AN ADVANCED CONCEPT FOR SURFACE COAL MINE RESTORATION IN SEMIARID LANDS

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Abstract: Long experience and commitment have been applied for the reclamation of surface coal mine zones. However, in many cases, practical results are quite poor and a lot of the "reclaimed lands" would need a new reclamation project. Application of an insufficient conceptual framework explains the failure of mining reclamation in practice. An advanced reclamation concept based on the hydroecological basin as the restoration unit is being developed in Teruel coalfield (NE Spain). Constructed basins are composed by gentle slopes with natural vegetation, flat areas for agricultural use and a drainage network with watercourses and natural simulated wetlands. Landform, soil, plants and hydrology are managed in an integrated fashion to optimize the supply of water and nutrients to plants and to control the erosion. Water circulation through the watershed and water quality in wetlands are improved while sediment is retained in selected sites. Hydrological impact on natural aquatic systems can be like this controlled. Earlier reclamation performances were based on the "spoil" concept, composed by flat platforms, steep slopes, berms and ditches for overland flow drainage. This design was not ecologically stable since water infiltration is very low and soil erosion strongly limits vegetation establishment. The next step enhanced the platform-bank-ditch model by constructing softer landforms where productive agriculture is carried out and slope banks revegetation is successful. However berms and ditches remain unstable yielding large amounts of sediments and water towards the natural watercourses. This advanced concept requires great effort in planning and design, and also an interdisciplinary approach. Implementation cost can be higher, but maintenance decreases and the value of restored site is much higher.

Keywords: extraction of minerals, identifying appropriate restoration objectives, surface mining reclamation

Introduction

Mining reclamation lies in building a whole new landscape, which includes the reconstruction of landforms, the formation of a new soil and the development of a functional biocenosis. The three subsystems must be reclaimed in an integrated way (Wade and Chambers, 1992). In the reclamation of ecosystems affected by earth movements, the final result is primarily conditioned by topographic reconstruction (Toy & Hadley, 1987). Many restoration projects have failed because topography designs have been unable to sustain functional ecosystems, and/or because of the exportation of runoff and sediments that have seriously damaged ecosystems downstream.

Landforms based on the platform-bank model with slopes angle of about 30º strongly condition plants establishment and development because rainfall infiltration is low in steep slopes and runoff leads to high rill and sheet erosion rates. In turn, rill erosion increases water deficiency at the slope scale by reducing opportunities for runoff reinfiltration into the soil downslope (Nicolau 2002).

Later, this model was further developed by reducing the angle of the slopes, incorporating substrates that favoured plant development and incorporating wide flat platforms where agricultural and/or forest uses have been carried out with satisfactory results.

A third conceptual model has been developed, based on the hydrological basin as unit for reclamation (Nicolau, 2003). This is composed by slopes with natural vegetation,

and a drainage network with watercourses, wetlands and some safety structures like sediment ponds, which minimise the water and sediment emissions towards the natural aquatic ecosystems. This topographic model is the best option when reclamation is oriented towards natural uses because of the heterogeneity of habitats that it supply and the stability of the soil-plant system that it allows.

In this paper we show the hydrological basin conceptual model and the first methodological approach that we have applied in an open coal maine where ENDESA S.A. company develops the restoration of an open coal mine. Our task has been to modify the original reclaimed topography based on the platform-bank model by introducing several small endorreic catchments. Further phases of our work will involve the reclamation protocols to construct it in practice –mainly dealing with soil and mineral re-allocation- as well as the ecohydrological monitoring to check the performance of the model and to obtain field parameters in order to enhance the models used to design the landforms of the catchments.

Materials and methods

The mining area where the hydrological basin model is being applied is W. Gargallo mine (30º37´20´´N, 0º37´51´´O) in Teruel coalfield (NE Spain),. It is located in Central-Eastern Spain at 850 m altitude. The climate is Mediterranean-Continental. Mean annual rainfall is 528.6 mm. The water deficit is 197.2 mm from June to October. The mean annual air temperature is 12.5°C (3.5°C in January and 21.5°C in July).

The design of topography has been based on the methodology proposed by the International Erosion Control Association (Fifield, 2004). In addition, wetlands have been designed following the ecological bases proposed by Mitsch and Gosselink (2000) and Comin et al. (2001).
Methodology is based on the following steps: a) Landforms design using AutoCAD software; b) Application of RUSLE 1.06 model (for mining, constructed sites and reclaimed lands) to estimate the stability of the designed landforms with respect to rainfall erosion: c) estimation of runoff, peak flow and sediment by means of the Sediment Yield Equation, which combines the MUSLE (Modified Usle), the Curve Number Method and Rational Method; d) Calculation of the catchments size; e) wetlands and watercourses design as buffer zones.

Results and discussion

Two designs (A and B) have been developed in order to modify the spoil bank from Gargallo W mine (figures 1 and 2). Both are based on endorreic small catchments with slopes where soil loss is limited up to 10 $t.ha^{-1}.year^{-1}$, which is considered the maximum erosion rate compatible with plant development (MFUSA, 2001). Other elements that form part of the catchments are watercourses and wetlands. The trajectory of the first ones is not straight but with meanders and they are made from rolling stones that favour sedimentation and plant establishment process. Wetlands show different depths and

irregular shape in order to maximize different ecological processes and to provide heterogeneity of habitats.
Hydrological response to the maximum rainfall event in 10 years of the two designed catchments is shown in tables 1 and 2. It is compatible with soil conservation and plant growth as well as with watercourses and wetlands conservation.

Table 1. *Hydrological response to maximum rainfall event in 10 years (64.38 mm/24 hs)*

Design A	Surface (ha)	Runoff volume (m3)	Sediments (m3)
Catchment 1	10.15	3111,41	7,26
Catchment 2	17.75	5152,70	11,89
Catchment 3	15.28	4682,98	9,12

Design B	Surface (ha)	Runoff volume (m3)	Sediments (m3)
Catchment 1	13,36	4094,53	17,86
Catchment 2	12,17	3372,03	20,98

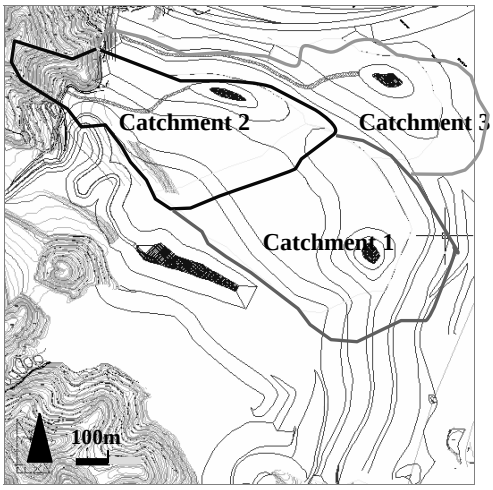

Figure 1. Design A

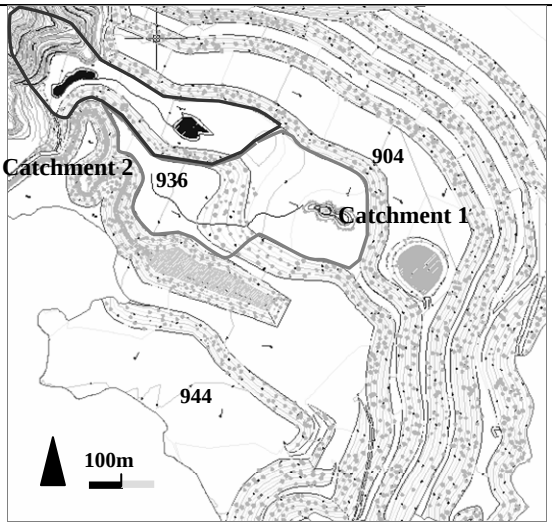

Figure 1. Design B

Conclusions

1. Main advantages of the conceptual model based upon the basin as unit for surface mining reclamation are the followings:

- Stability of soil and vegetation with respect to soil erosion (on-site effects)
- Control of emissions of water and sediments towards natural watercourses (off-site effects).
- Higher habitats heterogeneity and species diversity.
- Integration with the natural landscape because of the soft landforms.

2. The methodology applied to design this type of reclamations is very friendly to be used by the mining companies.
3. Next tasks to evaluate the feasibility of this model deal with the cost of earth moving and the monitoring of the ecohydrological process.

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References

Armstrong J.M., Brown G. & Kim I.F. (1998). The handbook of envionmental monitoring. Part II. Physiological processes. Apocalypse Academic Publisher Inc., London, New York, Montreal.

Bakker J.P. & Piersma T. (2006). Restoration of intertidal flats and tidal salt marshes. In: Van Andel J. & Aronson J. (Ed.): Restoration Ecology. Blackwell Science Ltd, Oxford, pp. 174-192.

Comín F.A., Romero J.A., Hernandez O. & Menendez M. (2001). Restoration of wetlands from abandoned rice fields for nutrient removal, and biological community and landscape diversity. Restoration Ecology 9:201-208.

Dorland E., Bobbink R., Messelink J.H. & Verhoeven J.T.M. (2003). Soil ammonium accumulation after sod cutting hampers the restoration of degraded wet heathland. Journal of Aplied Ecology 40, 804-814.
Mitsch W.J. & Gosselink J.G. (2000). *Wetlands*. John Wiley and Sons Ltd. New York.

Nicolau JM. 2002. Runoff generation and routing on artificial slopes in a Mediterranean-continental environment: The Teruel coalfield, Spain. *Hydrological Processes*, **16**: 631-647.
Nicolau, J.M. 2003. Trends in relief design and construction in opencast mining reclamation. *Land Degradation and Development*, 14: 215-226.
Toy TJ, Hadley RF. 1987. *Geomorphology of Disturbed Lands*. Academic Press Inc.
Wade, G. & Chambers, J. 1992. Introduction. In: Chambers, J. & Wade, J. (eds): Evaluating Reclamation Success: The Ecological Consideration: 1-2. USDA, General Technical Report EN-164.