Change over from Board and Pillar T/Cut to Dip Pillar Mechanised Mining Improving Grade and Profitability

LEON DU PREEZ
Business Area Manager
Rustenburg Platinum Mines Ltd
Frank Shaft

SYNOPSIS

In 2000, due to the rapid depletion of the Merensky ore reserve from the existing shaft infrastructures at RPM, it became necessary to investigate opening up of the required ore reserves from the UG2 reef horizons. In this paper the exploitation of the UG2 reserves at Frank Shaft will be addressed.

INTRODUCTION

Frank Shaft is well established, and has been mining Merensky Reef successfully since 1971. During 1999, Frank Shaft produced an average of 138ktpm of Merensky. Frank BA has been designed to link up with the fourth generation shaft (Frank 2#) by means of a cluster system and a vertical shaft that only handles men and material. Therefore all ore mined from Frank 2# needs to exit via Frank 1#.

In 1999 the Merensky ore reserves were depleting and some areas have already been mined to the boundaries. Over the next three years Frank Shaft would lose 10% of the production and within 5 years 30% of the production generated in 1999 due to mined out reserves taking the Merensky production levels to 95ktpm, making the business marginal.

All Merensky reef will then be mined from the sub incline area. The Frank 1 shaft at that stage had a hoisting capacity of 165ktpm later upgraded to 200ktpm. Some 140 metres below the current mining horizon, a second payable platinum bearing ore, the UG2 reef, virtually duplicates the Merensky reserve. This was untouched at Frank Shaft.

In order then to maintain the production profile it was decided to exploit the UG2 reef this allows the shaft then to fully utilise the installed hoisting capacity by replacing the decreasing Merensky production with UG2 production.

The two shaft areas stretch over a strike distance of 6 kilometres and mine at an average depth of 875 metres below surface.

HISTORY OF UG2 MINING SINCE 1999 – 2004 WITH SPECIFIC REFERENCE TOWARDS MINING METHODS

Mining Method Proposal 1999/2000 – Conventional

Mine Access

The UG2 will be accessed from Frank 1 vertical shaft from 19 level and above. The shaft infrastructure was adequate for the replacement production proposed from the UG2 reef to maintain production levels.

Development

Access to the UG2 would be by means of x/cuts on the different levels, to the footwall haulages 20m in the foot of the reef.

Between 19 and 19 inter level, a return airway was required to ensure adequate ventilation conditions. All other levels would be linked to the RAW by raise bored holes.

The existing levels at Frank are 85m apart with one inter level between. This gives a mining back of 292m. The UG2 development would follow the same structure.

The reef would be intersected by means of a travelling way and a boxhole from a tramming loop every 205m out of the F/W haulage.

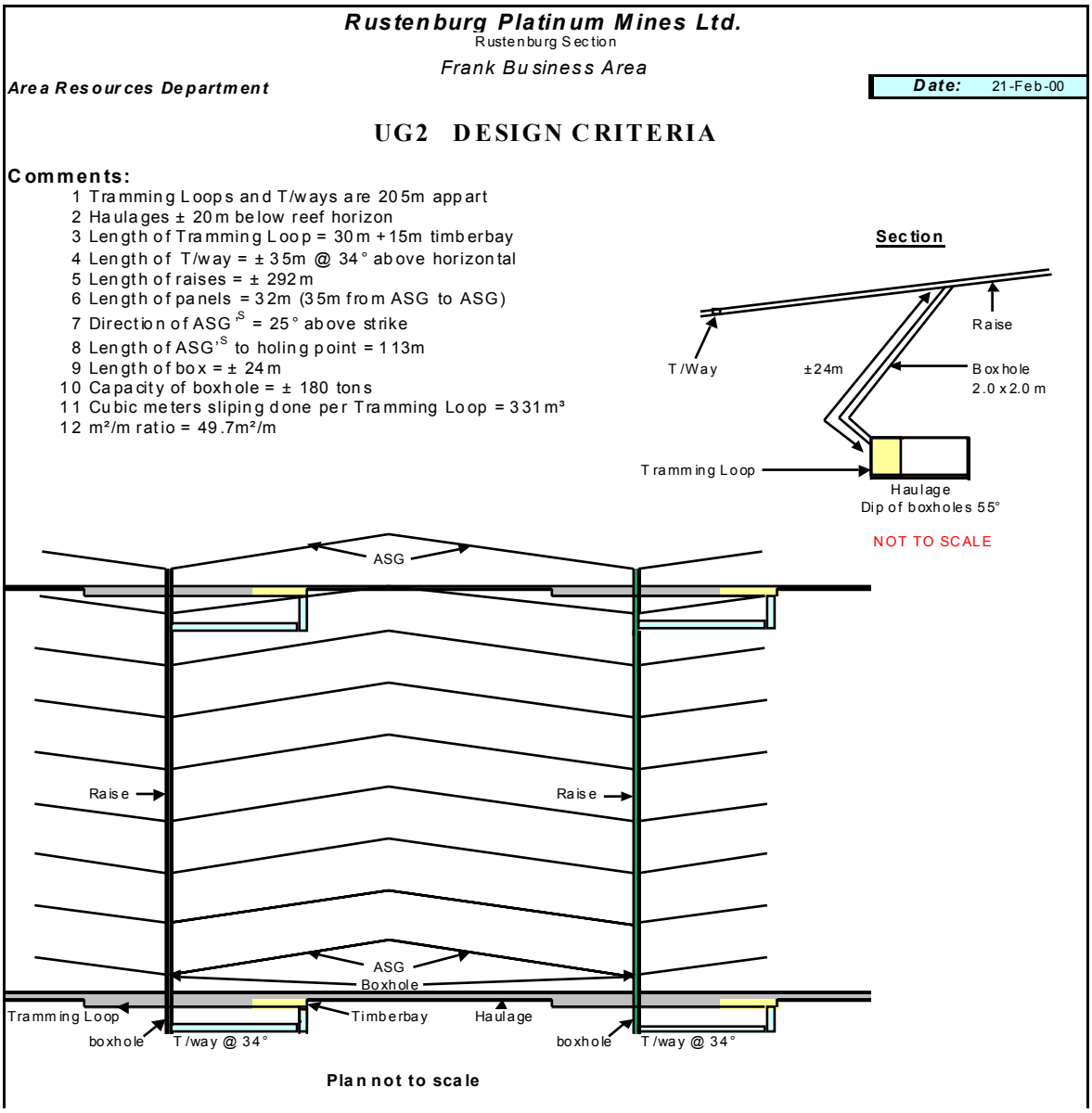
Stoping

The mining method would comprise of normal scattered breast mining with 32m panels. The scattered breast mining method is practised to facilitate the frequent potholes and geological structures anticipated.

Drilling would be done by hand held jack hammers, using drill steel 1,2m long giving an effective hole length of 1,05m.

Holes are drilled 70 degrees into the face at a burden of 45 – 50cm, the holes are charged, and normal slow fuse and igniters cord initiates the explosives. Scraping with winches would be used to clean the working faces.

Below the developing and stoping layout:



UG2 Scattered Stope Proposal

Development started in early 2000 in the footwall with the first excavation being developed, the 19 level haulage and incline to 17 level to create a return airway to ensure adequate ventilation conditions. This incline had to be holed in the bottom of the vent shaft on 17 level before any other major development could start.

Mining method proposal 2000/2001 Bord and Pillar

Introduction

During the later part of 2000 the Global conditions changed to such a extent that mining the UG2 became very lucrative and a request for early ounces was put to the shafts.

In the light of this, a decision was made in October 2000 to move to a Bord and pillar system as this would allow for early ounces and a rapid build up of reef tons, as all excavations would be moved to on reef and the only off reef excavation would be that of the RAW until it intersected the vent shaft and the incline to reef from 19 level.

Mining Access

The mining access on 19 level was as per conventional with the difference that now the only off reef development would be the 19 level incline RAW to 17 level vent shaft, and the 19 level incline to reef. From there all other excavations would be on reef.

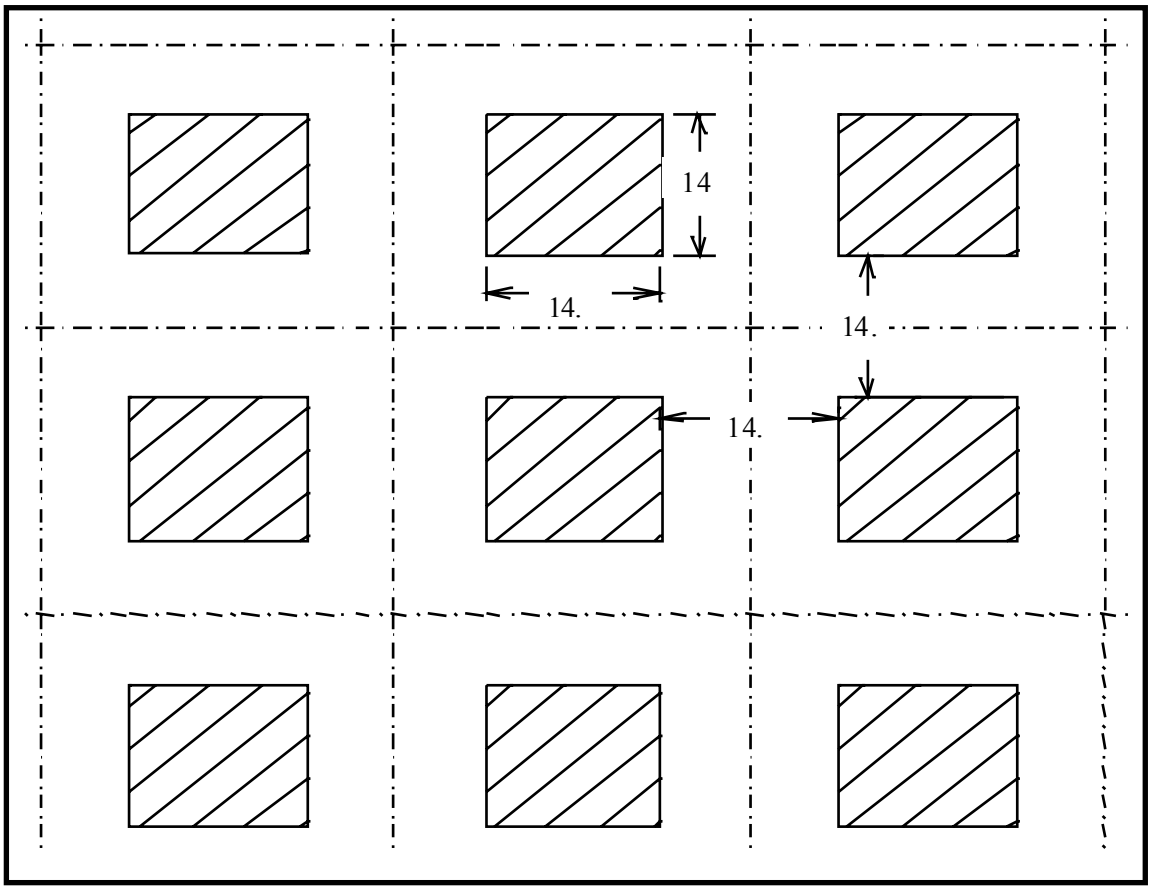
Mining Method

The Bord and pillar mining method was proposed for the early build up of reef tons and ounces. Bord dimensions would allow maximum productivity from trackless mining equipment.

The UG2 package comprises a main reef, a barren waste parting and a leader seam. The mining strategy proposed was to use fully mechanised, trackless equipment for drilling explosives charging and loading of ore. The minimum stoping height required by trackless equipment was 1,8m and would result in mining of the main seam only.

The geotechnical properties of the UG2 package would result in the waste and PGM bearing reef being blasted to different fragment size (more about this later in the problems experienced section). This would allow some segregation of waste to take place underground. It was assumed that there would be sufficient space to pack up to 45% of the internal waste into mined out areas underground.

Blasted material would be loaded onto conveyor belts for transport to the underground station ore pass system.



Bord and Pillar Layout / Design

Comments:

- Board and Pillar
- Panel length = 14.0m on strike
- Panel length = 14.0m on dip
- Pillar up to 650m below surface = 14.0m (dip) x 14.0m (strike)
- Pillar up to 700m below surface = 14.0m (dip) x 14.5m (strike)
- Pillar up to 750m below surface = 14.0m (dip) x 15.0m (strike)
- Pillar up to 800m below surface = 14.0m (dip) x 15.5m (strike)
- Pillar up to 850m below surface = 14.0m (dip) x 16.0m (strike)

Production Cycle

Mining would be performed on 2 by 8 hour shifts per day, 23 days per month. Reason being; 8 hour shift is a sufficient duration to allow the mining cycle to be completed in each shift. The mine will cover a large geographical area, the four hour interval between shifts will be adequate to ventilate the mine after blasting.

Mining will follow the normal drill – blast – load – support cycle on day shift, but on night shift only drill – load – support cycle would be followed. Drilling will be performed by mechanised single boom jumbos. Bord and pillar dimensions were selected in order to maximise jumbo efficiencies. Each bord (14m wide) would be drilled from 2 jumbo set – ups and the pillar parting (14m) would also be drilled from a double set up. Then charged with emulsions blasted cleaned and supported. LHD's would take the ore for loading on belts. A scalping grizzly would be at the delivery point segregating oversize waste.

Mining Method proposed 2001 – Bord and Pillar T-cut

Introduction

Early in 2001 a feasibility study was done and different mining methods were benchmarked to determine which method will have the best ROI for the purpose of adjudication (TM^3).

From the 14 operations ranked for the purpose of capital, Frank was ranked stone last. Although still making a profit, getting capital would be very difficult.

The options were ranked as follows:

OPTION	R/oz*	RANK	OPTION	R/oz*	RANK
Boschfontein Trackless	R 924	**1**	P/K Upper Conventional	R 1 154	**8**
Townlands Trackless	R 950	**2**	Waterval 2 Trackless	R 1 183	**9**
Townlands Conventional	R 1 016	**3**	P/K Lower Trackless	R 1 186	**10**
Boschfontein Conventional	R 1 033	**4**	Brakspruit Conventional	R 1 213	**11**
P/K Upper Trackless	R 1 046	**5**	Waterval 2 Conventional	R 1 248	**12**
Brakspruit Trackless	R 1 059	**6**	Frank Conventional	R 1 257	**13**
P/K Lower Conventional	R 1 085	**7**	Frank Trackless	R 1 284	**14**

** R/oz recovered 4E PGM, mining and milling costs only*

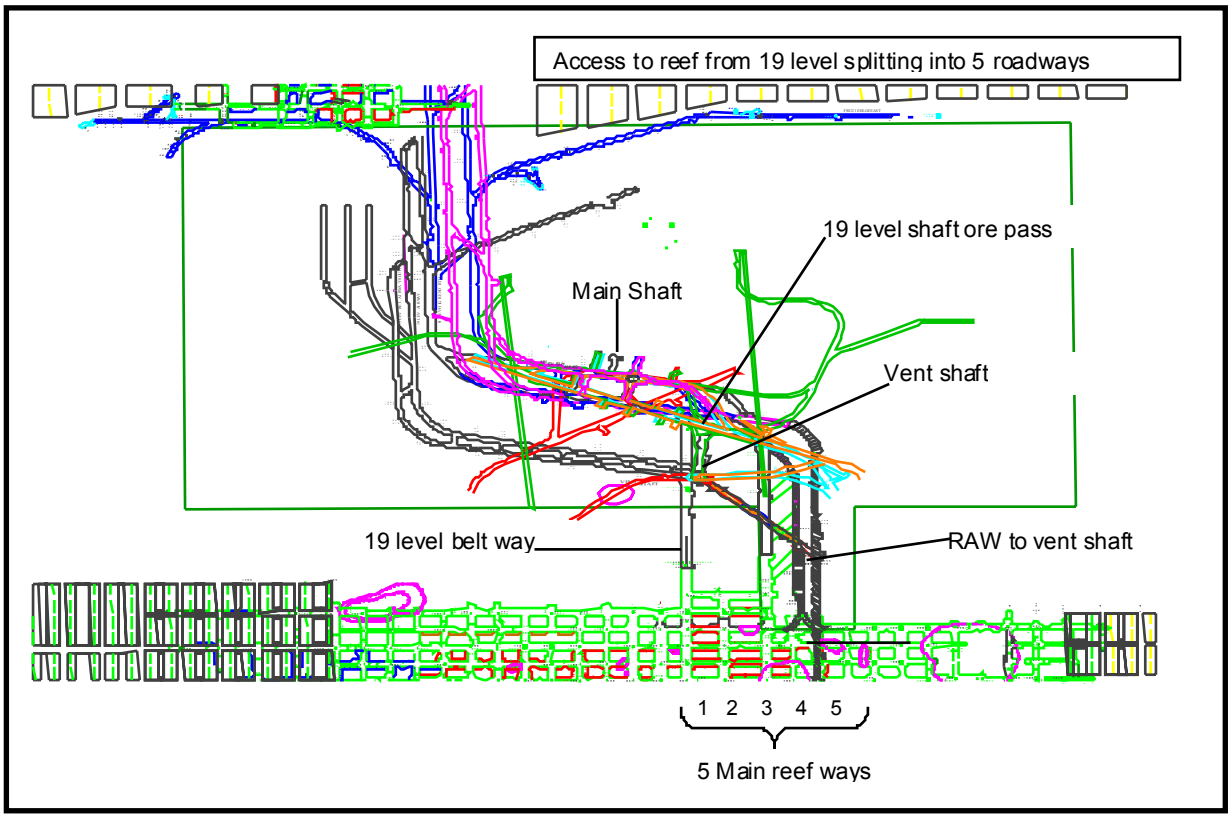
With this in mind the team set out to improve their situation on the ranking. The Operations Manager came up with a suggestion of introducing a T-cut method thus improving the grade by reducing dilution.

To this end the team convinced EXCO that the method could work and needs to be tested. In November 2001 an interim vote was approved for the new method and a full CBE was to follow producing 80 000 tons on the T-cut method, however concern was raised that issues such as dilution and extraction had to be looked at and be improved as the project progressed. On this basis the project was approved in 2002.

Mine Access

At that stage on 19 level a cluster of main access roadways had already been developed to reef. The access to the ore body was via a main belt incline and a main roadway. At the point of reef intersection the two main ends divided into 5 main reef inclines. These inclines are developed at 6,5 x 1,85m. The RAW will continue until it establishes holing into the main vent shaft via 19 inter level.

For the life of mine, the main development ends will be mined on reef in the form of a cluster system as mentioned above. The main belt was equipped during April 2002 for rock handling into the main vertical shaft with a conveyor belt system.



Mining Method 2002 – Bord and Pillar T-cut

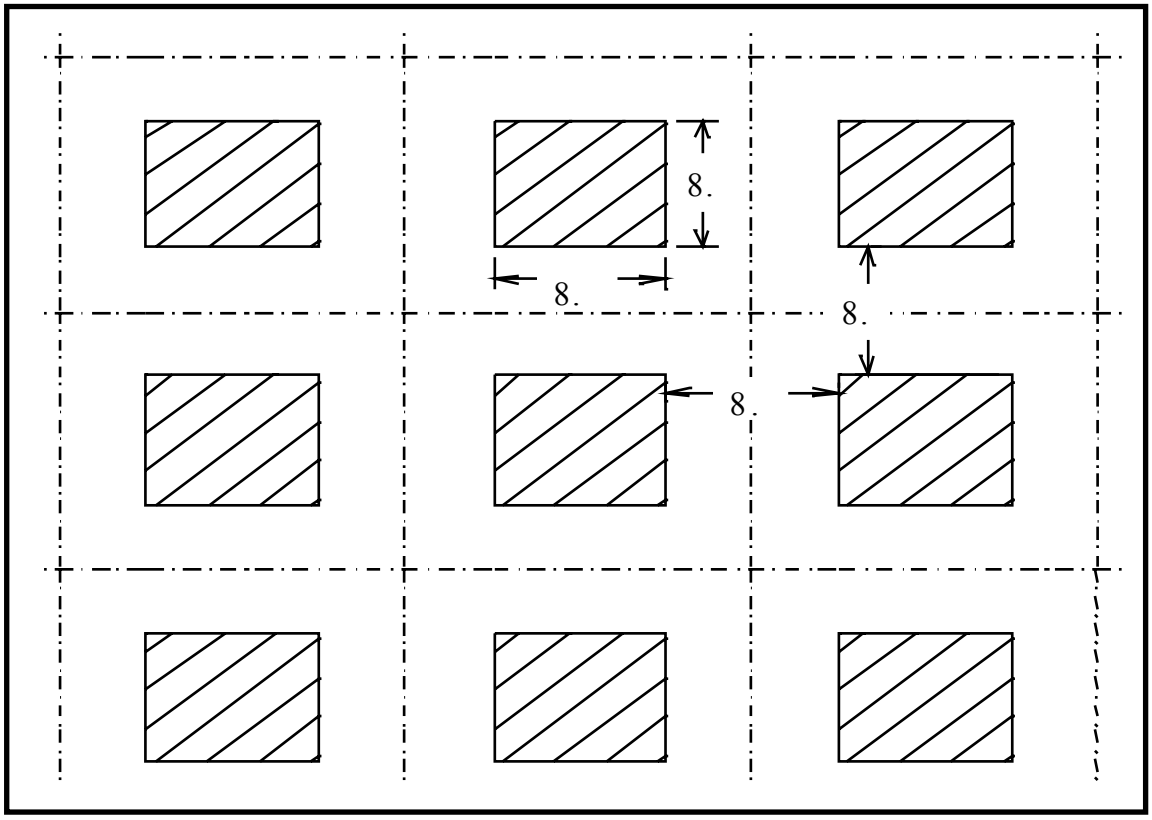
All mining operations are carried out on the reef horizon with the top contact of the Main reef + 15 to 25cm of waste being the Hanging Wall contact (A very distinct contact exists at Frank 1).

The general opening up of the mine will consist of the cluster system mentioned above. The main development will take place via inclines on the reef plane, and the stoping will take place via systems of 9 panels mined on strike.

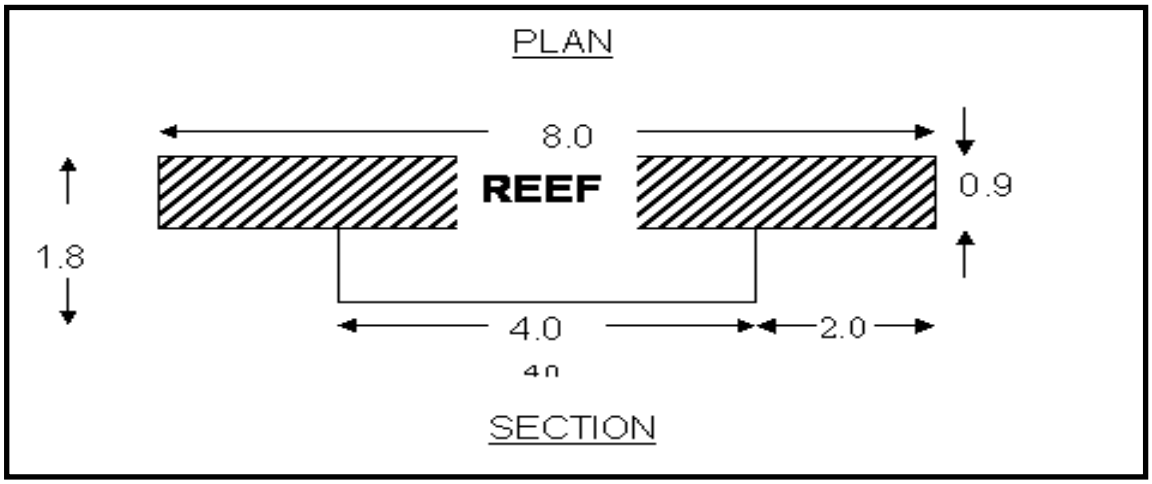
Main development incline dimensions are 6,5m wide x 1,85m high separated by 9, 0 x 9,0m pillars.

The bord and pillar mining method, uses the T-cut design. Bord dimensions will allow maximum productivity from trackless mining equipment. Pillar dimensions will increase with depth.

The T-cut will allow the 4m wide by 1.85m high access roadways to be developed ahead by at least 3m to that of the 2 x 2m deep shoulders mined at channel width. The drilling of the two 2m shoulders will take place by means of the new NVTF (Narrow vein telescopic feed) boom which is mounted on the standard Axera drill rig. The drilling direction of the two shoulders will always be to 90 degrees to strike on the dip of the reef. Using the new boom allows the extraction of the channel of reef only and thus increasing the head grade.

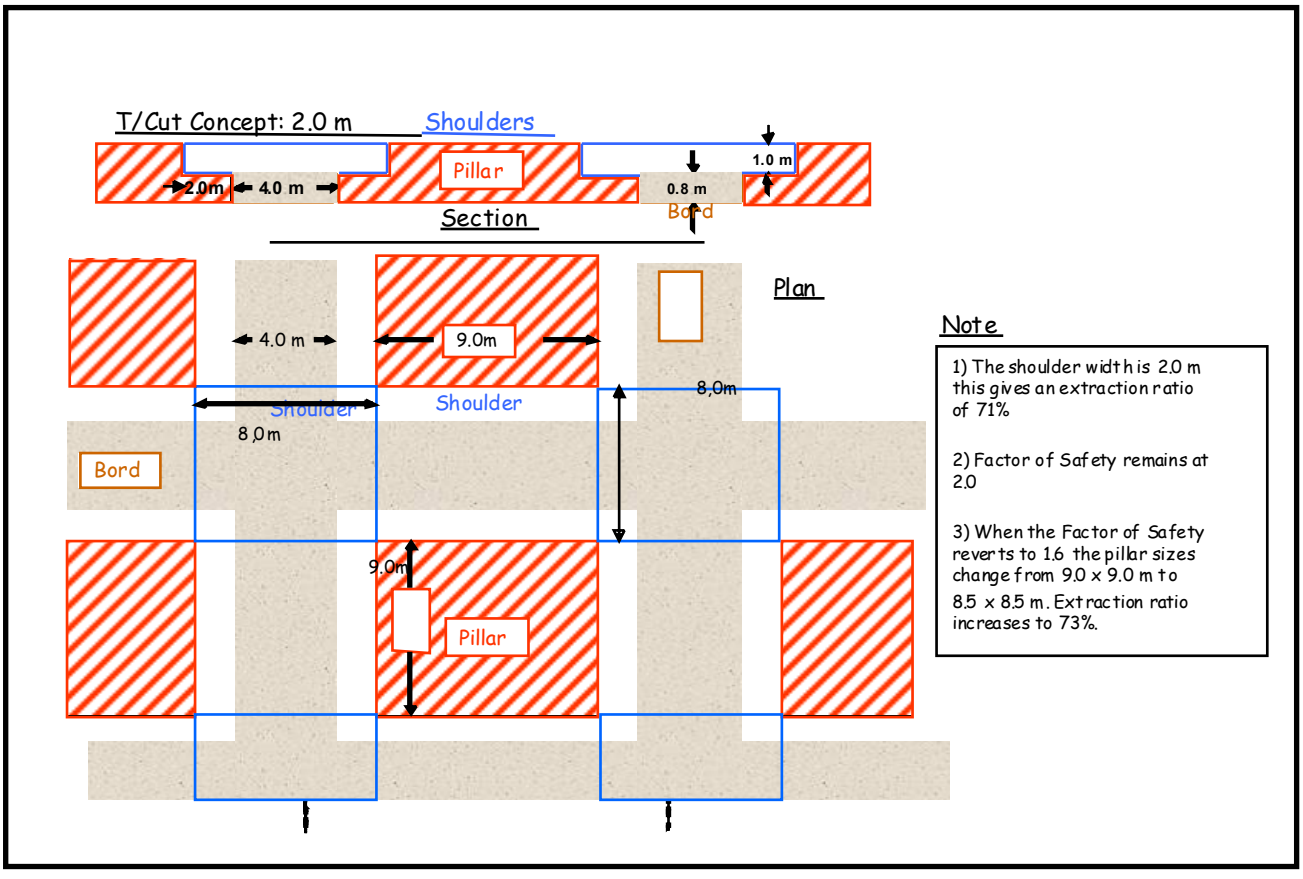


Mining Layout (T/Cut)

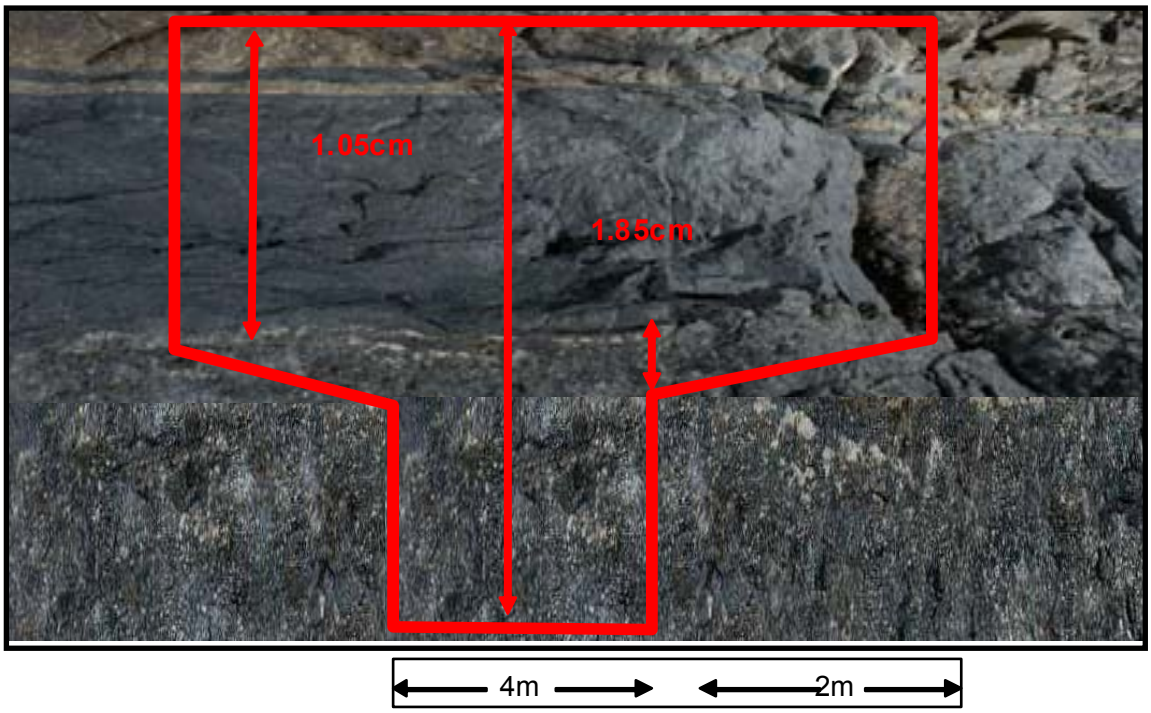


Pillar sizes and extraction ratios according to depth

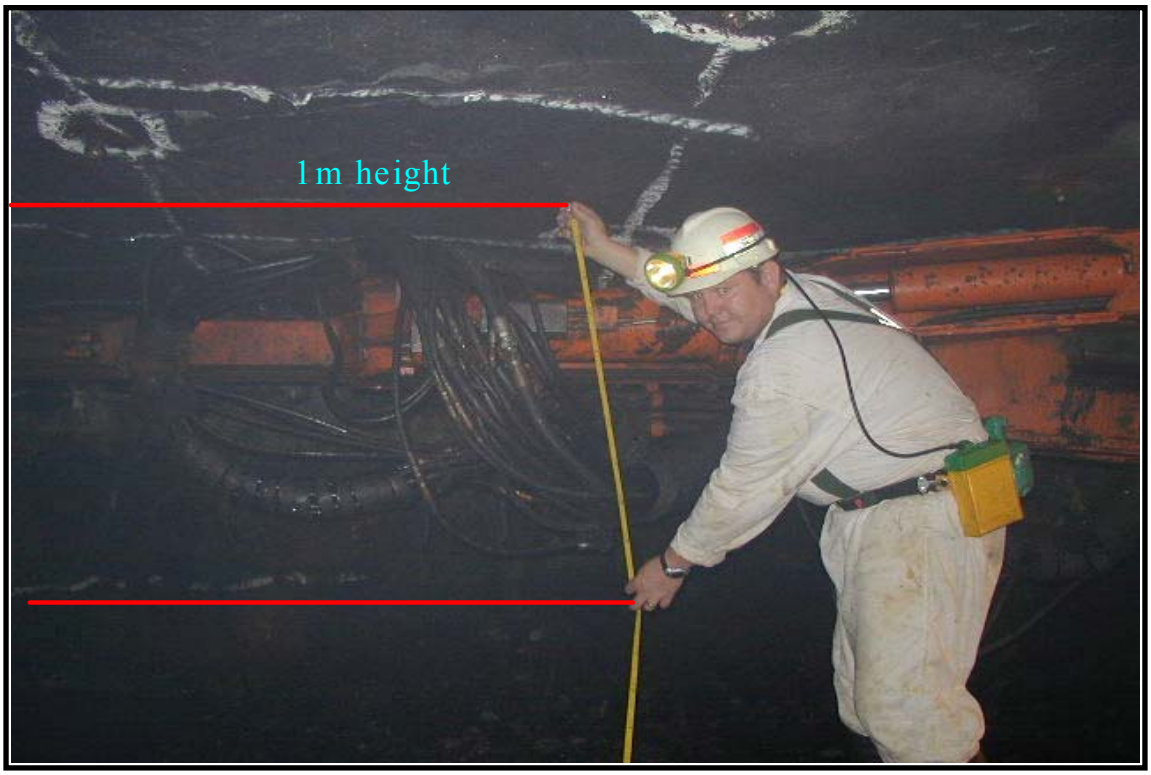
Depth [m]	Pillar Width [m]	Pillar Length	Span 1 [m]	Span 2 [m]	Extraction Ratio
350	7	7	8	8	78
450	8	8	8	8	75
550	8.5	8.5	8	8	73
650	9	9	8	8	71



T/Cut Design Extraction ration



T/Cut design before blasting
Picture not to scale



Picture of the Nvt Boom fitting in 1m height

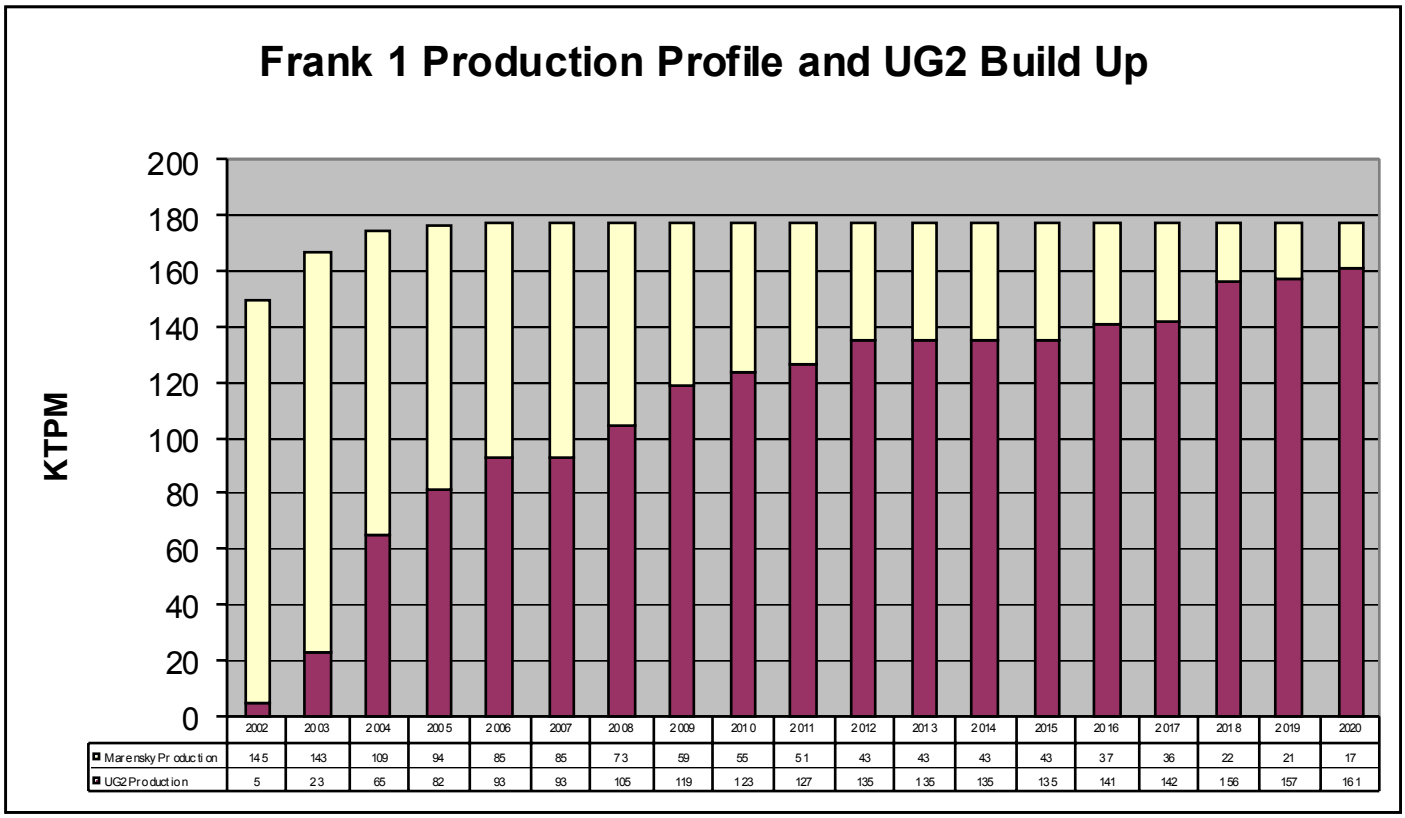
T/Cut after blast (2m shoulder)

T/Cut showing the distinct waste porting between reef and hanging wall of 15 – 25cm

Production build-up

The design allows for a rapid production build up, with a production rate of 80 000 tons per month delivered to surface achieved in month 37 of the schedule. Maximum production of 100 000 tons per month will be achieved in year 8.

The reserves above 19 level (to a depth of 635m below surface) are sufficient to allow a steady production level to be maintained until year 13. Mining downwards from 19 level towards 21 level commences to augment declining production from the block above 19 level.



The rest of the Bord and Pillar design stayed the same for the Production cycle e.g. drilling, blasting, cleaning etc. Waste packing was also still believed to be achievable.

Conclusion

For the year 2002 and 2003 the T-cut system did well achieving its targets and grade consistency, during 2003 it beat its tonnage profile by a substantial margin, achieving average tonnages of (40 000 tons) against a plan of 23 000 tons.

Furthermore, the T-cut was proved to be achievable.

Although performing well against targets, the global economical situation changed and with the rand strengthening and high working costs, a review of the system was required to ensure the UG2 stays profitable.

Mining Method Proposal 2003/2004 – Mechanised dip pillar

Introduction

During 2003 as a result of changes in global conditions, the impact of the dilution associated with the Bord and pillar method, the Rand/Dollar exchange rate, current PGm prices, the appreciating South African currency and high working costs, the CBE financial returns have been reduced. A review of the original mine design was again required.

Consideration also had to be given to the fact that the change from Bord and pillar T-cut method to the mechanised dip pillar is easily adopted and visa versa. It was also decided to reduce the mechanised section output from 80 000 Tons to 40 000 tons.

This reduction in tons was also part of a strategic change back to Merensky, using the capital reduced on the UG2 for sinking the Merensky cluster on 2 shaft deeper into the Merensky reserve, which this paper will not cover.

Mine Access and Development

Stays the same as previously discussed.

Mining Method Selection

High dilution, which resulted in low grade, caused the Bord and Pillar T-cut with a 2m shoulder to become no longer viable. Investigations were done to determine the most practical length of shoulder. Calculations were done on a 2.5m and 2.75m shoulder.

This was the limit to which the adapted drill rig could drill and still allow for a fully mechanised operation. It was then decided to do a further blast, an additional 2.5m, i.e. a 5m shoulder in all. It was felt that the second blast could be done with the existing development drill rigs.

Although the grade improved, it was still too low. It was then decided to blast an 8m shoulder conventionally. This was felt to be the limit of "Throwblasting". However, trials will be conducted to see if 10m, 11.5m, or 13m shoulders can be successfully throwblasted. The 13m shoulder configuration will result in a 30m span skin-to-skin between pillars. This is considered to be the maximum span that can be used safely from a rock engineering aspect.

A comparison was also made with conventional breast mining stopes. The stoping grades were better than any form of mechanised mining. However, this system was considered to be unsatisfactory, as it would take more than 5 years to get into production because of the long crosscuts to reef, about 1 500m.

A comparison was also made with a hybrid mining method where every second drive was stopped and a panel 34m long was mined in the conventional manner with hand held drills, scrapers etc. This system would have needed an additional compressor to come into production. It would also have been labour intensive and would have taken up much shaft time for transporting men and material, so it was abandoned.

Production Parameters

A re-assessment of the 80kt/month Board and Pillar planned for Frank 1 shaft UG2 indicated that the Mechanised Dip Pillar method of mining would produce better grades, 3.33g/t to 3.56g/t, (in fact, as scalping was never introduced, the real grade for Bord and Pillar with a 2m T-cut was 2.92g/t).

Below summarises some of the production factors:

	Units	Bord & Pillar T-cut	Mechanised Dip Pillar
Production	T	80,000	40,000
Shaft head grade	g/t	2,92	3,56
PGE production	Oz.	5,962	3561
Development	M	2011	610
Stoping	M²	6561	5905
Total shaft-head width	M	1,68	1,34

Planned Monthly Production

Mining Method

The mechanised Dip Pillar strategy incorporates the major current systems and methodologies of the existing Bord and Pillar and introduces a greater percentage of higher grade stoping ore to improve overall grade.

Mine Design

All mining operations will take place on the reef horizon with the top contact of the Main reef plus 15cm to 25cm of waste being the hanging wall contact, (a very distinct contact exists at Frank 1).

The mine has a cluster system mentioned before. Main development takes place via inclines on the reef plane. Main development incline dimensions are 6,5m wide x 1.85m high separated by 9.0m x 9.0m pillars. There is a centrally located strike conveyor in every second drive serving the panel above and below. See figures 2 and 3.

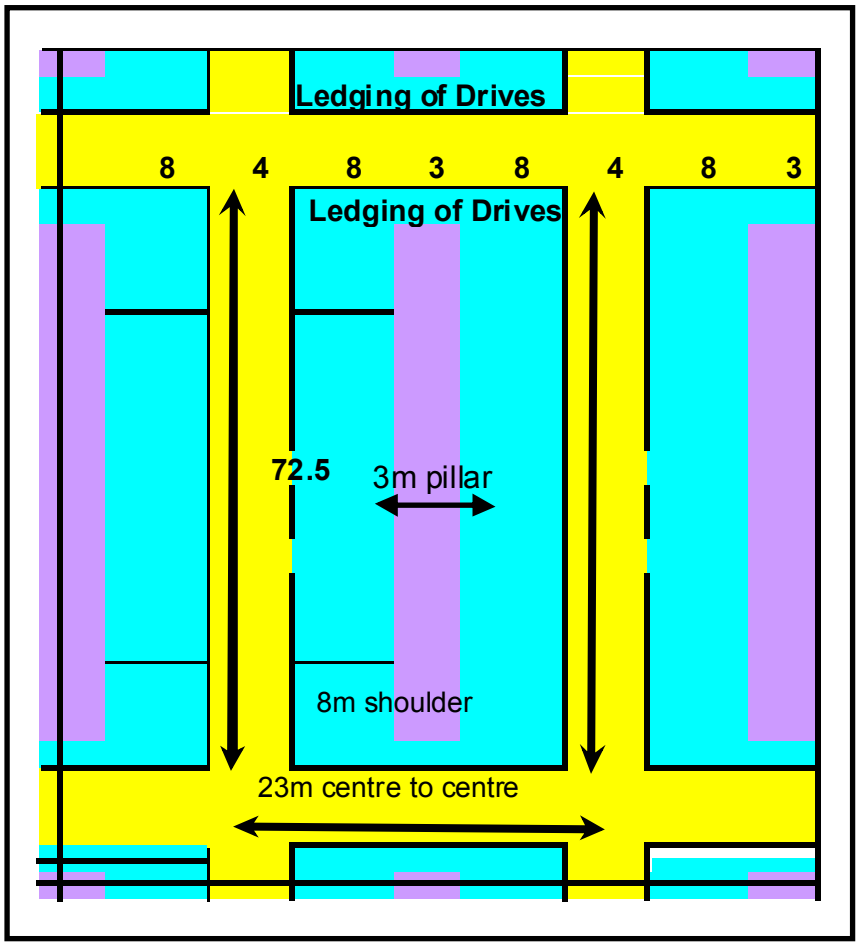


Figure 2 - Panel Layout

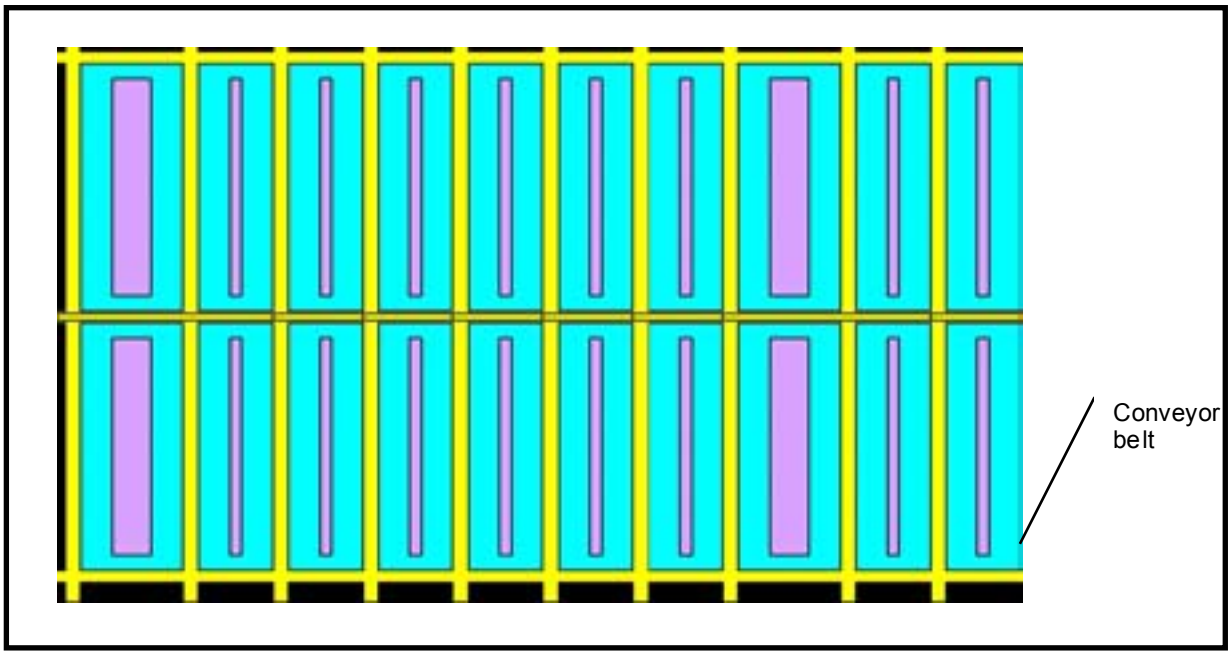


Figure 3 - General Layout

Stoping will take place via systems of 8 x8m panels per half level mined on dip, both up-dip and down-dip. Bord dimensions will allow for maximum productivity from trackless mining equipment.

Drives will be developed 85m and 68m centre to centre on dip. They will be connected by dip roadways 23m on strike.

Production Cycle

The production cycle would be followed as discussed in the T/cut method. On the 8m shoulder drilling would be done by hand held jackhammers as per conventional stoping, holes will be charged up with emulsions using shock tubes for initiation, ensuring ore is throw blasted to the road way in the centre.

Production Build up

The aim was to sustain the production profile achieved at the end of 2003, of 40 000 tons and then systematically step out of the old t/cut system to the new dip pillar method. The table below shows the increase in m², reduction in development meters, with the most important factor – the grade improving from 2,92 g/t to 3, 56 g/t.

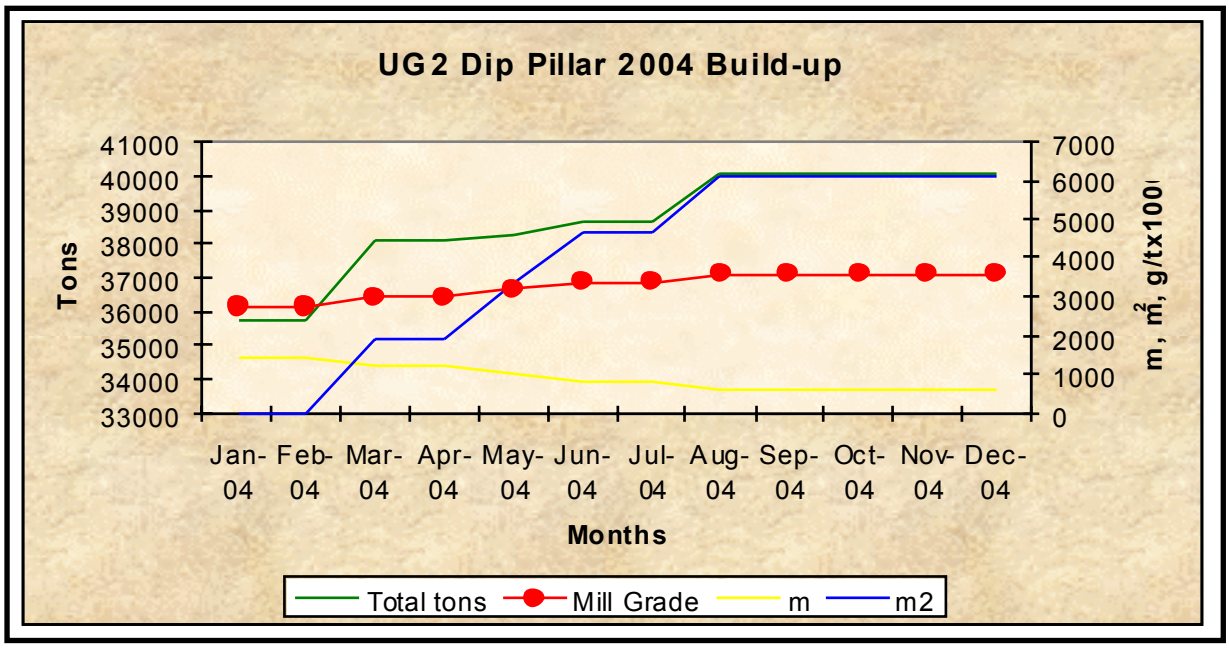


TABLE OF COMPARISONS

Bord and Pillar T-cut Mining Methods			
	T-Cut 2m	**T-Cut 2.5m**	**T-Cut 2.75**
1. Shaft Head Grade g/t	2.92	3.08	3.11
2. Stoping m²	2,330	2.806	3,003
3. Development replacement factor m²/m	2.0	2.5	2.8
4. Dilution %	29	27	26
5. Total shaft head width	1.63	1.59	1.57
6. Extraction %	69	75	78

Trackless Mechanised Mining Methods				
	MDP 8m	**MDP 10m**	**MDP 12m**	**MDP 13m**
1. Shaft Head Grade g/t	*3.56*	3.63	3.68	3.70
2. Stoping m²	*5905*	6333	6649	6778
3. Develop. Replacement factor m²/m	*10*	12	14	15
4. Waste dilution %	*14*	13	12	11
5. Total shaft head width (incl. overbreak)	*1.30*	1.27	1.25	1.23
6. Extraction %	*82*	85	87	88

ALL LAYOUTS COMPARED AT A FIXED SHAFT CAPACITY OF 40 000 TONS PER MONTH HOISTING CAPACITY AS WELL AS A FIXED RECOVERY	**CONVENTIONAL MECHANISED BREAST WITH TRACKLESS RAISE AND ASG**	**MECHANISED DIP PILLAR SYSTEM WITH WATERJET AND LHD CLEANING 8 m**	**3 STRIKE DRIVES LONG BACK WITH CONVENTIONAL RAISE AND ASGs (MUCK BAYS AT TOP AND BOTTOM END OF RAISE)**	**CONVENTIONAL BREAST (LAY-BYE)**
1. Head grade (4eg/t) (95% MCF)	3.60 g/t 4e	3.56 g/t 4e	3.81 g/t 4e	3.96 g/t 4e
2. Monthly stoping and ledging (m^2)	6201	5905	8112	8593
3. Development Replacement factor (m²/ m)	595	610	204	168
4. Waste dilution %	21%	22%	16%	13%
5. Tramming width (m)	1.28	1.30	1.20	1.25
6. Extraction	88%	82%	82%	88%

COSTS

PLANNED	PLAN	ACTUAL	
B2P T/Cut	Opex & Capital	Actual 2003	Actual 2004
	103.58	223	154

As can be seen, the cost estimates were over optimistic and pushed the project deeper into trouble. The major areas on under estimation were labour, maintenance and explosives. On benchmarking the rest of Anglo Platinum is was found that the average cost for mechanised operations were 161 R/Ton.

With this information the Frank team, with the knowledge they gained over the past 3 years, did a first principle budget and established an operating cost of R 138 for operating expenditure and R 29 for ongoing capital expenditure. The last 6 months in 2004, expenditure was at R 146.83 per ton.

As seen above, the project is not there yet but one must bear in mind that when the method is completely changed in April 2005, the cost should be achieved.

PROBLEMS EXPERIENCED

Scalping

It was realised early during the project that the benefits anticipated form scalping was not well-founded. The mine reason for this is that the grade loss associated with the process was higher than expected after investigation on results from ARC, and had to be stopped.

Mining Width

The expected mining width of 1,85 in the development was not achieved and was closer to 2m. The main reason for this was when rolls in the reef was experienced which regularly occur on the UG2 at Frank, the mining width was increased otherwise equipment would get stuck.

Plant Recoveries

Although tonnages were achieved, ounces allocated by the plant were lower than planned which obviously led to the argument which is as old as the mines, that from mining the plant is inefficient and from the plant is that mining is not delivering the required grade.

Costs

As discussed in the cost comparison with not enough information available on mechanised narrow reef flat dipping ore bodies, an over optimistic cost estimate was done.

Combining the above with a strong rand, it created a very unhealthy loss making situation and the team was forced to adopt or die. From this the mechanised dip pillar of Frank Shaft was born.

CONCLUSION

It is still early days, however to date the results are very encouraging with the UG2 making profit due to the higher grade and improved efficiencies. It is also believed that with some minor adjustments in the system the team at Frank will have a method that will allow the UG2 reserve to be mined profitably into the future.

INPUT AND VALUABLE INFORMATION FROM PEOPLE

The Author wishes to thank Management of RPM Rustenburg Section and Anglo Platinum for permission to publish this paper.

Special thanks is also extended to Hannes Hopley, Section Manager Frank 1 and to Frank Egerton for their excellent work and input to this paper.