DSPACE

https://dspace.org/

An economic evaluation of extraction of no 1 seam pillars at Elandsfontein Colliery, Witbank Coalfield.

Makakaba, Percy

2021
https://hdl.handle.net/10539/33400

Downloaded from a DSpace repository. https://dspace.org/



UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

AN ECONOMIC EVALUATION OF EXTRACTION OF NO 1 SEAM PILLARS AT ELANDSFONTEIN COLLIERY, WITBANK COALFIELD.

Percy Makakaba

Student Number: 1101098

School of Mining Engineering

Johannesburg, South Africa.

Supervisor: Mr. Clinton Birch

A research report is submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the degree of Master of Science in Engineering.

DECLARATION

I declare that this assignment is my own, unaided work. I have read the University Policy on Plagiarism and hereby confirm that no plagiarism exists in this report. I also confirm that there is no copying nor is there any copyright infringement. I willingly submit to any investigation in this regard by the School of Mining Engineering and I undertake to abide by the decision of any such investigation.

Date: 08 October 2021 Signature: 

ABSTRACT

The reserves of the Witbank Coalfield in Mpumalanga Province are diminishing leaving coal companies with no option but to explore the possibilities of pillar extraction. The purpose of the study is to conduct an economic evaluation of the pillar extraction at Elandsfontein Colliery. The geological, mining, coal handling and plant preparation, and environmental elements are evaluated. A Cashflow is calculated and discounted to determine the net present value, internal rate of return, and the payback period of the project.

A detailed literature study was undertaken on the Witbank Coalfield geology, mining methods, spontaneous combustion, and subsidence management. The colliery's borehole, assay, rock engineering, and groundwater data were obtained from the company's reports. This data was used to calculate gross in situ resource, reserves, production schedule, mining costs, processing costs which were used to compute cashflow.

The No.1 Seam generally is high-quality coal with raw ash of 32,87% and a Caloric value of 20,99 MJ/Kg. The gross tons in situ resource of the underground workings is 1,2 million and the mineable tons in situ is 1,04 million. Based on the competent roof of the No.1 Seam and other aspects including pillar width and surface subsidence the applicable method is checkerboard at the rate of 35 000t/month. The run-of-mine coal from the underground No. 1 Seam resources will be split between the export and domestic (Eskom) at 53,6% and 46,4% respectively.

Surface subsidence in collieries applying the checkerboard pillar extraction method is either minimal compared to those practicing full extraction or doesn't occur at all. There is no vertical hydraulic movement and the mine void does not impact the

shallow weathered aquifer. In underground mines, spontaneous combustion can occur where the air gets into the workings through cracks and openings and in the case where broken coal is left underground.

The export price is projected to be $61/t in 2021 which equates to R915/t. The Eskom coal price is currently R19GJ which equates to R380/t. The total capital expenditure is estimated to be R17.8 M. The total operating expenditure is estimated to be R270,04 M. The project has a high net present value and internal rate of return which amounts to R12,59 million discounted at 15% and 91% respectively. It has a short payback period of 3.8 months; therefore, the project is deemed economically viable.

ACKNOWLEDGMENTS

First of all, I want to thank God for his grace and for giving me the strength to complete this research. I will also like to acknowledge my colleagues including Riaan Joubert, Rene Rheeder, Jacques Theron, Vincent Letsoalo, Johan Dreyer, and Bridget Moeketsi for their contributions and support. Special thanks to:

- Mr. Jan Britz – Namane Resources COO

  For providing insight, mentorship, and funding, without him the research would not be possible.

- Mr. John Schoeman – Namane Resources CEO

  For availing the company's resources and allowing me to take time off to focus on my studies.

- Mr. Clinton Birch – University of Witwatersrand, Senior Lecturer

  For his patience and his guidance from the start of the project.

- Mr. Barned and Mrs. Francina Makakaba - My parents

  For their love and support which carried me all these years.

TABLE OF CONTENTS

DECLARATION i

ABSTRACT ii

ACKNOWLEDGMENTS iv

LIST OF FIGURES viiii

LIST OF TABLES x

NOMENCLATURE xii

1 INTRODUCTION 1

1.1 Purpose of the Study 1

1.2 Problem Statement 2

1.3 Research Background 2

1.4 Research Justification 4

1.5 Research Methods 4

1.5.1 Analysis 4

1.5.2 Practical consideration 5

1.6 Sources of Data 5

1.7 Research Objectives 6

1.8 Structure of the Report 6

2 LITERATURE REVIEW 8

2.1 Introduction 8

2.2 Case Study A: An opencast pillar mine in the Witbank Coalfield 8

2.2.1 Resource and reserve estimation 9

2.2.2 Mining 9

2.3 Case study B: An underground pillar method mine in Witbank Coalfield 10

2.3.1 Mining 11

2.4 Suggested Method of Extraction 13

2.4.1 Introduction 13

2.4.2 Pillar extraction 14
2.5 Mine Valuation 16
2.5.1 Cost approach 18
2.5.2 Market approach 18
2.5.3 Income approach 18
DCF 20
3 TECHNICAL ASPECTS 21
3.1.1 Regional geology 21
3.1.2 Local geology 26
3.1.3 Mineral resource 28
3.1.4 Assay data 31
3.2 Mining Elements 32
3.2.1 Safety risks 32
3.2.2 Rock engineering aspects 35
3.2.3 Mining method 44
3.2.3 Reserve statement 49
3.2.4 Production schedule 50
3.2.5 RoM 50
3.3 CHPP Elements 51
3.3.1 Introduction 51
3.3.2 Mining Plan 51
3.3.3 Feed Parameters 51
3.3.4 The Overall Coal Handling and Processing Plant 52
3.4 Environmental Elements 57
3.4.1 Surface subsidence 57
3.4.2 Groundwater 58
3.4.3 Sponcom 65
4 Economic Evaluation 68

5 CONCLUSIONS....86
6 RECOMMENDATIONS....90
Appendices....96

LIST OF FIGURES

Figure 1-1: Elandsfontein Colliery locality map……1

Figure 1-2: General stratigraphic column for the Vryheid Formation in the Witbank Coalfield……3

Figure 2-1: Layout of NEVID method……12

Figure 2-2: Borehole CM18/12 drilled at Elandsfontein Colliery……16

Figure 3-1: Outline for technical aspects……22

Figure 3-2. Limit of the Karoo Supergroup Rocks in the Witbank Coalfield……23

Figure 3-3. General stratigraphic column for the Vryheid Formation in the Witbank Coalfield……25

Figure 3-4: General stratigraphy at Elandsfontein Colliery……28

Figure 3-5: Cross-section through the No.1 seam at Elandsfontein Colliery……29

Figure 3-6: Elandsfontein Colliery old workings……30

Figure 3-7: Relative distribution of fatal falls of ground for different mining methods….34

Figure 3-8: North pit high wall at Elandsfontein Colliery. ……37

Figure 3-9: Illustration of systematic support layout……39

Figure 3-10: NEVID method cutting sequence……47

Figure 3-11: Extraction of pillars using split and fender method……48

Figure 3-12: Extraction of pillars using the angled cuts method…… ……49

Figure 3-13: Crushing and sizing unit……54

Figure 3-14: Fines treatment unit……56

Figure 3-15: Elandsfontein Plant layout……57

Figure 3-16: Hydraulic compartment in the mine void……64

Figure 3-17: Hydrogeological profile along with line AB in figure 3-17……65

Figure 3-18: Hydrogeological profile along line CD in figure 3-17……66

Figure 3-19: Sponcom formation……67

Figure 4-1: Coal prices Forecast……71

Figure 4-2: Project's Capex breakdown……74

Figure 4-4: Project's Capex and Opex distributed over the Life of Mine……83

LIST OF TABLES

Table 2-1: Coal qualities of mine A 9

Table 2-2: Comparison between bord and pillar with pillar extraction, longwall, and shortwall.....14

Table 2-3: Relationship between stages of development and valuation approaches for mineral assets.....21

Table 3-1: Resource statement for old workings pillars.....31

Table 3-2: No.1 seam average raw qualities for Elandsfontein Colliery.....33

Table 3-3: Calculated probability of failure of pillars designed with different FoS as well as the possible number of pillar failures in a million pillars mined with each safety factor.....41

Table 3-4: Summary of FoS of old workings at Elandsfontein Colliery.....43

Table 3-5: Condition of pillars related to safety factors.....45

Table 3-6: Condition of pillars related to age.....44

Table 3-7: Mining method and pillar sizes in South African Collieries.....46

Table 3-8: Reserve statement.....51

Table 3-9: Production schedule.....51

Table 3-10: Run hours.....53

Table 3-11: List boreholes and permeability values in the weathered aquifer.....60

Table 3-12: Water level in the underground void……..61

Table 3-13: Intrinsic and extrinsic sponcom factors……67

Table 4-1: Mining Capex cost breakdown……73

Table 4-2: Mining operating cost breakdown……75

Table 4-3: Summary of Opex……77

Table 4-4: Tax costs breakdown……81

Table 4-5: Economic evaluation summary……84

NOMENCLATURE

Acronyms	Description
FoS	Factor of Safety
NPV	Net Present Value
IRR	Internal Rate of return
SAMREC	South African Mineral Reporting Council
SAMVAL	South African Mineral Valuation Council
CV	Calorific Value
MJ	Megajoule
Kg	Kilogram
GJ	Gigajoule
CHPP	Coal Handling and Preparation Plant
LOM	Life of mine
PCD	Pollution control dam
No	Number
DMS	Dense medium Separator
RoM	Run of mine
$	US dollar
R	South African Rand
NC	No Cost incurred
Sponcom	Spontaneous combustion
FOB	Free onboard
NAR	Net As Received

Kc	Kilocalories
EBIT	Earnings Before Interest, Taxes
T	ton
KN	Kilo Newton
SARS	South African Revenue Services
VAT	Value added Tax

1 INTRODUCTION

The chapter is made up of the purpose, problem statement, background, justification, methods, sources of data, and objectives of the research. The research structure is also outlined in this chapter.

1.1 Purpose of the Study

The Elandsfontein Colliery, located in the western limit of the Witbank Coalfield in Clewer town in Witbank as shown in Figure 1-1, is one of Namane Resource operations. Mining at Elandsfontein Colliery began in 1981 and mostly consisted of underground bord and pillar with some opencast sections (Anker, 2017).

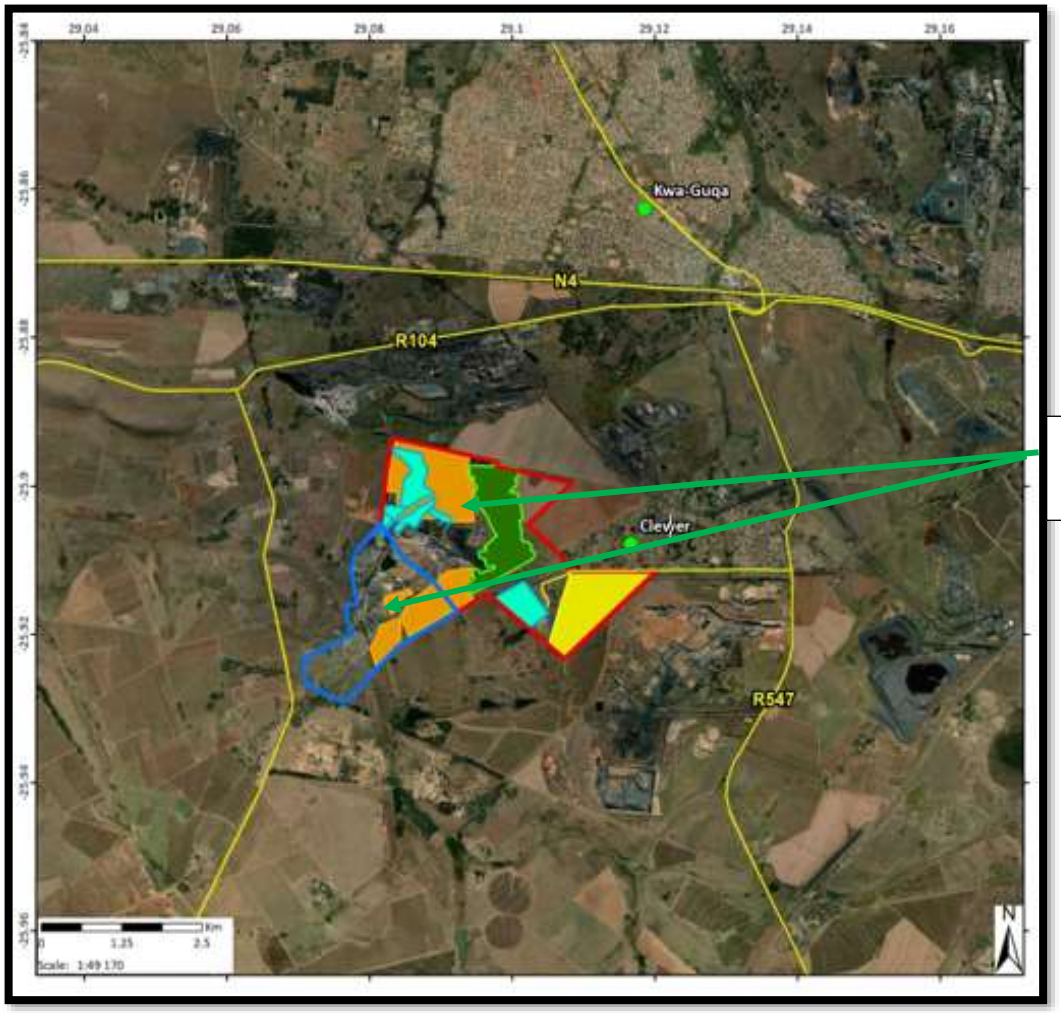


Figure 1-1: Elandsfontein Colliery locality map (Geosoil & Water, 2020).

The coal reserves for the mine are diminishing and, therefore, the company is exploring the possibilities of extracting the pillars left underground. The purpose of the study is to conduct an economic evaluation of the pillar extraction at Elandsfontein Colliery. The geological, mining, processing, and environmental factors will be evaluated. Cashflow will be calculated and discounted to determine the net present value (NPV), internal rate of return (IRR), and the payback period of the project.

1.2 Problem Statement

Elandsfontein opencast sections are becoming depleted and the company is planning to extract the No.1 Seam. The No.1 Seam roof is massive sandstone and is characterised by untimely caving, therefore, only low risks mining methods with lower extraction percentages will be applicable.

The company will need to revamp the underground infrastructure including the installation of roof support, ventilation, pumping, and electricity as the underground, to start the pillar extraction. The mine's underground operations stopped in 2014.

1.3 Research Background

The Witbank Coalfield which produces 50% of South Africa's saleable coal is found in the northern part of the main Karoo Basement (Hancox & Götz, 2014). The coal seams are found in the Vryheid Formation and are generally numbered from No 1 Seam being at the bottom and No 5 Seam at the top as shown in Figure 1-2 (Cairncross & Cradle, 1987). Elandsfontein Colliery is an existing coal mine, which has been producing coal for more than 25 years. Up to now the No. 1 Seam (mainly underground) and the No. 4 Seam (opencast), with minor No. 2 Seam (opencast) were the main producers. The present investigation found that the No. 4

Seam has been mined out, leaving the No. 1 Seam and the No. 2 Seam as the remaining future economic mining targets (Geosoil & Water, 2020). The No.1 Seam is the focus of this investigation since it is the one whose pillars are left as it was mined using the underground method. The parting between the seams varies across the colliery and ranges from 1m in the west and 20m in the north pit.

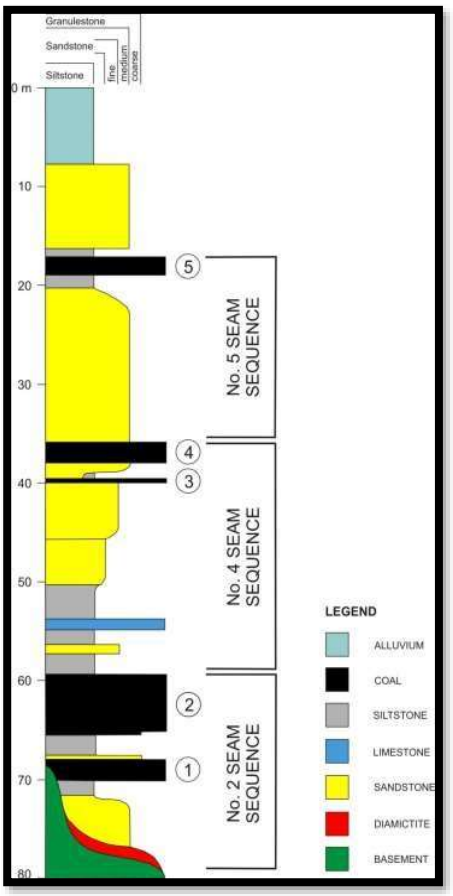


Figure 1-2: General stratigraphic column for the Vryheid Formation in the Witbank Coalfield (Hancox & Götz, 2014).

Namane Resource is a 100% black-owned private company that has mining rights in the Witbank (Elandsfontein) and Ermelo (Golfview) Coalfields. The opencast method was used to extract No. 2 Seam and the underground bord and pillar method was used to extract No. 1 Seam. The underground operation life of the mine ended in 2014 and the company continued mining the opencast sections (Anker, 2017).

1.4 Research Justification

The reserves of the Witbank Coalfield in Mpumalanga Province are diminishing leaving coal-producing companies with no option but to explore the possibilities of pillar extraction (Ngwenyama *et al*., 2017). Namane Resources is planning to extend the life of operation since its opencast sections' reserves are diminishing.

The pillar width ranges from 6 – 10 m with seam thickness ranging from 1,1m – 3 m. The coal is of high quality with calorific value (CV) ranging from 20 – 26 MJ/Kg and ash content as low as 14 % for washed product. It is proposed that approximately 53.6% of the coal will be sold to the export market and 46.4% blended with the lower quality coal and sold to Eskom (Anker, 2017). The factor-of-safety (FoS) for the old workings is 2 which is above the required FoS for secondary extraction which is 1.6.

1.5 Research Methods

To evaluate the viability of pillar extraction, data collection, and analysis of geological, mining, coal handling and plant preparation (CHPP), environmental, and social elements will be covered. The analysis will also include the calculation and analysis of cash flows.

1.5.1 Analysis

The research will analyze geological, mining, processing, and environmental data to construct a cash flow. The following analyses play a significant role in the evaluation:

- Geological analysis: the quality, depth, lithologies of the roof and floor, presence of geological structures such as faults and dyke.
- Mining analysis: mining capital and operational costs, production schedule, mining method, type of support and stockpiling strategy, monitoring, and instrumentation.

- CHPP analysis: processing costs, coal recovery, and plant administration; and
- Environmental analysis: environmental costs.

The resultant cash flow will be used to derive the following indices:

- NPV: refers to the sum of the present values of all yearly cash flows.
- IRR: refers to the discount rate at which NPV equals zero; and
- The payback period refers to the time it takes to make the money that is invested in the project.

1.5.2 Practical consideration

There is no access to the old workings due to potential flooding and methane and, oxygen build-up as the workings have been abandoned for some time. The volume estimation of the pillars will be done by calculation of the area of the pillar from the mine plan and the thickness of the seam from the borehole data.

1.6 Sources of Data

Geological data

The geological data consists of the borehole and assay data. There are several published papers about the geology of Witbank Coalfield, where the study area is found. Elandsfontein Colliery has drilled and surveyed several geological boreholes. The logging and surveying of the boreholes was done by competent persons according to the South African Mineral Reporting Council (SAMREC) Code. There is sufficient borehole data of the old underground working available for use in the research project. The borehole data comprises No 1 Seam, roof and floor coordinates, thicknesses, and depth. There is also seam quality analysis data which was done by a registered coal laboratory.

Mining data

Mining data consists of reserves, mining method, rock engineering, production schedule, and mining costs. The supplier's quotes and comprehensive literature were used for the derivation of the production schedule and mining costs.

CHPP data

The CHPP data consists of metallurgical information including recovery, processing costs, and processing flowsheet. The processing of coal is done by an in-house plant and the CHPP data is available to the mine and for the research project.

Environmental data

Environmental data include groundwater management, spontaneous combustion, and subsidence management. The environmental management of the mine is done by an in-house environmentalist. The environmental data in the form of reports are available for use.

1.7 Research Objectives

The economic evaluation aim is to determine whether the project will create value for the capital providers. The research objectives are to:

- Review literature on mineral project valuation;
- Analyze technical data to assist in determining whether an investment should be accepted or rejected; and
- Develop a discounted cash flow (DCF) for the project.

1.8 Structure of the Report

Chapter 1: Introduction - Provides the background, motivation, objectives, and structure of the report.

Chapter 2: Literature review - Gives an overview of pillar extraction including opencast pillar mining and underground pillar mining case studies in the Witbank Coalfield. It also gives an overview of mine valuation methods and DCF.

Chapter 3: Technical aspects - Provides an overview of technical aspects required for economic evaluation which includes geological, mining, CHPP, and environmental elements. The geological section provides a better understanding of the geology of the Witbank Coalfield and the study area. The mining section entails the safety risks associated with pillar extraction, mining methodology, production schedule, and run of mine (RoM). The CHPP comprises a coal processing flowsheet and environmental aspects include the groundwater, surface subsidence, and spontaneous combustion (sponcom).

Chapter 4: Economic evaluation - Evaluates and analyses the feasibility of the project by making use of a DCF model.

Chapters 5&6: Conclusions and recommendations of the report.

2 LITERATURE REVIEW

2.1 Introduction

Evaluation "*is the systematic process of judging the worth, desirability, effectiveness or adequacy of something according to definite criteria and purpose"* (Steele,1973, p5). Economic evaluation, a branch of evaluation, is the method used to determine the economic viability of a project. It is mostly used in mining. education, healthcare, agriculture, and finance for different purposes. For instance, in healthcare, it is used to assess the efficiency and allocation of resources to improve health outcomes (Steele, 1973).

Economic evaluation is particularly important in mining because it provides a base for capital investment decisions as mining is a capital-intensive industry. Typical capital investment decisions in mining include equipment replacement, expansion, exploration, new product development, and lease or buy decisions. Economic evaluation requires estimations of mining and processing parameters, royalties, operating costs, capital costs, and continual capital replacement.

As with other industries, when resources are depleted mining companies must look for other resources. The need to increase the mineral resource can lead companies to start with exploration or change the mining method, either way, capital will be required and therefore there is a need for evaluation.

2.2 Case Study A: An opencast pillar mine in the Witbank Coalfield

Coal Mine A, located in the Witbank Coalfield, produces export and domestic coal supplied to a nearby Eskom power station. The company has rights to mine No. 4 Seam, No. 1 Seam, and the No. 2 Seam pillars of old underground bord and pillar workings. The pillars were left when the underground life of mine (LOM) ended in the 1980s. The seam was mined using a

conventional drill and blast method. An evaluation to access the viability of mining the pillars focused on the resource and reserve utilisation, and the mining method.

2.2.1 Resource and reserve estimation

The qualities of the seams are high as shown in Table 2-1, however, the pillars were left more than two decades ago which would mean that the pillars are potentially not in good condition. The volume of coal left in the pillars was calculated from areal extraction and average mining height. Access to the working was not possible so most estimations such as the volumes of floor and roof were based on the survey plans which are not always accurate due to pillar scaling (Ngwenyama *et al*., 2017). The resources and reserves were estimated using the South African Code for the SAMREC Code guidelines for mining previous mined operations.

Table 2-1: Coal qualities of mine A (Ngwenyama et al., 2017).

Seam	Thickness (m)	CV (MJ/Kg)	Ash content (%)
No.4 Seam	2.3	24.6	22.7
No.2 Seam(S2RPB)	4.0	24.9	22.1
No.1 Seam	2.3	23.9	25.9

2.2.2 Mining

The pillars are planned to be mined using opencast pillar mining due to low stripping ratios, high recovery, controlled subsidence, and low pollution. Opencast pillar mining is similar to conventional opencast mining the only minor difference is that the opencast pillar method uses a 30m blasted buffer to control the spontaneous combustion and sinkhole formation (Ngwenyama *et al.*, 2017). Buffer blasting would refer to drill and blast to collapse the pillars and filling the voids between two mining strips. This will prevent the ingress of air into the bords and start spontaneous combustion (Ngwenyama *et al.*, 2017).

Opencast pillar mining utilizes a technique called bord collapse to maximise coal recovery. The bord collapse increases recovery because the machines would be able to extract all the areas that would have been unsafe to mine without the bord collapse. The disadvantage of the technique is that it increases dilution which lowers the qualities and yield increasing by washing plant operational costs. Opencast pillar mines also have challenges of spontaneous combustion which occur when the air penetrates the old underground workings.

2.3 Case study B: An underground pillar method mine in Witbank Coalfield

Tavistock colliery, an Xstrata Coal-owned mine, started producing coal in 1948. It has rights to mine No. 2,4 and 5 Seams of the Witbank Coalfield. The No. 2 and 5 Seams have been mined and there are remaining reserves of No 2 Seam but will not be mined due to their low yields and adverse geological conditions. Since its inception, coal was mined using the conventional bord and pillar method. The company is planning to mine No 5 Seam that was left as safety pillars to increase its reserves and extend the life of mine (Petho *et al*., 2012). An evaluation was conducted to access the viability of the pillar extraction and focused on the mining and geotechnical aspects.

2.3.1 Mining

Restrictions

The challenge observed at the colliery was the availability of the panels for pillar extraction due to the existing surface structures such as roads, buildings, and dams. Farmers that would be affected by the associated pillar extraction risks such as subsidence had to be consulted. There was a need to relocate people staying in nearby places (Petho *et al*., 2012).

Method.

The mine uses the NEVID, an acronym that stands for the names of creators of the method Neels Joubert and David Pothsma mining method. In this method, the pillars are cut at 45 degrees angles thus reducing the length in which the pillar is cut shown in Figure 2-1. The method has been successful because it requires discipline from the section workers because, to cut the 45-degree angled lift, the survey pegs and direction lines must be followed. Also, a stopper pillar that functions as a yield pillar, must be left every three rows to minimize the load on the pillars that are being extracted and to act as additional support to the snooks. The 45-angle cutting angle of the pillar ensures maximum protection of continuous miner, easier cutting, and direction control. The goafing follows the extraction of pillars by one row of pillars. The last row of pillars extracted is left open, this allows proper ventilation (Lind, 2005).

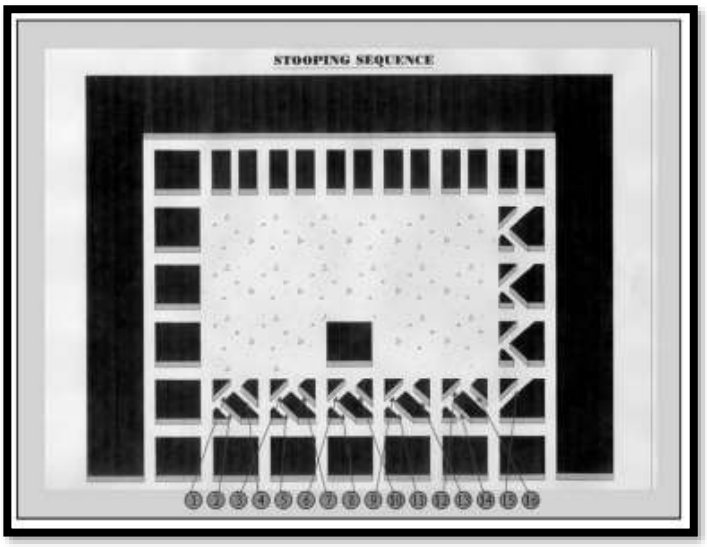


Figure 2-1: Layout of NEVID method (Lind, 2005).

Planning

The operation was deemed viable due to a positive NPV and minimum capital required. The forecast for production was projected to be 55 000t/month for the first three months and aimed to be increased to 80 000t/month (Petho *et al*., 2012).

For support, handheld support installation will be outsourced because of its versatility and to allow easy access to old workings. There is a need for pumping water out, fixing ventilation, sweeping and cleaning, construction of travel ways, power, and water supply (Petho *et al*., 2012). *A risk assessment for pillar extraction must be created to access the availability, adequacy, and efficiency of hard buries and identify required procedures and standards to address high-risk tasks"* (Petho *et al*., 2012., p114).

Geotechnical aspects

Geotechnical boreholes will be drilled to enable the calculation of the spans for panels and to evaluate the composition of the roof. The panel mapping was conducted for the assessment of

geotechnical parameters that may affect the behaviour of pillars during extraction. The parameters include geological features, the integrity of the pillars, signs of increasing stress, conditions of roof support, indications of the presence of water in the roof, and an indication of weakness and strengths of the host rocks (Petho *et al*., 2012).

2.4 Suggested Method of Extraction

2.4.1 Introduction

Coal in South Africa is commonly mined using underground and opencast methods. The choice between the underground and the opencast method mainly depends on the depth of the coal. The shallow deposits are mined by opencast and deep deposits by underground methods.

Table 2-2 shows the comparison between the underground methods used to mine coal. The bord and pillar method which involves panels and rows of pillars that are left as hanging wall support is deemed more profitable (Kumar, 1986).

Table 2-2: Comparison between bord and pillar with pillar extraction, longwall, and shortwall (Kumar, 1986).

Room and pillar with pillar extraction	**Longwall**	**Shortwall**
Small capital intensive	Capital intensive	Capital intensive
Flexible	Inflexible	Inflexible
Practical to complete pillar extraction depending on roof conditions	Impractical under some conditions	Impractical under some conditions
Decreased operating costs	High operating costs	High operating costs
Thick seams	Narrow seams	Medium seams only
Non-gassy seams	Excellent ventilation	Excellent ventilation
Longer training period	Shorter training period	Shorter training period
Controlled interaction between adjacent seams		Increased safety

2.4.2 Pillar extraction

The pillars are extracted because they have the same coal qualities as the mined-out areas(bord). The pillars are often mined by opencast methods (Case Study A) or underground methods (Case Study B). Due to the depth of the No 1 Seam in the Witbank Coalfield, it makes sense to mine using the underground methods. Also, Case study A shows that mining pillars using opencast methods have challenges of coal losses due to high dilution and spontaneous combustion associated with the method.

There are several underground pillar extraction methods. The most common methods are the Split and Fender method which consists of mining pillars in form of splits, the Longwall Knife Cave method which consists of mining a row of pillars by longwall cutting, and the Open Ending method where a lift is mined off one side of a block adjacent to a previously mined area (Kumar, 1986).

In most cases, underground services such as water, electricity, and ventilation have been developed when the operation was advancing and that reduces capital costs. However, these services may not be present in older workings, flooding and build-up of methane and oxygen may be prevalent and these conditions can result in injury or loss of life of mine workers and damage to equipment leading to mining companies opting for opencast methods. The benefits of extracting the pillars using underground methods often outweigh the associated risks.

Improved mining methods have been developed such as the NEVID method (Case study B), the Angled Cuts method where the pillars are extracted in splits, or the checkerboard method where every second pillar is not extracted and is left as roof support. A lower risk method is required especially in the case of Elandsfontein Colliery as the roof of No 1 Seam is massive sandstone as shown in Figure 2-2, which can result in serious damage in the case of untimely caving (Associated Rock Mechanics Services, 2019).

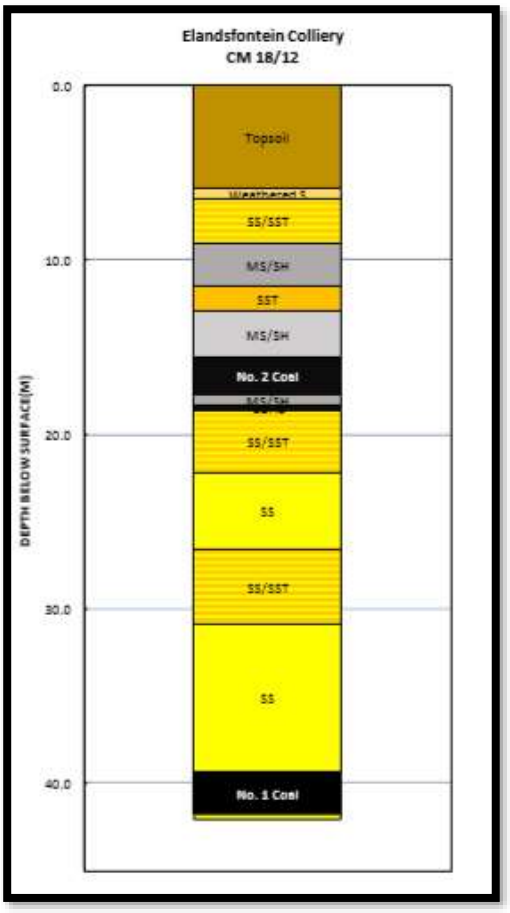


Figure 2-2: Borehole CM18/12 drilled at Elandsfontein Colliery (Associated Rock Mechanics Services, 2019).

2.5 Mine Valuation

Mine valuation is done by using the South African Code for the Reporting of Mineral Assets Valuation (SAMVAL Code). "*The SAMVAL Code sets out minimum standards and guidelines for reporting of mineral asset valuation*" (The South African Code for the Reporting of mineral asset valuation (SAMVAL Code), 2018, p3). It relies on the definitions and principles in the SAMREC Code. The purpose of the SAMVAL Code is to ensure consistency and provide minimum standards and guidance for mineral asset valuation. This reduces unethical valuation which could compromise the interest of investors (SAMVAL Code, 2018).

The valuation is based on the monetary value of the asset being valued. In the mining industry, the value is derived from the assessment of the unique technical characteristics of the asset being valued. To estimate the value for each mineral asset, the three mineral valuation approaches namely the cost, market, and income approaches are used.

2.5.1 Cost approach

The cost approach comprises the historical cost method and appraisal value method as defined in Table 2-3. "*It is a comparative approach to the value of the property of another asset, that considers as a substance for the purchase of a given property, the possibility of constructing another property that is the replica of the original or one can furnish equal utility with no undue to delay"* (Lilford & Minnet, 2005, p33). This approach does not apply to mining properties as it depends solely on the historical costs incurred in developing the project as shown in Table 2-3.

2.5.2 Market approach

"The market method is any approach to value-based upon the use of data that reflect market transactions and reasoning that corresponding to the thinking of the market approach" (Lilford & Minnet, 2005, p31). The market approach is made up of the following methods:

- Comparable transactions;
- Market cap per oz;
- Market cap per annual production oz;
- Option agreement;
- Geoscience factor; and
- Rules of thumb.

The approach is applicable across the mineral projects (mostly in precious metals) in every stage of development as shown in Table 2-3. It is subject to availability of the comparable transactions that are numerous enough to create a stable market for the commodity.

2.5.3 Income approach

"An income method is *a comparative approach to the value that considers income and expense data relating to the property being valued and estimates of the value through the capitalization*

process" (Lilford & Minnit,2005, p34). The income approach refers to the gross contained metal value, statistical method, decision tree analysis, and the common and most used valuation method, DCF. The Income Approach is the most preferred method for the valuation of producing assets as it incorporates more obtainable realistic data for analysis. The research project will use the income approach particularly, the DCF because the purpose of the research is to find out the economic viability of the project at its producing stage.

Table 2-3: Relationship between stages of development and valuation approaches for mineral assets (SAMVAL, 2016).

Valuation approach	**Early-stage**	**Advanced Stage exploration**	**Development properties**	**Production properties**	**Dormant properties**		**Defunct properties**
					Economically viable	Economically not viable	
Income	Not generally used	Less widely used	Widely used	Widely used	Widely used	Not generally used	Not generally used
Market	Widely used	Widely used	Less widely used	Quite widely used	Quite widely used	Widely used	Widely used
Cost	Widely used	Widely used	Not generally used	Not generally used	Not generally used	Less widely used	Quite widely used

DCF

The DCF method is the most used valuation technique across the world because of its strength over other techniques in the market and cost approaches. The method "*is based upon the principle that any initial investment in a mining opportunity, the investor will look to the future cash flows to provide a minimum return over their hurdle rate on that investment*" (Lilford, 2014, p6). Cashflow comprises revenues, costs, taxes, and royalties. The resultant DCF is used to calculate the NPV, IRR, and payback period.

3 TECHNICAL ASPECTS

The technical aspects chapter consists of the four important elements of the research namely the geological, mining, CHPP, and environmental elements.

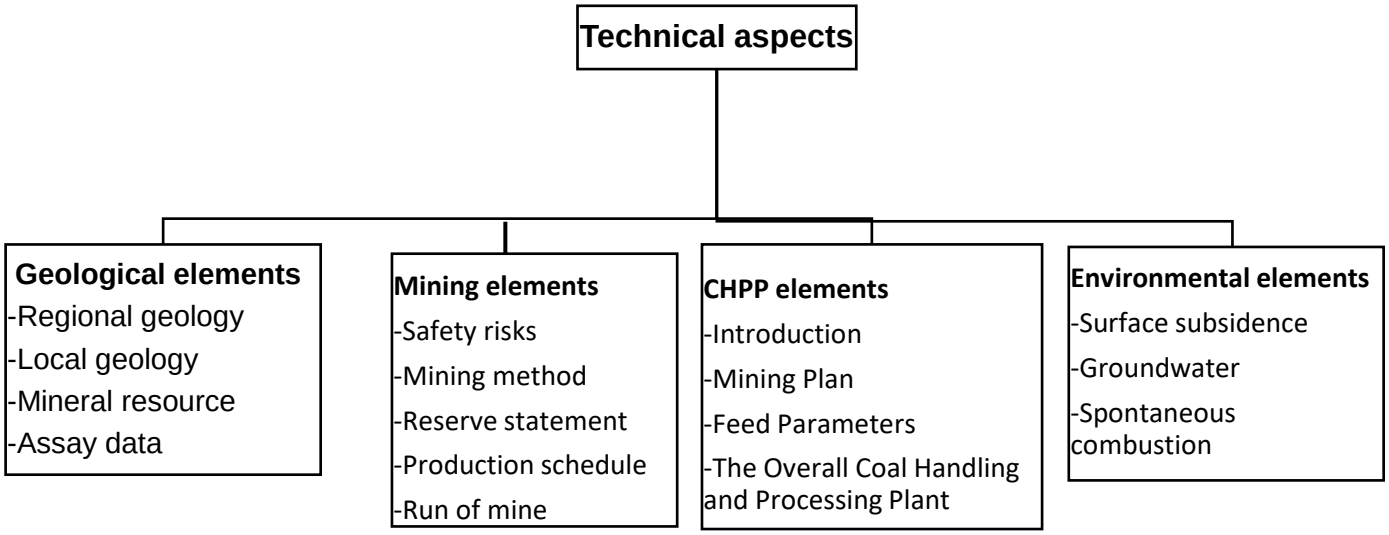


Figure 3-1: Outline for technical aspects

3.1 Geological Elements

The geological elements of the research include regional geology, local geology, assay data, and mineral resource estimation.

3.1.1 Regional geology

Introduction

Elandsfontein Colliery is found in the Ecca Group of the Karoo Supergroup, a stratigraphic unit that covers two-thirds of South Africa and was deposited between the Late Carboniferous and the Early Jurassic. The Ecca Group is underlain by the Dwyka Group which was deposited on the Archean basement during the retreating of the glacier in the Gondwana.

The group was deposited in a shallow marine environment and the northern part of the Main Karoo Basin comprises three formations namely the Pietermaritzburg Shale Formation overlain by Vryheid Formation and Volksrust Formation respectively. Vryheid Formation is responsible for the majority of economically extracted coal in South Africa. There are 19 coalfields in South Africa, the most productive ones are situated in the Vryheid formation amongst them are the Witbank Coalfield, Waterberg Coalfield, Ermelo Coalfield, Highveld Coalfield, and Limpopo Coalfield (Hancox & Götz, 2014).

Witbank Coalfield

The Witbank Coalfield is responsible for over 50% of the coal production in South Africa. The coalfield is found in the northern part of the Main Karoo Basin and has an area of 568 000 ha. It extends from the Springs in the west to Belfast in the east as shown in Figure 3-2 (Hancox & Götz, 2014).

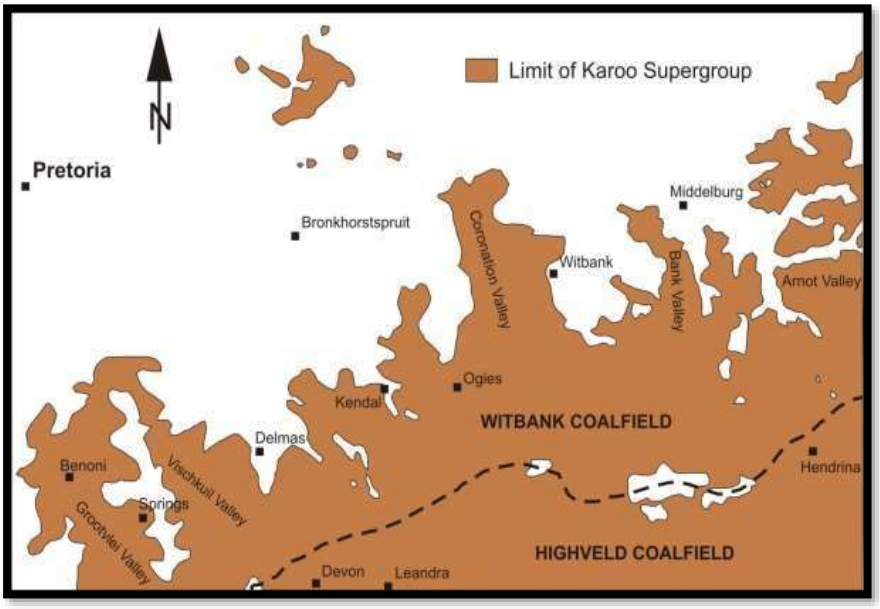


Figure 3-2. Limit of the Karoo Supergroup Rocks in the Witbank Coalfield (Hancox & Götz, 2014).

The Dwyka aged glacier resulted in the scouring of the basement and induced a paleo-topography of the basement that has valleys and ridges and these are displayed in the northern margin of the main Karoo Basin. The palaeo-topography is the greatest factor impacting the distribution of the coal seams in the Witbank Coalfield. These valleys increased the accommodation space and are filled with Dwyka and Ecca Group rocks. The Pietermaritzburg Shale Formation is absent in Witbank Coalfield, the coal-bearing rock succession was deposited directly on the Dwyka Group (Cairncross & Cadle, 1987).

The coal sequences

The coalfield consists of 5 coal seams numbered in numeric order with the No.1 Seam being at the bottom and the No.5 Seam at the top. The coal seams are grouped into three sequences namely No.2 Sequence, No.4 Sequences, and No.5 Sequence (Figure 3-3) (Hancox & Götz, 2014).

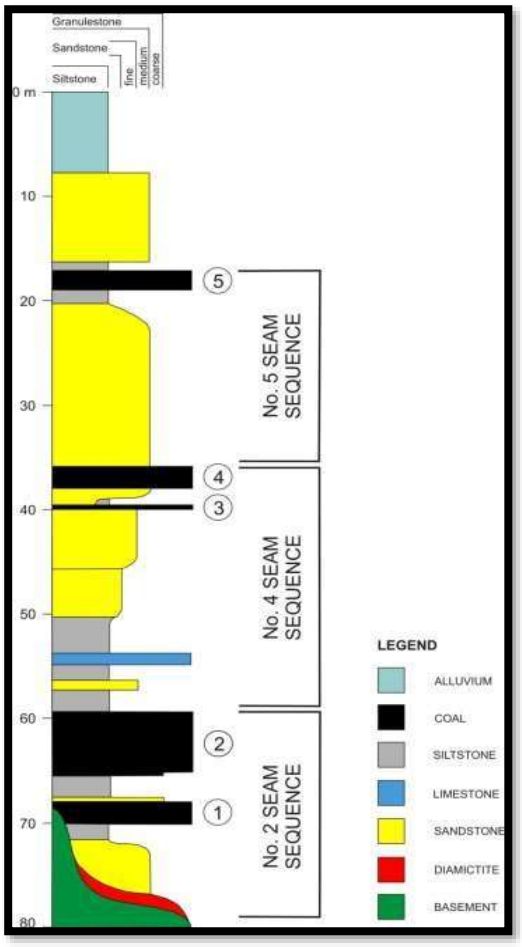


Figure 3-3. General stratigraphic column for the Vryheid Formation in the Witbank Coalfield (Hancox & Götz, 2014).

The No.5 Seam Sequence refers to the rock sequence from the top of No.4 Seam to the top of No.5 Seam. The No.5 and No.4 Seam are interbedded by a 25m thick succession of massive sandstone, cross-bedded granulestone, lesser bedded sandstone, and a lesser amount of interbedded carbonaceous siltstone. The No.5 Seam is generally found in paleo-topographic highs with an average thickness of 1.8m. It generally has high quality and volatile content except in the western region (Hancox & Götz, 2014).

The No.4 Seam Sequence refers to the rock sequence from the top of No.2 Seam to the top of No.4 Seam. The No.2 Seam is overlain by a lithological sequence consisting of carbonaceous

siltstone, overlain by micaceous bioturbated siltstone, interlaminated siltstone sandstone, fine to medium cross-bedded sandstone (Hancox & Götz, 2014).

The No.4 Seam is one of the most economical seams in the coalfield with thickness ranging from 2.5 - 4 m. The seam is divided into No.4 Lower; No.4 Upper and No.4 Seams and the seams are separated by partings made up of sandstones and siltstones. It is generally low-quality coal.

The No.3 Seam is poorly with an average thickness of less than 0.5m. It is high-quality coal but often not economical to mine.

The No.2 Seam Sequence refers to the rock sequence starting from the pre-Karoo basement to the top of the No.2 Seam. The seam sequence is made up of massive granulestone-sandstone, cross-bedded granulestone and sandstone, and subordinate carbonaceous. The No.2 Seam Sequence is more variable in the western Witbank Coalfield than the central part due to the irregular nature of the underlying Transvaal Group (Hancox & Götz, 2014).

No.2 Seam is responsible for most coal resources of the coalfield. It is high-quality coal with thickness ranging between 6.5m in the central and 2.5m in the east. The seam is divided into seven zones with the bottom five zones having high quality and the top two zones with low quality.

The formation of the No.1 Seam is controlled by the paleo-topography; average thickness of 6m in the central part (paleo-low) and 1-2m in the western parts (paleo-high) of the Witbank Coalfield. The No.1 Seam is divided into No.1 Seam Lower-Lower, No.1 Seam Lower, and No.1 Seam. No.1 Seam Lower- Lower and No.1 Seam Lower are separated by a 1.96m - 2.36m parting and No.1 Seam and Lower No 1 Seam are separated by a 0.36m parting. The seam

generally is a high quality dull to lustrous coal and it is a source of export quality and metallurgical coal (Hancox & Götz, 2014).

Structures and intrusions. The strata of the Coalfield are generally flat with a few areas tilted by dolerite intrusions. There are faults present with a minor displacement of not more than a few meters. Dolerite dykes and sills may be present in all the stratigraphic positions. The dykes trend east, northeast, and north with varying thicknesses from less than 1m to over 14m. Sills are most prominent in the basement and the Dwyka Group contact. The most prominent dyke is the Ogies Dyke which divides the Witbank into the north portion and large central portion (Hancox & Götz, 2014).

3.1.2 Local geology

Stratigraphy

Elandsfontein Colliery is situated in the western limit of the Witbank Coalfield and its stratigraphy consists of the Karoo sediments at the top of the sequence, which is underlain by the Rooiberg Group felsites. The lower part of the Karoo sequence consists of diamictites and tillites of the Dwyka Formation. The Dwyka Formation is overlain by the Vryheid Formation. The Vryheid Formation is made up of a sequence of shale, siltstone, sandstone, and granulestones interbedded by coal seams. There is a maximum of 8.2 m thick coal present at Elandsfontein Colliery (Geo Soil & Water, 2020).

Coal seams

The seams found at Elandsfontein are namely the No.5, No.4 Upper, No.4 Lower, No.3 Seam, No.2, No.1 Seam, and No.1 Seam Lower. The No.1 and No.2 Seam are of primary economic interest.

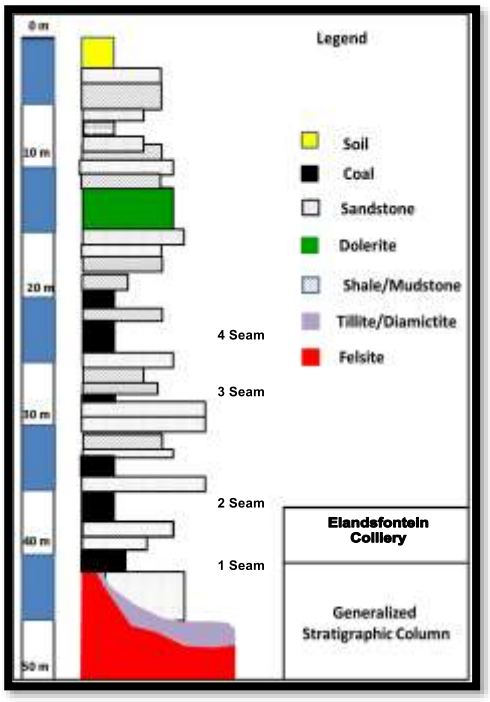


Figure 3-4: General stratigraphy at Elandsfontein Colliery (Geo Soil & Water, 2020)

In the Elandsfontein Colliery, the No.1 Seam occasionally splits into the No.1 Seam and the No.1 Lower Seam. The average seam thickness of the No.1 Seam is 2.11 m and 1.03 m for the No.1 Lower Seam. The two seams are separated by a 7.39 m rock parting (Figure 3-4). The No.1 Lower Seam occurs only in the south-eastern corner of Elandsfontein Colliery. The maximum depth from the surface to the seam of 80 m is found in the northeast of the study area. The floor of the No. 1 Seam dips southward due to the palaeo-topography of the basement and the general southward dip of the Karoo sediments in this part of the Karoo Basin (Geo Soil & Water, 2020).

The No.2 Seam is developed about 15 to 20 m above the No.1 Seam and consists of a relatively thick sequence of carbonaceous shale, shaley coal, and heavy dull coal. The seam thickness can reach up to 4.0 m but on average is about 2.6 m as shown in Figures 3-5 (Geo Soil & Water, 2020).

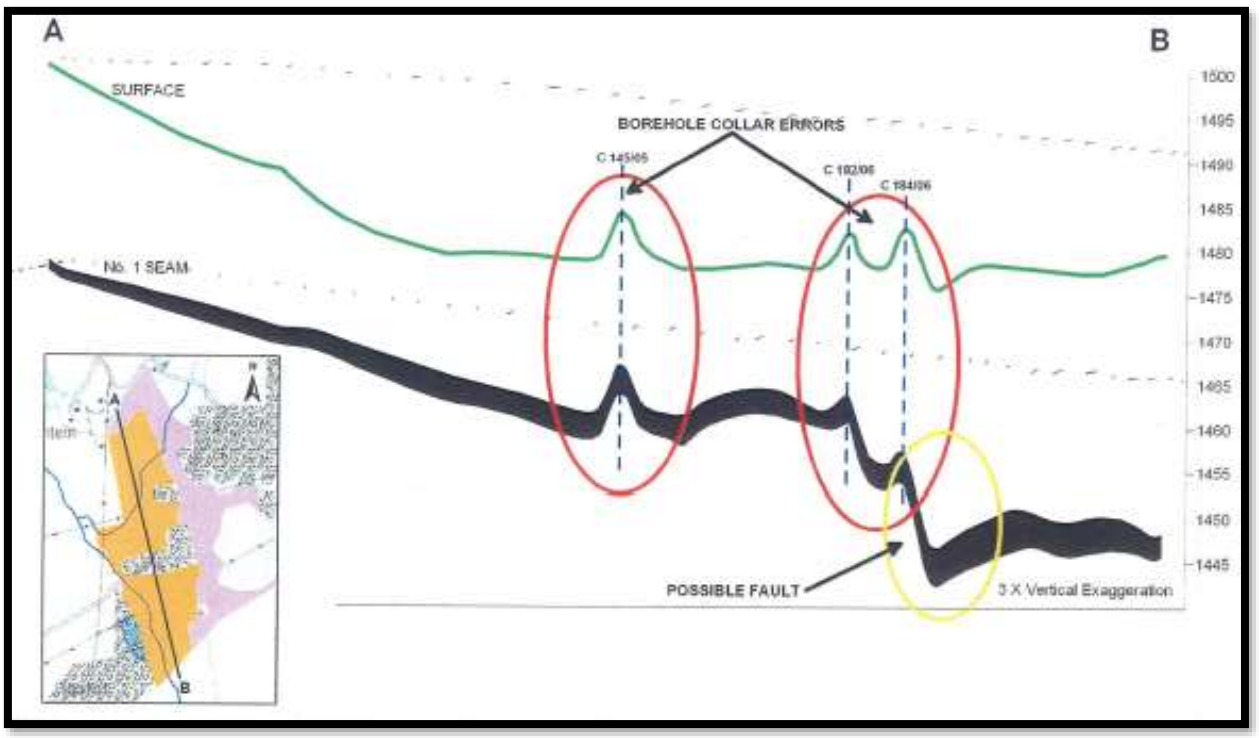


Figure 3-5: Cross-section through the No1 seam at Elandsfontein Colliery (Anker, 2008).

Structures

There are two fault zones present near the study area, striking in a north-south and southwest-northeast orientation. The colliery is predominantly underlain by an intergranular and fractured aquifer system comprising mostly fractured and weathered sedimentary rocks (Geo Soil & Water, 2020).

3.1.3 Mineral resource

Historical No. 1 Seam mining

Historically the No. 1 Seam was the main target of exploitation in the Elandsfontein mine and has been extensively mined both underground and opencast as shown in Figure 3-6 below. The coal was sold to the local and the export market, at a rate of ~500 000 t/annum. The underground method used to mine No.1 Seam was bord and pillar mining methods (Geo Soil & Water, 2020).

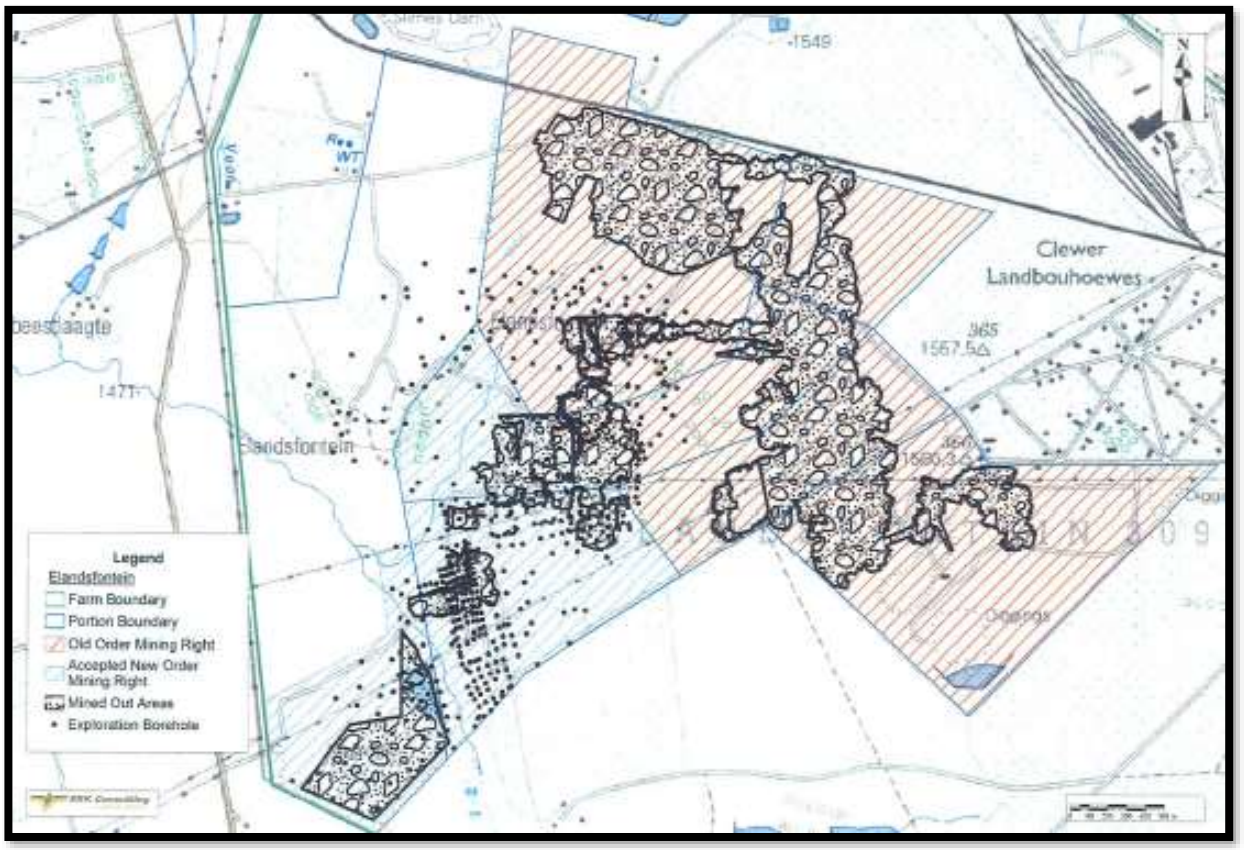


Figure 3-6: Elandsfontein Colliery old workings (Anker, 2008).

Mineral resource estimate

The pillars have been grouped in geological blocks due to their different geology; depth and thickness of No.1 Seam and the resultant mining parameters including the percentage of extraction and pillar size. The blocks have been numbered 1-34. The numbering was done randomly according to the sequence of area calculations.

The Gross Tonnes in Situ (GTIS) resources in the pillars at Elandsfontein Colliery old workings, for No.1 Seam coal at raw density (RD) of 1.6, are estimated to be approximately 1.2 M t at an average yield of 53,6 %. Deductions of 10% have been applied for geological losses (including faulting), and also to account for possible modelling errors, to result in Total Tonnes in Situ (TTIS). TTIS is estimated to be approximately 1,15 M t (Table 3-1).

Table 3-1: Resource statement for old workings pillars

Block	Area of the pillar (m^2)	Thickness (m)	Volume (m^3)	RD (Kg/m^3)	GTIS (t)	Depth (m)	Geological loss (%)	TTIS (t)
1	19844	2	40838	1,6	65342	23	0,1	58808
2	14200	2	32092	1,6	51347	53	0,1	46212
3	9184	3	31409	1,6	50255	60	0,1	45229
4	16169	1	25547	1,6	40875	44	0,1	36788
5	17020	2	41699	1,6	66718	60	0,1	60045
6	5290	3	16082	1,6	25730	55	0,1	23158
7	1979	2	4987	1,6	7978	60	0,1	7181
8	5454	3	15981	1,6	25 570	20	0,1	23013
9	12560	1	21478	1,6	34 364	47	0,1	30928
10	4716	1	5471	1,6	8 752	38	0,1	7878
11	10080	2	20432	1,6	32 691	48	0,1	29422
12	29952	2	78474	1,6	125 558	46	0,1	113003
13	9238	3	26789	1,6	42 862	32	0,1	38576
14	8820	2	16934	1,6	27 095	36	0,1	24386
15	5096	2	10804	1,6	17 286	29	0,1	15557
16	6422	1	10211	1,6	16 338	32	0,1	14704
17	8461	2	15737	1,6	25178	36	0,1	22661
18	18262	1	27028	1,6	43 244	67	0,1	38920
19	4968	2	10150	1,6	16 239	57	0,1	14615
20	15840	2	34531	1,6	55 250	49	0,1	49725
21	17160	2	41184	1,6	65 894	20	0,1	59305

22	3180	3	10303	1,6	16 486	20	0,1	14837
23	2464	4	8821	1,6	14 114	36	0,1	12 702
24	16800	2	38136	1,6	61 018	19	0,1	54 916
25	3696	4	14340	1,6	22 945	21	0,1	20 650
26	2520	3	8492	1,6	13 588	21	0,1	12 229
27	11268	4	42368	1,6	67 788	14	0,1	61009
28	1296	2	2667	1,6	4 267	23	0,1	3841
29	18704	2	46199	1,6	73 918	40	0,1	66526
30	16800	2	29064	1,6	4 6502	41	0,1	41852
31	9776	2	21604	1,6	34 567	51	0,1	31110
32	17820	2	40630	1,6	65007	50	0,1	58507
33	2340	3	6505	1,6	10408	54	0,1	9367
34	3626	2	6200	1,6	9 920	36	0,1	8929
			803187		**1285101**		**0,1**	**1156590**

3.1.4 Assay data

Examination of the quality data shows relatively high-quality coal that has an ash content of 32,87% and a CV of 20,99MJ/Kg, with a sulphur content of 1,28% (Table 3-2).

Table 3-2: No.1 seam average raw qualities for Elandsfontein Colliery

	CV (MJ/Kg)	Ash (%)	Volatile (%)	Moisture (%)	Total sulphur (%)
No.1 seam	20,99	32,87	20,15	3,07	1,28

3.2 Mining Elements

This section will evaluate how the pillars can be extracted economically and safely. The mining elements comprise of the following:

- Safety risks;
- Rock engineering;
- Mining method;
- Reserve statement;
- Production schedule;
- Run of mine; and
- Mining costs.

3.2.1 Safety risks

Stooping is considered to be a high-risk mining method as shown in Figure 3-7 (Coaltech, 2020). The typical rockfall-related risks associated with the mining of pillars can be categorised as large falls of ground (goafing events) and excessive abutment loading and possible pillar failures. Falls of ground can be large-scale caused by the development of caving or small-scale caused by weaknesses in the localised ground (Vuuren, 2002). Excessive abutment loading (stress) can often result in excessive loading of surrounding pillars, coal

pillar failures, pillar bumps, and roof instability. Delayed onset of caving (goafing) can potentially lead to damaging air blasts (Vuuren, 2002).

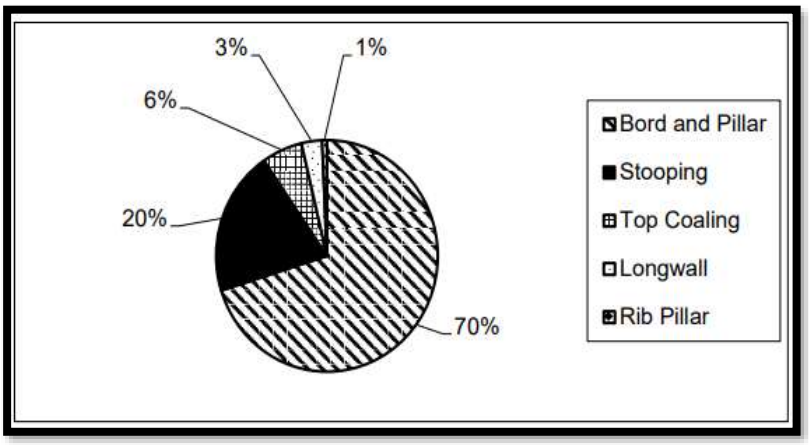


Figure 3-7: Relative distribution of fatal falls of ground for different mining methods.

The graph shows that bord and pillar has a higher percentage of fatal fall of the ground than stooping because it is the most used mining method therefore the percentage will be higher but it doesn't mean it is the least safe method as compared to stooping (Coaltech 2020, 2003).

Global stability risk factors

Global stability is dependent on pillar design. There are three pillar failures namely: pillar squeezes, massive collapse, and pillar bumps (Mark *et al*., 2003).

Pillar squeezes happen when the pillars are too small to support the load applied to them but are still relatively stiff as a result of their width to height ratios. This may result in the closure of entries, severe rib spalling, floor heave, and roof failure (Mark *et al*., 2003).

Massive collapses result from pillar failures in areas in which the pillars have relatively low width to height ratios and happen fast and typically involve large areas. This may result in destructive air blasts (Mark *et al*., 2003).

Pillar bumps happen when coal pillars burst due to high stress and this can result in the explosion of coal and rocks similar to typical rock bursts experienced in deep-level mines (Mark *et al*., 2003). Bumps are expected to be severe in deep coals.

Local stability risk factors

Cutting sequence. There are different types of cutting sequences: the left to right sequence (the cuts are taken on both sides) and the outside lift (cuts are taken on just one side) (Mark *et al*., 2003). The left-right sequence is the least safe method compared to the outside lift because more time is spent in the same position and wider unsupported spans are mined. **Final stump/pushout** helps support the active interaction, which is the weakest link, and once removed or reduced the interaction may become unstable (Mark *et al*., 2003).

Other risk factors

Roof geology. When the roof is made up of weak rocks such as shale, mudstone, and coal, it is prone to fracture and collapse under elevated levels of stress. A weak roof requires a high level (density) of roof support. A final stump (snook) must be left if the roof is weak. Areas with a weak roof should be identified and supported before mining (Mark *et al*., 2003).

Intersection span. Due to the typical intersection spans, failure of the roof is most likely to occur in the intersections than it is to occur in the bords or crosscuts leading to the intersection collapse. The larger intersection spans become even more hazardous when the roof stratigraphy is weak. Stable intersection span can be achieved by the following:

- Reducing the entry width, the number and depth of the boxing areas during development;
- Using longer, stronger bolts in the intersection; and
- Leaving an adequate snook

Depth of cover. High depth means high vertical and horizontal stresses. Proper pillar design is especially important in deep cover coal (Mark *et al*., 2003).

Multiple seam interaction. Where previous mining has taken place above or below the seam of interest, concentrated high stress can occur above or below old workings and subsidence can damage the roof (Mark *et al*., 2003).

Recovery of old pillars. Most of the old workings were only designed for primary extraction and the pillar dimension may be inappropriate for pillar extraction. Also, the roof may have degraded over time (Mark *et al*., 2003).

Non-uniform pillar dimensions. Where pillars have different sizes by design or poor mining methods will result in improvisation. Different pillar sizes can result in a large intersection span (Mark *et al*., 2003).

Operator positioning. At no time should any person in the section be allowed to enter the high-risk area beyond the position of the last active breaker lines formed between two solids during the process of pillar extraction (Mark *et al*., 2003).

Continuous haulage in primary extraction, the haulage system works out of the centre entry intersection, and this result in high productivity. This doesn't work well in pillar extraction because the pillars must be extracted from both sides towards the centre (Mark *et al*., 2003).

3.2.2 Rock engineering aspects

Overburden strata

The core samples indicate that the No.1 Seam is typically overlain by very competent roof material. The immediate roof of the No.1 Seam typically consists of a coarse-grained conglomeratic sandstone matrix, occasionally contain silty zones and laminae. The sandstone layer generally is self-supporting however a "false" layer often occurs at its base which must

be suspended from the overlying more competent layer and systematic support is also required in areas in which pinch zones occur as shown in Figure 3-8 (Associated Rock Mechanics Services, 2019).



Figure 3-8: North pit high wall at Elandsfontein Colliery (Associated Rock Mechanics Services, 2019).

Roof support

Systematic support will be required in all areas in which personnel is required to work or travel. Existing support could be assessed for its effectiveness however it is likely that the underground areas will have to be re-support as they are re-entered.

Areal sidewall support of discontinuities and stress-induced fractures should be considered for the rib sides.

Caving breaker line. The purposes of breaker line support in pillar extraction it is as follows:

- It controls the goaf edge and prevents it from extending into the current working area;

- It prevents the ingress of fallen goaf material into the current working area; and
- It prevents access to the goaf by acting as a barrier.

There are three types of breaker lines: timber supports, roof bolts, and mobile supports.

- Timbers were used in the past because it's simple to install them. They work best under small compression (Coaltech 2020, 2003).
- Roof bolts have the following advantages: they are cheaper, no disruption to mining activities, and they are independent of mining height (Coaltech 2020, 2003).
- Self-powered, hydraulic mobile supports are shield-type support units mounted on crawler tracks. They can be used during pillar extraction to enhance the safety of personnel and reduce material handling incidents. These mobile support units have however often been found to be difficult to manoeuvre and often get stuck in the hazard areas which often required personnel to enter high-risk areas in an attempt to recover them (Coaltech 2020, 2003).

Elandsfontein Colliery will make use of roof bolts breaker lines. Roof bolts were used in the primary extraction as shown in Figure 3-9.

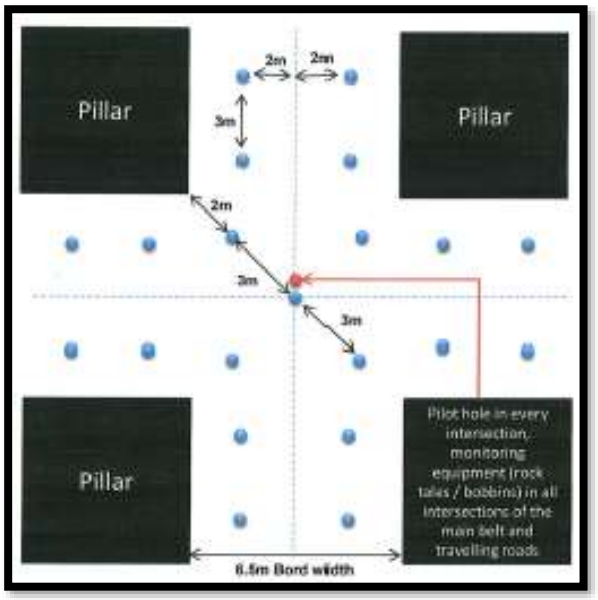


Figure 3-9: Illustration of systematic support layout (Associated Rock Mechanics Services, 2019).

Pillar design. The No.1 Seam at Elandsfontein Colliery was mined on a typical bord and pillar layout using drill and blast mining methods. The required pillar dimensions and road widths were designed by determining pillar strength, load, and FoS.

Pillar Strength. Salamon & Munro Pillar Strength Formula
Pillar strength is the strength of a coal pillar and depends not only on the strength of the material but also on the pillar's volume and shape (Associated Rock Mechanics Services, 2019). This pillar strength formula is given as:

Pillar strength = 7176 W exp (0.46)/ h exp (0.66)……[1]

Where:

- W = represents the width of the pillar; and
- h = mining height in meters.

Pillar Load is determined through the assumption that the pillar must carry the weight of the overburden immediately above it. This assumption is only applicable to pillars of the same size with a panel width that is larger than the depth of the seam (Associated Rock Mechanics Services, 2019).

The pillar load (q) for square pillars can be calculated from the formula:

Load = 25HC exp (2)/W exp (2)……..[2]

Where:

- H is the depth to the seam floor in meters;
- C is the coal pillar centre distances in meters; and
- w is the coal pillar width in meters.

In the equation, the number “25” is the unit weight of the overburden strata in kN/m3, a valid assumption, provided the overburden consists of sedimentary rock types.

Pillar FoS. The coal pillar strength is divided by the coal pillar load to get a pillar FoS.

FoS = Pillar strength/Pillar load……..[3]

The FoS represents the probability of a panel of pillars failing, the higher the FoS, the lower the probability of failure as shown in Table 3-3. For the studied cases, this occurs between FoS of 1.3 to 1.9 with the mean being 1.6 (Associated Rock Mechanics Services, 2019).

Table 3-3: Calculated probability of failure of pillars designed with different FoS as well as the possible number of pillar failures in a million pillars mined with each FoS (Associated Rock Mechanics Services, 2019).

FoS	Probability of a stable geometry	No. of pillar collapses in 1 000 000
2.1	0.999999	<1
2.0	0.999994	6
1.9	0.999974	26
1.8	0.999894	106
1.7	0.999586	414
1.6	0.998468	1 532
1.5	0.9947	5 300
1.4	0.9830	17 000
1.3	0.9508	49 200

Secondary extraction pillar parameters

The important factors in secondary extraction include fenders and snooks sizes and the mining height.

Fenders and snooks are remnants of coal left during pillar extraction and act as a medium to short-term local support. The width to height ratio of the fenders should be at least 3 for a mining height of 4.5m (Vuuren, 2002).

Snooks are smaller compared to the fenders and act as a crush pillar and acts as short-term support. The snooks are intended to stabilise the microenvironment without upsetting the

balance in the macro-environment. Excessive size of snooks can inhibit regular caving of the immediate roof. The ideal width to height ratio for snooks is 1 (Vuuren, 2002).

The Mining height where systematic support must be installed must be kept within the height of the Quadbolter (Vuuren, 2002).

Table 3-4: Summary of FoS of old workings at Elandsfontein Colliery.

Block	Pillar area (m^2)	w (m)	Bord (m)	h (m)	w/h	H (m)	FoS
1	36	6	6	2,058	2,9	22,95	4,08
2	54	7,69	6,77	2,26	3,2	52,59	2,22
3	46	7,51	6,95	3,42	2,2	59,39	1,39
4	23	4,29	6,5	1,58	2,7	43,8	1,44
5	46	7,84	6,14	2,45	3,2	59,9	1,85
6	46	7,84	6,14	3,04	2,6	54,75	1,95
7	46	7,84	6,14	2,52	3,1	59,92	2,02
8	50	8	5,93	2,93	2,7	20,45	5,2
9	36	6	6	1,71	3,5	46,99	2,37
10	36	6	6	1,16	5,2	37,53	1,69
11	36	6	6	2,027	2,9	48,32	2,05
12	36	6	6	2,62	2,3	46,37	1,69
13	36	6	6	2,9	2,1	31,67	2,35
14	36	6	6	1,92	3,1	36,23	2,8
15	26	5,66	7,75	2,12	2,7	28,8	2,84
16	26	5,24	6	1,59	3,3	32,42	2,9
17	36	6	6	1,86	3,2	36,36	2,85
18	46	7	6,7	1,48	4,7	66,6	2,087
19	46	7,5	6,95	2,043	3,7	56,6	2,09
20	46	7,5	6,95	2,18	3,4	49,47	2,27

21	46	7,63	6,5	2,4	3,2	20,16	5,1
22	53	8,1	5,69	3,24	2,5	19,86	5,18
23	56	8,1	5,22	3,58	2,3	35,69	3,06
24	56	8,08	5,29	2,27	3,6	18,75	7,71
25	56	8,1	5,22	3,88	2,1	20,88	4,6
26	56	8,1	5,22	3,37	2,4	21,47	5,04
27	60	8,29	5,27	3,76	2,2	14,47	6,52
28	36	6	6	2,058	2,9	22,95	4,08
29	56	8,1	5,22	2,47	3,3	40,2	3,6
30	60	8,29	5,27	1,73	4,8	40,83	3,39
31	46	7,31	5,18	2,21	3,3	50,67	2,76
32	36	6,5	6,4	2,28	2,9	49,93	1,92
33	36	6	7	2,78	2,2	53,6	1,3
34	42	7,13	5,78	1,71	4,2	35,9	4,05

Condition of pillars

The introduction of the continuous miner (CM) is recent, before, the pillars were developed using conventional drill and blast. The conventional drill and blast may result in uneven rib sides but pillar scaling is related to geology and stress rather than the mining method (Coaltech 2020, 2003).

Coaltech 2020 (2003) surveyed mines in South Africa and the focus was on the pillar next to the goafing as they showed the induced pillar scaling. It was observed that major scaling occurred in the pillars with a low FoS shown in Table 3-5. Major factors including the age of

the pillars were also considered and the results showed that the age of the pillar does have a considerable effect on the pillars as shown in Table 3-6.

Table 3-5: Condition of pillars related to FoS (Coaltech 2020, 2003).

FoS	Number of panels	No scaling	Slight/moderate scaling	Severe scaling	Tons mined/month
1.0-1.5	2	-	1	1	90
1.5-2.0	3	-	1	2	170
2.0-2.5	4	2	2	-	270
+2.5	6	5	1	-	60
Total	15	7	5	3	590

Table 3-6: Condition of pillars related to age (Coaltech 2020, 2003).

Age in years	Number of panels	No scaling	Slight/moderate scaling	Severe scaling	Tons mined/month
0-1	5	3	1	1	260
1-3	3	2	1	-	110
3-10	2	2	-	-	50
+10	5	-	3	2	160
total	15	7	5	3	580

3.2.3 Mining method

This research will focus only on the three common mine methods that are currently used in South African collieries namely the NEVID method, split and fender, and angled cuts (Coaltech

2020, 2003). For each method, the important aspects of the mining method including cutting sequence, strata control, ventilation, and extraction percentage, will be assessed. The selection of the pillar extractions method is based on the roof stratigraphy, pillar width, and other aspects such as surface subsidence which will be covered in the environmental section. The method that will be applicable will be the checkerboard.

Table 3-7: Mining method and pillar sizes in South African Collieries (Coaltech 2020, 2003).

Method	**Size of pillar**	**South African colliery**
NEVID	Medium to large pillars 28m	Sasol coal - Bosjesspruit Colliery
Split and fenders	Medium to large pillars 24m	Sasol Coal
Angled cuts	Small pillars 6m	Longridge, Ermelo mines
Checkerboard	Varying sizes	Sasol Coal

NEVID method

It was introduced in 1997 and it is the modification of the split and lift pillar extraction method (World Intellectual Property Organisation, 2015).

Mining sequence. After panel development, at the beginning of a new panel, the top middle pillars are split to increase overall extraction. The pillars are not extracted fully to prevent goaf in ventilation bleeder. The cuts are taken at 45 degrees from the centerline of the development following sequence from left to right as shown in Figure 3-10. The direction lines are installed at the righthand side of the CM first lift to ensure that the continuous miner operator can control the cutting direction from a safe position (Coaltech 2020, 2003).

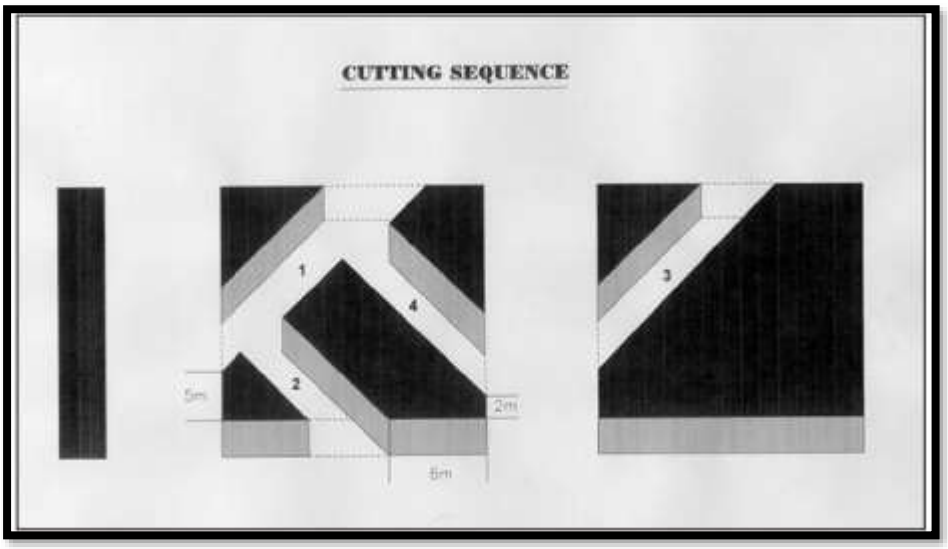


Figure 3-10: NEVID method cutting sequence method (World Intellectual Property Organisation, 2015).

Strata control. The 45-angle cutting angle of the pillar allows the fastest retreat should goafing take place. It also ensures easy cutting and direction control. The goafing follows the extraction of pillars by one row of pillars (Coaltech 2020, 2003).

Ventilation. Two critical ventilation aspects: bleeding methane out of the goaf and dust out of the workings. The general ventilation layout:

- Most intake air is taken over and behind the CM to the mined-out area
- From there it is taken in the return airway to ensure that methane and dust are taken away from the people

The last row of pillars extracted is left open to the mining of the next row to allow proper ventilation (Coaltech 2020, 2003).

Split and fender

The split and fender method was created as a means of optimization in the rib pillar method because the rib pillar has low production rates. The production rates of rib pillars are low due to long tramming, shuttle car change-out time, limited tramming roads, and cutting

interaction. The pillar is split into 2-3 fenders and is mined similar to rib pillar mining as shown in Figure 3-11 (Coaltech 2020, 2003).

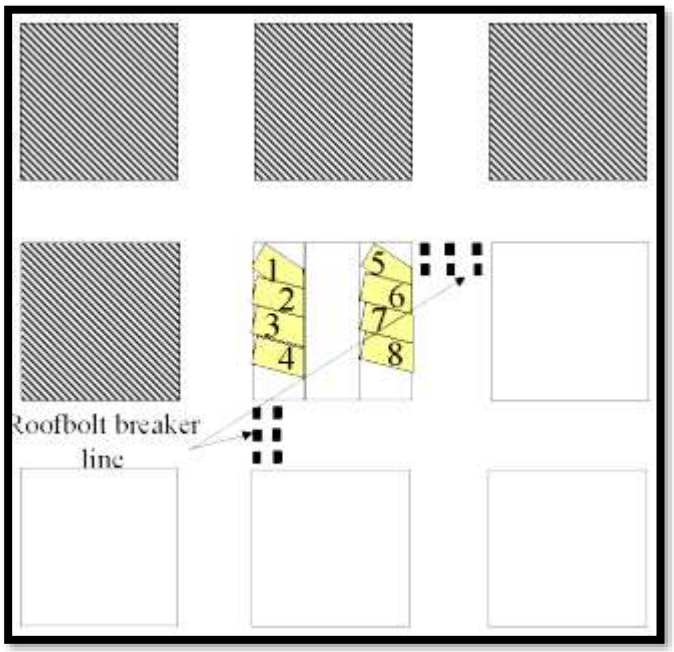


Figure 3-11: Extraction of pillars using split and fender method (Coaltech 2020, 2003).

Mining method and cutting sequence. For this method to be possible, pillar geometry should be able to be split into 6m fender and the FoS should be above 1.6. Pillar centres must be multiples of 12 or 14 in the direction. Angle cuts are lifted through the pillar to ensure that mining takes place away from the goafed area and also allows the safe position of the continuous miner operator and cable handler. The other advantage of the angled cuts is that it provides ease of movement of the CM and consistent snook sizes (Coaltech 2020, 2003).

Strata and roof support. Roof bolts breaker lines that comprise of 1,2m point anchor resin bolts spaced 1m apart are used throughout the panel. Timber support is installed and is used to detect any roof movements. Two timber props and roof bolts breaker lines are also used.

A diagonal rib of 1m is left on either side of the corner of the cutting to ensure the protection of the intersection and the CM during cutting. The rib size decreases towards the goaf to

ensure an increased percentage of extraction and proper goafing. A CM extractor is put in place for fast retrieval in case of emergencies (Coaltech 2020, 2003).

Ventilation. The ventilation flow from right to left through the section by line brattice. A jet fan is used to help the flow of ventilation. If the amount of methane is low, there is no need for bleeder roads.

Percentage extraction. This amounts to 60% of each pillar.

Angled cuts method

The approach is to make diagonal cuts through the pillar. The critical intersections are supported by a snook.

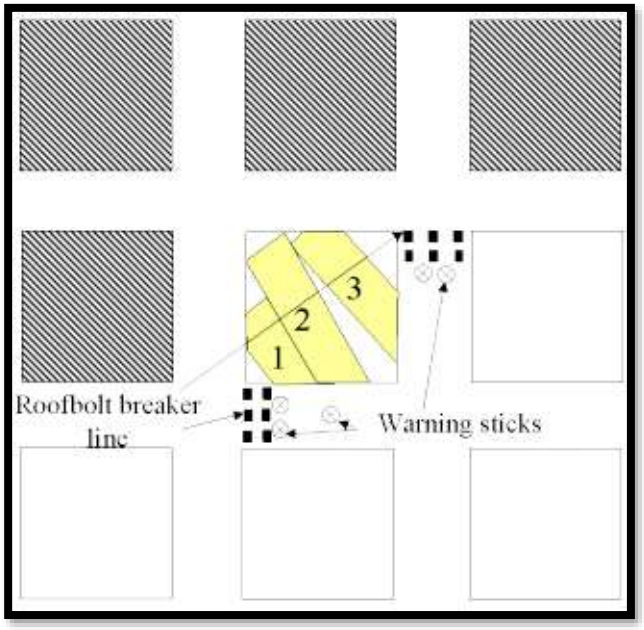


Figure 3-12: Extraction of pillars using the angled cuts method (Coaltech 2020, 2003).

Mining method and cutting sequence. The pillars are extracted from left to right at a 45-degree angle as shown in Figure 3-12. All the pillars are removed including the barrier pillars (Coaltech 2020, 2003). Pillars are split in the direction of the panel and fenders of 6m are left. Once the fenders are created, they are extracted by 45 degrees angled cuts.

Strata control and roof support. Roof bolts are installed comprising a double row of resin bolts spaced at 1m intervals. The split must be kept as small as possible without inhibiting the easy movement of the continuous miner. There are no roof bolts installed in the split. The split must be at 90 degrees to the consistency of the fender's sizes (Coaltech 2020, 2003).

Ventilation. The ventilation flow through the section from right to left. Depending on the methane liberation.

Extraction percentage. The extraction percentage is usually 75% on a normal 10m size pillar. The overall extraction will be 85% if the barrier pillars are not removed and 90% if the barrier pillars are removed (Coaltech 2020, 2003).

Checkerboard

Pillar extraction at Elandsfontein will be conducted using the checkerboard method due to the competent nature of the roof and other aspects such as surface subsidence. Checkerboard is the extraction method where every second pillar is left intact or extracts 50% of every pillar. The extraction percentage will be 50%. The ventilation and strata control will be the same as the Angled cuts method.

3.2.3 Reserve statement

As mentioned in the resource estimation section, the GTIS (1,28) was calculated as the product of the thickness of the seam, area, and RD, which was then used to calculate the TTIS where the geological loss of 10% was factored in. The TTIS (1,15Mt) was used to calculate MTIS by factoring a derating factor of 10% resulted in 1,04 Mt. Since the coal will be mined by checkerboard method, only 50 % of the reserves will be mined resulting in RoM of 520 465t. As mentioned before, the coal will be split between export and Eskom at 53,6% and 46,4% respectively as shown in Table 3-8.

Table 3-8: Reserve statement

Area (m^2)	Thickness (m)	Density (Kg/m^3)	GTIS (Mt)	TTIS (Mt)	MTIS (Mt)	ROM (50%) (t)	Export (53,6%) (t)	Eskom (46,4%) (t)
351 004	2,4	1,6	1 28	1, 15	1,04	520 465	278 969	242 537

3.2.4 Production schedule

The RoM is the tonnage produced while the RoM/t is the rate of pillar extraction and is estimated to be 35 000t/month. The LOM is 15 months.

Table 3-9: Production schedule

	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8
RoM (t)	35000	35000	35000	35000	35000	35000	35000	35000

	Month 9	Month 10	Month 11	Month 12	Month 13	Month 14	Month 15
RoM (t)	35000	35000	35000	35000	35000	35000	30465

3.2.5 RoM

The RoM coal is conveyed by haul trucks to the Elandsfontein Colliery RoM tipping point. The RoM is crushed and conveyed by conveyors into the dense medium separator (DMS) plant where it is beneficiated and the product is placed on the product stockpiles. The product is reclaimed by front-end loaders and loaded on haul trucks. It is then transported either to Oosbank siding (for export market) or Eskom. The discard is transported by haul trucks to the discard dumps and dumped back into the north pit (Geo Soil & Water, 2020).

3.3 CHPP Elements

3.3.1 Introduction

The plant will beneficiate the RoM coal from the underground No. 1 Seam resources to produce coal products with the split between the products being approximately 53,6% for the export market and 46,4 % for the domestic market. The underground coal resources from the No. 1 Seam will be washed and the primary product will be for the export market. The secondary product will be crushed and screened and then sold to Eskom (Geo Soil & Water, 2020).

3.3.2 Mining Plan

Contamination levels

Contamination occurs due to the nature of the mining method. The contamination can be floor or roof contamination. The floor and roof contamination is 5% each, estimated theoretically and from the plant data.

Tonnage throughput

The mine is planned to produce 520 465t at the quality of CV of 20,99MJ/Kg, an ash content of 32,87%, volatile 20,15%, total moisture of 3,07%, and total sulphur 1,28%.

3.3.3 Feed Parameters

The plant is located in the Northern corner of Elandsfontein Colliery.

Particle size distribution

The following are the particle size distributions:

- Coarse coal, nominally 50mmx10mm;
- Small coal, nominally 10mmx2mm;
- Fine coal, 2mmx0.2mm; and
- Slimes, -200microns.

Run hours

The plant run hours are shown in the table below. The plant operates 12 hours a day processing 300 t/hour.

Table 3-10: Run hours (Geo Soil & Water, 2020).

	Wash plant
t/annum	972 000
Total days/annum	270(3weeks/month)
Holidays	12
Total hours/annum	3240
Plant utilisation	0.7
Plant run hours	12
t/hour	300

Tonnage throughput

The tonnage throughput from the mine to the processing plant is 520 465t.

3.3.4 The Overall Coal Handling and Processing Plant

The coal handling and plant preparation section consist of three main areas:

- Run of mine receiving and crushing;
- The wash plant; and
- Product handling, sampling, stockpiling, and loadout system.

ROM receiving and crushing

The ROM section has been designed to receive mined coal with minimal crushing to reduce the coal to 50mm. The coal is mined from underground with a top size of +300mm (Namane Resources, 2013).

Mined coal will be hauled to the tipping facility and coal with a nominal top size of 300mm being discharged on a grizzly to remove +300mm and retained in the -300mm into the feed bin as shown in Figure 3-13 (Namane Resources, 2013).

The -300m feed material is reduced in size to -120mm by a jaw crusher. Thereafter the coal is conveyed in a closed circuit of double deck screen and roll crusher. Screen oversize (+50mm) is re-crushed in a secondary crusher to -50mm while the undersize material (-50mm) passes through the apertures of the deck into a bin and is conveyed to the DMS plant (Namane Resources, 2013).

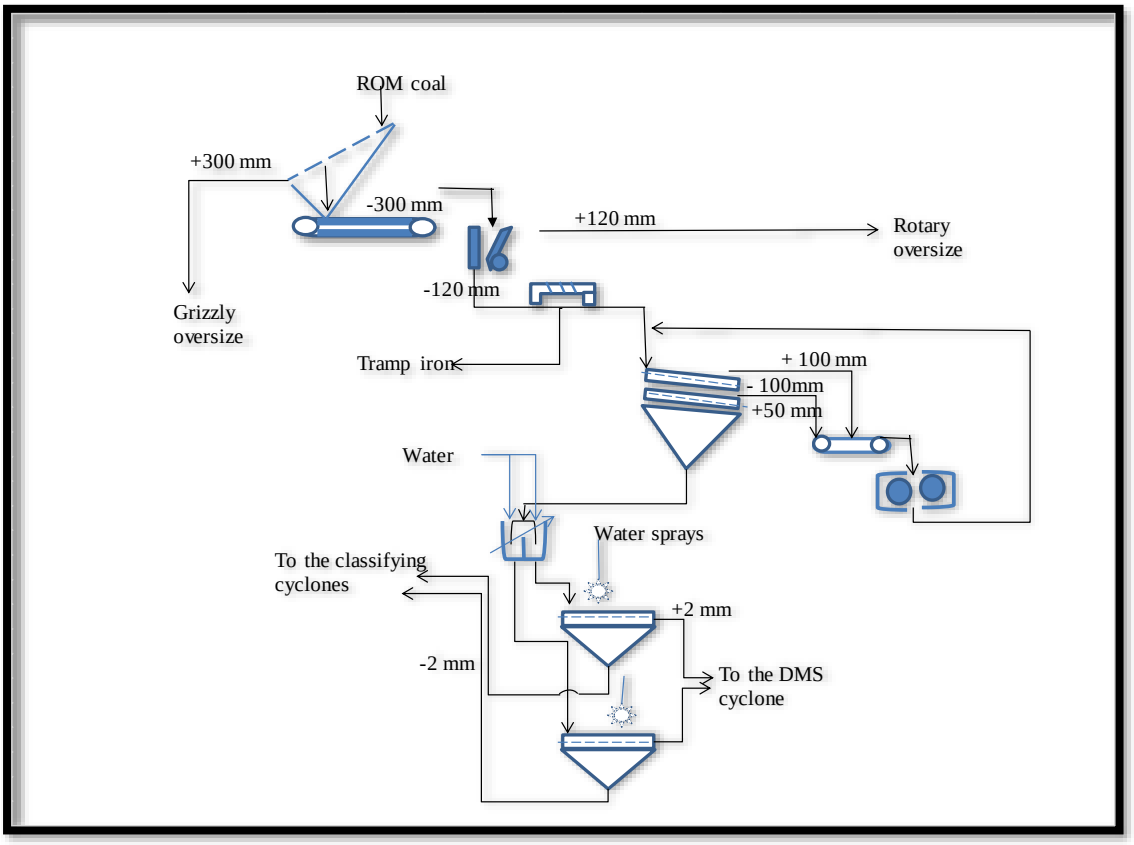


Figure 3-13: Crushing and sizing unit (Namane Resources, 2013).

Washing plant

Feed distribution. Distribution is achieved by the desliming process where vibrating screens are employed to exploit the size difference of the material. In this process, the material is mixed with water and passed through a vibrating screen fitted with panels of 2mm apertures. Slimes are recovered from the underflow and coarse coal (+2mm) is being retained on the screen deck as overflow. The coal being recovered will be fed to the feed distribution wash plant bins. Nominally -50mm is delivered at a controlled feed rate into a module of the wash plant (Namane Resources, 2013).

Wash plant modules. The following is the description of a generic DMS plant which is a well-known technology used by many coal operations in South Africa shown in Figure 3-13. The coal is separated from the waste rock by exploiting the density difference of the two materials. The material from RoM is then fed into the DMS plant (Namane Resources, 2013).

The material is passed over a de-sliming screen that removes the -2mm fraction from the feed. The remainder is then routed to the coarse DMS cyclones. The -2mm fraction reports to the fine coal processing circuit (Namane Resources, 2013).

Fines treatment. The -2mm slurry material from the desliming unit reports to the fines treatment circuit. The slurry is passed through a classifying cyclone to remove ultra-fines (-0,2mm). The -0,2mm slime report to the water treatment unit (thickener) where pure water is recovered from the slurry. The cyclone underflow (-2mm; +0,2mm) is passed through the spiral concentrator to achieve recovery of fine clean coal shown in Figure 3-15 (Namane Resources, 2013).

Both streams (fine coal and fine discard) are dewatered separately using a dewatering cyclone which removes approximately (50-60%) moisture then moved to a dewatering screen which further removes (20-40%) water from the dewatering cyclone material. The

final fine clean dry coal product is stockpiled and discard is conveyed to the discard bin (Namane Resources, 2013).

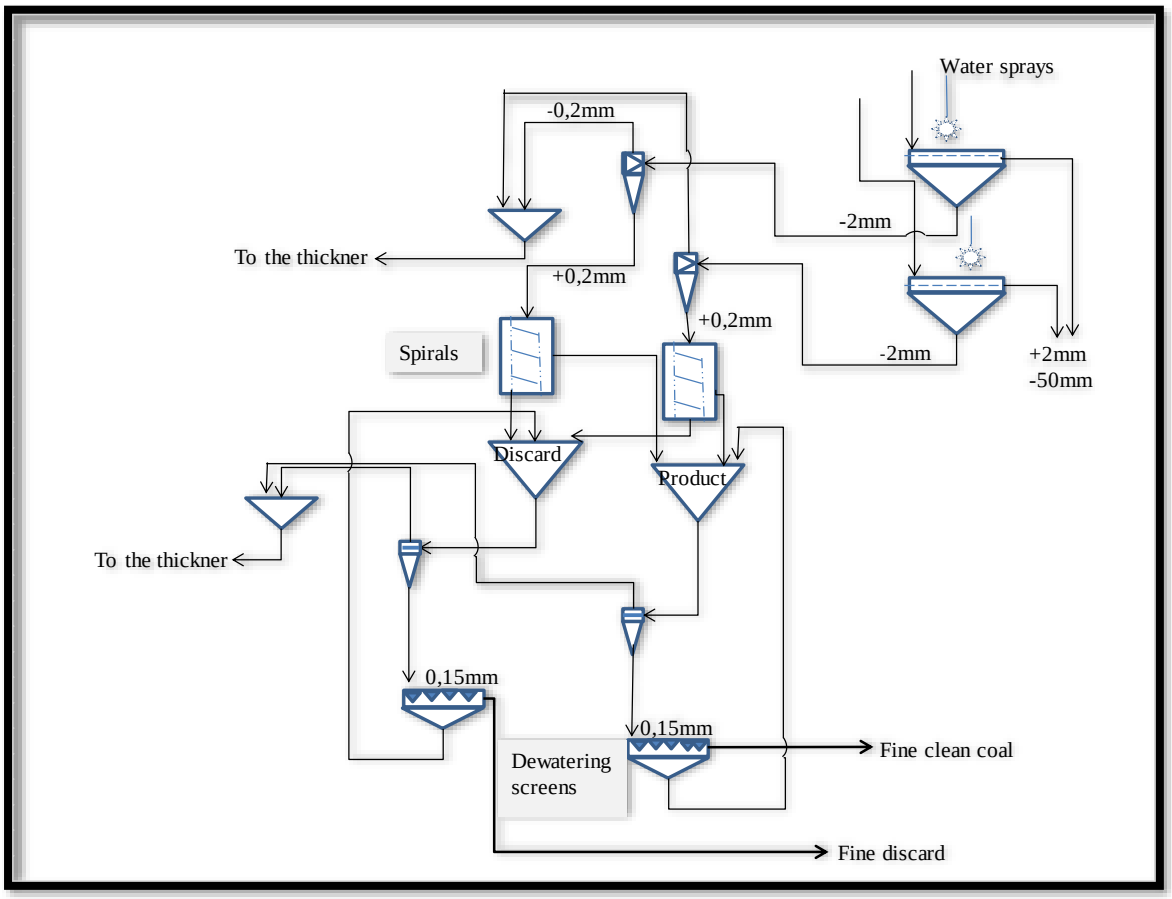


Figure 3-14: Fines treatment unit (Namane Resources, 2013).

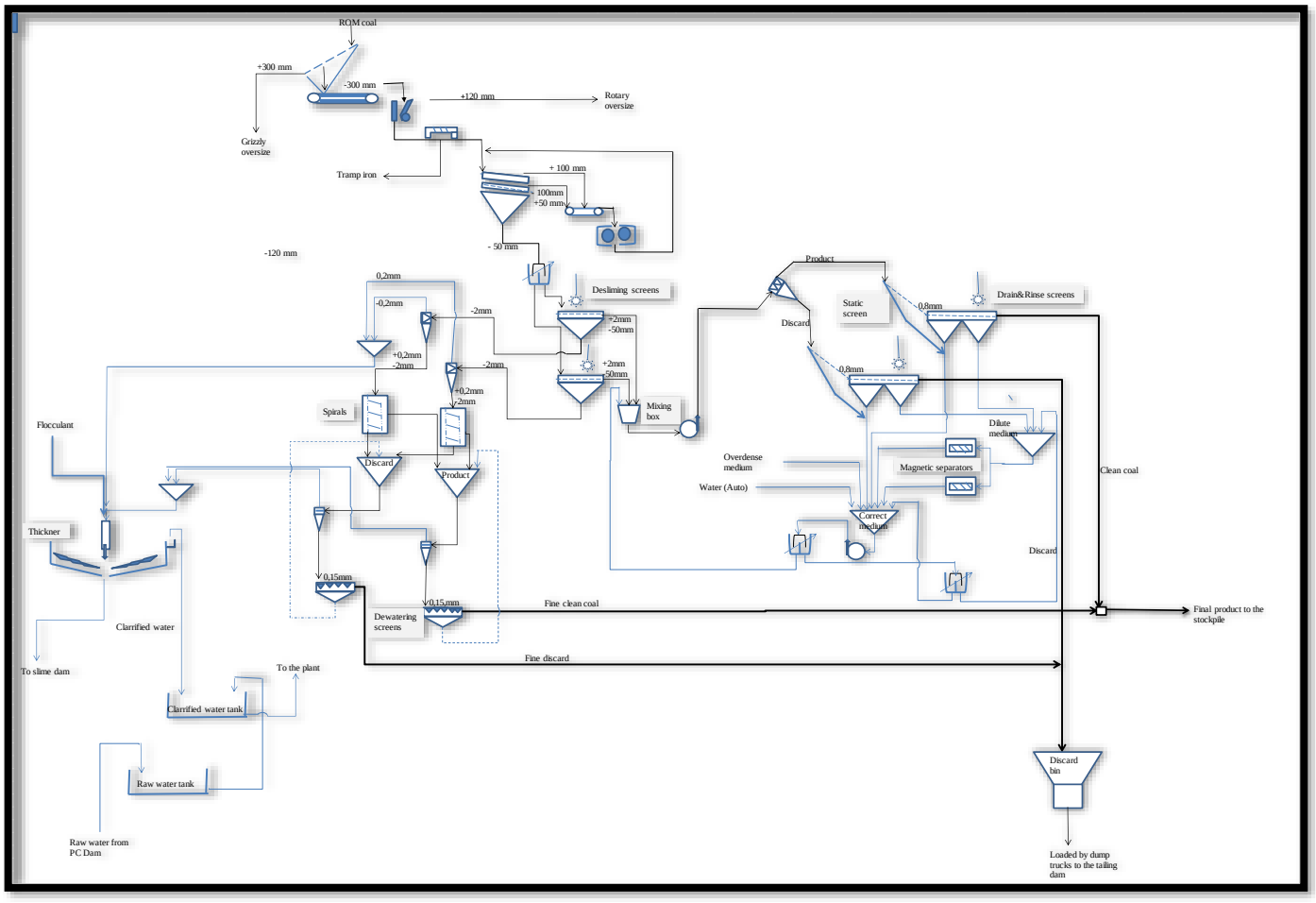


Figure 3-15: Elandsfontein Plant layout (Anker, 2008).

Products The product conveyor is sampled at the sampling plant which produces samples for laboratory analysis. An on-line analyser is used to allow the coal qualities to be pre-qualified as per Eskom requirements. Prequalifying means the product will be retained until the customer is willing to accept the coal (Geo Soil & Water, 2020).

3.4 Environmental Elements

The extraction of pillars has some adverse environmental effects. The most important potential impacts include:

- Surface subsidence
- Groundwater contamination
- Sponcom

3.4.1 Surface subsidence

Total or partial pillar extraction results in the collapse of the immediate overlying strata over the void. During total or partial extraction, extraction excavations become wide resulting in increased load on the coal pillars (Commonwealth of Australia, 2014). The goaf may collapse due to the geology and the mining dimensions. Factors influencing mine subsidence:

- Depth of cover;
- Panel width;
- Pillar width;
- Panel width to depth ratio;
- Seam thickness extracted;
- Proximity to adjacent previously mined panels in the current seam; and
- Proximity of adjacent previously mined panels in other seams under multi- seam conditions.

Surface subsidence is significant in mines practicing full extraction, it is reported to be from 33% of the extracted seam height at New Clydesdale Colliery to almost 80% of Boschman's Colliery. It depends on the depth and extent of the workings and the physical properties of the rock mass. Before mining can take place the presence or absence of aquifers and

aquicludes must be determined. The use of breaker lines supports improved safety and profitability of pillar extraction (Coaltech 2020, 2003). In the case of those collieries applying the checkerboard pillar extraction method, subsidence is either minimal or doesn't occur at all, which is what is expected in this project (Coaltech 2020, 2003).

3.4.2 Groundwater

Aquifer layers

Water level monitoring shows that there are two distinct aquifers at the project site: the shallow weathered aquifer and the underground void (Digby Wells, 2015).

Weathered Aquifer. The upper aquifer is associated with Ecca sediments which are weathered to depths 5 – 15m below the surface. This aquifer is recharged by rainfall and the recharge is estimated to be between 1% and 3% of the mean annual precipitation (Digby Wells, 2015). Aquifer tests were conducted by Digby Wells in 2015 on 9 boreholes within Elandsfontein Colliery. Based on the test results (Table 3-11), a permeability of 0.05 m/d was assigned to the weathered aquifer (Digby Wells, 2015).

Table 3-11: Listed boreholes and permeability values in the weathered aquifer (Digby Wells, 2015).

Boreholes	Y-coordinate	X-coordinate	K-value (m/day)
EB10	9778.81	-2866478	0.1
EB2	10296.46	-2867469	0.0001
EB3	9674.28	-2866111	1.2
EB4	9652.25	-2866093	0.5
EB7	8327.11	-2865297	0.003
GRBH1	10104.40	-2867847	0.005
GRBH2	9830.32	-2868882	0.05
EFNBH7	9682.89	-2865606	0.016
GRBH3	10389.73	-2868611	0.031
Average			0.05

The groundwater in the shallow aquifer has not been impacted by the underground mining underneath (Digby Wells, 2015). This is also supported by the water chemistry whereby the quality of the shallow aquifer is considerably better than the mine void (Digby Wells, 2015).

Underground Mine Void. The correlation between the topography and hydraulic head is only 27.0% in the underground void as shown in Table 3-12. The groundwater flow direction hardly correlated with the topography. The flow direction is towards the lowest mine floor

elevation.

Table 3-12: Water level in the underground void (Digby Wells, 2015).

Borehole Name	X-coordinate	Y-coordinate	Z-coordinate	Water level depth (m)	Water level elevation (m)
EB1	29.10	-25.92	1555.3	42.0	1513.3
EB2	29.10	-25.92	1555.0	47.4	1507.6
EFNBH1	29.11	-25.91	1557.3	36.7	1520.6
EFNBH2	29.11	-25.91	1555.3	30.2	1525.1
EFNBH3	29.086	-25.91	1511.2	5.7	1505.5
EFNBH4	29.089	-25.91	1519.9	13.0	1507.0
EFNBH6	29.099	-25.91	1549.9	42.4	1507.5
EFNBH5	29.095	-25.91	1545.7	23.3	1522.4

Based on the available water levels and mine plan, the mine void can be divided into four hydraulic compartments with a unique hydraulic head distribution. The approximate outline of the compartments is shown in Figure 3-17 and includes:

- Northern compartment (marked with a blue line);
- Western compartment (marked with brown line);
- Southern compartment (marked with a black line); and
- Eastern compartment (marked with green).

Northern Compartment. Boreholes EFNBH6 and EFNBH9 are in this compartment. The hydraulic head in this zone is approximately 1505 m above mean sea level and approximately 75% of the void is currently flooded. Both boreholes have consistently had the same water level since they were drilled in Mid-2015. This supports the idea that they intersect a hydraulically connected mine void. The water is acidic at a pH of 3.3.

Western Compartment. Boreholes EFNBH3 and EFNBH4 are in the western compartment. The hydraulic head in October 2015 was 1505 m and approximately 90% of the void was flooded.

The compartment was decanting at Decant 1 (Figure 3-17) at a rate of approximately 5 L/s in early 2015. The decant point has a topographic elevation of 1504 m. However, the water level in the compartment is now at 1497 m, and no decant is currently taking place as the water level is below the decant elevation of 1504 m. The reason for the lowering of the water level is not fully understood and could be associated with the low rainfall recorded in the last three years. The pH of the compartment, as measured in both boreholes, was 3.8; while that of the decant was 3.6 (Digby Wells, 2015).

The hydrogeological correlation between the northern and western compartments is shown in Figure 3-18. The cross-section is produced along with line AB of Figure 3-17. Although the water level in both compartments is the same, they are not hydraulically connected, since as per the available mine plans, there is a topographic high in between them (Digby Wells, 2015).

The hydraulic head in all the compartments is expected to fluctuate seasonally. Although the water level is currently at 1497 m and is not decanting, it is expected to rise to up to

1505 m and decant when rainfall increases. If sufficient recharge occurs, the eastern and western compartments may eventually meet. If this occurs, water from the northern compartment will overflow to the western compartment and the decant rate could potentially exceed the 5 L/s recorded during the wet months of 2015 (Digby Wells, 2015).

Southern Compartment. Boreholes EFNBH2 and EFNBH5 are in this compartment. Borehole EFMBH5 is in the unflooded part of the underground mine and is currently dry (Digby Wells, 2015).

The water level in EFNBH2 is approximately 1504 m and based on volumetric calculations 30% of the void is flooded. As is the case with all the compartments, the water level should be monitored to confirm if this is the static level or not. There is enough space for oxidation reaction and acid generation; and the recorded pH of 2.9 is a result of this (Digby Wells, 2015).

Eastern Compartment. Borehole EFNBH1 is in this compartment. The hydraulic head is currently at approximately 1521 mean sea level and the void is completely flooded.

The pH of this compartment is 5.4 and is higher than all the compartments discussed above. Since the void is filled, oxidation reactions are unlikely to take place and the pH is unlikely to deteriorate further. However, if the water of different compartments is mixed, the pH of the eastern compartment is likely to decrease (Digby Wells, 2015).

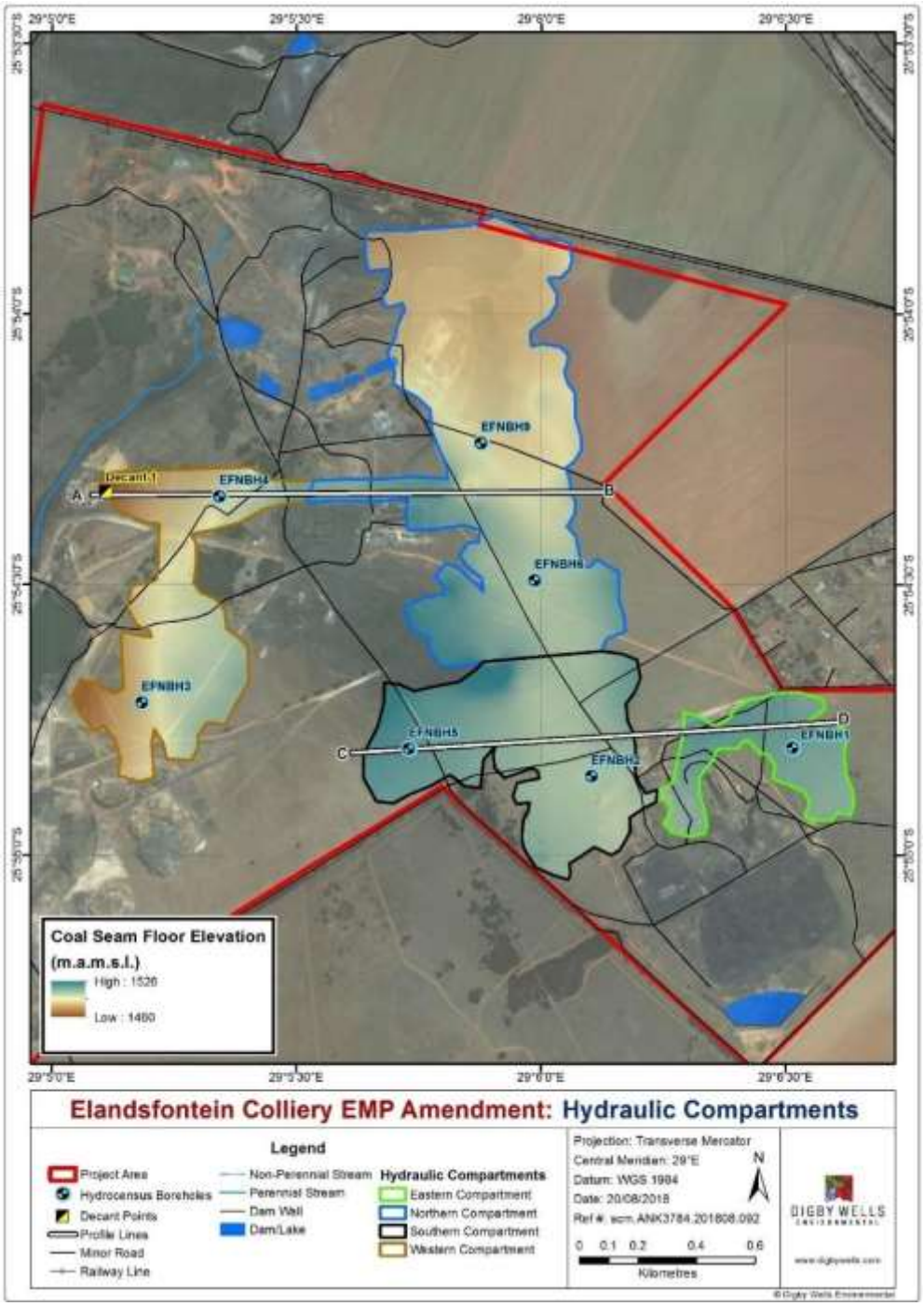


Figure 3-17: Hydraulic compartment in the mine void (Digby Wells, 2015)

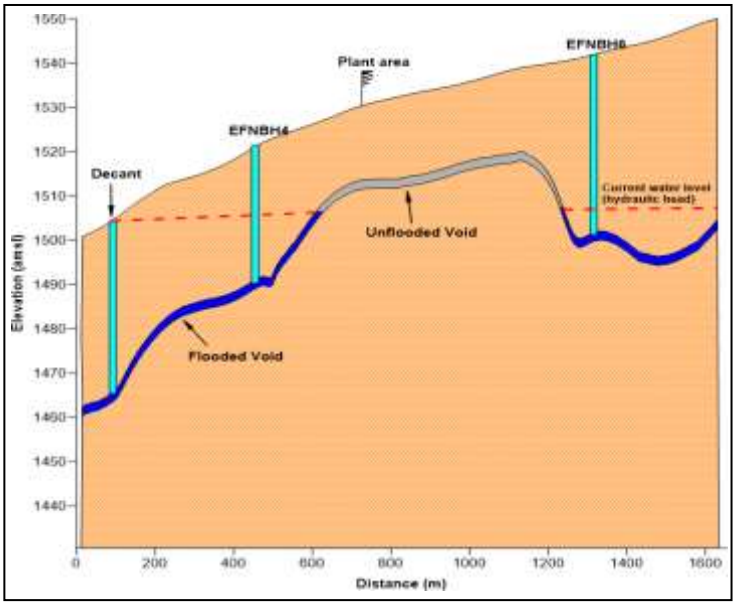


Figure 3-18: Hydrogeological profile along the line AB in Figure 3-17 (Digby Wells, 2015).

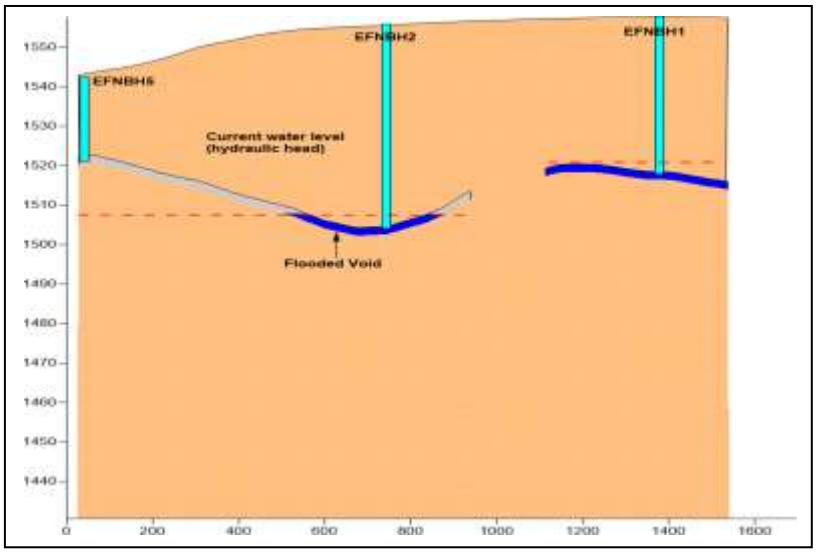


Figure 3-19: Hydrogeological profile along line CD in Figure 3-17 (Digby Wells, 2015).

Groundwater management

The inflow of groundwater to the underground workings is a function of rainfall. It is estimated on average 8 % of the rainfall recharges the groundwater.

The water reported in the underground workings during the primary extraction was 3 %. The groundwater must be pumped out of the workings but since the water is contaminated by chemical and biological processes that take place underground, the water needs to be treated. The water will be treated in pollution control dams (PCDs)

3.4.3 Sponcom

Sponcom of coal is the fire caused by the reaction between coal and oxygen (Coaltech 2020, 2011). The process resulting in sponcom is shown in Figure 3-20.

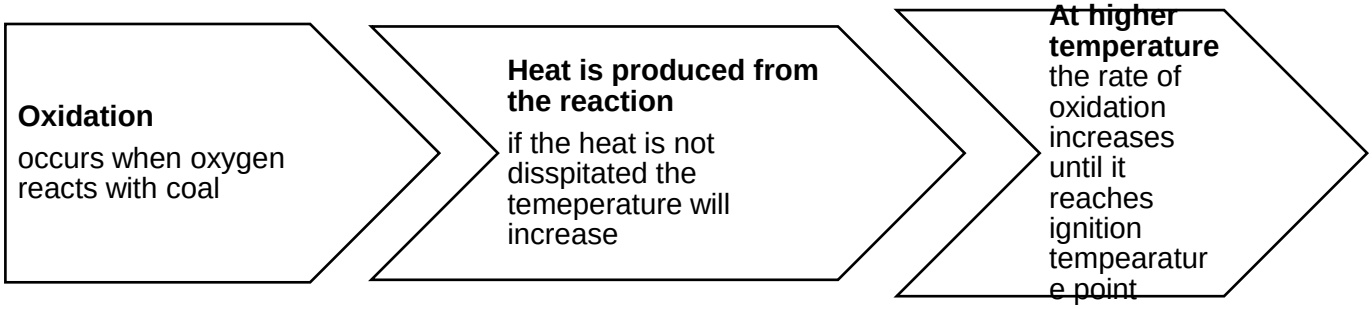


Figure 3-20: Sponcom formation (Coaltech 2020, 2011).

Factors affecting sponcom

The tendency of coal to spontaneously combust is due to intrinsic and extrinsic factors shown in Table 3-13.

Table 3-13: Intrinsic and extrinsic sponcom factors (Coaltech 2020, 2011).

Intrinsic	**Extrinsic**
-Coal type (composition, rank, and petrographically constituents) - Coal friability - Moisture content - The presence of pyrites	-Climatic condition -Stockpile compaction -Dump consolidation -Presence of timber -Excavation stability -Strata conditions -

Primary causes of sponcom

In underground mines, sponcom can occur where the air gets into the workings through cracks or openings. Where seams overlie the workings are being mined cracks can be induced. The sponcom can also form as a result of broken coal left underground that is

in contact with sluggish airflow. Only one out of ten underground pillar extraction mines investigated had problems with sponcom (Coaltech 2020, 2003). Proper ventilation will eliminate the heat and preventing increased coal temperature.

On the surface, sponcom is associated with coal and waste stockpiles. The problem increases as a result of rainfall as it exposes more coal to the atmosphere (Coaltech 2020, 2011). Sponcom may take place in the following conditions:

- Coal outcrops:
- Shallow workings exposed by subsidence; and
- Tailings dams.

Although there have been many cases of sponcom in underground coal mines in South Africa, Major occurrences of sponcom are associated with opencast pillar mining as mentioned in Chapter 2 (Coaltech 2020, 2011).

Preventing spontaneous combustion on surface

Tailings (plant rejects) and discard. Tailing dams should be covered with 1m of non-carbonaceous material and the area must be vegetated (Sloss, 2015).

Product. Attention must be placed when where there is a separation of material sizes because of stockpiling strategy. A layer of coarse material at the edges of the stockpiles may result in increased air passing through the coal (Sloss, 2015).

4 Economic Evaluation

The DCF method is the most used economical tool across the world to estimate the value of mineral assets. Cashflow is simply the money derived from the project subtracted by the money going out of the project. According to Lilford (2011, p6) the method "*is based upon the principle that any initial investment in a mining opportunity, the investor will look to the future cash flows to provide a minimum return over their hurdle rate on that investment*". The DCF requires estimation of the following;

- Production schedule;
- Saleable products;
- Products price;
- Capex;
- Opex; and
- Royalty and income tax.

The DCF model is constructed in an Excel spreadsheet format. The model is in Rand (R) currency. This economic evaluation is important for the company and investors as it evaluates the viability and profitability of the project. It can also assist other mining companies to assess the opportunity and risks associated with pillar extraction. The cashflow will analyse the following:

- Cashflow over 2,4 years (1 year of development and 1,4 years of production);
- NPV and IRR; and
- The Payback period of Capex

4.1 Project sales

Gross revenue is the product of the annual ton produced, ore grade, mine recovery, process recovery, and commodity price (Tashbrun, 2005). Namane Resources has only two markets that will be considered in the study and are as follows:

- Export; and
- Domestic (Eskom).

4.1.1. Export

Almost all South Africa's coal exports are routed through Richards Bay Coal Terminal (RBCT) via a dedicated coal railway line, with minor quantities exported through Maputo and Durban. The shareholders of these ports are mining companies that also use the facility to export their coal. Non-shareholders can use the port through negotiated agreements with one or more shareholders that have a spare capacity (Namane Resources, 2013).

RBCT 1

The RBCT (5,700 kc NAR (Net As Received) min) FOB (Free on board) marker assesses the price of coal out of Richards Bay, South Africa, with the following specifications:

- 5,700 kc/kg NAR minimum CV;
- 1% max sulphur;
- 17% max ash;
- 13% max total moisture; and
- 21% minimum volatile matter (Intercontinental exchange, 2020).

The No.1 Seam washability analyses done in 2011 reveals that the primary product has the aforementioned qualities of 17% ash, 26,86MJ/Kg CV, and 0,82% total sulphur which meets the Richard Bay specification. The price of export is estimated to be $61/t in 2020 as shown in Figure 4-1 which equates to R 915/t.

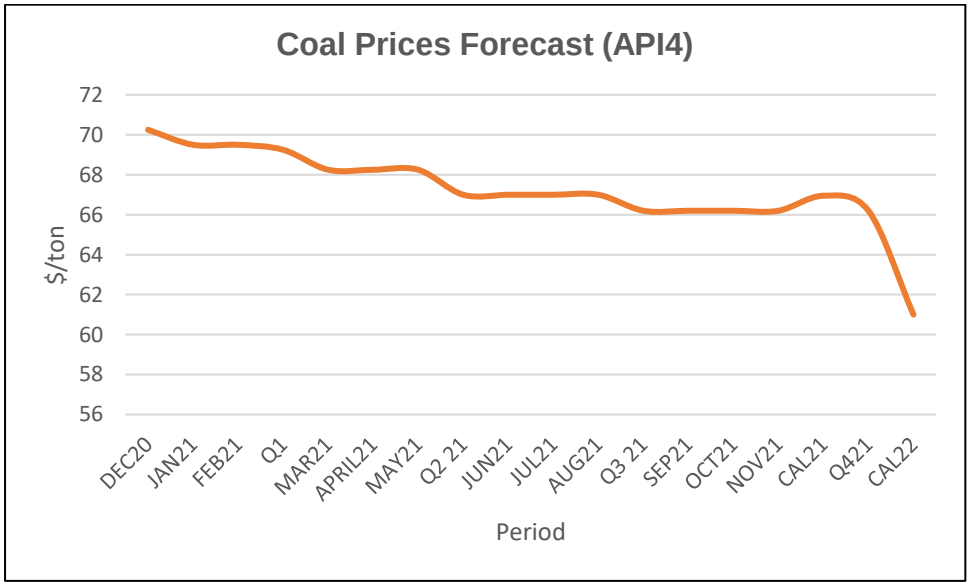


Figure 4-1: Coal prices Forecast (Intercontinental Exchange, 2020)

4.1.2 Domestic/ Eskom

Eskom's power stations have been specifically designed to burn low-grade coals which are abundant in South Africa. Eskom consumes ~62% of domestically sold coal per annum from which it provides ~90% of the country's electricity (Namane Resources, 2013). Eskom is currently purchasing coal as feedstock for the power station at approximately R19/GJ which equates to R380/t.

4.2 Projects expenditure/costs

The project's expenditure can be categorized into capital and operating expenditure. Capex is the money used to purchase items like machines to start a mine, working capital

is the money used for material and salaries and wages, and replacement capital and improvements. Opex (operating expenditure) are costs determined based on mining, treatment, engineering, and administration. Opex can be classified as direct, indirect, fixed, and other associated costs (Tashbrun, 2005). The cost inputs used in the DCF model have been based on a combination of recent manufacturer quotes and experience and are estimated to an accuracy of +/- 30%.

4.2.1 Project's Capex

The project's capital is categorized into mining, CHPP, and Environmental Capex. The total Capex is estimated to be ZAR 17.8 M.

Mining Capex

The mine workings were abandoned when the mine reached its end in 2013. Therefore, before mining commences, roof support and electricity must be installed. The existing shaft needs to be refurbished, a rock engineering study will be undertaken to investigate the stability of the existing potholes. There must be a re-establishment of the existing vent shaft and equipping it with a vent fan. The water accumulated underground must be pumped out therefore the mine will incur pumps and piping costs.

Table 4-1: Mining Capex cost breakdown

Service	Price R M
Shafts	2.5
Ventilation	3.8
Ventilation walls	1.5
Pumps and pumping (pumping water out)	1.1
Pumps and pumping (pumping water in)	0,9
Electricity	3.0
Support	2.0
Belt and belt structure	3.0
Total	**17.8**

CHPP Capex

Elandsfontein Colliery has an operating wash plant. Therefore, there is no Capex expected associated with CHPP.

Environmental Capex

As established in the previous chapter, the water that will be pumped out of the underground working before and during mining to the PCD as the water is contaminated. The mine has already put in place plans to construct PCDs to increase the water handling capacity of the mine. The construction of PCDs will therefore not be part of this research budget.

Capex summary

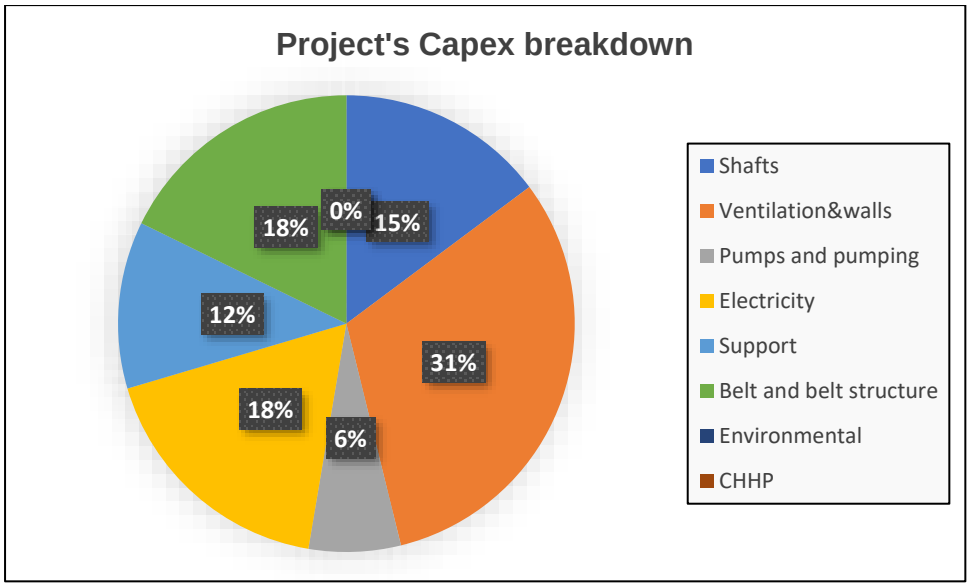


Figure 4-2: Project's Capex breakdown

As mentioned, 100% of the project's Capex will be mining Capex with CHPP and environmental Capex being 0%. The highest cost is ventilation costs followed by electrical installation and belt and belt infrastructure and the lowest costs are pumping costs as shown in Figure 4-2.

4.2.2 Project's Opex

The project's Opex is categorized into mining, CHPP, and Environmental and logistics costs. The total operating expenditure is estimated to be R270,041 M.

Mining Opex

The Mining Opex includes:

- Administration and supervision;
- Labour, supplies, and maintenance; and
- Water and electricity

Administration and supervision. Legal appointments of the mine manager cover the Elandsfontein operation. The safety officer, environmental officer, and training officer are employed. Technical services that include: rock engineering, geology, surveys are currently outsourced.

Labour, supplies, and maintenance. Mining, support, and maintenance will be done by a reputable contractor that will report to the owners to ensure compliance. The contractor option usually means higher operating costs and lower capital costs because the contractor uses their equipment. The total cost for the duration of the project will be R157,2 M. Cost to mine the 520 564t is shown in Table 4-2.

Table 4-2: Mining Opex breakdown

Mining Labour	RM	40,0
Support	RM	5,2
Conveying	RM	9,8
Ventilation control	RM	5,8

Equipment maintenance	RM	4,0
Continuous miner	RM	10,0
Shuttle cars	RM	10
Diesel Powered machines	RM	4,8
Sundries	RM	5,0
Repairs and maintenance	RM	9,6
Capital Replacement	RM	53,0
Total OPEX	**RM**	**157,2**

Water and Electricity. Electricity is required in a mining operation to power mining equipment and facilities. Water is used for dust suppression and cooling. Water will be derived from PCDs, the pumping cost to get the water into the mine has been accounted for in the mining opex and piping infrastructure and maintenance in the capex.

CHPP Opex

Although the plant is owned by the mine, the running and maintenance of it are done by a contractor. The processing cost is R60/t which is calculated using 520 465t as feed tonnage which up adds up to R31,23 M.

Environmental Opex

During mining the following environmental aspects need to be monitored to comply with the Department of Mineral Resources (DMR):

- Air pollution;
- Noise pollution; and
- Discard dump.

All the aforementioned aspects are currently monitored as the mine is still operating so no cost will be incurred.

Logistics costs

The cost for export is R250/t for rail and port charges which are calculated for export tonnages of 275 846t adding up to R68,91 M total for export logistics cost. The cost of transporting Eskom coal to the power station is R50/t which is calculated using Eskom tonnages of 244 619t adding up to Eskom coal logistics cost of R12,23 M.

Table 4-3: Summary of Opex

	RM
Mining Administration and supervision Labour, supplies, and maintenance	 NC 157,2
CHPP	31,23
Environmental	NC
Logistics Thermal	 12,13

Export	69,48
Total	**270,041**

**NC=no cost incurred.*

The mining costs for this project are higher followed by logistics and CHPP. The project has low capital costs compared to the operating costs and this is mainly because the project will take place in an operating mine that already has an existing wash plant, roads, and offices.

The Capex is projected to be incurred in the early months of development and not expected during production. Opex is projected to be incurred in the second year at the start of production and is constant for the duration of the mine until the last month where only half of the production will be produced (Figure 4-4).

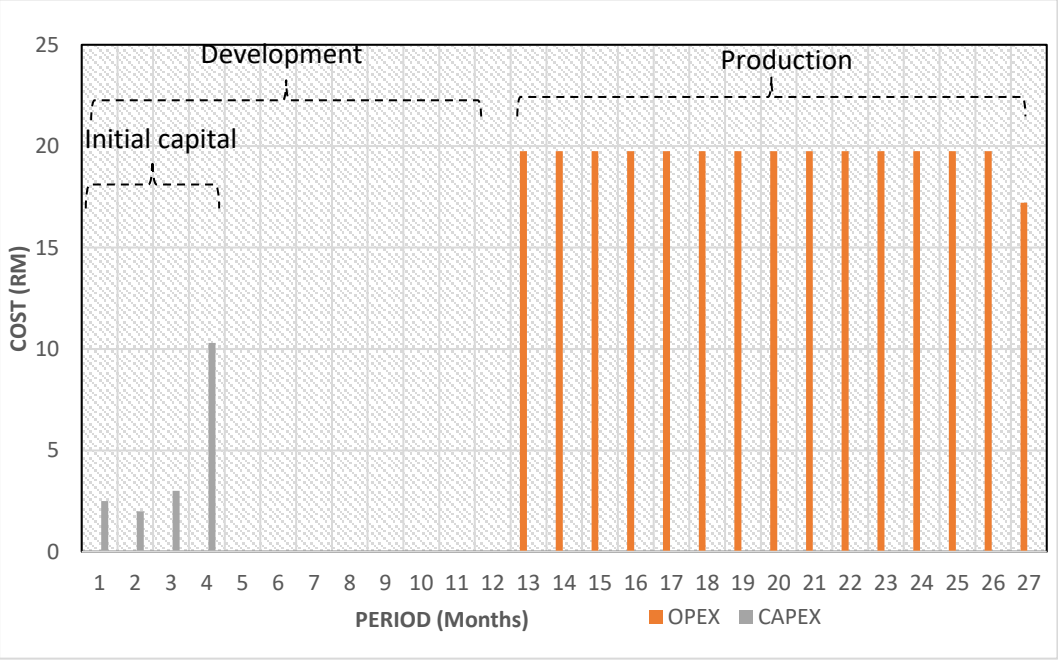


Figure 4-4: Project's Capex and Opex distributed over the Life of Mine.

9.3 Taxation

The types of taxes the host governments derive from the mine companies include:

- royalties which are taxes on the revenues;
- import taxes which are taxes on the operating profits;
- withholding taxes; and
- free ownership where the host country doesn't buy shares but still has a share of ownership (Allen, 2012).

South African Revenue Services (SARS) is responsible for the taxation of South African goods and services. "*SARS was established by the SARS Act as an organ of State within the public administration outside of public service*" (Cohen, 2010, p10).

SARS Act

"*To make provision for the efficient and effective administration of the revenue-collecting systems of the Republic and the control over the import, export, manufacture, movement, storage or use of certain goods; and, for this purpose, to reorganize the South African Revenue service and to make provision for the establishment of advisory committees; and to provide for incidental matters*" (Cohen, 2010, p11)

SARS is mainly responsible for collecting revenues and facilitating trade/customs. Taxes can be categorized into direct taxes, indirect taxes, and others.

4.3.1 Direct taxes

Direct taxes are taxes related directed at production(royalties) and profit (income tax).

Income/Corporate taxes

Income/ corporate taxes are administered under the Income-tax (corporate) act which section 5 states:

> *"Subject to the provisions of the Fourth Schedule (PAYE and Provisional tax) there shall be paid annually for the benefit of the National Revenue Fund, an income tax in respect of taxable income received by or accrued to or in favour of*
>
> *-any person (other than a company) during the year of assessment ended the last day of February each year; and*
>
> *-any company during every financial year of such company"* (Cohen, 2010, p13).

The income corporate tax is estimated to be 28% for this project.

Royalty tax

Royalty tax is administered by the Mineral and Petroleum Resources Royalty Act, No. 28 of 2008. The act states the following:

> ***"2**. A person that wins or recovers a mineral resource from within the Republic must pay a royalty for the benefit of the National Revenue Fund in respect of the transfer of that mineral resource.*
>
> *Royalty formulae*
>
> ***(1)** The percentage mentioned in section 3**(1)** is **0.5** + learnings before interest and taxes/ (gross sales in respect of refined mineral resources **x 12.5)] x 100.***

(2) *The percentage mentioned in section 3****(2)*** *Is* ***0.5*** *+ [earnings before interest and taxes/ (gross sales in respect of unrefined mineral resources x* ***9) | x 100.*** *(3) (a) The percentage determined in terms of subsection* ***(1)*** *must not exceed* ***5*** *percent."* (Cohen, 2010, p13).

4.3.2 Indirect taxes

Indirect taxes are taxes on transactional prices (Value added tax) and levies on imports and exports (excise tax).

Value-added taxes (VAT)

VAT is administered under the VAT act and it is 15% in South Africa levied on all goods and services.

Excise taxes

Excise taxes are administered under the Customs and Excise act 91 of 1964. It is levied on imported equipment and export production. The excise tax for coal is 0%.

4.3.3 Others

Other taxes among many include skills development and unemployment benefit fund.

Skills development levy

Skills development levy is administered under the Skill Development Levy Act which states the 1% of payroll must be directed to skills development.

Unemployment fund

Unemployment Fund tax administered under Unemployment contribution is 1% of the payroll.

Table 4-4: Tax costs breakdown

Tax	Percentage (%)
Income tax	28%
VAT	15%
Customs and excise	0%
Unemployment Insurance Contribution	1%
Skills development levy	1%
Royalty	7%

4.4 DCF

A DCF was constructed using the input parameters mentioned in sections 4.1-4.3 to analyse NPV, IRR, and the payback period. The following parameters were used for evaluation:

- the number of tons is 3500t per month until the 14th month and 30462t on the 15th month;
- the life of mine is 15 months;
- 53,6% of the produced will be for export and 46,4% for Eskom at a selling price of R918 and R380 respectively;
- The capital of 17,8 million;

- Operating costs R518 per ton;
- Corporate tax of 28% and;
- Royalty was calculated using the unrefined mineral formulae mentioned in 4.3.1.

The total operating costs were deducted from the revenues to determine cashflow before interest and tax (EBIT). The capex was deducted to determine operating profit after capex. The royalties were calculated as 2,96% throughout the LOM. The royalty was deducted to determine cashflow before tax. The corporate tax of 28% was deducted to determine the net cashflow. The net cashflow becomes positive on the fourth month of production.

Table 4-5: Payback period

Initial investment	17,8 million
Cashflow for month 1	R5 060 167
Cashflow for month 2	R5 060 167
Cashflow for month 3	R5 060 167
Cashflow for month 4	R3 229 172
Cashflow for month 5	R3 229 172
Cashflow for month 6	R3 229 172
Cashflow for month 7	R3 229 172
Cashflow for month 8	R3 229 172
Cashflow for month 9	R3 229 172
Cashflow for month 10	R3 229 172

cashflow for month 11	R3 229 172
cashflow for month 12	R3 229 172
cashflow for month 13	R3 229 172
cashflow for month 14	R3 229 172
cashflow for month 15	R3 229 172
Net Cashflow inflows	R 20 531 460
Payback period	3 months+(0,8) = 3,8 months

Table 4-6: Economic evaluation summary

	Units	**Value**
Physicals		
Mine Life	Months	15
Total RoM	t	520 465
Total export product	t	278 969
Total Eskom product	t	242 537
Economic results		
Sales Revenue	RM	346,023
Total Project costs	RM	287,84
Initial CAPEX	RM	17.80
OPEX	RM	270,041
NPV	*RM*	
Discount rate		
0 %		R 20 531 460
5 %		R 17 415 041

7,50 %		R 16 051 740
10 %		R 14 800 687
12,50 %		R 13 650 632
15 %		R 12 591 661
IRR	%	91
Payback period	months	3,8 months

5 CONCLUSIONS

5.1 Introduction

The pillar extraction cost model can be used to determine the economic viability of an old, existing, or new mining property or venture. It indicates whether the pillar extraction is economically viable after careful consideration of all technical aspects including geological, mining, CHPP, and environmental elements of the pillar extraction project.

5.2 Technical Aspects

5.2.1 Geological elements

The Coalfield is made up of three coal sequences: No.2 Seam sequence comprising of No. 1 and No.2 Seam, No.4 coal sequence comprising of No.3 and No.4 Seams, and No.5 coal sequences comprising of No.5 Seam. In Elandsfontein Colliery, the seams present are No.5, No.4 upper and lower, No.3 Seam, No.2 Seam, and No.1 seam, and No.1 Seam lower. The seam generally is high-quality coal that has an ash content of 32,87% and a CV of 20,99MJ/Kg. Sulphur content is 1,28%. The No.1 Seam was previously mined both underground and opencast at a rate of 5000t/annum. The gross in situ resource of the underground workings is 1,2 M t.

5.2.2 Mining elements

Pillar extraction is considered to be a high-risk mining method. The immediate roof of the No.1 Seam typically consists of a coarse-grained conglomeratic sandstone matrix. Elandsfontein Colliery will make use of roof bolts breaker lines. The selection of the pillar

extractions method is based on the roof stratigraphy, pillar width, and other aspects such as surface subsidence. The method that will be applicable will be the checkerboard. The RoM from pillar extraction is estimated to be 35 000t/month. The LoM is 15 months.

5.2.3 CHPP elements

The Elandsfontein plant will beneficiate the RoM coal from the underground No. 1 resources to produce coal products split between export (53,6%) and domestic (46,4%). The coal will be washed and the primary product will be for the export market. The secondary product will be blended with the No. 2 Seam from the opencast pit that will be crushed and screened and sold to Eskom.

5.2.4 Environmental elements

Subsidence in collieries applying the checkerboard, the pillar extraction method is either minimal or doesn't occur at all. There is no vertical hydraulic movement and the mine void has not impacted the shallow weathered aquifer. The underground void has been divided into compartments namely the Southern(dry), Northern (75% flooded), Eastern (completely flooded), and Western (90% flooded) compartments. The water reported in the underground workings during the primary extraction is 3%. The groundwater must be pumped out of the workings to the PCDs. There are some inconsistencies in the effect of pillar extraction on the water table.

Major occurrences of sponcom are associated with opencast pillar mining. In underground mines, sponcom can occur where the air gets into the workings through cracks on opening and can also be a result of broken coal left underground that is in

contact with sluggish airflow. Proper ventilation will eliminate the heat accumulation and thus preventing an increase in temperature underground.

5.3 Economic Evaluation

This economic evaluation is important for the company and investors as it evaluates the viability and profitability of the project.

5.3.1 Project's sales

The washed No.1 Seam has 17% ash, 26,86MJ/Kg CV, and 0,82% total sulphur which meets the RBCT 1 specification. The price of export is estimated to be $61/t in 2020 which equates to R915/t. Eskom is currently purchasing coal as feedstock for the power station at approximately R19/GJ which equates to R380/t.

5.3.2 Project's costs

The project's capex is estimated to be R17.8 M and Opex is R270,041 M. The mining opex for this project is higher followed by logistics and CHPP. The has low capital costs compared to the operating costs and this is mainly because the project will use the contractor option to extract pillars and the contractor will use their machinery. The other reason is that the project will take place in an operating mine that already has an existing wash plant, roads, and offices.

5.3.3 Taxes

Taxes are categorized into direct taxes, indirect taxes, and others. Direct taxes are taxes related directed at production(royalties) and profit (income tax) and are the only ones

that impact the cash flow significantly. The income tax is taxed at 28% and royalties at 2,9%.

5.3.4 DCF

The model was prepared with RoM of coal production 520 465 t over LoM of 1 year and 3 months. The normal tax rate of 28% for companies in South Africa was used in the model. The project has a positive NPV and high IRR which amounts to R12,59 M discounted at 15% and 91% respectively. It has a short payback period of 3,8 months; therefore, the project is deemed economically viable.

6 RECOMMENDATIONS

The mine should apply the checkerboard mining method to extract the No. seam pillars. Although the method has lower percentage extraction compared to NEVID, split and fender, and angled methods, due to the competent roof and sizes of the pillars the checkerboard is much safer.

Although the checkerboard method may have a lower extraction percentage, the project it's proved economically viable as it has a positive NPV and high IRR, and a short payback period (3,8 months).

REFERENCE LIST

Allen, H.E.K. (2012), Aspects of Evaluating Mineral Projects*, London: Imperial College of Science and Technology*.

Anker (2008), An Updated Independent Engineer's Report on the Due Diligence Audit of Anker Coal and Mineral Holdings South Africa (PTY) LTD. Unpublished company report.

Anker (2017), Amendment of the Environmental Management Program for the Elandsfontein Colliery. Unpublished company report.

Associated Rock Mechanics Services (2019), Rock engineering design for Elandsfontein underground section. Unpublished company report.

Cairncross, B., n.d. Cradle, A.B. (1987), A genetic stratigraphy for Permian coal-bearing Vryheid Formation in the east Witbank Coalfield, South Africa, *South Africa Journal of Geology,* Vol. 90(3), pp. 219-230.

Coaltech 2020 (2011), Prevention and Control of Spontaneous Combustion. Best practice guidelines for surface coal mines in South Africa. *Coaltech Research Association*.

Coaltech 2020 (2013), Economic and safe extraction of pillars and associated reserves using underground mining methods*. Coaltech Research Association*.

Cohen, A. (2010), Taxation in the mineral industry, 6 October, The University of the Witwatersrand.

Commonwealth of Australia (2014), Background Review - Subsidence from Coal Mining Activities. *Independent expert scientific committee on coal seam gas and large coal mining development*.

Digby Wells (2015), Amendment to the Environmental Management Program for Elandsfontein Colliery Groundwater Report. Unpublished company report.

Geo Soil & Water (2020), Elandsfontein Colliery Scoping Report. Unpublished company report.

Hancox, P.J, n.d. Götz, A.E. (2014), South Africa's Coalfields – a 2014 Perspective

Intercontinental exchange (2020), API4 Richards Bay Coal Futures. INTERNET Available at:https://www.theice.com/products/241/API4-Richards-Bay-Coal-Futures, [Accessed: 30 October 2020].

Kuestermeyer, A. (2001), Cash Flow Models-Dos, and Don'ts. *Pincock, Allen & Holt*, Vol. 6(16), pp. 4.

Kumar, A. (1986), Ground Control Ramification and Economic Impact of Retreat Mining on Room and Pillar Coal Mines. *University Microfilms international.*

Lilford, E. V, n.d. Minnitt, R. C. A. (2005), A Comparative Study of Valuation Methodologies for Mineral Developments*. The Journal of The South African Institute of Mining and Metallurgy, January 2005.* Vol. 102(7), pp. 29-41.

Lilford, E. (2014), Advanced methodology for mineral project valuation. *Australian Institute of geoscientists.* Vol. 53(53), pp. 50-62.

Lind, G. (2005), An Integrated Risk Management Approach for Underground Coal Pillar Extraction in South Africa. *The journal of the South African Institute of Mining and Metallurgy*, Vol. 105(2), pp. 137-146.

Mark, C., Chase. F., Pappas, D. (2003), Reducing the Risk of Ground Falls during Pillar Recovery. *National institute for occupational safety and health. Pitsburg.*

Namane Resources (2013), Temo Coal Project Feasibility Study. Unpublished company report.

Ngwenyama, P.L., de Graaf, W.W., n.d. Preis, E.P. (2017), Factors and Challenges Affecting Coal Recovery by Opencast Pillar Mining in the Witbank Coalfield. *The journal of the Southern African Institute of Mining and Metallurgy, Vol.* 117(3), pp. 215-222.

Petho, S.Z., Selai, C., Mashiyi, D., n.d. Van de Merwe, J.N. (2012), Managing the geotechnical and mining issues surrounding the extraction of small pillars at shallow depths at Xstrata Coal South Africa. *The journal of the Southern African Institute of Mining and Metallurgy, Vol.* 112(2), pp. 105-114.

Sloss, L.L. (2015), Assessing and managing spontaneous combustion of coal. *IEA Clean Coal Centre.*

The South African Mineral Asset Valuation Committee (The SAMVAL Code) (2016), The South African Code for the Reporting of Mineral Asset Valuation, (2016) Ed.

South African Mineral Resource Committee (The SAMREC code) (2017), The South African Code for the Reporting of Exploration Results, Mineral Resources, and Mineral Reserves, (2017) Ed.

Steele, S.M. (1973), Program Evaluation as an Administrative Concept. *University of Wisconsin - Madison, and Extension*, pp. 1.

Tosovic, D. (2017), Economic Evaluation of Small Deposits in the Applicable Function of the Business Decision in the Economy. *International journal of business and management invention,* Vol. 6(9), pp. 59-63.

Tschabrun, D. (2005), Economic Evaluation of Mining Projects. *Pincock Perspectives*, 85(71), pp. 4.

Vuuren. J.J. (2002), Assessment of Safe Mechanized Depillaring Methods for Anjan Hill, Chirimiri Colliery South Eastern Coalfields LTD India. *Rock mechanics Technology LTD*.

World Intellectual Property Organisation. (2015), Pillar Extraction Mining Method. *Patent Cooperation Treaty*.

Appendices

DCF calculated by excel model

DCF MODEL		2022											
	Month	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Period	0	0	0	0	0	0	0	0	0	0	0	0
PRODUCTION													
Total ROM Tonnes	t												
Export Product Tonnes	t												
Eskom Product Tonnes	t												
REVENUES													
Total Revenue	R/t												
Export Revenue	R915,00												
Eskom Revenue	R380,00												
COSTS													
Total Operating Cost	R661,65												
On-Mine Operating Costs	R361,65												
Mining	R301,65												
Coal Processing	R60,00												
Off-Mine Operating Costs	R300,00												
Transport	R50,00												
Port costs	R250,00												
EBITDA													
Gross Profit													
Gross Margin						-	-	-	-	-	-	-	-
CAPITAL													
Total Capital Costs	R	(R2 500 000)	(R2 000 000)	(R3 000 000)	(R10 300 000)								
Assessed loss carried forward		(R2 500 000)	(R4 500 000)	(R7 500 000)	(R17 800 000)	(R17 800 000)	(R17 800 000)	(R17 800 000)	(R17 800 000)	(R17 800 000)	(R17 800 000)	(R17 800 000)	(R17 800 000)
Operating Profit after Capex													
ROYALTY													
X=EBIT/Gross sales													
Royalty %=0,5+X/9 unrefined													
Royalty paid	R												
Operating Profit After royalty	R												
TAX													
Taxable Income	R												
Tax Payable	28%												
CASHFLOW		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Net Cashflow (monthly)	R	(R2 500 000)	(R2 000 000)	(R3 000 000)	(R10 300 000)	R0,00	R0,00	R0,00	R0,00	R0,00	R0,00	R0,00	R0,00

DCF MODEL		2023											
	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Period	1	1	1	1	1	1	1	1	1	1	1	1
PRODUCTION													
Total ROM Tonnes	t	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000
Export Product Tonnes	t	18760	18760	18760	18760	18760	18760	18760	18760	18760	18760	18760	18760
Eskom Product Tonnes	t	16240	16240	16240	16240	16240	16240	16240	16240	16240	16240	16240	16240
REVENUES													
Total Revenue	R/t	R23 336 600	R23 336 600	R23 336 600	R23 336 600	R23 336 600	R23 336 600	R23 336 600	R23 336 600	R23 336 600	R23 336 600	R23 336 600	R23 336 600
Export Revenue	R915,00	R17 165 400	R17 165 400	R17 165 400	R17 165 400	R17 165 400	R17 165 400	R17 165 400	R17 165 400	R17 165 400	R17 165 400	R17 165 400	R17 165 400
Eskom Revenue	R380,00	R6 171 200	R6 171 200	R6 171 200	R6 171 200	R6 171 200	R6 171 200	R6 171 200	R6 171 200	R6 171 200	R6 171 200	R6 171 200	R6 171 200
COSTS													
Total Operating Cost	R661,65	(R18 159 750)	(R18 159 750)	(R18 159 750)	(R18 159 750)	(R18 159 750)	(R18 159 750)	(R18 159 750)	(R18 159 750)	(R18 159 750)	(R18 159 750)	(R18 159 750)	(R18 159 750)
On-Mine Operating Costs	R361,65	(R12 657 750)	(R12 657 750)	(R12 657 750)	(R12 657 750)	(R12 657 750)	(R12 657 750)	(R12 657 750)	(R12 657 750)	(R12 657 750)	(R12 657 750)	(R12 657 750)	(R12 657 750)
Mining	R301,65	(R10 557 750)	(R10 557 750)	(R10 557 750)	(R10 557 750)	(R10 557 750)	(R10 557 750)	(R10 557 750)	(R10 557 750)	(R10 557 750)	(R10 557 750)	(R10 557 750)	(R10 557 750)
Coal Processing	R60,00	(R2 100 000)	(R2 100 000)	(R2 100 000)	(R2 100 000)	(R2 100 000)	(R2 100 000)	(R2 100 000)	(R2 100 000)	(R2 100 000)	(R2 100 000)	(R2 100 000)	(R2 100 000)
Off-Mine Operating Costs	R300,00	(R5 502 000)	(R5 502 000)	(R5 502 000)	(R5 502 000)	(R5 502 000)	(R5 502 000)	(R5 502 000)	(R5 502 000)	(R5 502 000)	(R5 502 000)	(R5 502 000)	(R5 502 000)
Transport	R50,00	(R812 000)	(R812 000)	(R812 000)	(R812 000)	(R812 000)	(R812 000)	(R812 000)	(R812 000)	(R812 000)	(R812 000)	(R812 000)	(R812 000)
Port costs	R250,00	(R4 690 000)	(R4 690 000)	(R4 690 000)	(R4 690 000)	(R4 690 000)	(R4 690 000)	(R4 690 000)	(R4 690 000)	(R4 690 000)	(R4 690 000)	(R4 690 000)	(R4 690 000)
EBITDA													
Gross Profit		R5 176 850	R5 176 850	R5 176 850	R5 176 850	R5 176 850	R5 176 850,00	R5 176 850,00	R5 176 850,00	R5 176 850,00	R5 176 850,00	R5 176 850	R5 176 850
Gross Margin		22%	22%	22%	22%	22%	22%	22%	22%	22%	22%	22%	22%
CAPITAL													
Total Capital Costs	R												
Assessed loss carried forward		(R12 623 150)	(R7 446 300)	(R2 269 450)									
Operating Profit after Capex		(R12 623 150)	(R7 446 300)	(R2 269 450)	5 176 850	5 176 850	5 176 850	5 176 850	5 176 850	5 176 850	5 176 850	5 176 850	5 176 850
ROYALTY													
X=EBIT/Gross sales		-54,09%	-31,91%	-9,72%	22,18%	22,18%	22,18%	22,18%	22,18%	22,18%	22,18%	22,18%	22,18%
Royalty %=0,5+X/9 unrefined		0,50%	0,50%	0,50%	2,96%	2,96%	2,96%	2,96%	2,96%	2,96%	2,96%	2,96%	2,96%
Royalty paid	R	(R116 683)	(R116 683)	(R116 683)	(R691 889)	(R691 889)	(R691 889)	(R691 889)	(R691 889)	(R691 889)	(R691 889)	(R691 889)	(R691 889)
Operating Profit After royalty	R	R5 060 167	R5 060 167	R5 060 167	R4 484 961	R4 484 961	R4 484 961	R4 484 961	R4 484 961	R4 484 961	R4 484 961	R4 484 961	R4 484 961
TAX													
Taxable Income	R	(R12 739 833)	(R7 562 983)	(R2 386 133)	R4 484 961	R4 484 961	R4 484 961	R4 484 961	R4 484 961	R4 484 961	R4 484 961	R4 484 961	R4 484 961
Tax Payable	28%	R0	R0,00	R0	(R1 255 789)	(R1 255 789)	(R1 255 789)	(R1 255 789)	(R1 255 789)	(R1 255 789)	(R1 255 789)	(R1 255 789)	(R1 255 789)
CASHFLOW		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Net Cashflow (monthly)	R	(R12 739 833)	(R7 562 983)	(R2 386 133)	R3 229 172	R3 229 172	R3 229 172,24	R3 229 172	R3 229 172	R3 229 172	R3 229 172	R3 229 172	R3 229 172

DCF MODEL		2024		
	Month	Jan	Feb	Mar
	Period	2	2	2
PRODUCTION				
Total ROM Tonnes	t	35000	35000	30462
Export Product Tonnes	t	18760	18760	16328
Eskom Product Tonnes	t	16240	16240	14134
REVENUES				
Total Revenue	R/t	R23 336 600	R23 336 600	R20 311 040
Export Revenue	R915,00	R17 165 400	R17 165 400	R14 940 120
Eskom Revenue	R380,00	R6 171 200	R6 171 200	R5 370 920
COSTS				
Total Operating Cost	R661,65	(R18 159 750)	(R18 159 750)	(R15 805 282)
On-Mine Operating Costs	R361,65	(R12 657 750)	(R12 657 750)	(R11 016 582)
Mining	R301,65	(R10 557 750)	(R10 557 750)	(R9 188 862)
Coal Processing	R60,00	(R2 100 000)	(R2 100 000)	(R1 827 720)
Off-Mine Operating Costs	R300,00	(R5 502 000)	(R5 502 000)	(R4 788 700)
Transport	R50,00	(R812 000)	(R812 000)	(R706 700)
Port costs	R250,00	(R4 690 000)	(R4 690 000)	(R4 082 000)
EBITDA				
Gross Profit		R5 176 850	R5 176 850	R4 505 758
Gross Margin		22%	22%	22%
CAPITAL				
Total Capital Costs	R			
Assessed loss carried forward				
Operating Profit after Capex		5 176 850	5 176 850	4 505 758
ROYALTY				
X=EBIT/Gross sales		22,18%	22,18%	22,18%
Royalty %=0,5+X/9 unrefined		2,96%	2,96%	2,96%
Royalty paid	R	(R691 889)	(R691 889)	(R602 195)
Operating Profit After royalty	R	R4 484 961	R4 484 961	R3 903 563
TAX				
Taxable Income	R	R4 484 961	R4 484 961	R3 903 563
Tax Payable	28%	(R1 255 789)	(R1 255 789)	(R1 092 998)
CASHFLOW		Jan	Feb	Mar
Net Cashflow (monthly)	R	R3 229 172	R3 229 172	R2 810 565

9