour banks can be built with laser technology to improve location precision, maximize effectiveness, and minimise cost of constructed earthworks (McCosker and Landberg, 2021). Gilley (2005) suggests that establishing new field boundaries on contour can eliminate off-shaped fields with short rows, reducing the inefficiencies associated with navigating cropping machinery around contour banks.

Contour farming is considered challenging due to driving machinery in complicated terrain with various row directions, however recent studies show that integrating the application of GIS spatial analysis capabilities and automated guidance systems can be used to optimize guidance operations for contour farming (Guo, 2018). Additionally, implementing contour farming techniques has been shown to reduce sheet and rill erosion, reduce sediment losses and increase water infiltration (Gilley, 2005; Guo, 2018; Farahani et al., 2016).

A review of the effects of contour farming published in 2016 revealed that contour farming reduced annual runoff by 10% compared to conventional cropping practices perpendicular to the slope, and reduced soil losses by 49.5% and surface water runoff by 32% when cultivation rows and vegetation was established along contour lines (Farahani et al., 2016). Due to the reduced runoff and soil erosion associated with contour farming, the benefits of cultivating on the contour with or without vegetation plantings are considered greater than the perceived inefficiencies related to machinery overlap compared to straight cultivation rows (L. Mudgway, personal communication, June 14, 2022).

2.1.3 Spill-out Points

Spill-out points, also called overbank outlets, refer to zones in the landscape where water flows from stream channels or contour banks onto adjacent land, directing moisture to fill floodplains or flow onto paddock ridges. As stated in CSIRO's Expert Panel Report, spill-out points are an important feature of Landscape Rehydration works because while the sediment deposition in the stream is limited to the cross-sectional area of the channel, water spilled out onto floodplains and selected pastures can be expected to continue to accumulate sediment for decades or even centuries (CSIRO, 2022).

Research done by Lear et al. (2020) in the WA Fitzroy River highlighted that the increases in drought occurrence and intensity due to climate change poses a significant threat to freshwater ecosystems, where a reduction in wet season flooding, and overbank flooding causes a decline in the health condition of aquatic species. Utilising Landscape Rehydration and targeted spill-out points can help to improve wet season flooding, which was shown to improve the health condition and drought resilience of aquatic species (Lear et al., 2020).

A case study of a catchment in south-west WA showed that extensive land clearing and the transition to agricultural land use reduced the annual plant transpiration, increasing groundwater recharge which led to the upsurge of saline groundwater in addition to a run-off rate four times greater than pre-clearing rates (Callow, 2011). An analysis of rainfall and run-off in the WA Toolibin Lake Recovery Catchment suggests that increased catchment runoff due to reduced ground cover is most significant during medium rainfall events that occur within 72-hour rainfall threshold of 20 to 80 mm (Caittlin et al., 2004). In addition to increased run-off due to agricultural development, in WA, current climate change predictions of higher intensity summer rainfall have increased the need and feasibility of surface water interventions such as contour banks and spill-out points (Callow and Bell, 2021). Spill-out points along contour banks and stream channels, when correctly sized, can mitigate the scouring of topsoil or guttering of the immediate floodplain by surface water flows during high intensity rainfall events, as experienced in both WA and Qld (Tinely and Pringle, 2014; Silcock and Hall, 2014). In north-west and south-west WA spill-out points along contours have been utilized to spread water over dehydrated landscapes and have led to increased native vegetation germination and quick establishment (Wiley and O'Bree, 2020; Wiley, 2017a).

2.2 Vegetation

Rangeland NRM emphasizes the importance of vegetation in WA landscapes, stating 'vegetation simplification through overgrazing renders arid rangelands vulnerable to climatic change as they are close to tipping points towards desertification, or woody weed dominance' (Tinely and Pringle, 2014). One of the recognised benefits of Landscape Rehydration in WA is the revegetation of landscapes (Callow and Bell, 2021). Revegetating the landscape forms an essential component of Landscape Rehydration works, both in the form of physical planting of vegetation and by encouraging native germination and succession by re-instating the natural water cycle.

Vegetation is an important tool to slow the speed and energy of surface water flows and has been shown to increase infiltration rates and water holding capacity of soils on scalded flats in SW Qld (McCosker and Landsberg, 2021). Permanent revegetation such as the re-introduction of perennial plant species increases the soil organic carbon (SOC) within the landscape (Chen et al., 2022; Means et al., 2022; Ledo et al, 2020). Benefits from increasing soil organic carbon in WA's agricultural and rangeland areas through increased vegetation, also includes increased soil water holding capacity which extends to greater soil rehydration across the landscape (DPIRD, 2021).

Native plants have proven extremely effective at stabilising stream beds and banks and contributing to rapid stream-channel recovery by supporting oblique accretion (Keene et al., 2007; Wiley, 2017b). Callow (2011) suggests that revegetation in sections of the stream channel with higher gradients have the greatest potential to mitigate stream velocity and power. WA's Rangeland NRM's field guide highlights that ground cover vegetation such as native lemongrass (*Cymbopogon ambiguus*) or canegrass (*Phragmites australis*) act as a living plant filter, stabilising vulnerable soils from surface water flows, wind erosion and trapping sediment, litter and seeds, and can encourage the buildup of creek sandbanks (Tinley and Pringle, 2014). The WA Rangelands NRM also recommend using scrub and brush vegetation filters to stabilise existing rill and gully erosion (Tinely and Pringle, 2014).

In north-west WA, a mix of perennial pastures and native shrubs were also shown to successfully establish down-hill of contour banks, utilising extra surface water flows (Wiley and O'Bree, 2020, Wiley, 2017a). A case study in south-west WA showed an influx of native tree-saplings and couch grass germination in salt scalds after the construction of Landscape Rehydration works and at contour and stream-channel spill-out points (Wiley and O'Bree, 2020).

2.3 Pastoral Perspective

Catchment function analysis completed in north-west WA shows that the most productive grazing land is located within floodplains associated with major drainage channels (Wiley, 2017b). Landscape Rehydration aims to increase the availability of moisture and nutrients available to pastures by re-instating the natural water cycle, increasing the landscapes' ability to trap and retain organic matter, and promoting regular overbank flows. These flows transport nutrients and moisture either from the stream channel to the adjacent floodplain, or from surface water flows via contour banks to targeted spill-out zones such as infertile ridge lines.

Landscape Rehydration methods do not occur in isolation from managed grazing regimes, instead the approach exists in a mutually beneficial relationship with regenerative pastoral management where pastures are sufficiently rested between grazing periods dependent on pasture growth phase and climatic conditions. WA's Rangeland NRM describes the rehydration process as 'improving perennial groundcover, particularly grasses, and sustainable livestock productivity by rehydrating the land through control of total grazing pressure and strategic interventions to slow water flow' (Tinely and Pringle, 2014), which also highlights the importance of managed grazing in the successful implementation of Landscape Rehydration. CSIRO's Expert Panel Report further substantiates this, showing that pasture productivity improved due to changes in stream hydrology such as the construction of in-stream structures and was also enhanced by non-structural measures such as managed grazing regimes (CSIRO, 2002).

A study of the Mulloon Creek in NSW shows that the ability of Landscape Rehydration to trap, retain and recycle organic matter and soil allows for greater productivity of pastures, however the study also suggested Landscape Rehydration may result in downstream landholders receiving less sediment-based nutrient loads during floodplain inundations due to improved upstream retention (Dobes et al., 2013).

2.4 Dryland Salinity Risk

A study into sustainable water and energy management in Australia's farming landscapes states that inappropriate agricultural and pastoral practices causing streambed and floodplain degradation has led to both increased surface flows and velocities during high rainfall events and increased water salinity (Hurditch, 2015). The ARC Linkage report highlights that in a NSW case study, weathered minerals, washed down from river terraces by surface water flows are a major contributor to stream salinity, where stream salt loads are highly variable depending on the intensity of rainfall events (Bush, 2010). According to DPIRD, in addition to saline stream loads derived from surface water flows, as of 2022, more than one million hectares of once productive agricultural land in south-west WA are now severely affected by dryland salinity (DPIRD, 2022b).

Western Australian landscapes can be delineated into either shedding or receiving landscapes. Shedding landscapes are relatively steep sloping landscapes that generate run-off and so are generally not at risk to salinization, and receiving landscapes are low gradient areas such as valley floors where run-off loses momentum and inundates the soil. By inundating the soils of receiving areas, evaporative and capillary forces remobilize and force salt concentrations towards the ground surface resulting in dryland salinity (Caittlin et al., 2004).

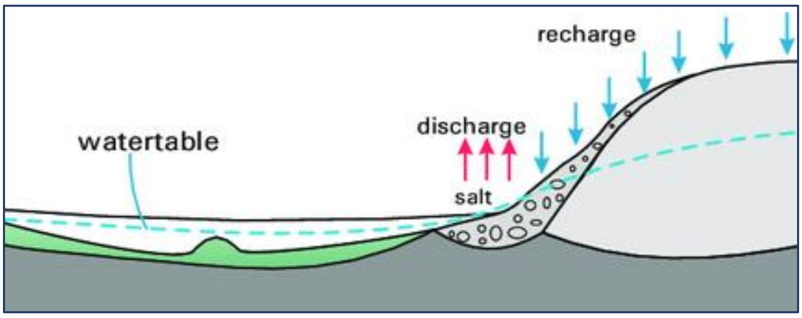

Figure 1: Salt mobilisation in shedding and receiving landscapes. (Schematic modified from Spies and Woodgate, 2004)

Landscape Rehydration uses in-stream structures, hillslope earthworks and revegetation to strategically retain surface water run-off and stream flows with the aim to return landscapes from erosive to their natural depositional state. This approach allows moisture to rehydrate the landscape, promotes natural revegetation and prevents surface run-off mobilising weathered mineral and nutrient deposits. As described by Hurditch (2015), 'this process involves the reconnection of stream waters with their adjacent alluvial groundwater systems, promoting a form of natural irrigation', and 'where the permanent, water-filled stream channel exhibits perched features producing a hydrostatic head of fresh water that effectively prevents saline water intruding from the surrounding hillslopes'. However, due to the ephemeral or highly seasonal nature of WA waterways, where permanent stream flows are rare, the ability of hydrostatic pressure forming from a freshwater lens may not be applicable.

Research by the University of Western Australia concluded that there is no published data or independent expert opinion on whether Landscape Rehydration will cause a hydrostatic head of fresh water in WA landscapes (Callow and Bell, 2021). Based on the lack of published case studies and scientific evidence, the efficacy of Landscape Rehydration on mitigating dryland salinity is widely contested in south-west WA. Concerns currently exists that if the Landscape Rehydration methods designed for eastern Australian properties are mimicked in the shallow groundwater, low gradient and saline lower rainfall areas of south-west WA, the landscape may experience increased land degradation from salinity (Callow and Bell, 2021).

A Landscape Rehydration case study at Toodyay, in the WA Wheatbelt documented that despite observed salinity, Landscape Rehydration works (including the ponding of water along streamlines) has led to the reduction of salt scalded areas as increased water availability has caused existing and newly germinated vegetation to grow vigorously (Wiley and O'Bree, 2020). WA's Rangeland NRM describe the beneficial impact of ponding water over highly saline soils, where 'gradually the salt is washed out of the soil profile and plant cover can return' (Tinely and Pringle, 2014). Case studies in NSW and Qld also show significant reductions in salinity and improved productive land capacity using Landscape Rehydration methods (Hurditch, 2015; CSIRO, 2002).

Published research into the interactions between stream flows and groundwater in rehydrated landscapes is severely lacking. A quantitative case study into the hydrological relationship between alluvial groundwaters and stream channel flows was conducted in NSW. The results revealed that in localized areas around in-stream structures, stream flow percolated into the adjacent groundwater, however outside the effects of in-stream structures, results indicated that alluvial groundwater discharged into the stream channel transporting with it increased salt and mineral loads (Keene et al., 2007). The study suggests that alluvial groundwater drains from the hyporheic zone (region of sediment and porous space beneath and alongside a stream bed) to the channel in baseflow conditions, carrying salt and mineral deposits with it, except around in-stream structures where stream water has ponded.

While the role of in-stream structures and floodplain overflows on mitigating dryland salinity issues are unclear, the revegetation aspect of Landscape Rehydration is anticipated to provide a beneficial role in reducing salinity. Research by the University of Western Australia concludes that 'revegetation of the landscape (where not associated with earthworks structures) may also work to sufficiently de-couple the capillary fringe from the surface and break the cycle of inundation and exfiltration of salts in the soil profile' (Callow and Bell, 2021).

2.5 Waterlogging

In Western Australia, areas situated low in the landscape, with little relief and relatively high rainfall (greater than 450 mm) are highly susceptible to waterlogging (DPIRD, 2022c). Landscape Rehydration aims to reinstate the natural flow of water through the landscapes, where the practice is tailored to each property. In areas that are susceptible to waterlogging, in-stream structures and spill-out points must be integrated with appropriate perennial vegetation and strategically designed to alleviate the extent of waterlogging and restore the natural drainage flow.

In WA, contour banks have been used to effectively reduce flooding and waterlogging on low-lying land (Thyer, 2021; Henschke, 1989). In the saline WA landscapes, structural failures such as leaks within contour banks can act as a source of groundwater recharge and may lead to salt waterlogging (Callow and Bell, 2021). It is therefore important that contour banks are correctly designed and constructed to contain or strategically release excessive surface run-off volumes.

2.6 Profitability

Both published research and available case studies analysing Landscape Rehydration in Australia lack technical evaluations of the long-term productivity and profitability benefits (Hurditch, 2015; CSIRO, 2002; Callow and Bell, 2021; Dobes et al., 2013). A financial and economic review of Landscape Rehydration at Mulloon Creek, NSW suggests that a focused, multidisciplinary research effort is needed to assess if Landscape Rehydration is financially viable or socially beneficial for individual properties (Dobes et al., 2013).

Landscape Rehydration aims to increase the availability of moisture and nutrients available across the landscape using strategic interventions to capture and retain moisture and redirect surface water flows away from vulnerable drainage lines onto targeted spill-out zones. Landscape Rehydration effectively spreads the water across the landscape, rather than allowing surface water flows to concentrate down drainage lines. Research shows that in grain farming systems, profitability is maximised when the maximum volume of rainfall is made available to the crop at relatively homogenous rates across the paddock (Callow and Bell, 2021). This highlights the potential of Landscape Rehydration to maximise profitability for grain farming systems, as hillslope earthworks and spill-out points can direct water flows and increase water availability across the landscape.

CSIRO's Expert Panel Report concludes that increases in pasture productivity, achieved through Landscape Rehydration practices 'appear to translate into increases in economic productivity' and highlight that the relatively small financial investment to implement Landscape Rehydration works may substantially increase the profitability and market value of properties (CSIRO, 2002). The perceived benefits of Landscape Rehydration also include a reduced reliance on high-cost artificial inputs such as fertilisers which leads to a reduction in farm expenses and a greater economic farm profit (Hurditch, 2015).

A cost-benefit analysis of Landscape Rehydration works in Southern Qld was estimated based on anecdotal evidence presented by Dr. Terry McCosker OAM. Hillslope earthworks designed to rehydrate the landscape on a livestock grazing operation was estimated to provide a $15/ha return profit due to increased water holding capacity and pastoral yield (McCosker and Landsberg, 2021).

The economic value of agricultural land in Western Australia may be based on the carrying capacity of the land, and so the capital value increases proportionally. During a phone interview conducted on May 4, 2022, Tim Wiley, Senior Rangelands Scientist at Tierra Australia, stated that investing in Landscape Rehydration works including revegetation and managed grazing infrastructure generally costs 10–20% of the initial property value but will provide between a 10% and 20% return on investment. Tim Wiley has worked on Landscape Rehydration works across Western Australia, including specific projects in Geraldton, Toodyay, Muresk, and Dandaragan.

As discussed in Section 2.1, a review conducted by the University of Western Australia suggested that while contour banks may be successful at capturing and retaining surface water flows, the banks may also lead to operational inefficiency for grain farming systems during sowing and harvesting which may hinder economic profitability.

A series of eastern-Australian case study reports presented by Soils for Life indicate that farm innovations such as Landscape Rehydration practices have led to increased sustainable profitability, primarily due to reduced farm input costs associated with the cessation of agrochemical use and the transition to regenerative practices (Soils For Life, 2012; Soils For Life, 2022). Adopting Landscape Rehydration practices were also shown to increase the stability of profits, despite decreases in local rainfall (Soils For Life, 2012).

3 Conclusion

This literature review consolidates the impacts of Landscape Rehydration on stream and floodplain dynamics, mitigating existing land degradation, farm productivity and landholder profitability in Western Australia.

Available research and documented case studies show that Landscape Rehydration works play an important role in stabilising erosion, reducing stream sediment pollution, increasing water and nutrient availability across the landscape, ameliorating waterlogging, and facilitating extensive native revegetation. There is no independent, quantitative evidence that Landscape Rehydration will alleviate dryland salinity by increasing freshwater recharge, however, emerging case studies in WA indicate that Landscape Rehydration works can drive a surge in native vegetation, which provides a beneficial role in mitigating dryland salinity. Research shows Landscape Rehydration works, complemented by managed grazing regimes, can substantially improve the productivity of grazing systems.

The absence of a recently published, independently sourced scientific review of the Western Australian landscape functions and the capability of the Landscape Rehydration to restore ecosystem services and agricultural productivity is apparent. In addition to a modern, independent scientific study, indigenous understanding, and cultural knowledge relevant to landscape function, erosion control, and dryland salinity mitigation has not been investigated, but may provide valuable insights.

It is also evident that quantitative documentation of productivity and profitability assessments for Landscape Rehydration is currently inadequate. There also appears to be a gap in available research regarding the cost-benefit-analysis of Landscape Rehydration works on external ecosystem services such as improved water quality for downstream uses, such as water supply, fishing industries, alleviation of state desalination requirements due to reduced stream salt loading, and catchment scale drought and bushfire resilience.

Existing reviews into the impacts of Landscape Rehydration conclude that there is a need for government organisations to reassess completed projects across Western Australia. These results can be used to quantify the efficacy of previous mitigation measures and inform current projects.

While the positive productivity and profitability outcomes are unclear, an opportunity exists for the efficacy and economic viability of Landscape Rehydration to improve as available knowledge, resources and support services become available. Based on currently available literature and relevant case studies, Landscape Rehydration provides an opportunity to remediate land degraded by vegetation decline, erosion, waterlogging and dryland salinity.

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Appendix 1 – Abstract/Summary of Reviewed Literature

Below are summaries of a selection of the reviewed literature predominantly referred to within the Literature Review.

Catchment Function Analysis using Google Earth Mapping | Tim Wiley

This paper presents a Catchment Function Analysis utilising Natural Sequence Farming and Ecosystems Management Understanding, as conceptual frameworks for system functioning, together with Google Earth, to indicate critical features of a catchment and the resulting public and private policy implications for catchment management.

Connectivity of stream water and alluvial groundwater around restoration works in an incised sand-bed stream | Annabelle Keene, Richard Bush and Wayne Erskine

The drainage of Australian streams since European settlement has resulted in widespread incision, with catastrophic widening leading to increases in sediment yield. This has left many thousands of kilometres of streams isolated from their floodplains, resulting in the loss of in-stream geomorphic complexity and associated changes to stream health and water flows. Widden Brook, a right bank tributary of the Goulburn River in the Hunter Valley, NSW, is an active sand-bed channel characterised by low to moderate specific mean annual flood and high to very high flood variability. On Widden Brook, floods have caused substantial bank erosion with the whole floodplain being reworked since first European settlement, but rapid channel contraction is now occurring. In this study, strong hydrological linkages existed between stream water and alluvial groundwater table depths. However, the effect of an in-stream structure on the stream water groundwater exchange zone was localised despite changes in geomorphic complexity and water quality. The implications of the de-coupling of streams from their floodplains are only now beginning to be understood, with significant impacts on hydrological connectivity.

Expert Panel Report: The "Natural Farming Sequence" | CSIRO

In response to a request from the Honourable John Anderson MP, Deputy Prime Minister of Australia, CSIRO Land and Water formed an "Expert Panel" to assess the "Natural Farming Sequence" (NFS) as implemented at Tarwyn Park in the upper Bylong valley, New South Wales. The panel included expertise in hydrogeology, surface water hydrology, fluvial geomorphology, biogeochemistry, dryland salinity, landscape ecology, agricultural systems and agricultural economics. The panel made its assessment on the basis of professional interpretations of verbal and written descriptions of NFS, and an inspection of Tarwyn Park on 23 May 2002. The lack of quantitative data and the limited resources for the study precluded quantitative assessment.

Gunningrah – Shifting mindset from animals to the land, A Regenerative Agriculture Case Study | Soils For Life

Initially inspired to perform a trial of new management practices to better manage received rainfall, Charlie and Anne Maslin ended up following their instincts - fully changing focus from their animals to the land - and they have never looked back.

Impacts of rehabilitating degraded lands on soil health, pastures, runoff, erosion, nutrient and sediment movement. Part II: Literature review of rehabilitation methods to improve water quality flowing from grazing lands onto the Great Barrier Reef. | Richard G Silcock and Trever J Hall

Over 200 potential references were reviewed with many covering aspects of water quality, grazing lands, and their effects on the Great Barrier Reef (GBR), and rehabilitation of degraded landscapes. There was little reported information on the mechanical rehabilitation of bare, D-condition grazing lands in the reef catchments. There is, however, literature on machinery suitable for soil surface disturbance, pasture technology for developing permanent perennial pastures and on grazing management for improving C-condition land.

Regenerative Agriculture Case Studies| Soils For Life

Three individual case studies incorporating NSF practices Jillamatong, Gunningrah and Brownlow Hill published by Soils For Life. Case studies present the ecological, production and social changes on the properties over the entire period.

Landscape Rehydration and Regenerative Agriculture – whole farm demonstration on Jack Wood's farm at Toodyay | Time Wiley and Rod O'Bree

Jack Wood and family own a 377 ha farm 6 km southwest of Toodyay on the main road from Perth. The Wood family have commenced the redevelopment of the farm based on Landscape Rehydration, Regenerative Agriculture and Carbon Faming principles.

Landscape Rehydration – Blog by RCS | Terry McCosker and Glenn Landsberg

Landscape Rehydration in Southern Qld Landscapes, including mitigating erosion features, spreader banks, strategic timber windrow placement and landscape appropriate grazing practices. Includes cost benefit analysis, infiltration data and risk assessment.

Rangeland Rehydration Field Guide |Ken Tinley and Hugh Pringle

This field guide is focused on helping restore the 'indicator landscapes' or 'best country' as part of a whole station ecological management approach that can benefit generational continuity of biodiversity conservation and rangeland enterprises "where the degree of success is high and the treatment cost-effective" (Ludwig et al. 1990). Here we provide a guide for ecological management of rangelands, based on drainage, with some tools to repair them. We also strongly support local initiative and creativity in building unique, best-fit solutions.

Rehabilitation of an incised ephemeral stream in central New South Wales, Australia: identification of incision causes, rehabilitation techniques and channel response | N. A. Streeton, R. S. B. Greene, K. Marchiori, D. J. Tongway and M. D. Carnegie

The degradation of semiarid agricultural rangelands in Australia can be traced back to the 19th century when Europeans expanded into these areas. That environmental degradation remains today and continues to harm agricultural productivity. The rehabilitation of a strongly incised ephemeral stream, 'Spring Creek', in central New South Wales, as an example of what can be achieved readily by landowners, is described. The causes of environmental degradation and the main environmental factors leading to the stream erosion were identified, rehabilitation began and the behaviour of the regime for 5 years within Spring Creek and the adjacent floodplain was monitored. It was found that intrinsically unstable sub-soils and sparse ground cover due to persistent grazing by domestic livestock were the major factors leading to incision. Several physical and chemical properties were found to be the primary causes of the soil's instability.

Rehabilitation focussed on stabilising the soils alongside the stream, promoting sedimentation and re-vegetation of the stream bed, with a longer-term objective of increasing the transfer of water, sediments and nutrients between the stream and its adjacent floodplain. The measures, implemented by local landowners, included the provision of in-stream porous rock weirs and the lowering of the grazing pressure on the stream bed and adjacent floodplain. Monitoring in 2007, 2009 and 2011 indicated that sedimentation was substantially faster above weirs than where there were no weirs. The rehabilitative measures resulted in the retention of fine sediment (<0.2 mm) along the stream bed behind weirs.

Restoring hydrological connectivity of surface and ground waters: Biogeochemical processes and environmental benefits for river landscapes. | ARC Linkage-Project

This project examines the restoration of lateral hydrological connectivity to improve floodplain structure and function. The connections between stream flows and both shallow groundwaters and floodplains are critical in sustaining river landscapes. Degrading land and water management practices compounded by natural climatic extremes have severed this link. Restoring hydrological connectivity is vital for replenishing groundwater storage and increasing base flows that affect fundamental riverine processes. Using an innovative approach to sustainable agriculture, our project unites multidisciplinary scientific and industry expertise to investigate the biogeochemical and biophysical effects of secondary floodplain channels and in-stream structures on riverine groundwater processes

Stream-bed and flood-plain rehabilitation at Mulloon Creek, Australia: a financial and economic perspective | Leo Dobes, Nathan Weber, Jeff Bennett and Sue Ogilvy

Prior to European settlement, many Australian rivers were characterised by interconnected 'chains of ponds', with riparian vegetation preventing scour and subsequent channel erosion. Damage and destruction of vegetation by grazing animals has resulted in stream-channel incision and associated lowering of water tables on adjacent flood-plains. Proponents of natural sequence farming seek to restore hydro-geomorphic functionality by raising stream levels through construction of leaky weirs and revegetation. Lack of documentation of 'before and after' production data precludes evaluation of either the financial viability or the broader economic merits of raising stream levels.

A case study, based on financial and economic costs, and possible benefits, at one site, highlighted the need for more targeted research that can be combined with an economic evaluation of stream rehabilitation. Only a more focussed, multidisciplinary research effort can reveal whether it is likely to be financially viable for individual properties or to be socially beneficial. The study also identified that government agencies should commission, and publish, the results of assessments of alternative schemes that have been used to control erosion or to rehabilitate streams, for comparative purposes. Similarly, a comprehensive cost–benefit analysis should be undertaken to ensure an objective basis for regulatory control over the management of water resources on Australian properties.

Surface Water Assessment for the Toolibin Lake Recovery Catchment, For the Department of Conservation and Land Management | Travis Cattlin, Darren Farmer, Neil Coles and David Stanton.

The Engineering Water Management (EWM) group at Department of Agriculture, Western Australia was contracted to undertake a surface water assessment of the catchment and develop a conceptual management strategy.

The objective of the recovery plan is to ensure the long-term maintenance of Toolibin Lake and its environs as a healthy and resilient freshwater ecosystem suitable for the continued visitation and breeding success by the presently high numbers and species of water birds. The recovery project is implementing a range of actions, both biological and engineering, to ameliorate the threatening processes causing degradation within the recovery catchment. Actions taken to achieve the recovery plan's objective are considered in consultation with other landholders and government departments.

The hydrological evaluation was completed in consultation with the Natural Resource Assessment Group (NRAG), Department of Agriculture who undertook to assess the soil land form units which are described in a companion report by Verboom et al. (2004).

Sustainable water and energy management in Australia's farming landscapes | W. J. Hurditch

Australia's ancient geology, continental isolation and long, stable biophysical evolution have produced a unique and biodiverse flora and fauna complex, and well-balanced mechanisms for handling water, nutrients and organic production in its landscapes. When humans arrived more than 40,000 years ago, Australia's water, nutrient and energy systems were essentially self-sustaining. Western agricultural methods have since uncoupled parts of the innate productivity system that had long sustained these natural landscape functions.

Many Australian farming and grazing businesses are today challenged from unreliable rainfall, declining soil health and rising debt. New landscape management approaches are now emerging. Some involve rehydration to reinstate Australia's natural biophysical landscape functions and processes and can deliver both ecosystem resilience and profitability to farming enterprises. Benefits of landscape rehydration for farmers include greater water reliability, improved soil organic content and reduced reliance on high-cost artificial inputs. It also assists in mitigating climate change, as vegetated, rehydrated landscapes dissipate incoming solar thermal energy via the plant-driven photosynthetic process and the daily water cycle. This feature, until now little recognised in mainstream climate change discussions, adds a major dimension to this opportunity for the world's landscapes. Keywords: Australia, salinity, rehydration, fertility, sustainable farming, soil.

The applicability, efficacy and risks of natural sequence farming in the dryland agricultural zone of south west Western Australia the dryland agricultural zone of south west Western Australia | Nik Callow and Rose Anne Bell

The Department of Primary Industries and Regional Development ("DPIRD") engaged The University of Western Australia ("UWA") to undertake a review encompassing the broader principles and practices of Natural Sequence Farming (NSF). The review has combined information available from the literature, relevant case studies, as well as outcomes and findings from interviews with knowledge holders and stakeholders to achieve the following objectives:

1. Develop a working definition and description of NSF as developed, described and documented by Peter Andrews and associates
2. Document the key principles and practices associated with NSF

3. Identify the expected benefits and associated risks with the application of NSF in the south west of Western Australia (SWWA) dryland agricultural zone, with a focus on broadacre wheat and sheep farming, and to summarise the hydrological and production benefits and risks, specifically addressing:
    a. The landscape component – floodplain and on hillslopes
    b. Landscape geomorphology (hydrology/hydrogeology) and how the risks and opportunities change across the hydrological zone transitions in SWWA
4. Design a landscape monitoring protocol to enable objective assessment of the performance of NSF as applied on any farm or catchment, including factors to consider about site assessment before implementation and related requirements.

Wet season flood magnitude drives resilience to dry season drought of a euryhaline elasmobranch in a dry-land river | Karissa O.Lear, David L.Morgan, Jeff M.Whitty, Stephen J.Beatty, Adrian C.Gleiss

The increase in severity and occurrence of drought from environmental change poses a significant threat to freshwater ecosystems. However, many of the mechanisms by which periodic drought affects aquatic animals are poorly understood. Here we integrated physical, physiological, and behavioural measurements made in the field over a twelve-year period to provide a comprehensive understanding of the factors affecting the loss of body condition of fish in arid rivers, using the Critically Endangered freshwater sawfish (Pristis pristis) in the dryland Fitzroy River, Western Australia, as a model species. Sawfish lost condition throughout the long dry season in all years and had significantly poorer body condition throughout years characterized by low volumes of wet season flooding and little occurrence of overbank flooding. A mechanistic examination of factors leading to this loss of condition using measurements of body temperature, field energetics, and habitat use from telemetry techniques showed that the loss of condition throughout the season was likely due to substantial habitat compression and low productivity in drier years, while high rates of competition were more likely to drive this pattern in wetter years. This information can be used to forecast how climate change and water abstraction will affect aquatic fauna experiencing intermittent drought and can inform management decisions to help mitigate these threats.

'Yanget Farm' Rehydration Project by Rod O'Bree and Peter Andrews, Catchment Function Analysis by Tim Wiley | Tim Wiley

In early 2008 Rod and Bridie O'Bree purchased 'Yanget Farm' which is 25 km east of Geraldton. Soon after Rod engaged Peter Andrews to advise him on implementing Peter's Natural Sequence Farming (NSF) methods on Yanget. Most of the earth works for NSF were completed by the end of 2009. http://www.nsfarming.com/

Yanget is the longest running example of NSF principles in WA. This makes it an ideal study and demonstration site. Rod has followed up on the earth works by introducing a wide range of perennial plants to enhance the NSF system. Rod has also used Peter Andrew's methods of mulching of weeds and placing heaps of manure at spill points along the contours.