

COST EFFECTIVE REHABILITATION OF AN OPEN CAST CHROME MINE IN THE NORTH WEST PROVINCE

by

Nadia Catharina CROUS

Mini-dissertation submitted in partial fulfillment of the
requirements for the degree of



MASTER OF SCIENCE

In
UNIVERSITY
OF
JOHANNESBURG

ENVIRONMENTAL MANAGEMENT

in the Faculty of Science

at the

RAND AFRIKAANS UNIVERSITY

Supervisor: Prof J.T. Harmse

October 2003

ACKNOWLEDGEMENTS

It is with great appreciation and recognition that I wish to thank the following persons and institutions for the tremendous efforts and contributions that they made to the completion of this study:

- Prof. JT. Harmse, my supervisor, for his time and effort spent both on the review and motivation of this study.
- Prof. F. van Wyk (Potchefstroom University for CHE), for his help and support during the completion of this study as well as the contributions he made to expanding my knowledge of botany and vegetation dynamics.
- The Chairman of the Assore Board, Mr Desmond Sacco for allowing me the privilege to contribute to the company's environmental effort and policies. In this regard I would like to acknowledge and thank the following persons for their contributions to this study in terms of time, leadership, motivation and general overall support:
 - Andries Mouton - A constant source of information and support, always helpful and eager to contribute to the environmental cause of both this study and the company's environmental objectives.
 - Josef Le Grange - Even after retirement from the project, allowing me to be a part of the "Model Maker" rehabilitation modelling process and assisting me in the understanding of the rehabilitation effort.
 - Julia Marsden - As a friend, mine surveyor and draftswoman, sacrificing her time in front of the computer and draughting table, digitising and extracting the maps that were used in the compilation of this study.
 - Jacqui Zietsman - For all the time spent on corrections during the review and final compilation of the study.
 - Adrian van Niekerk - For resolving the computer problems that had occurred during the transfer of information.
 - Ian Coetser - For organising the language review and final compilation as well as printing of this dissertation.

- Tom McLaughlin - For the language review which contributed significantly to rendering this dissertation meaningful.
- Last but not least I wish to thank my family, fiancée Vaughan, and his parents for their constant encouragement, motivation, support and guidance all through this study and my life.



LIST OF CONTENTS

	Page
ACKNOWLEDGEMENTS	ii
CHAPTER 1	
INTRODUCTORY PERSPECTIVE AND PROBLEM STATEMENT	1
1.1 Disturbed Land: An International Problem and Associated Legislation	3
1.2 Disturbed Land: A South African Problem and Associated Legislation	6
1.3 Specific Problem Statement	8
CHAPTER 2	
STUDY AREA AND RESEARCH METHODOLOGY	11
2.1 Mine Location	11
2.2 Ecological Heterogeneity	11
2.2.1 Geology	11
2.2.2 Soils	14
2.2.3 Topography and drainage	16
2.2.4 Climate	16
2.2.5 Vegetation Cover	17
2.3 Research Methodology	27
CHAPTER 3	
EVALUATION OF APPROACHES TO MINE REHABILITATION	32
3.1 Ecological Approach	32
3.2 Legislative Approach	35
3.3 Mining Approach	37
3.4 Guidelines for Rehabilitation of Disturbed Open Cast Mining Surfaces	41



CHAPTER 4	
REHABILITATION EVOLUTION AND DESIGN	45
4.1 Configuration of a Rehabilitation Plan and Model	45
4.2 Evaluation of a Rehabilitation Design	47
4.3 Limitations to Rehabilitation	48
4.3.1 Rainfall	48
4.3.2 Artificial Limitations	49
4.3.2.1 Soil Texture and Structure	50
4.3.2.2 Slope Gradients and Lengths	51
4.3.2.3 Compaction	53
4.3.2.4 Seed Mixtures	54
4.3.2.5 Determination Criteria for Seed Mixtures	56
4.3.2.6 Terrain Evaluation	57
4.3.2.7 Factors Influencing Plant Species	59
4.4 Planning	60
4.4.1 Policy Mechanisms and Institutional Support	62
4.4.2 Environmental Impact Assessment and Social Impact Assessments	62
4.4.3 Technology	63
4.4.4 Company Strategy	63
4.4.5 Education, Research and Training	64
4.5 Water Control	65
4.6 Cost Implications	75
4.7 Model Sustainability and Sustainable Land Use	79
CHAPTER 5	
REHABILITATION VERSUS: RESTORATION, RECLAMATION AND REVEGETATION	82
5.1 Rehabilitation	82
5.2 Restoration	82
5.3 Reclamation	83
5.4 Revegetation	83

CHAPTER 6	
CONCLUSION	85
LIST OF REFERENCES	88
ABSTRACT	94
OPSOMMING	96
LIST OF FIGURES	
<i>Figure 1: Lithostratigraphic subdivision of the Rustenburg Layered Suite – Western Bushveld</i>	12
<i>Figure 2: The geology of the North West Province</i>	13
<i>Figure 3: Regional setting and drainage area of Rustenburg Minerals</i>	18
<i>Figure 4: Combined land degradation map of the North West</i>	19
<i>Figure 5: Veld types of South Africa – Rustenburg Minerals</i>	22
<i>Figure 6: A checklist of ecosystem properties to be evaluated prior to determining rehabilitation strategy and end-uses</i>	33
<i>Figure 7: Ecosystem rehabilitation in a matrix of ecological, economic, social and aesthetic considerations</i>	37
<i>Figure 8: Rustenburg Minerals rehabilitation area 1991</i>	39
<i>Figure 9: Rustenburg Minerals rehabilitation area 2000</i>	40
<i>Figure 10: Rehabilitation model as developed by Bradshaw & Chadwick (1980) detailing the need for observations and experiments to ensure that operations are planned correctly</i>	46
<i>Figure 11: Rustenburg Minerals flood damage at quarry 3B</i>	49
<i>Figure 12: Rustenburg Minerals 20 November 1997- rip against the slope</i>	52
<i>Figure 13: Rustenburg Minerals 25 November 1997 - dragging thorn bush to even out soil and intermix seeds</i>	52
<i>Figure 14: Desired slope in terms of end-use</i>	53
<i>Figure 15: Rustenburg Minerals - slimes dam modified contour plan indicating 20-meter intervals in red.</i>	68
<i>Figure 16: Rustenburg Minerals – cross sections showing final profile</i>	69
<i>Figure 17: Rustenburg Minerals – plan showing original contour plan with positions of cross sections.</i>	70
<i>Figure 18: Rustenburg Minerals –plan showing the setting out data and a general profile of cross sections</i>	70
<i>Figure 19: Typical Sections through rehabilitated areas</i>	71
<i>Figure 20: Backfill design to drain quarry</i>	72

<i>Figure 21: Backfill design to retain some water in the quarry</i>	72
<i>Figure 22: Backfill design to control possible floodwater in long quarries</i>	
<i>Figure 23: Sloping dump and highwall</i>	73
<i>Figure 24: Sloping dump and highwall - watercourses</i>	74
<i>Figure 25: Partial rehabilitation</i>	75
<i>Figure 26: Options for improving degraded ecosystems.</i>	84
<i>Figure 27: Rehabilitation model for an open cast chromite mining operation.</i>	87

LIST OF TABLES

<i>Table 1: Chemical analysis of soil samples collected at Rustenburg Minerals</i>	14
<i>Table 2: Physical analysis of soil samples collected at Rustenburg Minerals</i>	15
<i>Table 3: Average climate statistics for the Pilanesberg region</i>	20
<i>Table 4: Average rainfall recorded for the Rustenburg Platinum Mines – Precious Metals Refinery</i>	21
<i>Table 5: Checklist of plant species and habitats found in the area</i>	24
<i>Table 6: Species used for earlier rehabilitation/revegetation practices</i>	54
<i>Table 7: Final seed mixtures at Rustenburg Minerals</i>	56
<i>Table 8: Rustenburg Minerals - 1996 budget estimate for quarries 1 to 6</i>	78
<i>Table 9: Rustenburg Minerals rehabilitation expenditure for the period 1997-2003</i>	79

ABSTRACT

A review done of earlier literature showed that areas disturbed by mining activities became the focus of attention only during the changing environmental consciousness that swept the world in the early eighties. Although revegetation attempts of such areas had already been initiated in the thirties, it was only during the early fifties that legal incentives were introduced to ensure sustainable practice and land rehabilitation. Most of the earlier research referring to such rehabilitation practices was conducted abroad and often had very little in common with indigenous vegetation or local aspects. Furthermore, most of the research conducted was based on, and mainly only applicable to, the revegetation of gold mine dumps.

Further research also showed that many other methodologies had been attempted, such as soil stability testing and chemical treatment to improve dust suppression in those areas, but it was ultimately agreed that the most effective way to achieve maximum results was to revegetate.

Internationally, legislation was passed in the fifties stipulating that disturbed areas due to mining activity, had to be revegetated to limit further impacts such as soil erosion and contamination. Similar legislation was passed in South Africa - The Mines and Works Act No 27 of 1956 was directly aimed at revegetation. In 1980, this legislation became far more stringent when it was realised that revegetation would not solve many of the other major problems associated with post-mining activity.

It only become evident in early 1984, when South African-based research had been conducted, that differences in climate, soil type, geology, topography and vegetation would influence the rehabilitation process, as this research was spread across many mines within South Africa and the borders of Leboa and Ka Ngwane. This lead to a major shift in rehabilitation practice when it was realised that individual solutions could be applicable only to site specific situations and conditions; and that no single recipe could suit all locations. Site specific applications were experimented with and yielded far more successful results than any earlier attempts.

From these investigations it became clear that the implementation of an indigenous grass species program rendered more successful results than previous cases, but also did not solve all the associated problems. This lead to a more holistic approach being followed by researchers and executors alike, taking into account soil and topography studies such as slope gradients and lengths, surface temperatures and associated aspects, which resulted in a more sustainable approach to rehabilitation strategies.

This study uncovers general ecological principles which, when incorporated in an holistic model, could ultimately be the solution to many of the rehabilitation issues facing mining companies today. In this study it becomes clear that every effort should be made to reinstate the environment to a condition as closely resembling the natural state as possible and proving benefits similar to those which it yielded before commencement of the mining disturbance. To create an environment which is both cost effective and self-sustaining, it is necessary to develop a habitat wherein ecological factors comply with the tolerance limits of the environment in which it is situated. This ultimately implies that the general terminology often referred to in rehabilitation processes would have to be revised to encompass all aspects of the process and of the environment alike. And the practice of rehabilitation be revised to become an holistic method aiming for sustainable best practice, especially when mining operators have cost effective program options available to them.

