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# SIMULATION AND ASSESSMENT OF GEOMORPHIC STABILITY OF THE RANGER MINE AND ENVIRONMENTAL DESIGN CRITERIA

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## ABSTRACTs

Environmental disruption from mining activity has increased markedly in the 21st century leading to increased emphasis on reconstructing natural environmental processes in post-mining landscapes. We present simulation and assessment approach to designing post-mining landforms at Ranger Uranium Mine in Northern Australia. A mine landform design was developed from mine planning estimates of waste rock and pit volumes. Landform design parameters were developed from analogous natural landscapes using digital terrain analysis. Evaluation of erosion, water balance and visual impact identified areas of localized erosion and links between soil reconstruction and the viability of native woodland ecosystems. The simulation and assessment approach identified where further refinement of the ecosystem reconstruction strategy was needed. In addition, it provides the basis for communication of plans to a wide audience, including traditional land owners.

## INTRODUCTION

Current practice for landscape reconstruction following opencast mining relies on topographic reconstruction, adaptive land management and botanical characterization. Environmental processes may be altered where reconstructed landforms have significant relief. Consequently, environmental outcomes in cases where there is large scale land forming are unpredictable. Moreover, landscape restoration lacks an integrated methodology, and while many mine closures have detailed ecosystem and biodiversity objectives based on natural analogue areas there has been no reliable way to design these objectives into mine landforms. The methods used in landscape restorations to describe reference conditions are based on generalized environmental factors using regional information and incorporating conceptual models. Such models lack the precision and accuracy required to understand and restore hillslope environmental pattern at mine sites. However, methodological integration and statistical inference models underpinning the spatial inference methods in conservation and landscape ecology, and penology may be applied to solve this problem. These inference models utilize digital terrain models as the core environmental data incorporating ecological theory to predict biodiversity and species distribution. Also, numerical mass balance models such as water and solute balance, which have been applied to understand environmental processes in landscapes, can be used to assess mine landform design. The objective of the work reported here was to investigate environmental variation, with sufficient accuracy and precision, in natural landscapes to design mature mine landforms and to demonstrate the capacity to predict ecological outcomes.

This first phase, reported in investigated the reliability of conceptual landscape models used in regional ecological mapping in predicting ecological patterns in terms of vegetation and soil. The Tiwi Islands

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was selected because of the relatively uniform parent material and its simplified climate. This allowed the study of physiographic control of soil and vegetation patterns. The results identified correlations between vegetation pattern and landform that were confounded by a subjective and complex land unit model of ecosystems. This investigation enabled the development methodological approach to analogue selection and ecological modelling at Ranger uranium mine – a site that will require a restoration approach so as to meet environmental closure objectives.

The study then shifted from mined land back to a selected natural analogue landscape at Ranger mine. The fine grained variation in terrain attributes is described to support a landform design that allowed for mine plan estimates of waste rock volumes and pit void volumes. A process of developing and evaluating the landform design was put forward, in the case of Ranger that begins with key stakeholder consultation, followed by an independent scientific validation using published landform evolution and integrated, surface groundwater water balance modelling. The natural analogue and draft final landforms were compared in terms of terrain attributes, landform evolution and eco-hydrological processes to identify where improvements could be required. The results of the independent design reviews are contained in confidential reports to Ranger mine and in conference proceedings that are referenced in Chapter 6. Independent validation will be a key element of an ecological landform design process and the application of published eco-hydrological and landform evolution models at the Ranger mine case study site are presented as an example of current best practice. Also, detailed assessment was made of environmental variation and soil and geomorphic range in the selected analogue landscape to support the landform design process with the mining department.

Two sub-catchments within the Tin Camp Creek Basin, 2032 and 2947 m2 , with average slopes of 19 and 22%, respectively, were instrumented during the wet season of 1990. Both sites are incised and channelized, and are representative of the overall 50 ha catchment. The study sites were monitored during rainfall events from December to January 1992. At this time, the catchments had a good covering of speargrass that quickly regenerated each wet season. To calibrate the erosion and hydrology models, complete data sets of sediment loss, rainfall, and runoff for nine discrete events were collected, allowing calibration for the two individual catchments. The rainfall–runoff monitoring data were used to calibrate the DISTFW (Field & Williams, 1983) rainfall–runoff model. The calibrated DISTFW model was used to derive long-term average hydrological parameters for SIBERIA. The parameters of SIBERIA represent average temporal properties of the runoff and erosion processes occurring on the landscapes (Table 1) (Moliere et al., 2002).

## Surface mine restoration

Surface mining operations often take place in forest areas of high landscape and ecological value, severely modifying them. The environmental effects of mining are drastic: the result is a deep alteration of the landscape and almost the total destruction of the affected ecosystems. Therefore, the purpose of restoration is always to rebuild natural ecosystems. (Jorba et al. 2008).

The restoration of these areas is regulated by national and regional legislations. However, the technical and environmental requirements are poorly defined. Within this legislative framework, the restoration is

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evaluated according to the criteria of each competent agent involved in the process. Too often, the pressure from local authorities to obtain short-term visible results leads to the application of fast revegetation treatments to reduce visual impact. However, these measures may condition the future evolution of the restoration, directing it towards to ecosystems other than those desired. (Chambers et al. 1994; Holl 2002; Jorba et al. 2002).

The International Ecological Restoration Association defines ecological restoration as the process of assuring the restoration of an ecosystem that has been degraded, damaged or destroyed. In the case of quarries, ecosystems need to be completely recreated and reintegrated into the landscape.

The restoration process in the mining sector should make compatible the fast stabilization of substrates under extreme conditions of stability, short-term naturalization and increasing the richness of species from the earliest stages of revegetation. The term ecological restoration is strongly anchored in the extractive sector and encompasses all recovery interventions over the years. Thus, the restoration of the mining areas will be approached from three points of view: hidro-geomorphology, vegetation and soil. Following, there is a review of what has been researched so far, the degree of development achieved to date as well as the present situation.

Aerial image of a mine in a public forest

The main problems encountered in actual mine restorations may be grouped into the following points:

a) Severe erosion
b) Hydrological impacts (sedimentation of ravines, ditches, and suspension in river waters)
c) Rectilinear topographic designs
d) Concealment of visual impacts through dumps
e) Use of artificial elements (concrete, granite, bolts, meshes, etc.) f
f) Unstable areas and geomorphological movements
g) Design of haul roads that favor erosive processes
h) Failure or ditches plugging
i) Problems in the substrates that do not allow stabilization of vegetation
j) Landscape affection

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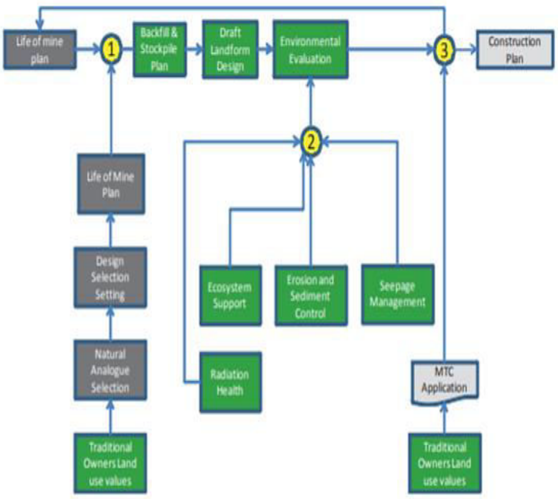
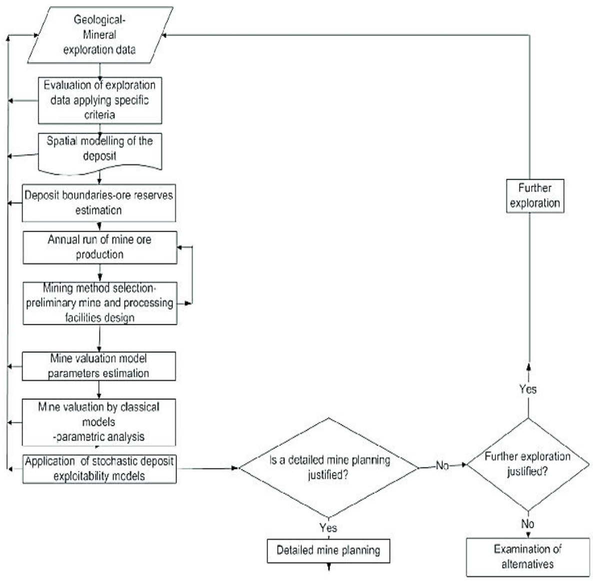



Landform design process

## LITERATURE REVIEW

- Nicolau (2003) considered the critical ecological issue to be integrating geomorphology with the soil and vegetation, so as to describe the formation of functional, self-sustaining ecosystems. This conclusion is repeated elsewhere (Brown, 2005; Duque et al., 1998; Ehrenfeld and Toth, 1997; Holl et al., 2003; Jim, 2001; Wang et al., 2001) and is considered to be a major factor limiting the success of rehabilitation programs in open cast mining (Johnson and Miyanishi, 2008)
- There are some methodological and theoretical hurdles to this integrated approach to landscape restoration. Holl (2003) opined that landscape level restoration lacked a methodology. Other authors considered that landscape restoration works lacked a basis in ecology (Lipsey and Child, 2007; Temperton, 2007; van Diggelen et al., 2001). However, unless substrate conditions are extreme, ecosystems on mine sites function similarly (over time) to comparable ecosystems on adjacent unmined analogue sites (Huttl and Bradshaw, 2001).
- Consequently, analogous natural landscapes have been used to guide ecosystem restoration strategies for mine landforms — by providing some capacity to identify long term outcomes and accelerate natural remediation processes (Bradshaw and Huttl, 2001; Wang et al., 2001). Although, inaccurate representation of water, nutrient, erosion and sediment distribution processes in mine and natural landscapes has lead to poorly defined or unrealistic ecological goals (Bell et al., 1997; Choi, 2007; Ehrenfeld, 2000; Ehrenfeld and Toth, 1997). The main focus has been on managing the revegetation process (Hobbs, 2007; Holl and Crone, 2004) rather than designing landforms to support biodiversity. Addressing this gap would conceivably improve mine rehabilitation from an ecosystem perspective and have broader application to restoring landscape degradation more generally.

## FLOWCHART




## CONCLUSION

Water balance simulation implied the long-term average recharge for the rehabilitated mine area will be something like 8 to 9% of rainfall for the areas overlaying a subsoil and 10% of rainfall for the areas overlaying the pits. In the natural situation, excess water vents from the system via stream flow, which accounts for more than 20% of the water budget (compared with 34% for Howard River) while estimated ET was 1,240 mm yr-1 for Corridor Creek (compared with 1,110 mm yr-1 for Howard River). This assumes that the revegetation reaches a density similar to that of the surrounding native areas. Runoff generation processes in areas with waste rock cover material behave differently from those with vegetation cover. The covered areas are capable of generating runoff during intense rainfall events via an infiltration excess process, while the uncovered areas may be subject to a combination of excess saturation and interflow processes. In addition, there appears to be no interflow from the covered areas at the cover–soil interface. Therefore the groundwater system should be capable of absorbing a net recharge rate of around 9.4% of rainfall to prevent groundwater rise, although this remains to be determined.

## REFERENCES

[1] Boggs, G., Devonport, C., Evans, K. & Puig, P. (2001) Rapid assessment of erosion risk in a small catchment in the wet/dry tropics of Australia using GIS. Land Degrad. Develop. 12(5), 417-434.

[2] Evans, K. G. (2000) Methods for assessing mine site rehabilitation design for erosion impact. Aust. J. Soil Res. 38, 231–247.

[3] Evans, K. G., Willgoose, G. R., Saynor, M. J. & House, T. (1998) Effect of vegetation and surface amelioration on simulated landform evolution of the post-mining landscape at ERA Ranger Mine, Northern Territory. Supervising Scientist Report 134. Supervising Scientist, Canberra, Australia.

[4] Evans, K. G., Willgoose, G. R., Saynor, M. J. & Riley, S. J. (2000) Post-mining landform evolution modelling. I. Derivation of sediment transport model and rainfall–runoff model parameters. Earth Surf. Processes Landf. 25(7), 743–763.

[6] Field, W. G. & Williams, B. J. (1983) A generalised one-dimensional kinematic catchment model. J. Hydrol. 60, 25–42.

[7] Flint, J. J. (1974) Stream gradient as a function of order, magnitude and discharge. Water Resour. Res. 10(5), 969–973.

[8] Hancock, G. R. (2004) The use of digital elevation models in the identification and characterisation of catchments over different grid scales. Hydrol.Processes (in press).

[9] Hancock, G. R. (2003) The effect of catchment aspect ratio on geomorphological descriptors. In: Prediction in Geomorphology, Geophysical Monograph Series vol. 135 (ed. by P. Wilcock & R. Iverson). American Geophysical Union, Washington, DOI: 10.1029/135GM015.

[10] Hancock, G. R., Loch, R. & Willgoose, G. R. (2003) The design of post-mining landscapes using geomorphic guidelines. Earth Surf. Processes Landf. 28, 1097–1110.

[11] Hancock, G. R., Loughran, R. J., Moliere, D. R. F., Evans, K. G. & Balog, R. (2004) Estimation of soil erosion using caesium–137 and the SIBERIA erosion model in an undisturbed catchment in Arnhem Land, Northern Territory, Australia. Aust. J. Soil Res. (in review).

[12] Hancock, G. R., Willgoose, G. R., Evans, K. G., Moliere, D. R. & Saynor, M. J. (2000) Medium term erosion simulation of a abandoned mine site using the SIBERIA landscape evolution model. Aust. J. Soil Res. 38, 249–263.

[13] Hancock, G. R., Willgoose, G. R. & Evans, K. G. (2002) Testing of the SIBERIA landscape evolution model using the Tin Camp Creek, Northern Territory, Australia,

field catchment. Earth Surf. Processes Landf. 27(2), 125–143.
[14] Moliere, D. R., Evans, K. G., Willgoose, G. R. & Saynor, M. J. (2002) Temporal trends in erosion and hydrology for a post-mining landform at Ranger Mine, Northern Territory. Supervising Scientist Report 165, Supervising Scientist, Darwin NT, Australia.
[15 Naden, P. S. (1992) Spatial variability in flood estimation for large catchments: the exploitation of channel network structure. Hydrol. Sci. J. 37(1), 53–71.