Native ecosystem rehabilitation in Queensland

Implications for leading practice

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- Rehabilitation of native vegetation to represent *natural historic* ecosystems after mining is considered leading practice.
- Where restoration of a *natural historic* ecosystem is not feasible, operators should investigate the potential for establishment of a *natural substitute* system from the bioregion in which the mine is located.
- Where the inherent biophysical limitations of the land require, a *hybrid* or *novel* ecosystem might be identified as the target but should not be used to 'lower the bar' on achieving high quality ecosystem rehabilitation.
- It is leading practice to define specific outcomes and objectives for rehabilitation, consequently *unplanned novel* ecosystems cannot be supported as an intended outcome.
- Uncertainty exists as to the sustainability and future maintenance burdens of *hybrid* and *novel* ecosystems.
- Management of *hybrid* systems towards achieving the improved outcome of a *natural* ecosystem would represent a leading practice.
- Proposals for ecosystem rehabilitation should present:
  - a detailed description and justification for the target native ecosystem(s) type to be achieved
  - details of current ecological knowledge about appropriate ecosystem trajectories
  - an outline of the predicted beneficial environmental outcome(s) that can be measured
  - quantifiable completion criteria that align with the predicted beneficial environmental outcome(s) and the monitoring methodology suitable to demonstrate achievement of criteria.

Background

The Queensland Mine Rehabilitation Commissioner (QMRC) engaged Aspect Ecology Pty Ltd to prepare three technical papers evaluating options for native ecosystem rehabilitation on mine sites in Queensland. These can be found on the QMRC website (www.qmrc.qld.gov.au). Native ecosystem rehabilitation is a common post-mining land use (PMLU) proposed by miners and authorised under environmental authorities for resource activities.

This “Implications for leading practice” document distils the work undertaken and presents our views on how it may be used by those working towards leading practice native ecosystem rehabilitation.

Native ecosystem outcomes as proposed by individual operators over the years, has resulted in various degrees of specificity regarding what constitutes native ecosystem rehabilitation.

Rehabilitation to recreate or restore the historical ecological communities that existed on a site prior to mining is leading practice. However, ecosystem restoration is challenging as the process of mining fundamentally changes the environment by causing significant localised disturbance, limiting restoration of original landforms, soils, topography, hydrology and system connectedness. Thus, while reinstatement of *natural historic* ecosystems may be leading practice, the obstacles faced by operators to achieve this PMLU prompt us to consider what alternatives exist, what level of ecosystem services can be provided by the alternatives and when alternative systems can be proposed as a viable outcome.

Native ecosystem rehabilitation

Despite the challenges associated with rehabilitation to a native ecosystem outcome, stakeholders surveyed placed a high value on the role of regional native floristics to achieve native ecosystem rehabilitation outcomes (Baskerville et al 2023).

The Society for Ecological Restoration has developed international principles and standards for the ecological restoration and recovery of mine sites: the Mine Site Restoration Standards (MSRS) (Young et al. 2022). The MSRS provide a framework for the recovery of ecosystems, designed to encourage the highest achievable level of ecosystem restoration, underpinned by eight ecological restoration principles for mine sites and is useful to define, guide and measure ecological restoration activities and outcomes.

The technical papers published by the QMRC identify that where biophysical conditions similar to those that existed pre-mining can be restored, then rehabilitation that targets *natural historic* ecosystems is leading practice, aligning with a key objective of the MSRS. Within Queensland, such ecosystems must resemble a naturally occurring regional ecosystem (RE).The RE framework is based upon three major attributes that include broad-scale landscape patterns as described by bioregion; geology, soils and landforms described as land zones; and vegetation described in terms of structure and floristics (Nelder et al 2019). The concept of *natural* rehabilitation was expanded to include *substitute* ecosystems, which allows for operators to select another RE within the bioregion that more closely resembles the post-mining conditions. Establishing local natural ecosystems restores local species that have evolved for local conditions and the ecosystem is therefore more likely to be sustainable in the long-term with lower ongoing maintenance burdens (Gould, 2012; Guimarães et al., 2013; Gastauer et al., 2019). Natural ecosystems also deliver ecosystem services such as water supply, carbon sequestration, recreational and cultural areas and genetic resources (Costanza et al. 2017) that are appropriate for and exist within the region naturally (Rosa et al. 2020).

At times the constraints on practicably restoring natural systems are attendant and further guidance is needed on what alternative rehabilitation outcomes are possible. Table 1 summarises the various classes of native ecosystems described in the technical papers and provides an example for each. In this context, *natural* systems are those restored to the extent of historic succession trajectory; *hybrid* ecosystems are considered to have some but not all of the characteristics of the natural/historic landscape and some novel attributes; and *novel* systems are new assemblies of abiotic and biotic attributes resulting in a stable alternative ecological form that does not resemble natural ecosystems (Doley et al. 2012, Doley and Audet 2013). Both *historic* and *substitute natural* vegetation classes are analogous to a regional ecosystem whereas *hybrid* and *novel* classes are considered as no-analogue systems (Seastedt et al., 2008; Hobbs et al., 2013; Evers et al., 2018). The term ‘analogous’ has been used in place of ‘reference’ in acknowledgment that rehabilitation is occurring on anthroposol profiles. Table 1 is hierarchical, with *natural historic* representing the top of the hierarchy as it achieves the highest level of endemicity.

Implications for leading practice

Early planning and identification of clearly defined objectives and targets for native ecosystem rehabilitation is important and necessary. Frameworks such as the MSRS can be adopted early and used to optimise native ecosystem outcomes. For example, the six key ecosystem attributes; setting clear goals and objectives, and monitoring using measurable indicators; and the ecological recovery wheel outlined in the MSRS may assist (Principle 3 and Table 3; Principle 5; and Principle 6 and Figure 12 of Young et al. 2022, respectively).

Mine rehabilitation plans should include a comprehensive description of and justification for the target native ecosystem(s) to be achieved and detail current ecological knowledge regarding appropriate ecosystem trajectories. The plans should also articulate the predicted beneficial environmental outcomes, ensuring these are measurable and accompanied by quantifiable completion criteria. It is crucial that plans detail a monitoring methodology suitable to demonstrate achievement of completion criteria. Indicators of success and various monitoring methods are further explored and evaluated in Spain et al. (2023).

Early selection of the vegetation assemblage is necessary. Identification of analogue sites at this stage will inform the choice of target species. At times it is difficult to identify a totally undisturbed analogue site and in such instances the principle of “Best on Offer” is a relevant consideration (Eyre et al., 2017). Respondents to the stakeholder survey indicated benchmarking against reference sites is a common method to assess rehabilitation success (Baskerville et al., 2023). Stakeholders also identified the importance of ensuring reference/analogue sites match the end land use and are analogous to the post mining landform. The role of analogue sites, particularly for *hybrid* and *novel* systems, is discussed in Appendix 2 of Spain et al. (2023).

Availability of seed/seedlings is an important consideration when planning rehabilitation activities and can have a significant impact upon species selection. Leading practice is to establish the species composition for the target vegetation community early and plan to ensure seed availability does not become a limiting factor in rehabilitation efforts. This may include establishment of a site-specific nursery or commercial arrangements ahead of time to avoid a situation where a species list needs to be reverse engineered based on the choice of seed commercially available just prior to revegetation works.

Where disturbance of land from mining activities results in minimal impact upon biophysical characteristics and is surrounded by an existing *natural historic* ecosystem (such as a laydown, seismic line or well pad), reinstatement of the *historic* ecosystem should be the stated objective.

The inclusion of *substitute* ecosystems as a natural ecosystem class has the benefit of broadening the range of native ecosystems that can be targeted, whilst utilising co-evolved suites of species that will be consistent with the climate and landforms of each site’s bioregion. Consequently, where restoration of a *natural historic* ecosystem is not feasible, establishment of a *natural substitute* system from within the bioregion of the site must be investigated as the next preferred option. It is noted that a proper interpretation of the RE framework requires the underlying land zone of the rehabilitation area to be the same as that of the substituted system. While the land zone is a key attribute used to describe an RE, we acknowledge that most rehabilitation will occur on an anthroposol, resulting in a different underlying land zone. Therefore, in the context of the technical papers, the focus is on the floristic attributes of the RE. As such, seeking a co-evolved suite of species on a land zone analogous with the post mining landform would achieve the intent of a substituted historical system and represents a leading practice. Furthermore, targeted species selection from those which overlap several REs associated with the relevant land zone may improve the success of rehabilitation.

Hybrid, planned novel and *unplanned novel* ecosystems inherently imply greater uncertainty in terms of ecosystem sustainability and resilience, compared to rehabilitated *natural* ecosystems. While these categories of native ecosystem are presented as separate entities, they should be considered as points along a continuum. These classifications are used to explain ecosystems that have developed in disturbed unmined landscapes, so care must be taken when interpreting and applying the concepts to mine rehabilitation planning. Further information regarding how these classifications were determined is presented in Hobbs et al. (2009) and Doley and Audet (2016).

Concerns have been voiced that the concept of *novel* ecosystems may promote *laissez-faire* attitudes to conservation and restoration (Murcia et al., 2014; Higgs, 2017). Some researchers and rehabilitators contend that acceptance will facilitate the degradation of land through less stringent regulation (Clewell and Aronson, 2013; Aronson et al., 2014), although this is debated (Hobbs et al., 2014).

At a minimum, the formal incorporation of *novel* ecosystems as a target in mine rehabilitation activities would acknowledge that, in some cases, impacts are severe enough to hinder the ability to restore a *natural* ecosystem. This may be seen as problematic (Perring et al., 2013), in that “settling” on *hybrid* or *novel* ecosystems as a target may stifle innovation and the development of new techniques for establishing *natural* rehabilitation. Thus, operators should remain cognisant of the distinctions between *planned novel* (i.e., *designer*), *unplanned novel* and *hybrid* ecosystems. Leading practices define specific outcomes and objectives, consequently *unplanned novel* ecosystems cannot be supported. Furthermore, operators should consider the implications of future management requirements for the final rehabilitated ecosystem. This is important as these no-analogue rehabilitated ecosystems will likely require increased ongoing management compared to rehabilitated *natural* ecosystems, therefore these alternative native ecosystem PMLUs should be considered with caution.

Notwithstanding this need for caution, some sites may need to implement *hybrid* or *planned novel* ecosystem rehabilitation and must strive to maximise the beneficial ecosystem services that the rehabilitation can provide. The concept of ecosystem services is discussed in Spain et al. (2023). A definition is also provided in the MSRS (Young et al. 2022). In determining a *hybrid* or *planned novel* outcome, a thorough assessment of the biophysical limitations present at the site should be undertaken and the resultant considerations presented in the mine rehabilitation plan. In assessing whether such an outcome is the only alternative, the operator must firstly attempt to identify a relevant analogue site to the substrate on which the rehabilitation is to occur, and prioritise the production of a growth media suited to the analogue RE.

An ongoing challenge for the industry and regulators is the promotion of leading practices amongst the legacy of historical approaches which have resulted in a variety of rehabilitation outcomes and standards. The approvals process is site specific, risk-based and reflective of best practice and available technology at the time. High levels of performance (e.g., diligent recovery and direct transfer of topsoil) are often a result of standards required as conditions of approval. *Hybrid* systems may provide a useful steppingstone to the improved outcome of a *natural substitute* ecosystem and leading practice would encourage such management.

Table 1. Rehabilitated native ecosystem classes, characteristics and management considerations

Class	Subclass	Characteristics of the rehabilitated native ecosystem	Management considerations	Example
Natural	Historic	Abiotic and biotic characteristics of the RE that was present pre-mining.	Post-mining management expected to be similar to that of pre-mining RE.	Same assemblage as present prior to disturbance.
Natural	Substitute	Abiotic and biotic characteristics that differ from those in the pre-mining RE, but analogous to another RE within the bioregion and from a relevant land zone.	Post-mining management expected to be similar to management of REs of the surrounding bioregion.	Example for a coal mine waste rock dump in the Bowen Basin - RE 11.10.4 contains a variety of species and occurs on very rocky shallow soils.
Hybrid	n/a	Ecosystem functions are similar to an RE, but ecosystem is characterised by unique attributes not found in an RE. The unique aspects can be overcome by management to move the ecosystem towards an RE.	Management action can be taken to manipulate these systems towards an RE.	Must be dominated by native species to be considered native ecosystem rehabilitation. May comprise native species from a homogenised mix of different habitats and landscape positions.
Novel	Planned	A planned native ecosystem that meets specific ecosystem services objectives but has no RE analogue (i.e., it is intentionally novel). Also known as a designer ecosystem.	Self-sustainability unknown, though expected to require management. Cannot be manipulated to become a RE.	Must be dominated by native species to be considered native ecosystem rehabilitation. E.g., Native seed orchard (Nichols et al., 1985; Gardner and Bell, 2007; Annandale et al., 2021) Bush tucker gardens (Annandale et al., 2021), Carbon sequestration (Ntshotsho, 2006; Ahirwal and Maiti, 2017)
Novel	Unplanned	The unintentional result of attempts to establish an RE where biophysical limitations or rehabilitation techniques have resulted in a unique and stable assemblage that does not have an analogous RE. These unique aspects cannot be managed to move the ecosystem towards an RE.	Stable ecological form that cannot be manipulated to become an RE via management intervention.	Must be dominated by native species to be considered native ecosystem rehabilitation.

References

Ahirwal J and Maiti SK (2017) 'Assessment of carbon sequestration potential of revegetated coal mine overburden dumps: A chronosequence study from dry tropical climate', *Journal of Environmental Management*, 201:369–377, doi:10.1016/j.jenvman.2017.07.003.

Annandale M, Meadows J and Erskine P (2021) 'Indigenous forest livelihoods and bauxite mining: A case-study from northern Australia', *Journal of Environmental Management*, 294(May):113014, doi:10.1016/j.jenvman.2021.113014.

Aronson J, Murcia C, Kattan GH, Moreno-Mateos D, Dixon K and Simberloff D (2014) 'The road to confusion is paved with novel ecosystem labels: A reply to Hobbs et al.', *Trends in Ecology and Evolution*, 29(12):646–647, doi:10.1016/j.tree.2014.09.011.

Baskerville L, Spain CS, Nuske S, Gagen E (2023) 'Options for Native Ecosystem Mine Site Rehabilitation in Queensland: Stakeholder Survey Report'. Brisbane: Office of the Queensland Mine Rehabilitation Commissioiner, Queensland Government.

Clewell A and Aronson J (2013) 'The SER primer and climate change', *Ecological Management and Restoration*, 14(3):182–186, doi:10.1111/emr.12062.

Costanza R, de Groot R, Braat L, Kubiszewski I, Fioramonti L, Sutton P, Farber S and Grasso M (2017) 'Twenty years of ecosystem services: How far have we come and how far do we still need to go?', *Ecosystem Services*, 28:1–16, doi:10.1016/j.ecoser.2017.09.008.

Doley D and Audet P (2013) 'Adopting novel ecosystems as suitable rehabilitation alternatives for former mine sites', *Ecological Processes*, 2(1):22, doi:10.1186/2192-1709-2-22.

Doley D and Audet P (2016) 'What part of mining are ecosystems? Defining success for the "restoration" of highly disturbed landscapes', in *Ecological Restoration: Global Challenges, Social Aspects and Environmental Benefits*. Nova Science Publishers, Inc., 57–88, Available at: https://www.researchgate.net/publication/289504951.

Doley D, Audet P and Mulligan DR (2012) 'Examining the Australian context for post-mined land rehabilitation: Reconciling a paradigm for the development of natural and novel ecosystems among post-disturbance landscapes', *Agriculture, Ecosystems and Environment*, 163:85–93, doi:10.1016/j.agee.2012.04.022.

Evers CR, Wardropper CB, Branoff B, Granek EF, Hirsch SL, Link TE, Olivero-Lora S and Wilson C (2018) 'The ecosystem services and biodiversity of novel ecosystems: A literature review', *Global Ecology and Conservation*, 13:e00362, doi:10.1016/j.gecco.2017.e00362.

Eyre TJ, Kelly AL and Neldner V (2017) *Method for the Establishment and Survey of Reference Sites for BioCondition*. Version 3. Brisbane, Queensland: Queensland Herbarium, Department of Science, Information Technology and Innovation.

Gardner JH and Bell DT (2007) 'Bauxite mining restoration by Alcoa World Alumina Australia in Western Australia: Social, political, historical, and environmental contexts', *Restoration Ecology*, 15(SUPPL. 4):3–10, doi:10.1111/j.1526-100X.2007.00287.x.

Gastauer M, Souza Filho PWM, Ramos SJ, Caldeira CF, Silva JR, Siqueira JO and Furtini Neto AE (2019) 'Mine land rehabilitation in Brazil: Goals and techniques in the context of legal requirements', *Ambio*. 2018/04/11, 48(1):74–88, doi:10.1007/s13280-018-1053-8.

Gould SF (2012) 'Comparison of Post-mining Rehabilitation with Reference Ecosystems in Monsoonal Eucalypt Woodlands, Northern Australia', *Restoration Ecology*, 20(2):250–259, doi:https://doi.org/10.1111/j.1526-100X.2010.00757.x.

Guimarães JCC, de Barros DA, Alves Pereira JA, Silva RA, de Oliveira AD and Coimbra Borges LA (2013) 'Cost analysis and ecological benefits of environmental recovery methodologies in bauxite mining', *Cerne*, 19(1):9–17.

Higgs E (2017) 'Novel and designed ecosystems', *Restoration Ecology*, 25(1):8–13, doi:https://doi.org/10.1111/rec.12410.

Hobbs RJ, Higgs E and Harris JA (2009) 'Novel ecosystems: implications for conservation and restoration', Trends in Ecology and Evolution, 24(11):599–605, doi:https://doi.org/10.1016/j.tree.2009.05.012.

Hobbs Richard J, Higgs ES and Hall CM (2013) 'Defining Novel Ecosystems', in Hobbs, R.J., Higgs, E.S., and Hall, C.M. (eds) *Novel Ecosystems*. (Wiley Online Books), 58–60, doi:https://doi.org/10.1002/9781118354186.ch6.

Hobbs RJ, Higgs ES and Harris JA (2014) 'Novel ecosystems: Concept or inconvenient reality? A response to Murcia et al.', *Trends in Ecology and Evolution*, 29(12):645–646, doi:10.1016/j.tree.2014.09.006.

Murcia C, Aronson J, Kattan GH, Moreno-Mateos D, Dixon K and Simberloff D (2014) 'A critique of the "novel ecosystem" concept', *Trends in Ecology and Evolution*, 29(10):548–553, doi:10.1016/j.tree.2014.07.006.

Neldner V, Butler DW and Guymer GP (2019) *Queensland's Regional Ecosystems: Building and maintaining a biodiversity inventory, planning framework and information system for Queensland*. Version 2. Version 2. Brisbane: Queensland Herbarium, Queensland Department of Environment and Science, Available at: https://www.publications.qld.gov.au/dataset/d8244c14-d879-4a11-878c-2b6d4f01a932/resource/42657ca4-848f-4d0e-91ab-1b475faa1e7d/download/qld-regional-ecosystems.pdf.

Nichols OG, Carbon BA, Colquhoun IJ, Croton JT and Murray NJ (1985) 'Rehabilitation after bauxite mining in South-Western Australia', *Landscape Planning*, 12:75–92.

Ntshotsho P (2006) *Carbon sequestration on the subtropical dunes of South Africa: a comparison between native regenerating ecosystems and exotic plantations*. University of Pretoria.

Perring MP, Standish RJ and Hobbs RJ (2013) 'Incorporating novelty and novel ecosystems into restoration planning and practice in the 21st century', *Ecological Processes*, 2(1):18, doi:10.1186/2192-1709-2-18.

Rosa JCS, Morrison-Saunders A, Hughes M and Sánchez LE (2020) 'Planning mine restoration through ecosystem services to enhance community engagement and deliver social benefits', *Restoration Ecology*, 28(4):937–946, doi:10.1111/rec.13162.

Seastedt TR, Hobbs RJ and Suding KN (2008) 'Management of novel ecosystems: are novel approaches required?', *Frontiers in Ecology and the Environment*, 6(10):547–553, doi:10.1890/070046.

Spain, CS; Nuske, S; Gagen, EJ. 2023. Evaluating methods for assessing native ecosystem mine rehabilitation success. Brisbane: Office of the Queensland Mine Rehabilitation Commissioner, Queensland Government.

Young R, Gann GD, Walder B, Liu J, Cui W, Newton V, Nelson CR, Tashe N, Jasper D, Silveira FAO, Carrick PJ, Hagglund T, Carlsen S and Dixon, K (2022) 'International principles and standards for the ecological restoration and recovery of mine sites', *Restoration Ecology*, 30(S2): 1 – 47, doi:10.1111/rec.13771.