No. 5 seam mining at Kriel Colliery opencast

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Synopsis

The Kriel Colliery is an Anglo Coal mine which is contracted with Eskom to produce No. 4 seam for Kriel power station. The mine previously found it uneconomical to mine No. 5 seam due to the low qualities and tonnages of the seam, both at the opencast and underground sections. An area has been encountered for the first time at Kriel Colliery opencast pit 5, where the tonnage and qualities of No. 5 seam warrant further investigation. The primary reason for the investigation of No. 5 seam by Kriel Colliery is because of the advantage of the high selling price (R450/t) that the market is currently prepared to pay for the No. 5 seam.

The aim of this project is to mine No. 5 seam economically without interrupting No. 4 seam mining operations. The problem is that the equipments that are currently being used at the mine belong to Eskom and are dedicated to mining No. 4 seam only, not No. 5 seam.

Through geology investigation, it is found that the whole No. 5 seam (No. 5 seam upper and lower) has an average thickness of 1.8 m. It also contains a parting of carbonaceous shale which divides the seam into two parts. No. 5 seam upper contains less tonnage compared to No. 5 seam lower. The calorific value and ash content of No. 5 seam lower is far better than No. 5 seam upper, but would still require washing the coal. This makes No. 5 seam lower the preferred seam to mine because it meets the requirements of the customer which is Highveld Steel.

It is a coincidence that the area containing No. 5 seam under investigation encounters high overburden problems. The problem of drilling to No. 4 seam was going to be encountered because the thickness of the overburden ranges from 35 to 39 m. The Gardner Denver at the mine can drill blastholes only to a depth of 34.5 m, meaning the full overburden will not be drilled at once. This means the mining of No. 5 seam will do favours for Eskom because the overburden thickness will be minimized. This then led to an agreement between Anglo Coal and Eskom to mine No. 5 seam because both companies benefit from the project.

In order to identify a suitable mining method for No. 5 seam lower, literature studies took place. It is found that San Juan mine from the USA has similar geological features to Kriel Colliery's No. 5 seam. Through comparisons, it is found that truck and shovel mining would suit the geology of Kriel Colliery's No. 5 seam since San Juan mine is using it.

The sequence of mining No. 5 seam lower allows for a clearance of two cuts between the truck and shovel operation and the dragline. The mining sequence of No. 5 and 4 seam will be in the order of top soil removal; soft overburden pre-stripping; pre-strip drilling; pre-strip hard overburden; No. 5 seam lower coaling; interburden drilling and blasting; interburden stripping and No. 4 seam coaling.

Financial evaluation of the project shows that a contractor will charge Kriel Colliery (Anglo Coal) approximately R 102.2 million to mine No. 5 seam successfully. The sales of No. 5 seam lower will provide a profit of R99.4 million at a yield of 70% from the washing plant. The project is beneficial to both Eskom and Anglo Coal because Eskom will have eliminated the problem of pre-stripping and Anglo Coal will generate additional profit.

Through investigation and analyses of the project, it is proven to be viable and should take place. This is after looking at the advantages that the project has for Anglo Coal and Eskom.

Keywords

No. 5 seam, truck and shovel mining, Kriel Colliery, No. 5 seam mining at Kriel Colliery opencast, Anglo Coal and Eskom, No. 5 seam upper and lower, top soil removal, soft overburden pre-stripping, pre-strip drilling, pre-strip hard overburden, No. 5 seam lower coaling, interburden drilling and blasting, interburden stripping, No. 4 seam coaling.

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Introduction

Mine background

Kriel Colliery is an Anglo Coal mine which started operations in 1973. It has a life of mine of 19 years worth of reserves to mine and is expected to close down in 2029. The mine is producing coal and is contracted to mine No. 4 seam for Eskom[1]. There is underground room and pillar mining and opencast strip mining. The underground operations contain six continuous miner sections and the opencast contains two strip mining operations at pit 5 and pit 6. Table I represents the annual budgets for underground and opencast operations.

Locality

The mine is in the northern part of the Highveld coalfield, approximately 30 kilometres from Ogies and Bethal in Mpumalanga. The mine offices are adjacent to Kriel Power Station and are placed 12 km northwest of Kriel town. There is a network of tarred roads connecting Kriel Colliery with other collieries and surrounding towns. The road distances to Pretoria and Johannesburg are approximately 140 km, via the Pretoria/Middelburg motorway (N4) and Johannesburg/Witbank motorway (N12) respectively[2]. Figure 1 shows the location of Kriel Colliery in a red circle relative to other collieries.

General stratigraphy

The Kriel Colliery reserves are situated on the northern margin of the Highveld coalfield. Sediments of Vryheid and Dwyka formations underlay the area which was deposited on a glaciated Pre-Karoo basement consisting of Rooiberg felsites. The Vryheid formation is essentially an interbedded succession of sandstone with lesser gritstone, siltstone and mudstone, which contains five coal seams of the Highveld coalfield, as shown in Figure 5[3].

Surface and coal rights

Anglo Coal own the mineral rights in the mining authorization area allocated to meet the contractual coal supply commitment to Eskom. Anglo Coal owns 484 ha and the remainder of the surface rights belong to either Eskom or private landowners[2].

Project background

Kriel Colliery previously found it uneconomical to mine No. 5 seam due to the low qualities and tonnages of the seam, both at the opencast and underground. Therefore research into mining No. 5 seam has never taken place. An area has been encountered for the first time at Kriel Colliery opencast pit 5, where the tonnage and qualities of No. 5 seam warrant further investigation. The overburden thickness of No. 5 seam is shallow at a depth of between 8 m and 14 m, which includes both the hard and soft overburden[4].

Figure 2 shows the layout of No. 5 seam at Kriel Colliery and the area in a red circle is the area of study at the opencast pit 5. Figure 3 shows the enlargement of the study area which is divided into different cuts and zones for better identification of locations at the study area. The primary reason for the investigation of No. 5 seam by Kriel Colliery is the advantage of the high selling price (R450/t) that the market is currently prepared to pay for the No. 5 seam[5].

Table I

ROM annual budget for 20091

	ROM (Mt)
Underground	5
Opencast	5.5

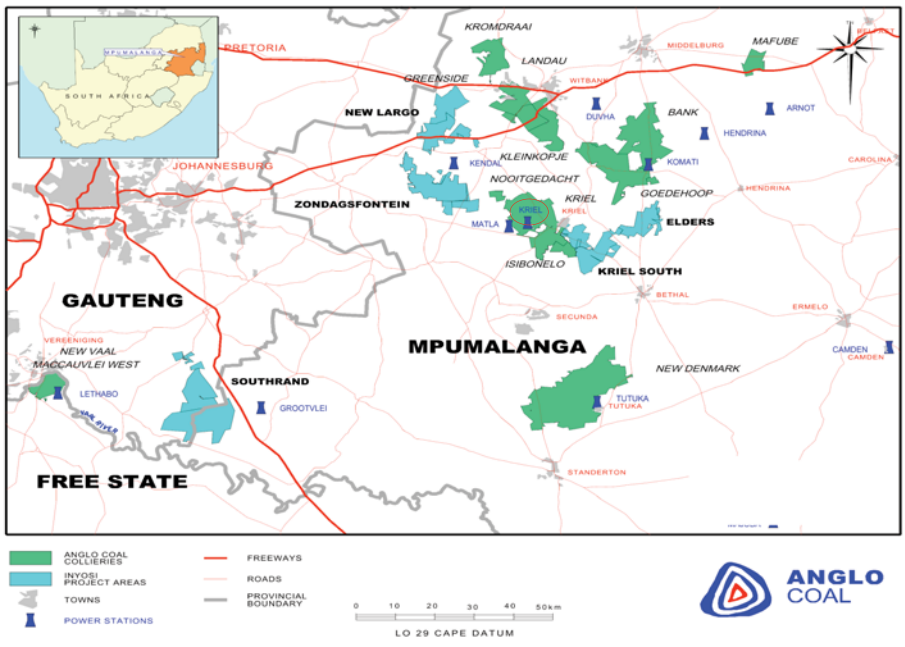

Figure 1—Location of coal mines[2]

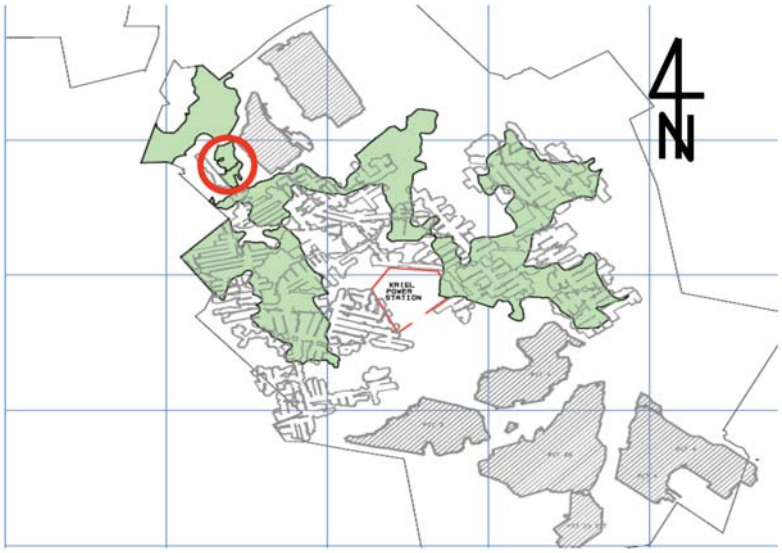

Figure 2—No. 5 seam layout at Kriel Colliery[6]

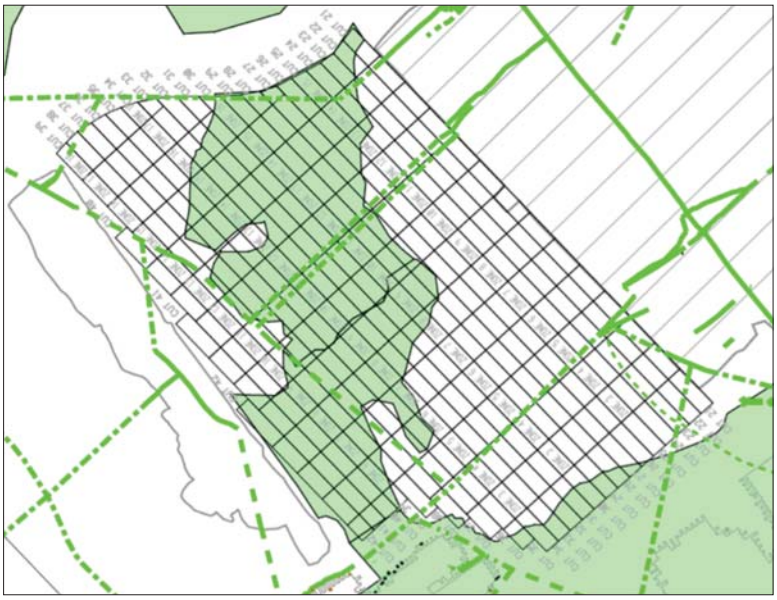

Figure 3—No. 5 seam layout of study area[6]

The same area contains No. 4 seam which Kriel Colliery has planned to mine for Eskom. The constraint now is how to mine No. 5 seam without disregarding No. 4 seam.[5]

Problem statement

The aim of this project is to mine No. 5 seam economically without interrupting No. 4 seam mining operations. Limitations have been encountered in the options of how No. 5 seam can be mined because of the geology and equipment availabilities. The following limitation is encountered in the mining of No. 5 seam:

- The equipment that is currently being used at the mine belong to Eskom and are dedicated to mining No. 4 seam only[4]. This means other equipment is needed to mine No. 5 seam.

Objectives

The objectives of the project are as follows:

- To investigate the geology of the study area and No. 5 seam, in order to obtain results. This may identify the high-quality areas to mine
- To analyse the results found from the investigation
- To prescribe a mining method of No. 5 seam, which will not interrupt No. 4 seam mining operations

This will focus on:

  - The equipment that will be involved
  - The sequence of mining the seam
  - Identifying limiting factors of mining No. 5 seam

- To investigate the financial valuation of mining No. 5 seam and how Eskom and Anglo Coal are affected

- To draw conclusions from the investigations and prescribed mining method
- To recommend solutions to the limiting factors of mining No. 5 seam.

Scope of study

The project was done at Kriel Colliery opencast. The research from the mine was carried out within a period of seven weeks during December 2009 and January 2010. The limitation on the research was the minimum time spent on practical exposure at pit 5 of the study area.

The No. 5 seam geology investigation was done with the help of the geology department. Information on the calorific value and seam thickness was obtained, together with the overburden thickness of No. 4 seam and No. 5 seam. The tonnages of the soft and hard overburden were also investigated. Certain qualities of No. 5 seam were not investigated because the potential market buyer of No. 5 seam was interested only in the calorific value, ash content and volatile matter content. Therefore the following qualities were not covered:

- Moisture content
- Coking properties
- Sulphur and phosphorus content
- Liability to spontaneous combustion.

A mining method was chosen and it suited the type of geology at pit 5. The sequence of mining was done, but there were no specifications on the exact type of equipment model required. Financial studies were done on the project and included transport and washing costs at Greenside.

Methodology

In order to accomplish the goals set for this project, the following methods were used:

- Visits to the opencast mine were done regularly to observe the current No. 4 seam mining operations.
- Interviews were conducted with certain employees at the opencast offices and mining site of opencast pit 5. This was done to get a better understanding of how draglines and other equipment operate on a daily basis.
- The geology of No. 5 seam was investigated.
- Literature review – researched similar projects from other mines.
- Investigated all the available options to mine the No. 5 seam.
- Analysed all the financial aspects of the project.

Literature study

San Juan mine background

Different mining methods are applied to suit the geological settings of the area of interest. San Juan mine is a coal mine located in the USA. It is situated in the state of New Mexico adjacent to Colorado. The mine started operations in 1973 and supplied coal to a power plant. The coal at the mine lies in the Juan Basin which is one of the largest coal basins in the United States. There are only two mineable seams at San Juan. The seams are 4.6 and 1.5 m thick with the thicker seam present throughout the property and the 1.5 m seam occurring at a higher elevation over about half of the property[7].

Pre-stripping equipment and method

The two large draglines used at San Juan mine had already developed over half of the pits. It then reached a stage when it was necessary to mesh the pre-stripping design into the existing dragline operation. Pre-stripping involves removing material in advance of the dragline, around the end of the pit, and depositing it on top of the dragline spoil several rows behind the dragline[8].

In selecting the method and equipment, the system must be:

- Compatible with the dragline operation
- Technologically proven
- Capable of doing the job
- Cost-effective[8].

Based on these parameters, several alternatives were considered by San Juan mine.

Truck and shovel

This system has many advantages, with the main one being that it is a proven system around the world and is flexible as evidenced by the wide range of applications[8].

Conveyors and stackers

The conveyors and stackers are loaded by shovels or draglines. It is a continuous haulage system which appears to be an increasingly popular mode of material transport. The system's advantages are that it is less labour intensive and usually the operating cost is less per ton. The major disadvantages are the high capital cost, less flexibility operationally, and lack of adaptability to changes in production levels[8].

Conveyor/stacker and bucket wheel excavator combination

Bucket wheel excavators have many attractive features but are limited to primarily loose, unconsolidated soils or sediments. Overburden, which requires drilling and blasting, does not suit bucket wheel excavators. The overburden of San Juan mine is composed of sandstone and shale layers, some of which requires blasting with a relatively high powder factor. This means bucket wheel excavators would not be an option[9].

Best alternative chosen by San Juan mine

From the available options considered, a truck and shovel system was selected. The two seams at San Juan were separated by 32 to 36.6 m of parting. The overburden over the upper seam ranges up to 47 m. It was then decided by the mine that the draglines would operate at the bottom of the upper seam and strip the partings. The shovel would then simultaneously strip the overburden above the upper seam leaving 60 degrees slope of bench walls, as illustrated in Figure 4. This was done to avoid the problems inherent in multiple seam dragline operations and for safety[9].

Geology investigation and results

Stratigraphy

As mentioned before, Kriel Colliery is part of the Highveld coalfields. Approximately 500 boreholes have been drilled.

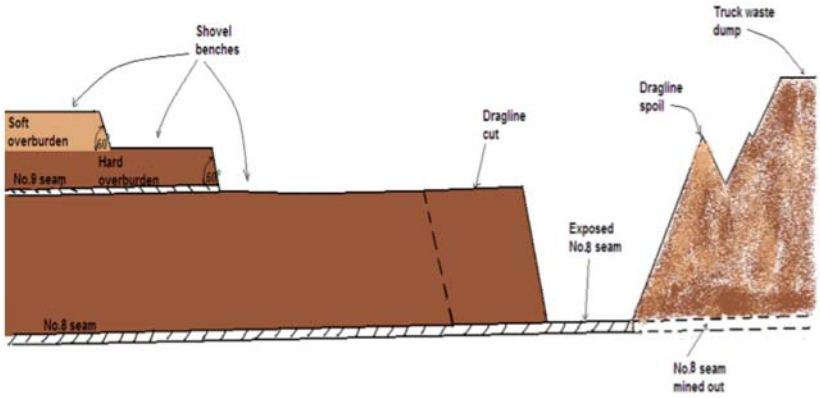

Figure 4—Typical mine plan cross-section of San Juan[9]

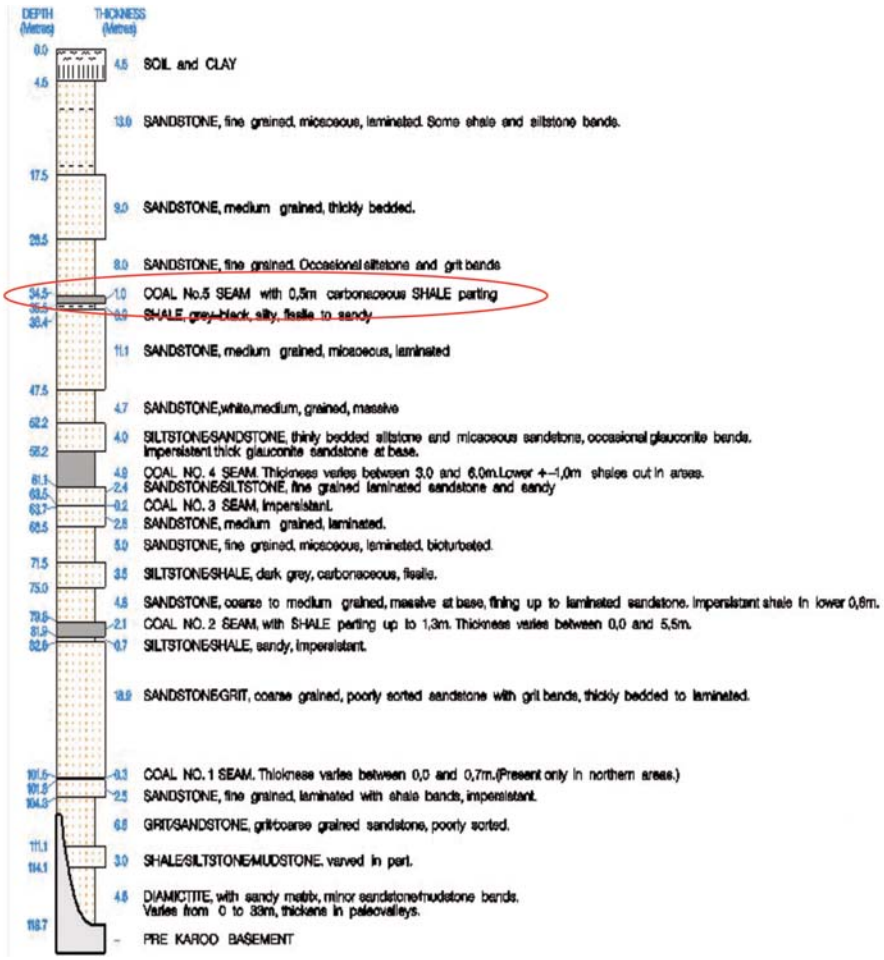

Figure 5—Stratigraphic column of Kriel Colliery[6]

The data collected from the boreholes helped to gain knowledge about the geology and stratigraphy. Figure 5 represents the stratigraphy of Kriel Colliery which is uniform throughout the Kriel coalfields. The red mark surrounds No. 5 seam which is the seam under investigation. The No. 4 seam below No. 5 seam generally has a flat to gently undulating topography. In areas where a dolerite sill has cut through, the seam encounters faults and some areas slightly tilted along the margins of the fault. The coal is generally burnt in those areas. The intrusions caused vertical throw on the faults which vary from 6 to 25 m. Few dykes have been located on the surface. It is probably so because they are not numerous and the thick soil covers them[10]. Weathering of the sandstone from surface has taken place on certain parts of the mine. The depth of the weathering varies and leaves behind soft overburden. Below the soft overburden is non-weathered sandstone which overlies the whole No. 5 seam and is regarded as hard overburden[6].

No. 4 seam

The No. 4 seam is found in most of the area and it is unmined in areas that have undergone weathering or been burnt by dolerite. The seam has thicknesses that vary from 3 to 6 m, but is remarkably consistent at approximately 4.9 m in thickness. The coal is commonly dull-lustrous, with a few bright bands, and has an average calorific value of 21 MJ/Kg. The top third of the seam contains inferior coal interbedded with bands of shale, carbonaceous shale and coaly shale[10].

No. 5 seam

The No. 5 seam is found on certain parts of Kriel Colliery as shown in Figure 2. Figure 6 shows the No. 5 seam which is of interest to mine. The whole seam (No. 5 seam upper and lower) has an average thickness of 1.8 m. It contains a parting of carbonaceous shale which divides the seam into two parts. The parting has an average thickness of 0.2 m. No. 5 seam upper is sporadically developed and generally has less thickness of approximately 0.5 m. No. 5 seam lower is more consistently developed and has a thickness of approximately 1.1 m. No. 5 seam upper is overlain by non-weathered sandstone with fine particles of siltstone and underlain by the parting. No. 5 seam lower is overlain by the parting and underlain by shale[11]. The neighbouring Matla coal has the same No. 5 seam but with much more thickness and they mine the coal in a longwall mining method[6].

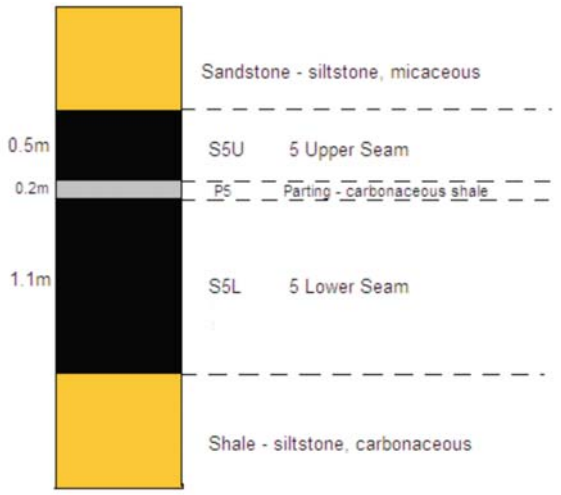

Figure 6—No. 5 seam stratigraphy[6]

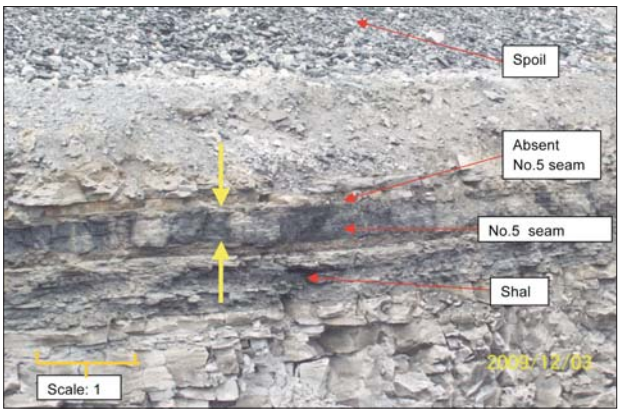

Figure 7—Exposed No. 5 seam lower

During the visit at the opencast, No. 5 seam lower was observed from the side of a highwall in cut no.23. No. 5 seam upper was absent in that area of No. 5 seam. The shale rock can be observed to be below the No. 5 seam at that area. The thickness of the seam in that area is approximately 0.5 m.

Overburden thickness

No. 4 seam overburden thickness

No. 4 seam has an overburden which needs to be stripped before exposing the coal seam. This takes place in the current strip mining operations. Figure 8 represents the overburden thickness of No. 4 seam. The thickness ranges from 25 to 42 m. The area surrounded by a black boundary is the study area of No. 5 seam. The thickness of that area ranges from 35 to 42 m. Kriel Colliery has practicsed pre-stripping in areas that have high overburden depths[4].

No. 5 seam overburden thickness

No. 5 seam, which is located above No. 4 seam on the stratigraphic column, contains overburden of lower thicknesses compared to No. 4 seam. The black boundary in Figure 9 surrounds the thickness of No. 5 seam overburden which has a thickness ranging from 5 to 15 m. The areas outside the black boundary do not contain No. 5 seam. The soft overburden of the area has more tonnages compared to the hard overburden. These values are shown in Table II together with the carbonaceous shale partings.

No. 5 seam qualities and thicknesses

Coal qualities and thicknesses are very important in making decisions on whether the seam is worth mining or not. No. 5 seam is identified to contain No. 5 seam upper and No. 5 seam lower, as shown in Figure 6. Therefore a separate investigation on No. 5 seam upper and lower has been done to identify the mineable areas.

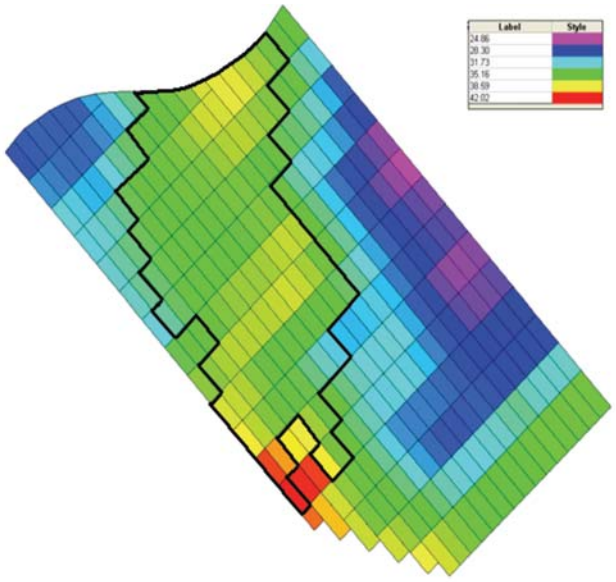

Figure 8—No. 4 seam overburden depth[6]

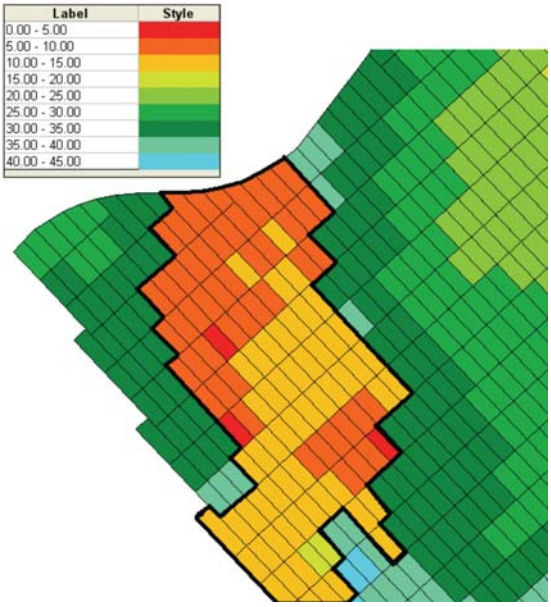

Figure 9—No. 5 seam overburden depth[6]

Table II

Overburden tonnages of No. 5 seam[6]

Material	Tonnages
Soft overburden	4 491 043.2
Hard overburden	234 995
Parting – carbonaceous shale	96 705

No. 5 seam upper

Calorific value of No. 5 seam upper

The black boundary in Figure 10 surrounds the calorific value of No. 5 seam upper. It is found that the calorific value of No. 5 seam upper varies between 5 and 25 MJ/kg. The average calorific value of the whole No. 5 seam upper is approximately 19 MJ/kg. It is also seen that there are about three zones of high calorific values in a red colour. The purple colour represents the areas that have an absence of No. 5 seam upper[6].

Thickness of No. 5 seam upper

Coal contamination during mining is mostly minimized by mining thick enough coal seams. Cut-off thicknesses of coal seams above 0.5 m has been the accepted thickness to mine[4]. Figure 11 represents the thickness of No. 5 seam upper and the black boundary surrounds the acceptable thickness of above 0.5 m. It has also been learnt that less tonnages are available compared to No. 5 seam lower. Table III represents the area, run of mine (ROM) volumes and tonnages of No. 5 seam upper.

No. 5 seam lower

Calorific value of No. 5 seam lower

The calorific value of No. 5 seam lower is surrounded by a

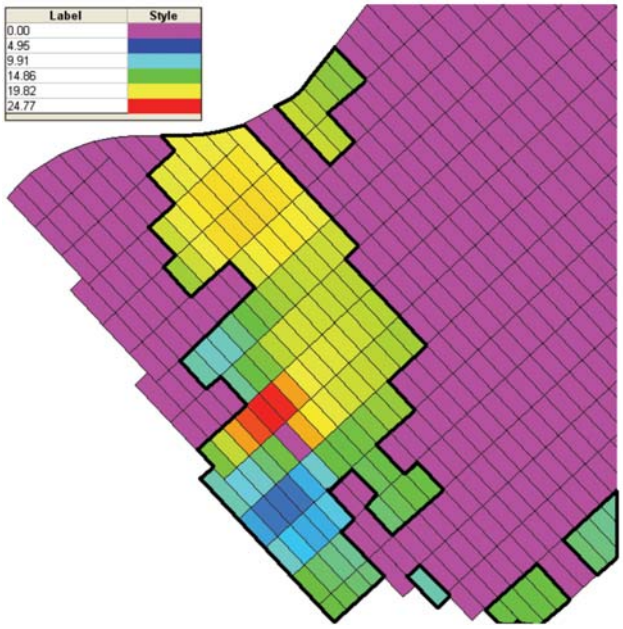

Figure 10—Calorific value of No. 5 seam upper[6]

Figure 11—No. 5 seam upper thickness[6]

Table III

No. 5 seam upper area, volumes and tonnages[6]

ROM tonnages	251 836 tons
ROM volumes	145 806 m^3
Area	145 806 m^2
Average CV (MJ/Kg)	19.0 MJ/Kg
Average volatile %	24.0 %
Average ash %	34.7 %

black boundary in Figure 12. The purple areas do not contain No. 5 seam lower. It is found that the calorific value of No. 5 seam lower varies between 20 and 26 MJ/kg. The average calorific value of the whole No. 5 seam lower is approximately 24 MJ/kg[6]. The quality is a lot better than No. 5 seam upper based on the available calorific values.

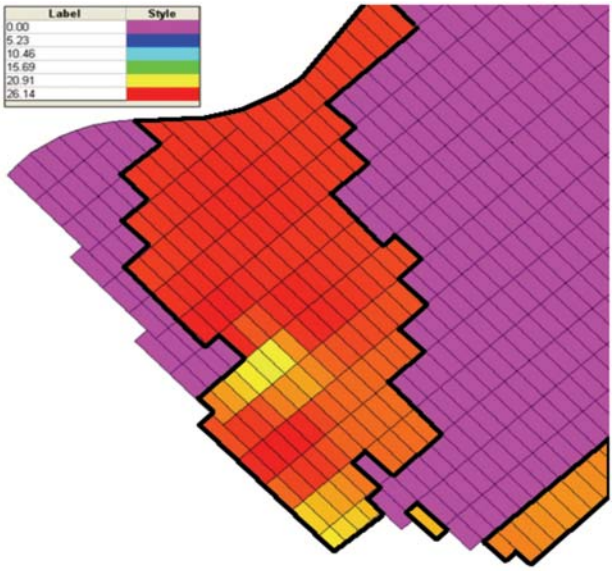

Figure 12—Calorific value of No. 5 seam lower[6]

Thickness of No. 5 seam lower

The thickness of No. 5 seam lower is represented by Figure 13. When using the cut-off thickness of 0.5 m, it is learnt that No. 5 seam lower contains more tonnages, volume and area compared to No. 5 seam upper. The area is represented by the black boundary. These values are represented by Table IV.

Analysis of geological results

Analysis of quality requirements by Highveld Steel

Table V represents the quality requirements by Highveld Steel together with the results of No. 5 seam upper and lower.

Analysing the investigation results, it is clear that No. 5 seam upper does not meet the requirements of the customer, particularly on the calorific value. No. 5 seam lower is within the range of what the customer is requesting, with the exception that the ash percentage will be reduced by washing the coal. No. 5 seam lower also contains more tonnages compared to No. 5 seam upper, which is a positive point.

These results then allow planning of mining No. 5 seam lower to take place because it has been identified as meeting the requirements. Figure 14 shows the area of interest in a black boundary for No. 5 seam lower, taking into consideration that the cut-off thickness is 0.5 m to avoid contamination of the coal during mining. This holds approximately 640 000 tons of coal[4].

Overburden thickness analysis

Kriel Colliery has a history of pre-stripping in areas of the opencast which have overburden thickness of 34.5 m and above. This is so because the Gardner Denver (GD) at the mine is limited to drilling overburdens with maximum thicknesses of 34.5 m[4]. Analysing the overburden thickness of No. 4 seam, it is found that the thickness ranges from 25 to 42 m, as stated earlier. It is also found that the same area containing the investigated No. 5 seam has thicknesses ranging from 35 to 39 m. This information gives evidence that pre-stripping was without doubt going to take place at areas with thicknesses above 34.5 m. The only unusual experience is that this time there is No. 5 seam located in the same area. Therefore taking into account that No. 5 seam

Table IV

No. 5 seam lower area, volumes and tonnages[6]

ROM tonnages	622 651 tons
ROM volumes	448 201 m^3
Area	501 465 m^2
Average CV (MJ/Kg)	24.9 MJ/Kg
Average volatile %	30.1 %
Average ash %	19.1 %

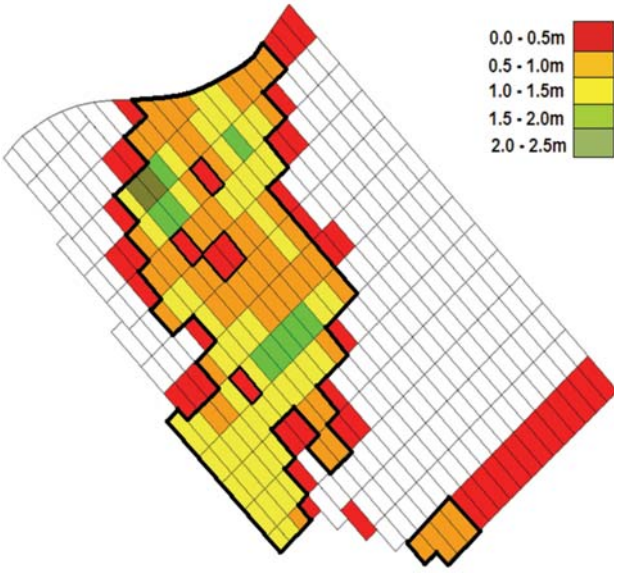

Figure 13—No. 5 seam lower thickness[6]

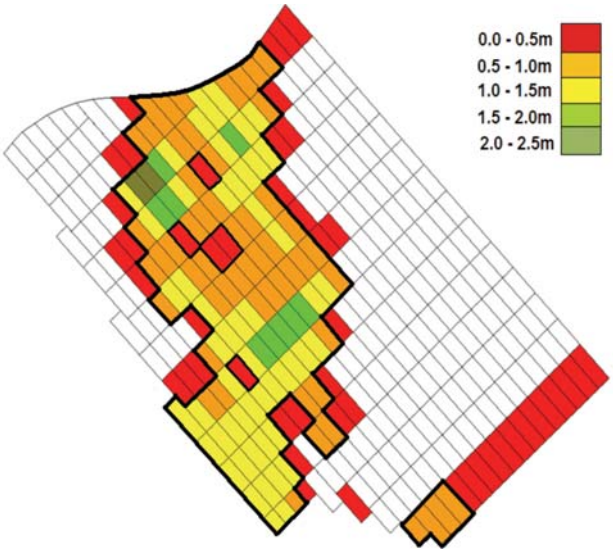

Figure 14—No. 5 seam lower thickness and area of interest[6]

lower needs to be mined and that pre-stripping needs to take place, Figure 15 shows the boundary within which No. 5 seam lower mining and pre-stripping must take place. The pre-stripping will involve removing the soft and hard overburden of No. 5 seam together with No. 5 seam upper and parting in order to expose No. 5 seam lower.

Investigation into mining method of No. 5 seam lower

Well-matched mining method of No. 5 seam lower

A literature study has shown that San Juan mine is successfully mining No. 9 seam with a truck and shovel method, whereas No. 8 seam is mined by dragline. The investigation into how No. 5 seam lower should be mined will start by comparing the mining environments of San Juan and Kriel Colliery. Table VI shows the comparison between the two mines.

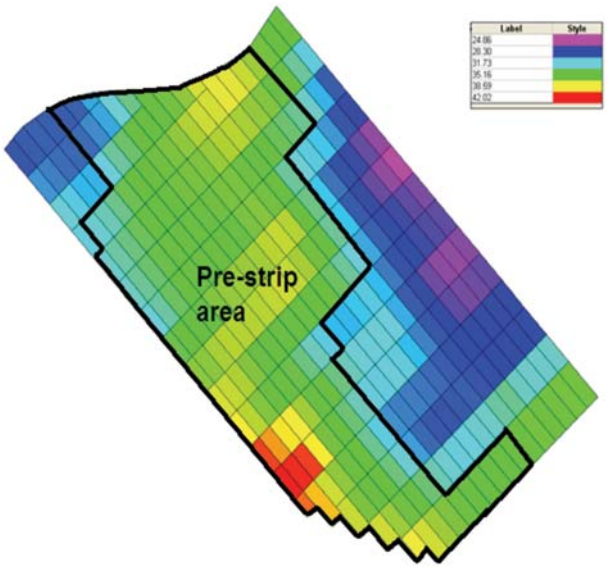

Figure 15—No.4 seam overburden depth with pre-stripped area[6]

Kriel Colliery and San Juan mine both encounter similar mining conditions as seen in Table VI. As mentioned, other alternatives such as conveyors and stackers system together with conveyors/stackers and bucket wheel excavator system were evaluated at San Juan mine. These systems failed mainly because of the following disadvantages:

- High capital costs
- Less flexibility operationally
- Lack of adaptability to changes in production levels
- Bucket wheel excavator is suited only for primarily loose and unconsolidated soils or sediments[8].

Based on the similarities between the two mines, a truck and shovel mining method would be recommended to mine No. 5 seam lower. This method has the advantage of good flexibility and has been proven to be successful internationally[8].

Sequence of mining

To achieve a well balanced mining operation of truck and shovel together with the dragline, enough clearance between the two operations would be necessary, and truck and shovel mining should be at least two cuts ahead of the dragline. This would avoid interruptions between the two mining operations. Figure 16 illustrates the plan view of the study area with all the operations that need to take place in their sequence. The legend represents the numerical order of the mining sequence.

Explanations of the operations that must take place are as follows:

- Top soil removal—this is the first operation that takes place in the sequence of mining. Trees and grass are removed by bulldozer and truck and shovel. They strip the top soil to the boundaries of the mining site so that the soil can be placed back during rehabilitation. Removal of the top soil will expose the soft overburden.
- Soft overburden pre-stripping—truck and shovel do the stripping and loading in one cut until the whole cut is

Table V

Coal qualities of No. 5 seam[11]

	Customer requests	No. 5 seam upper	No. 5 seam lower
Calorific value (MJ/Kg)	22.50–28.49	19.0	24.9
Ash %	12.9	34.7	19.1
Volatile %	32.0	24.0	30.1

Table VI

Comparison of Kriel Colliery and San Juan mine

Kriel Colliery	San Juan mine
Two mineable seams encountered which is No. 4 and No. 5 seam	Two mineable seams encountered which is No. 8 and No. 9 seam
No. 4 seam is 4.9 m thick	No. 8 seam is 4.6 m thick
No. 5 seam is 1.8 m thick	No. 9 seam is 1.5 m thick
Pre-stripping has been done before	Pre-stripping has been done before
Pre-stripped overburden is placed on top of dragline spoil[4]	Overburden of No.9 seam is placed on top of dragline spoil
Overburden composed of sandstone-siltstone and shale	Overburden composed of sandstone and shale
The two seams are separated by 30 m interburden[11]	The two seams are separated by 32 to 36.6 m of parting
Soft and hard overburden is encountered above No. 5 seam	Soft and hard overburden is encountered above No. 9 seam

completed. This operation does not require blasting because the overburden is weathered. The completion of this operation will expose the hard overburden.

- Pre-strip drilling—the shovel would not manage to load the hard overburden without drilling and blasting it. Therefore pre-strip drilling and blasting takes place to loosen the hard overburden for loading. In this case, drilling holes through No. 5 seam upper and the parting (carbonaceous shale) would minimize contamination of No. 5 seam lower. This operation has to always follow the soft overburden pre-stripping.
- Pre-strip hard overburden—once the drilling and blasting of the hard overburden and No. 5 seam upper has taken place, the truck and shovel come back and load the hard overburden. This operation will allow No. 5 seam lower to be exposed.
- No. 5 seam lower coaling—the coal will need to be drilled and blasted in order to achieve good fragmentation for loading with shovel into trucks. The completion of this operation will have left the mining site pre-stripped and allow the Gardner Denver to drill comfortably to the top of No. 4 seam.
- Burden drilling and blasting —this operation must take place in areas which never required pre-stripping and mining of No. 5 seam lower. Normal burden drilling by the Gardner Denver must take place in those areas to the No. 4 seam. Emulsion explosives are used because they can withstand wet conditions[13].
- Overburden stripping—the dragline removes the blasted overburden by first creating a solid pad on the blasted overburden to sit on. It then removes the overburden by loading it into the bucket and creating spoils on the mined out areas[13].
- Interburden drilling and blasting—this operation takes place in areas which have already been pre-stripped. It can be in areas that either had No. 5 seam lower mined out or pre-stripped areas because of high overburden thickness. Drilling is done by Gardner Denver until the top of No. 4 seam and emulsion explosives must be used because they withstand wet conditions[13].
- Interburden stripping —the dragline will also be removing the interburden in order to expose No. 4 seam. It will still have to create a pad on the blasted interburden to sit on. It will remove the interburden and create spoils on the mined out areas.
- No. 4 seam coaling—drilling and blasting of No. 4 seam will take place in order to achieve a good fragmentation for loading with a shovel into trucks. Drill techs are used to drill the coal and emulsion explosives are also used[13].

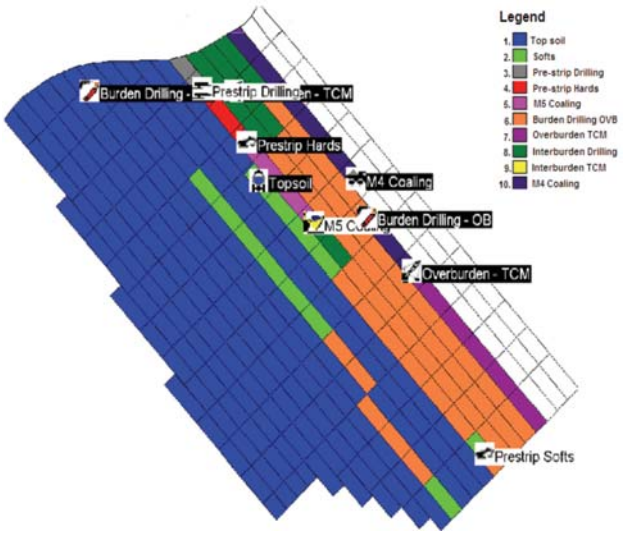

Figure 16—Mining sequence of No. 4 and 5 seams[12]

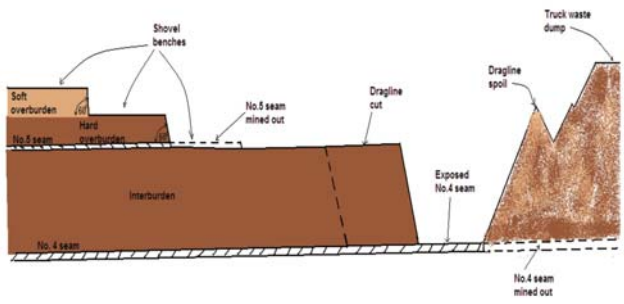

Figure 17—Cross-section view of No. 4 and 5 seam mining

Figure 17 shows a cross-section view of how the operations must take place simultaneously. The dragline will sit on top of hard interburden below No. 5 seam.

Placement of overburden and No. 5 seam lower

It has been mentioned before that Kriel Colliery has done pre-stripping. The overburden was placed on top of the dragline spoils. Placement of overburden from No. 5 seam needs to also be placed on top of the spoils in this case. It would avoid disturbance of the No. 4 and 5 seam mining if it had to be done. Figure 18 shows the aerial view of pit 5, the area where No. 5 seam is located. The yellow lines are the roadways onto the spoils where overburden must be placed while mining operations of No. 5 seam take place. The cuts which are shown are the ones which have not been mined out yet.

Stockpiling of No. 5 seam lower must be at an old area next to pit 5 called Moolman's End. The area is shown in red in Figure 18, and this place will minimize travelling distances by the trucks. The coal will be transported to a washing plant at Greenside because the average ash content of No. 5 seam lower is higher than the customer's requirements, as shown in Table V.

Limiting constraints of mining No. 5 seam

The pre-stripping and mining operations of No. 5 seam lower will be taking place only on certain parts of pit 5. This area is shown by Figure 15. It is therefore evident that bench walls will be left behind at the pit once pre-stripping and mining of No. 5 seam lower takes place. This will cause a problem for the dragline to move on the high benches as it will be following the truck and shovel in the mining sequence. This limiting constraint may be solved only by ramp construction. The dragline will manage to construct the ramps to move on.

Financial valuation and benefits

From the investigation of the mining method of No. 5 seam, it has been identified that a number of different operations will be taking place. All the operations will be generating a

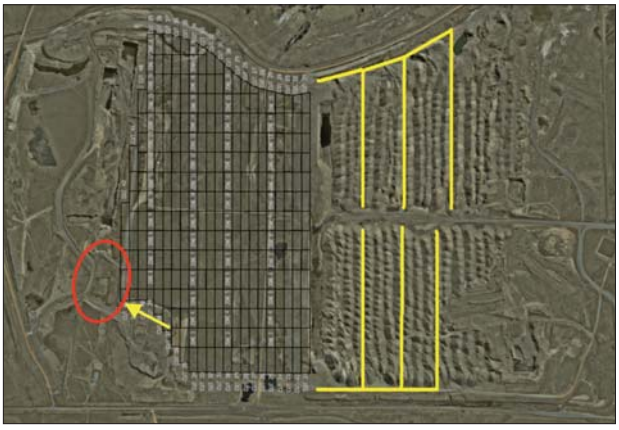

Figure 18—Aerial view of pit 5 at Kriel Colliery

certain amount of operating costs. The No. 5 seam lower will also be generating a certain amount of revenue.

Estimated operating costs

The operations and additional costs that will be generating the total costs from mining No. 5 seam lower will be the following:

- Pre-strip of soft overburden
- Pre-strip of hard overburden
- Removal of parting (carbonaceous shale)
- No. 5 seam lower coaling
- Transport of No. 5 seam lower to a washing plant
- Washing plant of No. 5 seam lower
- Ramp construction.

As stated in the problem statement, the equipment of Kriel Colliery is dedicated to mine No. 4 seam for Eskom not No. 5 seam. Therefore contracting will be the only option available to mine No. 5 seam lower. The unit costs incurred are shown in Table VII and VIII together with the calculated operation costs of mining No. 5 seam lower, excluding diesel costs. See appendix A.

The operations exclude the charges for diesel which is represented in Table IX.

The No. 5 seam lower will need to be transported from the stockpile point to Greenside in Witbank. Washing of No. 5 seam lower will take place at Greenside plant and the costs are represented by Table X.

Ramps will need to be constructed during mining of No. 5 seam lower by the dragline. This will enable the dragline to move from high bench walls to lower bench walls and vice versa. Table XI represents the costs of constructing a ramp.

After including all the expected costs of mining, the estimated total cost of mining No. 5 seam lower is R102.2 million.

Estimated revenue

The yield of No. 5 seam lower is approximately 70%[11]. This would mean 70% of the 0.64 tons of No. 5 seam will be recovered after having gone through the washing plant. It was also stated that the current market price for the coal is R450/t. There is estimated revenue of R201.6 million expected from No. 5 seam lower. This would then give an estimated profit of R99.4 million.

Benefits to Eskom and Anglo Coal

The No. 5 seam project holds important advantages and recommendations

The dragline must create its own ramp when it encounters high bench walls. The dimensions of the ramps will differ because of the different heights of the bench walls. Hard material must be placed on the ramp to create a solid platform for the dragline to move on. The ramps must be constructed with the help of dozers to put them at their required gradients of 2 degrees[13]. Figure 19 the shows location of the recommended ramps in red circles, which must be constructed by the dragline.

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Table VII

Charges from contractor to mine No. 5 seam lower[4]

Operation	Unit cost (R/m³)	Volumes (m³)	Operation costs (R million)
Pre-strip soft overburden	15.53	3 207 888	49.8
Pre-strip hard overburden	23.52	93 998	2.2
Pre-strip parting	23.04	38 682	0.9

Table VIII

Costs of No. 5 seam lower coaling

Operation	Unit cost (R/t)	Tonnages (t) (R million)	Operating costs
No.5 seam lower coaling	11.09	640 000	7.1

Table IX

Diesel costs

	Unit cost (R/t)	Costs (R million)
Diesel	1.01	3.97

Table X

Transport and washing costs

	Unit cost (R/t)	Costs (R million)
Transport	36.7	23.5
Washing	21.4	13.7

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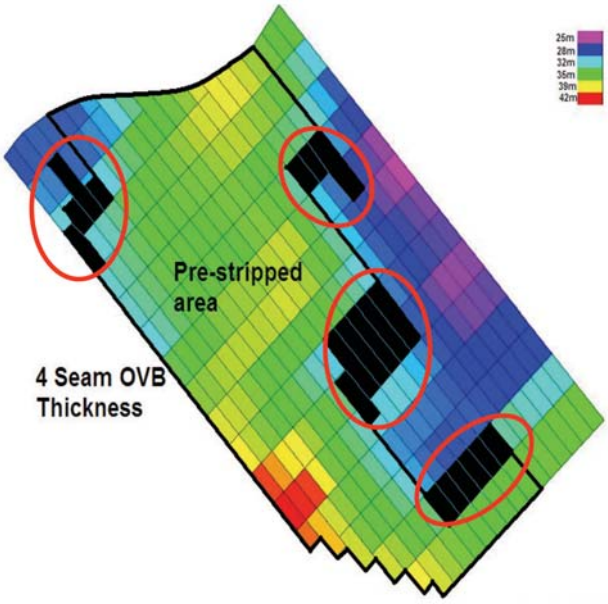

Figure 19—Location of ramps during mining of No. 5 seam

Table XI

Ramp construction costs

	Unit cost (R/m³)	Volumes (m³)	Costs (R million)
Soft overburden	1.34	641 577	0.86
Hard overburden	7.23	23 500	0.17

Appendix A

Calculations of the estimated profit

Costs

- Pre-strip soft overburden: Soft overburden volume * Rand per volume [1]
  3 207 888m³ * R15.53/m³ = R49 818 501
- Pre-strip hard overburden: Hard overburden volume * Rand per volume [2]
  93 998 m³ * R23.52/m³ = R2 210 833
- Parting: Parting volume * Rand per volume [3]
  38 682 m³ * R23.04/m³ = R891 233.28
- Coaling: Coal tons * Rand per ton [4]
  640 000t * R11.09/t = R7 097 600
- Diesel: Diesel litres * Rand per litre [5]
  3 934 575 l * R1.01/ℓ = R3 973 921
- Transport cost: Available tons * Rand per ton [6]
  640 000 t * R36.7/t = R23 488 000
- Washing plant: Available tons * Rand per ton [7]
  640 000 t * R21.4/t = R13 696 000
- Ramp construction:
  - Soft overburden handling * Rand per volume [8]
    641 577 m³ * R1.34/m³ = R859 714
  - Hard overburden handling * Rand per volume [9]
    23 500 m³ * R7.23/m³ = R169 901

Total cost: **R102 205 703**

Revenue

- Tonnage yield: Percentage yield * Coal tons [10]
  70% * 640 000 t = 448 000 t
- Total revenue: Coal price * Tonnage yield [11]
  R450/t * 448 000 t = R201 600 000

Profit

- Project profit: Total revenue – Total costs [12]
  R201 600 000 – R102 205 703 = R99 394 297

Table XII

Advantages and disadvantages of No. 5 seam to Eskom and Anglo Coal

Eskom	
Advantages	**Disadvantages**
Once No. 5 seam lower is mined out, the overburden thickness to No. 4 seam will have minimized. This means the dragline will handle smaller volumes of overburden.	If an interruption of No. 5 seam lower mining takes place, No.4 seam coal production will be greatly affected. This would mean Kriel Power Station will have less coal to burn.
The Gardner Denver will drill the interburden comfortably till the top of No.4 seam.	
Anglo Coal	
Advantages	**Disadvantages**
An estimated profit of R99.4 million is expected after the sales of No. 5 seam lower.	More risks of mining are going to be encountered because No. 4 and 5 seam mining operations will be taking place simultaneously.
	If interruptions of No. 5 seam mining take place, No. 4 seam coal production will be greatly affected. The mine will then be penalized for failing to meet Eskom's contractual obligations.

No. 5 seam mining at Kriel Colliery opencast