CHAPTER 8: ECONOMICS OF THIN SEAM COAL MINING.

8.1. Introduction.

It is a known fact that thin seam mining can be very expensive, both in monetary value and in human life. The main decision to pursue thin coal seams is made on both strategic and financial factors. In modern society and with legislated protection the human cost will outweigh economic factors. With modern technology and the speed of modern day transport, strategic reasons do not play such a big role as in the early to middle decades of the previous century. Countries have become less dependent on coal and with open market economies and the "global village" concept any grade of coal can be sourced and delivered in very short periods of time. It seems that financial evaluations dictate decision making but risks (human lives) can terminate these same decisions. The use of computer constructed financial models makes it easy to calculate a Net Present Value (N.P.V.) and Internal Rate of Return (I.R.R.) for a specific project. It also has the added benefit that sensitivity parameters can be built in which can be changed to see the effect on the N.P.V.

8.2. Notes on the Financial Model.

It has been assumed that the thin seam area will be mined concurrently will the other sections and will be fully extracted by the time the mine closes. This exercise must not be regarded as a stand-alone evaluation for a new mine. The thin seam area will supply additional coal to the current operation and markets and may in future replace some of the current sections as these tail down towards the end of the mine's life.

In the construction of the thin seam financial model a few assumptions were made. The following were regarded as sunk cost:

a.) Cost of lease or rights to the mine.

b.) Cost of exploration and evaluation.

c.) Cost of establishing the surface infrastructure.

d.) Cost of establishing and developing the underground facilities. The thin seam resource forms the northern boundaries of the current southern mineable reserve, called South Main (see fig. 3.14). All current and future mining in this area will be done up to where the seam thins down to below 1.5m. Extending these mining panels into the thin seam resource should not cost additional money and may not need any development through barren grounds. Some development had taken place to reach South Main (called the "Neck Development", after the thin and narrow area that needed to be developed, see Fig. 3.14) and an established main conveyor belt, ventilation road and travel road were established to connect South Main with the northern part of the reserve.

e.) Cost of the washing plant.

f.) Some costs already incurred and accounted for during previous mining to develop the South Main Area, for instance the 2 thin seam battery haulers, roof bolters and belting infrastructure.

g.) All yields quoted are theoretical yields but in the financial model a plant factor has been used in order to get to a practical yield. All financial calculations are based on the practical yield.

The financial model was constructed for a ten year period of thin seam mining. This period coincides with the closing of the mine in the year 2013 and the introduction of the thin seam must be done sooner than later as only one operating section on the mine will not be feasible. An extraction rate of 70%, geological loss of 10% and a mining loss of 10% were factored in to reduce the 7,06mil. in situ tons to 3,56 mil. R.O.M. tons. The production rate was calculated by using current knowledge gained from current mining with the Joy 12HM15 and the Wirth trial. Zwaigin's method of production rate calculations (Class notes, 2002) is inappropriate for this exercise as his formula provides for a multiple section mining operation. Using his formula (tons/annum = 390 x (in situ tons)$^{0.5}$) will yield a tonnage of 4100 tons per day, which is about three times more than practical for a single thin seam section.

The first year's production rate will be at 1,250 tons per day R.O.M. which is 50% of the current Joy production in a 1.8 to 2.0m thick seam. This tonnage should add up to 313,750 tons per year. The production rate will increase to 1,500 R.O.M. tons per day, or 376,500 tons per year, for six years. This increase is due to the learning experience during the first year of production. The production will fall back to 1,250 R.O.M. tons per day for the last three years due to the very low area to be mined at the end of the mine's life. These production rates will result in the extraction of 99.55% of the potential R.O.M. thin seam resource.

The main capital equipment is the full cost of the Wirth machine at R 15,000,000 while provision was made for an additional Stamler hauler in year 2004 at a current cost of R 4,000,000. Financing of this equipment has come from the operating profits of the mine and has been budgeted for in the preceding year. All other capital and operational expenditure from the year 2003 onwards were allocated pro-rata to the thin seam section at a rate of 30%. This was done on the assumption that eventually 30% of ROM production will come from this section.

The overhauling of the Wirth will be done every four years while money is allowed for continuous repairs and overhauling of the other machines (haulers and roofbolters) throughout the life of the project. This should see the equipment through till the end of the life of mine as this kind of mining machinery practically have an unlimited life and only become redundant when new technology replaces them.

Provision was made for additional support of the parting. Extraordinary support was provided for under Capex while normal support falls under the contractor's rates. The current contractor, LTA Grinaker, will charge 10%

above his normal rate for working in thin seam areas. This additional cost was factored in under Operational Costs and includes the additional labour cost for thin seam mining.

No additional costs were allocated for roof brushing. The combined belt and travel road will be one intersection, 8 m wide, and is the only road that will be brushed to a height of 2.0m. The only additional roof brushing will be done in the very low areas of 1.2 m, where the total seam height is in the order of 1.7 m. The brushing will mainly entail the pulling down of the parting and upper seam and in a few instances the blasting into the proper sandstone roof above the No. 2 upper Seam.

The discount rate of 15% was chosen based on T.C.S.A. policy. This rate is based on country risk and market related risks used by the foreign mother company (TOTAL) to evaluate projects in South Africa. Escalations are factored into the financial model (Annexure 10) only as from year 2004 as all costs and increases for 2003 are fixed for the rest of the year. The inflation rate is based on government guidelines to keep inflation between 3 and 6% per annum. The maximum figure is used. The P.P.I. (production price index) used is 5%, based on current figures of 5.4% (Finansies en Tegniek, 9 April 2003, p. 62). The capital escalates at 10% based on the annual devaluation of the Rand against the U.S. Dollar and worldwide inflation of about 2% per year. Inland selling price increases at inflation rate (6%) while the average dollar-selling price for the past 5 years is used for the export sales (US$ 27.77). All other operational costs escalate at 6% per annum.

The yield used in the model is that of the current practice at Dorstfontein to beneficiate to an ash content of 13.5%. At this yield value (95.7%) the N.P.V. is R 27,206 mil. at a discount rate of 15% while the I.R.R. is 305.2% compared to the company's hurdle rate of 15%. The equivalent values at a R.D. =1.6 cutting point is R 15,180 mil. and 120.7% (See

Table 10 Fig. 8.1). The I.R.R. seems to be extremely elevated but it must be kept in mind that this area forms part of the current mine and the capital expenditure is minimal. From Fig. 8.1 it can be seen how the N.P.V. and I.R.R. are influenced by yield increases.

Table 9. N.P.V. and I.R.R. at different product bases.

Product Base	Yield	N.P.V (R mil.) at 15% discount rate	I.R.R (%)
R.D. = 1.6	89.2	15,180	120.7
R.D. = 1.8	93.0	22,252	204.7
Ash = 13.5%	95.7	27,206	305.2

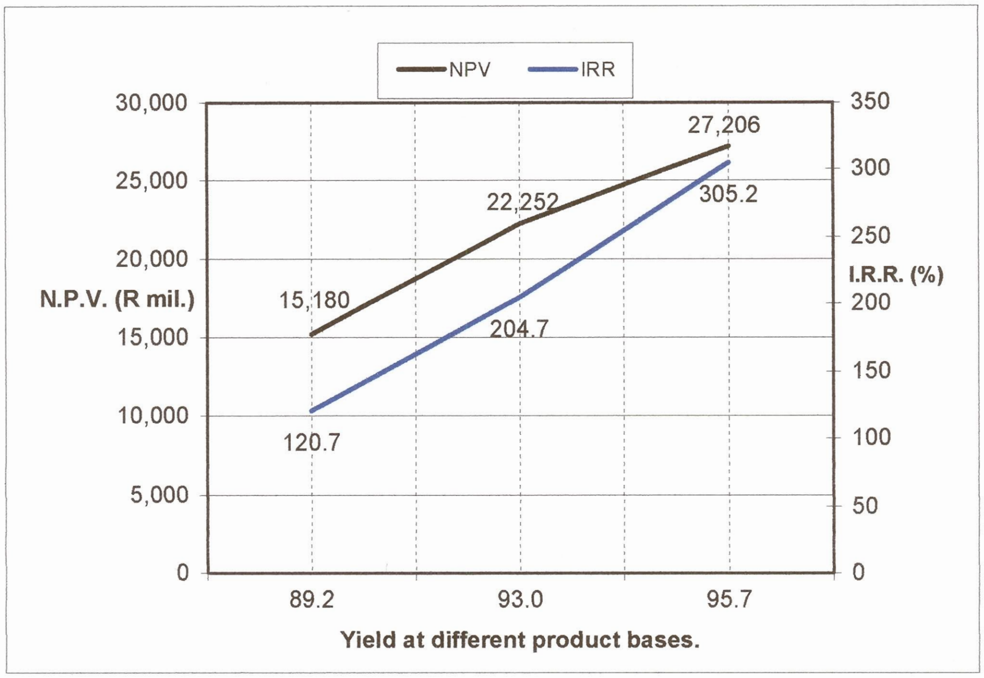


Fig. 8.1. N.P.V. and I.R.R. at different product bases.

The plant factor used in the model might appear to be elevated but it must also be assumed that this factor will increase as less parting is being mined and thus the dilution decrease. It is therefore very important that the mining horizon be maintained and that minimal floor and roof be cut.

Table 10. The N.P.V. for the product bases at different discount rates.

Discount Rate	0.0%	2.5%	5.0%	7.5%	10.0%	12.5%	15.0%	17.5%	20.0%	22.5%	25.0%
13.5% Ash	46,302	41,878	38,078	34,790	31,926	29,417	27,206	25,246	23,501	21,939	20,536
RD = 1.6	26,170	23,686	21,527	19,637	17,972	16,496	15,180	14,000	12,939	11,979	11,107

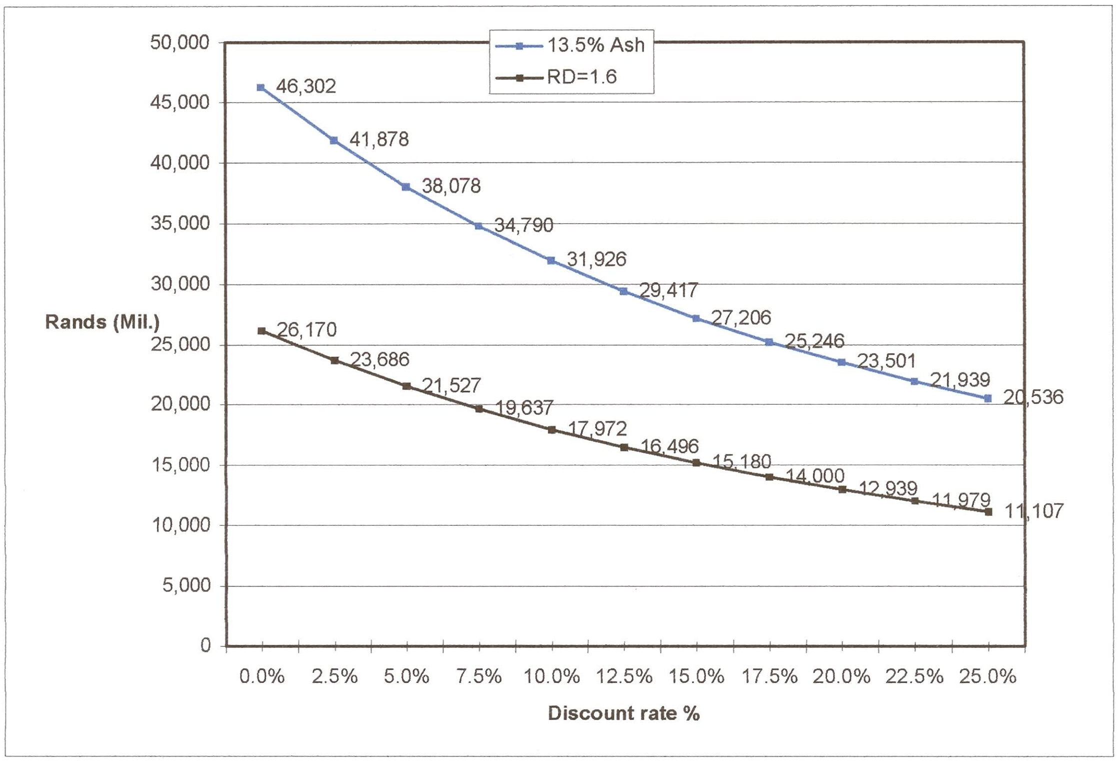
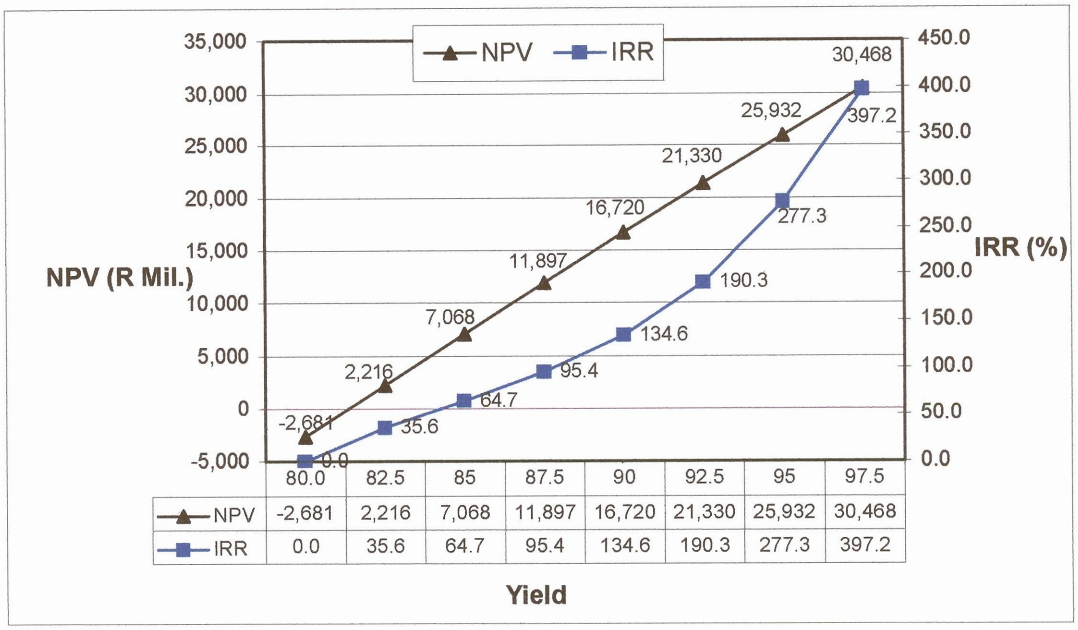


Fig. 8.2. The N.P.V. for the product bases at different discount rates.

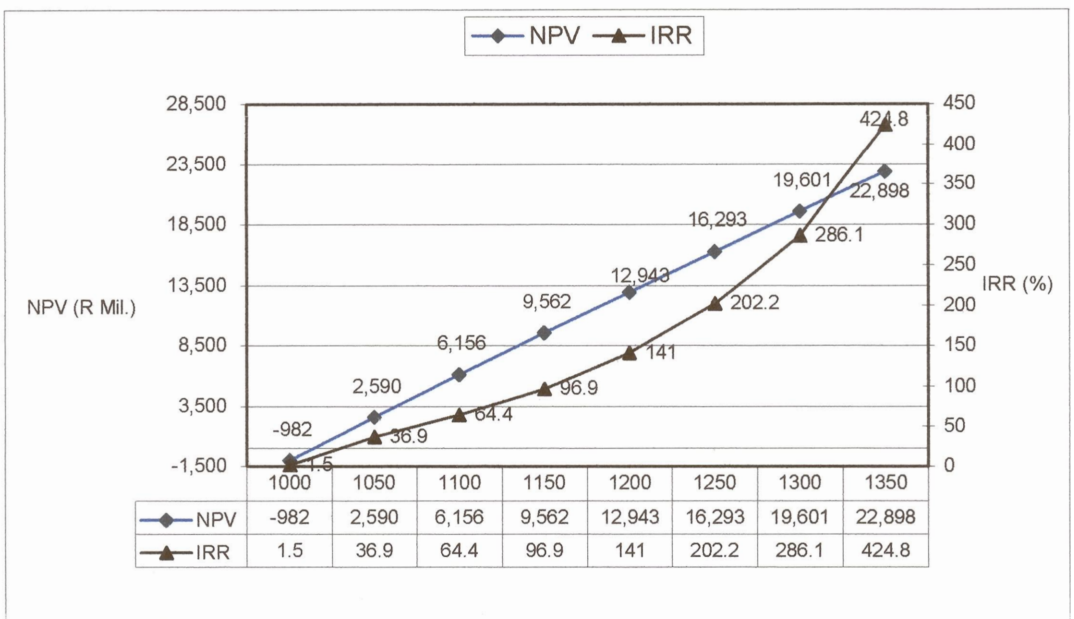
The breakeven yield for the thin seam area is 81.4% (Fig. 8.3) at a discount rate of 15%. This breakeven point is very important as a small amount of contamination can easily make the thin seam uneconomical. This stresses the fact that the seam-split parting should not be mined and that strict horizon control must be maintained during mining. As can be seen the N.P.V. follows a linear line of increase while the I.R.R. exponentially increase or decrease with yield changes. The exponential curve of the I.R.R. line can be explained by the increase in capital expenses during years of machine overalls while all other factors remain constant for the N.P.V.



	80.0	82.5	85	87.5	90	92.5	95	97.5
NPV	-2,681	2,216	7,068	11,897	16,720	21,330	25,932	30,468
IRR	0.0	35.6	64.7	95.4	134.6	190.3	277.3	397.2

Fig. 8.3. N.P.V. and I.R.R. against Yield at a 15% discount rate.

The average breakeven production is 1014 tons per day (Fig. 8.4) at a discount rate of 15%. The payback period is 1.84 years.



	1000	1050	1100	1150	1200	1250	1300	1350
NPV	-982	2,590	6,156	9,562	12,943	16,293	19,601	22,898
IRR	1.5	36.9	64.4	96.9	141	202.2	286.1	424.8

Fig. 8.4. N.P.V. and I.R.R. against daily production rate at a 15% discount rate.

From Fig. 8.4 it can be seen that the N.P.V. an I.R.R. follow similar trends to that of the yield. It is imperative that the production be kept above 1100 tons per day to make this thin seam economical. Many factors influence production in thin seam mines and these adverse conditions will need constant monitoring and management.

8.3. Sensitivity analysis.

Sensitivity analyses were done for the N.P.V. and the I.R.R. at the 13.5% ash content yield and at a discount rate of 15% for the N.P.V.

The following parameters were used to construct a spider diagram (Fig. 8.5) for the sensitivities:

a.) Operating Costs
b.) Selling Price (Export)
c.) Selling Price (Domestic)
d.) Yield
e.) Production
f.) Capital Expenditure

Table 11. Sensitivity of the N.P.V. to certain parameters.

		N.P.V. at 15% discount rate	
Parameter	Variation	Low (R mil.)	High (R mil.)
Operating Costs	30% to -40%	-7,008	70,024
Selling Price (Export)	-40% to 30%	-38,799	68,729
Selling Price (Domestic)	-40% to 30%	-4,515	49,647
Yield	-40% to 0%	14,562	27,206
Production	-40% to 30%	20,072	32,155
Capital Expenditure	30% to -40%	15,425	42,274

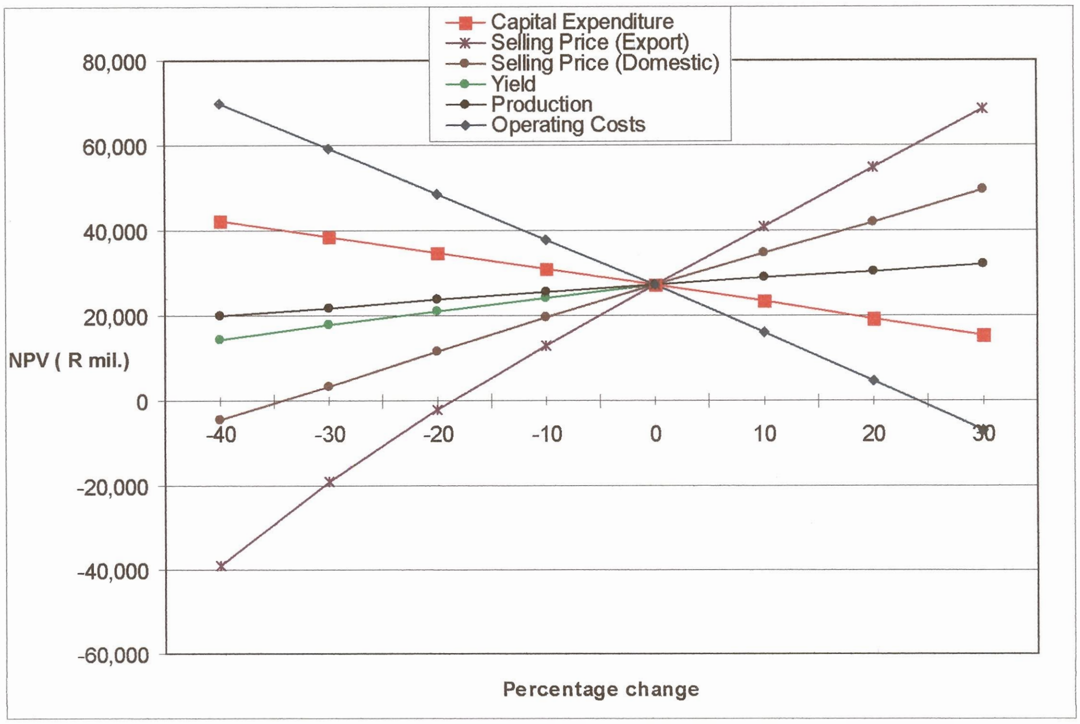


Fig. 8.5. Spider diagram of N.P.V. changes influenced by changes in the sensitivity parameters. (Yield at 13.5% Ash and 15% discount rate)

From Fig. 8.5 it is clear that the project is very sensitive towards export and domestic selling price as well as operating costs. The project is only sensitive to extreme changes in the other parameters (-40% and +30%) which are only likely to happen during or after catastrophic events. See Annexure 7 for detail on the cash flow, Annexure 8 for capital expenditure, Annexure 9 for working cost and Annexure 10 for the escalations used in the financial model.

Table 12. Sensitivity of the I.R.R. to certain parameters.

		I.R.R.	
Parameter	Variation	Low (R mil.)	High (R mil.)
Operating Costs	20% to -10%	54.5	893.4
Selling Price (Export)	-15% to 5%	55.0	561.5
Selling Price (Domestic)	-20% to 5%	101.0	403.6
Yield	-15% to 0%	14.2	305.3
Production	-25% to 10%	37.0	751.5
Capital Expenditure	20% to -10%	126.9	558.9

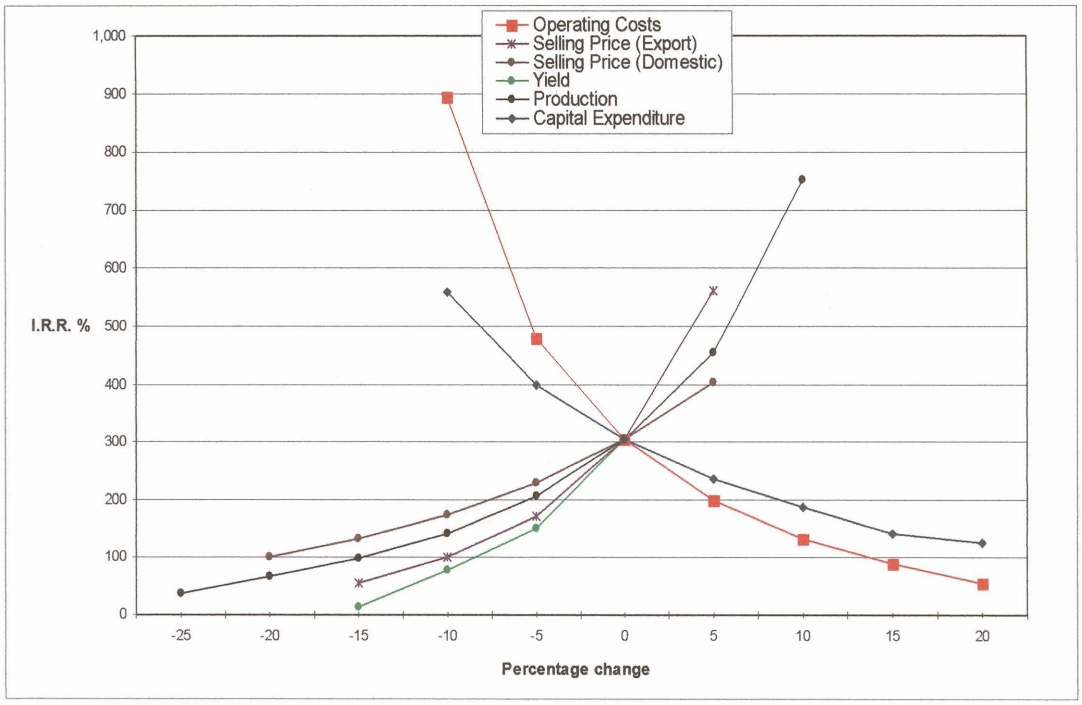


Fig. 8.6. Spider diagram of I.R.R. changes influenced by changes in the sensitivity parameters. (Yield at 13.5% Ash)

The I.R.R. is very sensitive to any changes in the parameters. Small amounts of capital input, the low production rate from the thin seam and sensitivity towards the yield and export prices, result in a very sensitive I.R.R. There is enough confidence in the yield to make the project economic but the greatest uncertainty is the US$ export price which yields a negative I.R.R. at a price drop of about 17% and influences the N.P.V. The good quality of the coal should bring confidence that the export price should not drop excessively low as this rank of coal is well sought after and buyers are willing to pay a premium for this product.

8.4. Shortcomings

There are some shortcomings in the construction of any financial model. The most common problem is the length of time the model should cover. For a shorter life of the mine the model is more accurate than for longer periods and more accurate N.P.V.s and I.R.R.s can be calculated.

Another shortcoming is the escalations that should be built in over a period of time. Few would have predicted that inflation would be 13% in 2002 when it was around 6% in 2001. Who knows what inflation will be in 2008?

Unknown global events will have or can have a huge effect on profitability of an operation. Incidents such as terrorist attacks (U.S.A. bombings), changing governments and legislation can impact heavily on the profitability of an operation.

Another shortcoming is the unpredictability of market requirements. Overseas clients can change specifications on coal, which might negatively affect the coal price. Changes in environmental legislation in the European Community can negatively affect the perception of coal.

Another unpredictable factor is the production rate in the future. There may be a sudden increase in demand from customers, which could positively affect the profitability but negatively affected the life of mine. The opposite is true as a decreasing demand for coal can negatively affect the profitability, as operating costs per R.O.M. ton (R/t) will increase as production decreases. These outside influences are unknown and unpredictable and cannot be accounted for in the discount rate and financial model.

CHAPTER 9: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS.

Dorstfontein Coal Mine has some 7.06 mil. tons of bituminous coal in a thin seam resource with heights varying from 1.2 to 1.4 m. The geological setting of this colliery makes it is a more difficult mine to operate and result in many mining problems. Some mining related problems in the past four years were due to geological features encountered during mining. Experience gained from the past mining can be employed in the thin seam resource area. The big advantage at Dorstfontein is the high quality of the coal. High yields, low sulphur, low phosphorous and low ash values make it a well sought after product. The proposed product from the thin seam resource is a coal with an ash value of 13.5% at a theoretical yield of 95.7%. An alternative product is achieved at a relative density cut of 1.6, which gives a yield of 89.2% and an ash content of 11.25%. Initially this was the product specification until the market started to accept slightly higher sulphur and ash values.

In the south of the Dorstfontein Mine reserve, a persistent seam splitting parting exists varying in thickness from 0.1 to 0.75m. The upper coal seam is very thin (0.1 to 0.35m) and is uneconomical while the lower seam varies from 1.0 to 1.75m in thickness. In the study area the lower seam ranges from 1.2 to 1.4m in thickness and forms the lower economic unit. During extraction of the lower seam the seam-split parting will form the roof. The purpose of this study was to:

a.) determine the possibility of mining the thin seam resource,
b.) study the possible risks,
c.) review and comment on other thin seam coal mining,
d.) to determine the economic value of the thin seam deposit and
e.) quantify the resource in the category 1.2 to 1.4m seam thickness.

The extraction of thin seam coal occurs throughout the world. The definition of thin seams varies from country to country and some countries regarded the cut-off seam height at 24 inches (0.60m) while some European countries regard the cut-off as 1.0m. The largest thin seam coal producers are the U.S.A. and the

Ukraine. Many countries in Europe produced coal from thin seams. Thin seam coal mining became unfavourable due to its low production rate and very high cost of mining. Only a few strategic mines were kept open and heavily subsidized by governments in order to keep them in production for the higher quality coal they produced and to prevent small villages becoming ghost towns due to unemployment. In the U.S.A. many small thin seam collieries exist around West Virginia and the other southern states. Production from these mines is very low and tax incentives were introduced to keep them operating and to act as an incentive for new mines.

In South Africa most thin seam mining took place in KwaZulu-Natal. The most common product was anthracite produced for the steel industry and the export market. Most of the Natal mines are now defunct and only a few small-scale operators are mining under very difficult conditions. The largest operating colliery in KwaZulu-Natal is the Zululand Anthracite Colliery, owned by the Ingwe Plc group. Current production at the mine is 60 000 tons per month.

Most of the literature used in this study comes from old publications since many of the worldwide thin seam collieries were mined in the 1900s and started to tail off in the 1970s to 1980s. A publication by Clarke et al. (1982), Thin Seam Coal Mining Technology, was very helpful in order to determine the risks of thin seam coal mining, health and safety problems and to get an overview of worldwide thin seam mines in the 1970s. In the R.S.A. a few publications on the defunct KwaZulu-Natal collieries was helpful in order to determine the coal fields mined, defunct collieries and current operations.

The advent of the mechanized continuous miner technology has changed the economic parameters pertaining the mining of thinner seams and especially within the range of 1.2 to 1.4m as considered here. This combined with the dwindling high quality thick seam resources may be seen as the principal reason for the current investigation.

One continuous miner section and two drill and blast sections undertake the current mining at Dorstfontein. Most of the mining took place at seam heights in excess of 1.5m. Various mining methods were looked at to extract the thin seam but the most cost effective and productive current technology is the continuous miner method. Currently a thin seam mining trial with an imported German-designed continuous miner (the Wirth Paurat) is taking place. Numerous problems were encountered during the first few months of the trial but availability and production has started to increase. Much of this section's equipment is already on the mine and the only capital expenditure required is that for the continuous miner and possibly a third Stamler thin seam hauler. Additional support needs to be installed to keep the parting up. In the mining trial the parting behaves well and forms a strong beam under which safe working conditions exist.

In the financial model an extraction rate equivalent to 10 years of mining was used. An average daily production of 1400 R.O.M. tons per day for 10 years means that a total extraction of 99.55% of the possible R.O.M. tons can be achieved. The Net Present Value (N.P.V) is R 27,206mil. at a discount rate of 15% and at the yield equivalent to 13.5% ash content. The corresponding I.R.R. is 305.2%. The distorted and high I.R.R. is the result of very low capital expenditure due to the fact that much of the capital equipment has been regarded as sunk costs. Furthermore it must be kept in mind that this is not a stand-alone mine but forms an additional reserve block to the current mining reserve. The real cash flow, at a discount rate of 15% and yield equivalent to 13.5% ash content, is listed in Table 13 and illustrated in Fig. 9.1. The effect of the annual 10% escalation in the capital expenditure is pronounced in year 2010.

Table 13. Cash flow.

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Real Cash Flow (Mil. Rands)	-2,884	8,861	9,847	3,936	8,020	8,358	6,244	-3,678	3,140	4,459
Accumulated cash flow (Mil. Rands)	-2,884	5,976	15,823	19,759	27,779	36,137	42,381	38,703	41,843	46,302

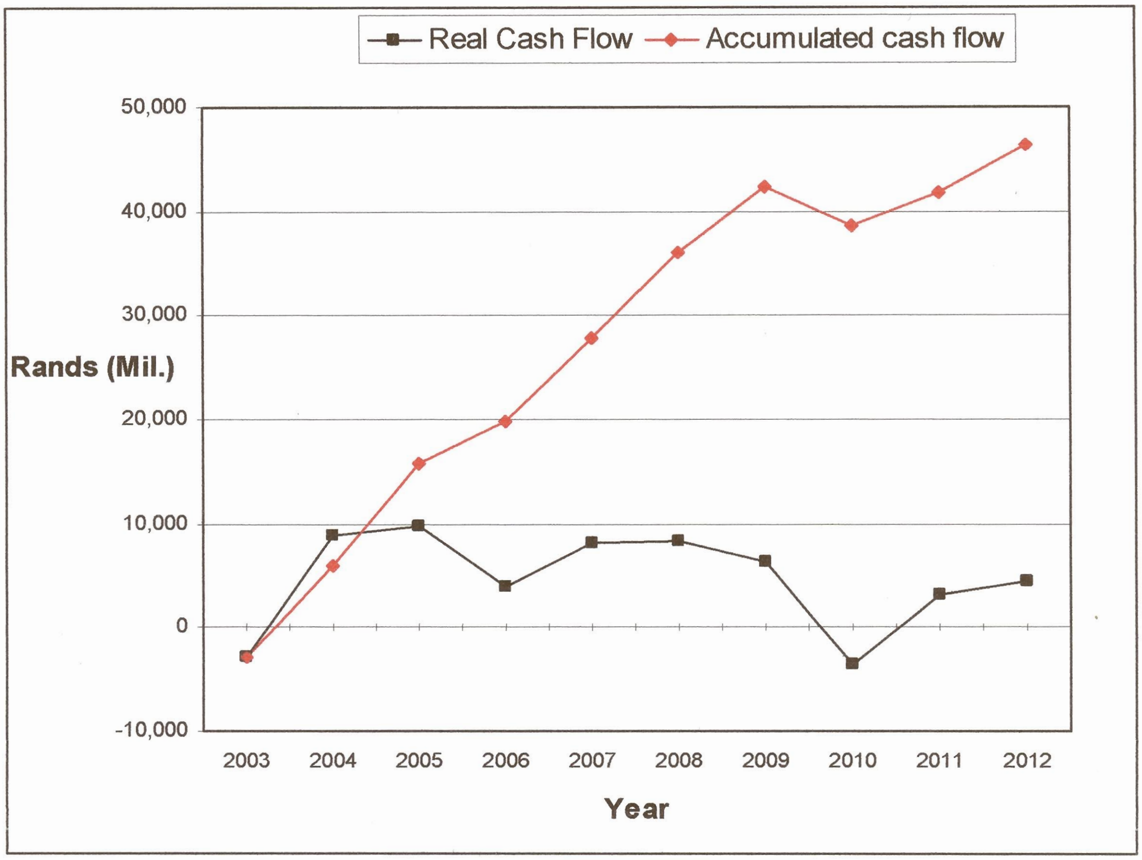


Fig. 9.1. Cash flow.

The project is the most sensitive to the export selling price, operational cost and yield. The sensitivity to the other parameters only becomes a factor at large changes (-40% and 30%). Due to the influence of the sensitivities, especially the yield, on both the N.P.V. and I.R.R. it is recommended that the thin seam coal be washed to a 13.5% ash as this project will not make the hurdle rate of 15% at yields lower than 81.4%. At a yield of 89.2% at RD = 1.6, little margin for error exists.

From this study it is clear to see that the thin seam coal resource at Dorstfontein Mine is of economic importance and of great value. The thin seam coal mining will not be easy and numerous problems may exist. It is worth pursuing the thin seam areas for their high quality coal, high yields and the additional life of mine it presents. It is important to note that mining the thin seam will involve more management input in addressing the risks, auditing the health and safety issues and the training of people to familiarize them in the working of those more difficult mining conditions. Better training and difficult mining conditions will add to more expensive labour. In the financial model the additional labour costs has been added to the contractor's rate.

It is recommended that a similar study is undertaken on the thin seam resources below 1.2 m. Heights ranging from 1.0 m to 1.2 m are regarded as intermediate seam heights in many countries. It is further recommended that short-wall mining methods are investigated for the whole of the thin seam resource within the height range of 1.0 to 1.4 m. Many overseas countries, especially the U.S.A., make successfully use of short-wall mining methods and achieve good production rates under these conditions.

To conclude, one must stress the fact that thin seam mining is only one of the avenues, and probably the most difficult, to increase the potential resource of high grade export and metallurgical coal. The successful and economic exploitation of the thin seam coal reserve at Dorstfontein Mine will impact on the potential for further investigation of similar deposits which may lead to the successful establishment of small scale mining operators from previously disadvantaged communities.