Primary development using hydropowered drilling and watergel explosives at a South African gold mine.

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Preamble

70 papers have been published by the Association of Mine Managers of South Africa under the heading "development" since 1931; in other words, an average of less than one per year. Clearly the rate of change in this area of the business has been slower than in some of the others.

A report by SH Westcott was published in 1987 on the hydraulic drilling experimentation and trials which had been conducted over a number of years at West Driefontein. In the synopsis, the following statement can be found *"It is clear that the hydraulic machine outperforms the pneumatic machine, however where the main objective of any company is to make a profit, the future of hydraulic rockdrilling looks a little dark"*. Later, in a section headed "Future developments" one reads, *"It can be expected that hydropower will be used in pure water hydraulic machines, hydraulic props, high-pressure waterjets and other equipment in the not too distant future and will become part of a new mining system"*. By the end of the twentieth century, Eksteen and Kendall at Northam had reported the regular achievement of 2,9m advance per blast in an end with dimensions of 2,9m by 3,7m, using a hydraulic rig to drill a 64-hole round. They wrote *"effective advances are equally dependant on the correct choice of explosive. ..... It is adviseable to involve the explosives supplier from the outset to confirm drilling patterns, explosives and initiating devices"*. Today in 2005, the work at Kopanang shows that some light has penetrated the darkness observed by Westcott, and the validity of Eksteen's advice is demonstrated.

Synopsis

This paper records the approach and considerations applied to the utilisation of a hydropowered drilling rig at Kopanang for use in urgent primary development.

Some associated projects (not described in detail here) were undertaken simultaneously as part of the overriding business objective of opening additional mineable reserves, and thereby extending the profitable life of the mine. Hydropower was selected as the energy source on the basis of cost-effectiveness and time. The conventional alternative, ie compressed air, would not have been available in reliable volumes and pressure until a significant upgrade of the reticulation had been completed. Utilisation of hydropower enabled this work to be performed as a parallel activity to the primary development. Not only was innovation in explosives usage an integral element in the project's successful completion, but it also incorporated the organisational development intervention known on Kopanang as "Power team" training. Interested readers can find a detailed description in the paper by FJ Fourie on "Development and implementation of the self-directed work team concept at Kopanang Mine" which has also been published by the Association.

1. Introduction

A long-suffered problem at Kopanang is its constrained ventilating air volume. This is particularly applicable to the remote workings at the South-west corner of the lease. The possibility of mining an extension of the lease known as the EDOM block added importance to the issue, and gave rise to specific analyses and searches for a solution. Using *inter alia* the "Vuma" and "Gebler heatflow and refrigeration models", the required quantities of ventilating air were confirmed, and thereby the need for an additional airway together with a booster fan. Corporate best practice guidelines permit a maximum distance of 360m to be served by a single airway. Twin ends were therefore required. In all, 6 km of haulage and return airway development were envisaged. Simultaneously, upgrades to the infrastructure and services, as well as improvements to the men and material transport systems serving the area were included into the scope of the project.

This paper concentrates on the development of the haulage and return airway. However, for completeness, the other elements of the project were

- development and support of the 800 kW booster fan chamber
- development of workshops, battery bay and access thereto
- development of pipe raise and chairlift to 56 level
- equipping of engineering back-up services
- upgrade of compressed air, water and rail infrastructure

Development of the haulage and return airway was planned to take place from August 2002 to December 2006. This is a period of 52 months, or put another way, an average advance rate of 115m per month was required. Whilst such a rate of advance is not dramatic, the cost aspect of the project was what drew the attention of management of what is a relatively low-grade operation. A number of unique features led to the decision to proceed with a hydropower option. These included:

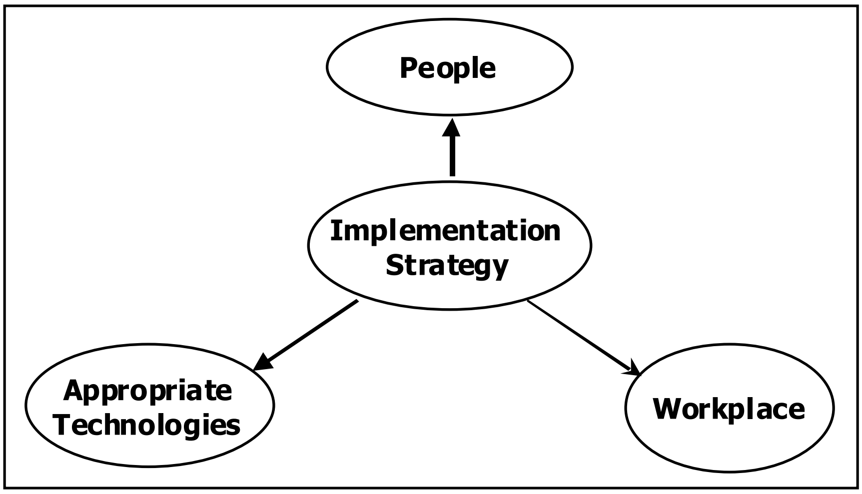
- the fact that Kopanang had the advantages of an existing drill rig, as well as crews with experience of similar technology;
- the isolation of the location meant that no other traffic would interfere with the work;
- the involvement of suppliers for equipment maintenance contracts.

Following a successful application for funds, the in-house project management methodology was put into place, together with the requisite control and reporting procedures. Details of the project management structure are included as Appendix 1. It must be noted that the budget approval was primarily based upon a commitment that the existing budgetary constraints would not be exceeded. Ventilation constraints dictated that multiblast conditions would never be achieved, so the work could only be undertaken as a single blasting shift operation. For these reasons, the achievement of the planned advance per blast became one of the most critical elements of the project, and therefore the evaluation and selection process of the chosen explosive receives what might otherwise be considered to be a disproportionate amount of space in this paper.

Previous attempts at the introduction of hydropower for use in development at sister mines had been unsuccessful. Kopanang had to be certain that the reasons for these failures would not be repeated. Three interlinked elements were identified as contributing to the success or failure of the initiative. All three required a similar degree of attention. They are:

- the employees themselves, and in particular their ability and motivation towards the use of a new technology;
- the efficacy of the explosives; and
- the cycle of operations.

Kopanang's strategy is encapsulated in the diagram showing how the three elements must be considered in relation to each other, and how all three are essential parts of an effective implementation strategy.



A description of the empowerment process applied at Kopanang (the "Power team" concept) has been separately published, so it will not be covered in detail here. The modus operandi of hydropowered drills is also well-known, and therefore does not warrant repetition. The paper will provide the project management considerations and cover the explosives selection process before describing key results and achievements.

Although the project was always considered on its own merits, there was a potential additional benefit arising from its successful completion. That was to usefully employ effective techniques developed during the work in other areas of Kopanang. One element in particular held hope in this regard, namely to perfect the drilling accuracy and associated blast design.

2. Project management

The following details have been included for reference purposes, and to acquaint the reader with some of the main concerns and considerations which management of the project needed to address. Despite the work being identified as a standalone project, supervisors were not dedicated to it; their responsibilities were merely extended to include it.

2.1 Criteria for success

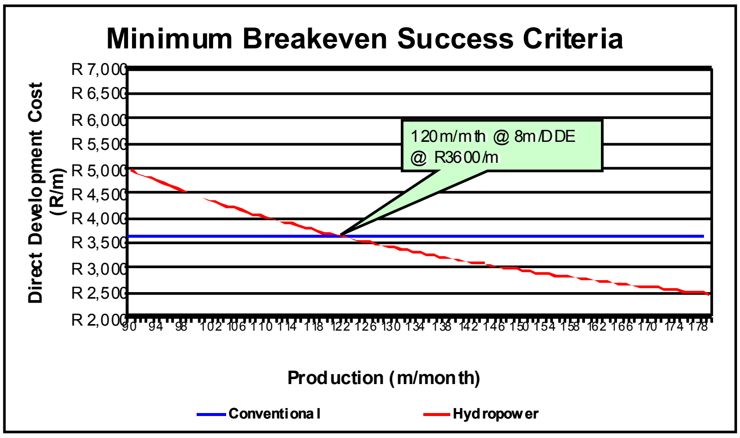
The breakeven cost/m was calculated and is displayed in the graph below. The cost elements that were included into the calculation were:

- maintenance contract cost for the drill rig
- maintenance costs for the Rockdrills
- all direct costs
- labour
- drill steel
- amortisation

Note that maintenance costs for the explosives mixing and charging equipment is included into the unit price, and therefore is included as a direct cost.

Other key factors for success were identified as:

- ventilation districts for the south-western portion of the lease area and for the EDOM block to be planned, scheduled and executed in conjunction with the LOM plan in order to create an ambient temperature of < 28^0C
- planned maintenance services from the engineering department on HPE and LHD equipment and assistance on infrastructure upgrade of an exceptional standard
- infrastructure upgrade to sustain production levels
- training on new technology to be completed and audited
- precautionary cover drilling for methane and geological structure to be complete as per schedule
- quality of the maintenance supplied by outside companies has to be maintained
- a suitable incentive scheme for the whole team is required



2.2 Risk analysis

The result of a risk analysis is depicted in the tabulation below.

Risk description	Probability rating (1 – 10)	Impact rating (1 – 10)	Risk factor (1 – 100)	Indicated management emphasis
Completion of workshops for maintenance	2	5	10	Detailed scheduling, ensure timely material supply, close monitoring of progress
Commissioning of fan	2	10	20	
Trackless equipment – fresh air	6	5	30	
Old infrastructure – development rate	5	10	50	
Availability of RBM 7	3	5	15	
Rating scales: 1 = low, 10 = high				

2.3 Project plan and organisation

Detailed planning and control of the project utilised Anglo Gold Ashanti's in-house methodology. Meeting schedules for regular review and progress reporting were set up. The project plan was the reference document for the meetings which were scheduled as shown in the table below. This demonstrates the close supervision to which the project was subjected.

Meeting	Attended by	Frequency
Steering committee	Members and project manager	Monthly
Project team	Members	Weekly
Operations teams	Members	Daily
Evaluation - production	Mine Overseers	Weekly
Performance review	Project team and Project Manager	Weekly

2.4 Cost and time charge estimates

A tabulation of the consolidated cost estimates is shown below.

Cost component		Project cost	% of total
1	Development & cleaning equipment	R3 754 777	4,7
2	Blower & fans	R2 242 430	2,8
3	Workshops, store equipment	R1 096 316	1,4
4	Mining excavation	R47 307 718	58,9
5	Electrical installations	R2 381 960	3,0
6	Piping	R5 188 269	6,5
7	Escalation	R12 056 845	15,0
8	Contingencies	R5 143 632	6, 4
9	Fixed reimbursable	R1 187 174	1,5
	Total	R80 368 660	

3. Technical details of the rig

Drill rig data	
Supplier	HPE
Mass	1,8 tonne
Length of chassis	4,1m
Length of boom	3,9m
Thrust force	190kg
Height of scissors	3,7m
Power source	4,6 bar
Water consumption	0,2l/s
Drills	Sulzer new generation

4. Equipment selection

As mentioned earlier, the entire project was constrained by a requirement not to exceed the anticipated cost for conventional development. In order to ensure that the required rate of progress could be achieved, the project management team needed to establish with a high degree of confidence that the equipment suite to be employed on the project was adequate. A set of criteria was developed, against which the equipment's performance was evaluated. Project management needed to be satisfied that the equipment could:

- match the planned operational cycle
- provide the requisite degree of drilling accuracy
- drill all breakaways
- drill rounds longer than 3,0m
- support the blasted areas to the required density

Despite this step in the decision-making process, it was not entirely successful. The initial choice of loader needed to be revised for reasons of underestimated operating cost. Hydropowered loaders could not be accommodated within the budget constraints, so a Wagner 3,5T LHD was the first choice for cleaning equipment. Its unacceptably high operating cost forced a change, and in its place, Salzgitter pneumatic loaders were chosen. The rock transport fleet consisted of 2 x 8t battery locomotives supplied with 16 x 4t hoppers. Support was drilled with HPE's development roofbolter.

The full suite consisted of:
2 x HPE's 3-boom hydropowered drill rig with remote power packs
20 x Sulzer hydropowered Rockdrills
2 x Salz gitter pneumatic loaders
2 x 8t battery powered locomotives
16 x 4t hoppers
1 x HPE's single-boom hydropowered development support drill rig

5. Crew training

Despite the benefit accruing to the project from the availability of crews who had previous experience with non-conventional technology, in this case trackless equipment, they were nevertheless exposed to the team-building and motivational elements of Kopanang's "Power team" training programme. This is an organisational developmental intervention intended to grow the self-sufficiency of production crews for self-management and motivation to enhanced output. For details, the reader is referred to the paper "Development and implementation of the self-directed work team concept at Kopanang Mine" by FJ Fourie, who is the architect of the programme and currently General Manager of the mine. The additional benefits that exposure to this intervention brought to the crew was a behavioural change enhancing their self-reliance, and an ability to positively influence their bonus-earning potential. It marries the concepts of empowerment and enablement.

Development crews are exposed to those aspects of the course that are applicable and relevant to their work. This is covered in a one-week period, rather than the three-week duration for stoping crews. In this way they are empowered.

Training in the use of the drilling rigs was provided by HPE on site; thus adding the enablement element.

6. Target-setting and operating cycle

The required average rate of advance was 115m per month over a 52 month period. Local circumstances meant that multi-blast conditions could not be sustained. The distance to be developed precluded consideration of a single end. Thus the project required twin-end development on a single blasting shift cycle. A daily advance target of 3m would meet the required average and allow for about 10% leeway to cater for unplanned delays and maintenance. However, budgetary constraints prevented the acquisition of a hydropowered loader, so a compressed air column would have to be provided. Also, the best consistently achieved advance with conventional explosives was only 2,4m per blast. Provided that means could be found to increase this to 3m per blast, it was anticipated that the other elements in the operating cycle could be accommodated. Investigations were undertaken into the possibility of applying emulsion explosives to achieve the required advance per blast.

As manufacturer and supplier of the drilling rig, HPE was intimately involved with the explosives experts from AEL and UEE-Dantex who were approached for assistance with both the design of the round to be drilled as well as for the supply of explosives. This work is described in the next section.

The operating cycle that was accepted was as shown below, and was applied to a 23-shift month.

A multi-skilled artisan provided by the equipment manufacturer performed maintenance of the drill-rig. This approach overcame the need to train a company employee and ensured that the manufacturer's quality standards were maintained.

Night Shift	
End 1:	Clean and Support
End 2:	Clean
Day Shift	
End 1:	Drill & Blast 3m round
End 2:	Support, Drill & Blast 3m round

Success was not only to be measured in purely production terms. The full set of success criteria for production was:

- safety: no incidents related to FOG and explosives
- quality: line, grade, overbreak
- cost: competitive with the conventional development benchmark as at 2003
- progress: remain within 10% of the maximum potential monthly advance

7. Explosives evaluation and selection

Due to its critical importance in the achievement of the project objective, and thereby meeting the financial and time constraints of the project, this topic is covered in some detail. It will be remembered that the required rate of advance was 3m per blast. Also, the advice of Eksteen and Kendall quoted in the preamble regarding the involvement of explosives supplier will now be recalled.

The pumpable bulk explosive concept means a mixture of two non-explosive compounds that are transferable into an explosive condition after both have been intimately mixed in a blasthole. Pumpable bulk explosives systems were investigated because they have the following properties:

- Safer explosives application (2 non-explosive components)
- Lower cost than cartridged explosives.
- Both components are handled as non – detonatable chemicals, therefore Regulations controlling the transport and handling of explosives are not applicable
- Coupling ratio of 100%
- Variable strength of explosive
- Possibility for mechanisation of charging-up providing short charging-up times

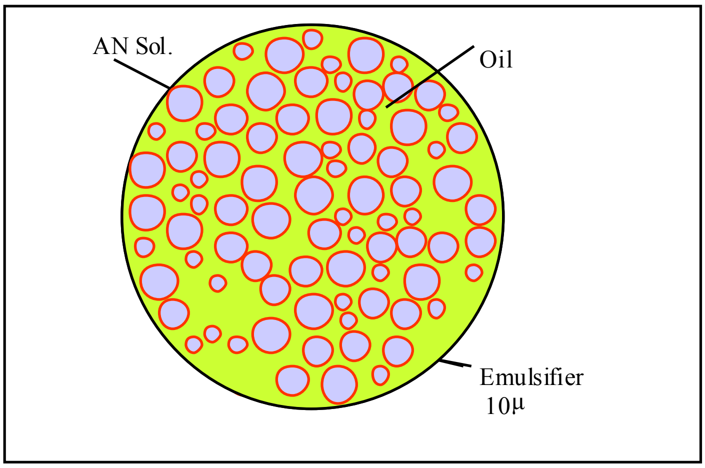
Two bulk explosive systems were chosen for testing, namely from AEL, their R100G pumpable emulsion explosive and, the RIOFLEX pumpable watergel explosive from UEE-DANTEX. These suppliers were chosen on the condition that after successful implementation in a development application, the product should be easily adapted to stoping requirements. The services of Anglogold's Mining Technology section (AMT) were utilised to assist in the specification of the test criteria, as well as in the monitoring and interpretation of results.

A project approach was taken to the evaluation process. The following selection criteria were applied. The selected product had to:

- be safe to use
- be cost-effective
- achieve the full advance per blast
- create smoothwall conditions
- require a short charging time

The alternatives selected for evaluation are described in detail below.

7.1 AEL - Pumpable Emulsion Explosives (R100G)

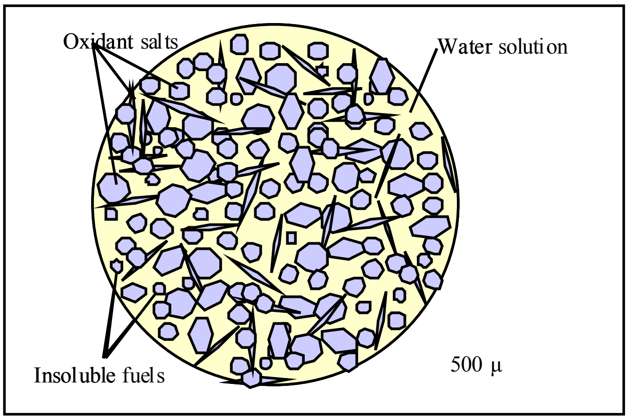


This product is a mixture of non-detonatable emulsion and a gassing solution in the ratio of base emulsion ± 97% to gassing solution ± 3%.

The base emulsion is manufactured by blending oxidizer (ammonium nitrate solution) and fuels (oils) with additions of various pH regulators and catalysts to stabilise it. The gassing solution is a mixture of sodium nitrate and water, the amounts being dependent on the required final density and strength.

During the sensitisation process, sodium nitrate from the gassing solution reacts under pressure with the ammonium nitrate in the base emulsion and produces micro nitrogen bubbles, making the final product a cap sensitive explosive.

7.2 UEE- Dantex Pumpable Watergel - RIOFLEX



RIOFLEX is a member of the ammonium nitrate family of the bulk watergel explosives. It consists of two main components, namely the RIOFLEX matrix and a sensitiser or crosslinker. The matrix is a fully crystallised suspension of ammonium nitrate salts and soluble and insoluble fuels in an aquaeous solution, with additions of other chemicals to achieve a gel. The crosslinker consists mainly of sodium nitrate in a water solution.

Comparable properties of the explosives are given in the table below.

Parameter	AEL: R100G (emulsion)	UEE: RIOFLEX (watergel)
Density (g/cm^3)	1,18	1,15
VOD (m/s)	4500	3800
Gassing rate (minute)	5	1
Critical diameter (mm)	22	25
Critical density (g/m^3)	1,25	1,2 (underground gold mine conditions)
Sensitivity	8D	6D
Energy (bulk) (MJ/kg)	2,43	3,14
Waterproof?	Yes	Yes

7.3 Charging-up equipment

AEL's unit is referred to as the U117E, and is pictured below.

UEE Dantex used an ex - AEL unit that had been redesigned and modified by AMT and UEE-Dantex for the purposes of trial. The following modifications were made:

i) Sensitizer pump: the CAT pump was replaced with Orbit M835.
ii) Hose lubricator system: stripped as it is not required for RIOFLEX.
iii) Burst Disc: 40 bar disc replaced with 20 bar disc, thus increasing the safety of the unit.
iv) Mixers: the modernizer, mechanical system was replaced with a simple static mixer.

v) Dual density switch: the charging explosives density is obtainable by manually changing the gearbox ratio.

vi) Gearbox: the sprocket-type gearbox was modified to obtain desired mixing ratios and flows.

vii) Controls: PLC-based controls and remote controls were removed to simplify the operation and maintenance.

Operational parameters of the units are compared in the table below.

Parameter	AEL - U117E (emulsion)	UEE– DANTEX (watergel)
Size L x W x H (m)	1.8 x 1.4 x 1.2	Same
Mass (kg)	1100	Same
Base tank capacity (l)	1400	Same
Sensitizer tank capacity (l)	60	Same
Flow rate (kg/min)	40-50	21-26
Dual density arrangement	Not available	Mechanical switchgear, low and high density application
Cost	R187 000	R160 000
Working pressure	28 – 30 bar	20 bar
Power medium	525 v – electrical	Same
Mixing arrangement (lance/unit)	On line unit modernizer	Lance with static mixer
Main pump	Orbit 0504- Electrical speed reducing gearbox – chain driven	Same
Secondary pumps	2x Cat 2ES 20/35 high pressure pumps	M 83 Orbit pump
Bursting disc pressure	56 bar	20 bar
Electrical safety PLC	48 bar high; 5 bar low	None – no high-pressure pumps
Additional tanks	Yes, hose lubrication and flushing, 60l capacity	None

The total cost of the modification was approximately R 29 500 (ie approximately 15% of the new item cost) and was met jointly by AMT and UEE-Dantex.

7.4 Comparison tests

Over a two-month period, each supplier was assigned one of the ends on the 53 level project for the first month of the trial and thereafter they swapped. Identical initiating systems were employed and the results were monitored on a daily basis.

The test procedure specified that only one variable would be introduced at a time, and that it would be applied to both ends concurrently.

The goals to be achieved by competing suppliers were:

- Each blast must achieve 100% advance, which is 3,0m/blast.
- The overbreak must be reduced to 0%; this should reduce the total number of hoppers generated per blast to 20.
- The explosives used will have the capacity to be set off with 8D detonators only, that means without primers.
- Only pumpable bulk explosives can be used.
- The quality of the blast will be measured by the presence of the barrels on the sidewalls.
- No incidents or accidents related to explosives handling may occur
- Cost as measured in terms of R/m advance must be minimised.

The project phases were:

Phase I — Fuse and igniter cord used as the initiation system.

Phase II — Shock tube (Tunnelmaster® by AEL) used as the initiation system. The primer being eliminated.

Phase III — The density of the explosives mix for the perimeter holes changed to obtain barrels and 0% overbreak.

For all project phases, the main criterion of 3,0m advance per blast remained unchanged.

7.5 Test results

During the test, the pumpable watergel product showed superior performance in terms of breaking. All blasts resulted in a clean break and very few sockets were created; those sockets that remained did not affect the advance per blast. The emulsion product performed very well when the correct mix ratio for the base emulsion was obtained.

The results for both months are summarised in the table below.

Month		No of blasts	Blasted metres	Drilled metres	Advance per blast m	Blasting efficiency %	Explosives kg/m
Sept 2003	Emulsion: RAW	10	25.19	30.00	2.52	91	68.52
	Watergel: Haulage & conn x/c	11	32.67	32.89	2.97	99	60.47
Oct 2003	Emulsion: Haulage	9	25.31	27.46	2.81	92	No data
	Watergel: RAW &	10	29.93	29.87	2.99	100	61.0
	conn x/c	5	15.15	14.95	3.03	107	60.30
Emulsion total		**19**	**50.5**	**57.46**	**2.66**	**91**	
Watergel total		**26**	**77.75**	**76.91**	**2.99**	**100**	**60.67**

The watergel system outperformed the emulsion by 11,4% in terms of average advance achieved per blast. Watergel achieved 2,99m/blast, where the emulsion achieved 2,66 m/blast.

Availability of the system was determined by the ratio of the number of meters blasted by the respective systems to the total meters surveyed at the end of the measuring month. The results are shown in the table below.

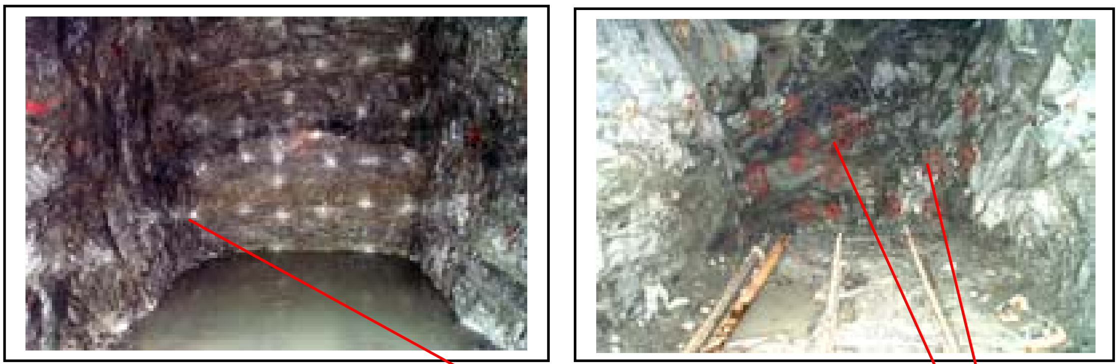
	Survey meters measured	Emulsion		Watergel		Other	
		m	%	m	%	m	%
Sep 2003	80,7	25,19	31,2	32,67	40,5	22,84	28,3
Oct 2003	70,6	25,31	35,8	45,1	63,9	0,19	0,3

During the trial, the watergel system demonstrated better reliability and availability, which can be attributed to the following attributes:

- mechanically sound
- very little servicing required
- simpler

No blasts were lost during the October measuring month using the UEE-Dantex system, and it met the test objective of initiating the explosive charges without the use of the primer or pentolite booster.

Tests revealed that both products are sensitive to an 8D detonator, however the watergel achieved a clean break, whereas the emulsion product broke only 1.40m out of 3.0m hole leaving 1.60m long sockets.



On left: RIOFLEX barrel seen on the left sidewall, on right: R100G blast. (Sockets are marked with red rings).

The smooth blasting objective was not fully met during the test period, only a few barrels were observed. However, towards the end, the number of barrels per blast did rise to about 30 % of the total number of perimeter holes. This was attributed to better utilisation of the dual density facility by the crew. The project team concluded that changes were required to the blast design before the desired objective could be achieved. The final design is discussed later.

7.6 Cost comparison

A cost comparison was performed, taking only the direct explosive costs into consideration. All the other parameters were either constant, or changes to them were common to both working-places. AEL supplied their product at a fixed unit price. UEE provided a volume-related pricing structure.

Consumption rates were derived from the monitoring reports, and were found to be 66,02kg/m for AEL and 60,64kg/m for UEE. For completeness of the exercise, the cost/m of development with Magnum 365 and Powergel 816 was included. As can be seen from the table below, RIOFLEX is also competitive with conventional explosives used in development.

Product	Consumption kg/m	Cost R/m
AEL R100G emulsion	66,02	345,88
UEE RIOFLEX watergel	60,64	295,32
Variance	5,38	50,56 (=14,6%)
AEL Magnum 365	46,85	316,24
AEL Powergel 816	44.07	253,84

7.7 Other factors

A consideration that favours the choice of a watergel explosive is that being fully crystallised, it is completely stable. Emulsions on the other hand suffer from the disadvantage that rough handling, shock and the passage of time can cause the oxidiser to crystallise, resulting in a loss of sensitivity due to non-uniform mix, and thereby a reduction in performance.

7.8 Summary and conclusion of comparison testing

The evaluation showed that RIOFLEX not only outperformed R100G, but that it met the requirements in terms of advance per blast. Charging-up time was recorded and an average of about 31 minutes was required to charge the 51 hole round; this was felt to be satisfactory in terms of the operational cycle. UEE was therefore selected as the explosives supplier, and work on the design of the round was conducted in conjunction with HPE.

To summarise the reasons for utilising the selected bulk explosives system, the following are the key elements:

- safety
- consistency of results
- one man remotely controlled charging-up operation
- no wastage
- no booster or primer required for initiation
- less than 1% overbreak

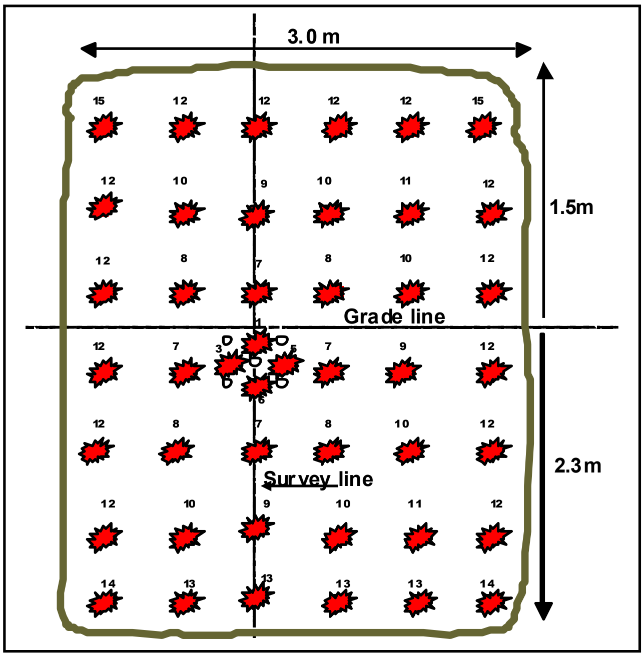
- 100% advance per blast
- capability to provide variable density of product to suit perimeter holes
- underground silo storage
- long shelf-life
- short charging-up time

8. Details of the round

Blast design took into account the following parameters:

- breaking angle of rock in situ
- relationship between hole diameter and powder factor
- timing of the round
- requirement for smoothwall blasting
- shape of the excavation

Initially, a five-hole burn cut was drilled, but after experiencing poor advances, this was changed to a nine-hole burn cut. The entire round consists of 50 holes drilled with 42mm knock-off bits on 3,2m by 25mm hexagonal forged collar steels. Forty-five holes are charged. The blasting sequence is shown by the annotated numbers in the sketch.



Barrels on sidewalls

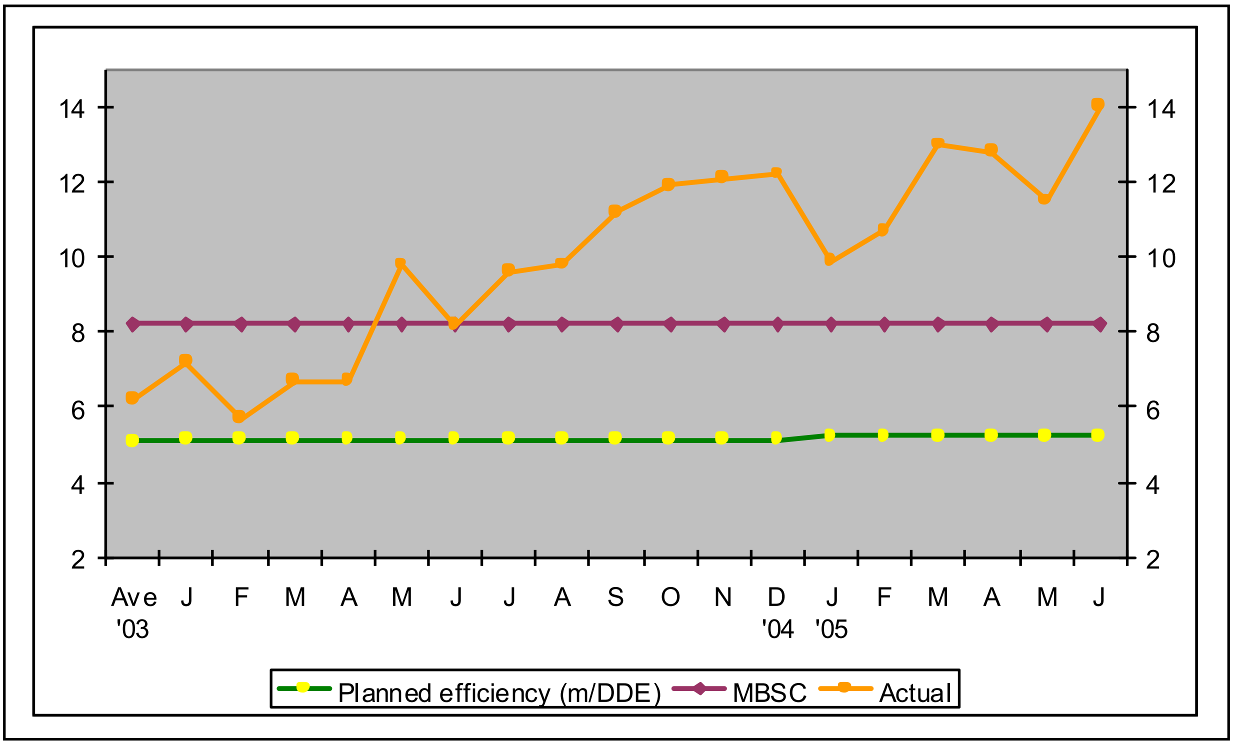
9. Additional data, results and achievements

9.1 Crew strength

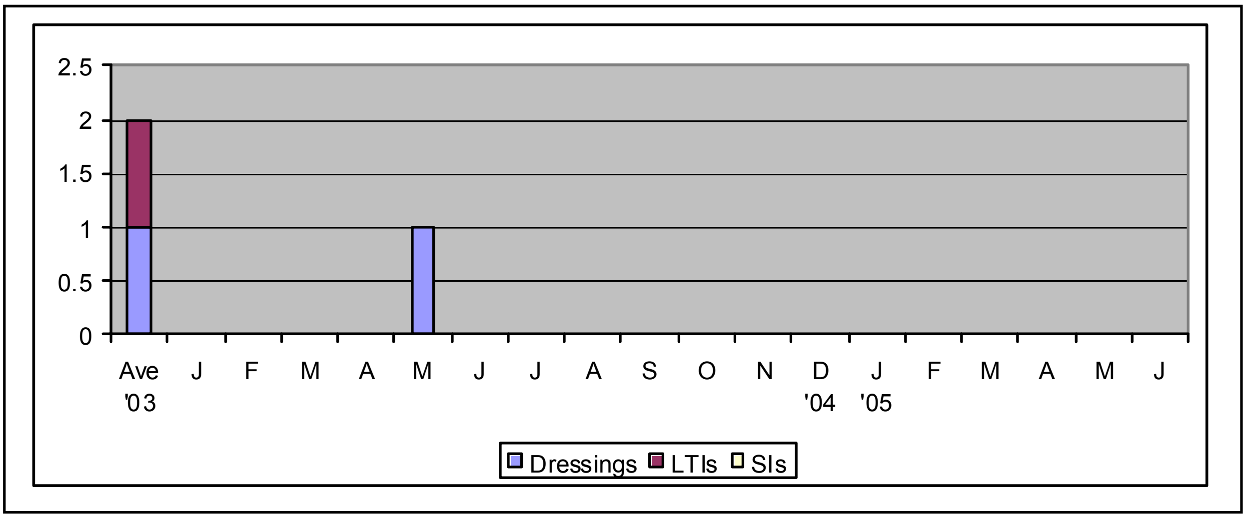
A total of fourteen people comprised the crew; a breakdown by category is shown in the tabulation.

	Crew members		
Occupation	Dayshift	Nightshift	Total
Shift overseer	1	1	2
Developer	0	0	0
Development Team Leader	1	1	2
Development construction	2	0	2
Drillers	3	2	5
Loader operator	0	2	2
Miner's assistant	0	0	0
Multi-tasked artisan	1	0	1
Artisan assistant	0	0	0
	8	6	14

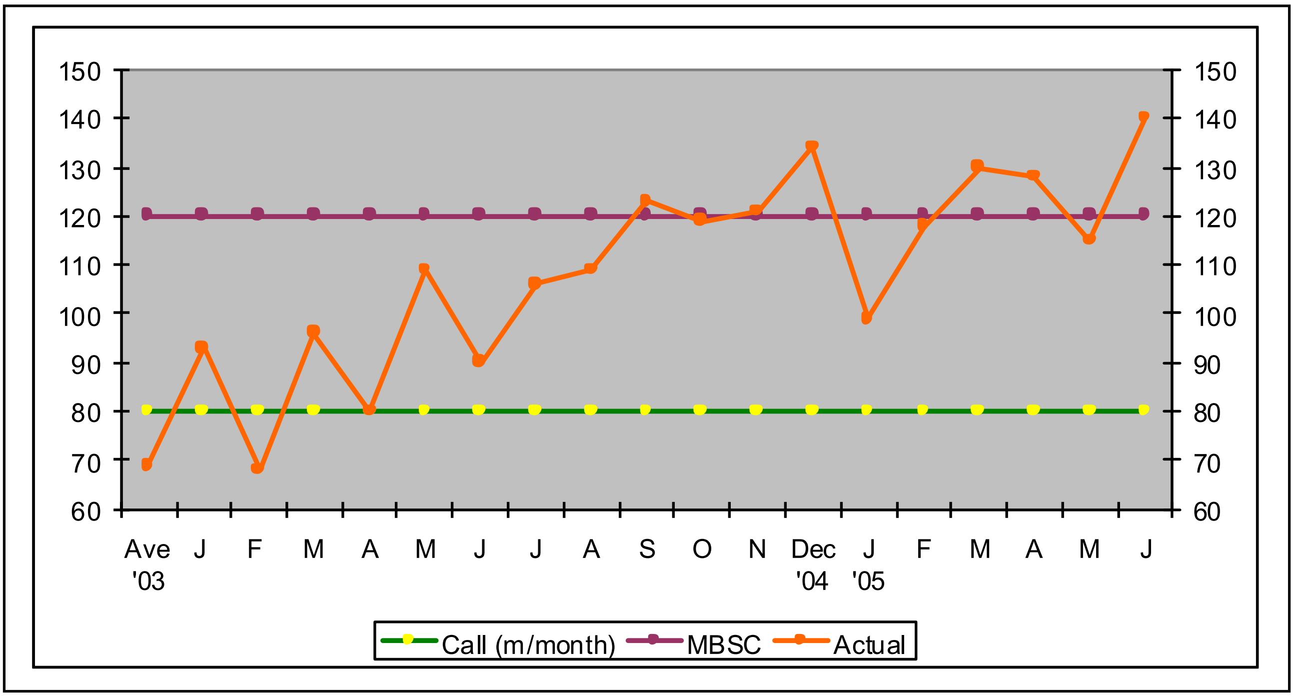
9.2 Labour efficiency achieved



9.3 Safety statistics



9.4 Production performance



10. Conclusion

Hydropowered drilling and bulk watergel explosives have been a successful combination of technologies for Kopanang's 53 level development project. While it is understood that many of the concerns and issues discussed here may be peculiar to Kopanang, the material will hopefully be of value and assistance to others who may be contemplating similar activities. It is for this reason that detailed derivation of some of the conclusions has been omitted as it could have unnecessarily extended the length of the paper. To provide an indication of the scope of the benefits that have accrued to Kopanang as a result of this choice, the development time required to reach the extension of the lease has been reduced by 30 months, and the labour cost is nearly 30% less than it would have been using conventional methods. It was thought to be of limited value to include the bases of these calculations in the paper itself, mainly because the parameters on which they are based are local in nature. As order-of-magnitude indicators, they are nevertheless worth repeating.

Reference was made in the preamble to some worthy precursors in the field of hydropowered drilling. Going even further back into history, the tabulation below shows how Kopanang's results compare with what at the time was a record for flat development.

	Loraine Gold Mine 48 level project 1962	**Kopanang Gold Mine 53 level project 2005**
Dimensions (m)	3m x 3,8m	3m x 3,8m
Total monthly advance (including units)	858m	130m
Shifts per month	29	22
Number of ends	1	2
Number of blasts per day	4	1
Rockdrills in face	10	Rig with 3 drills
Shift overseers	4	2
Developers and General Miners	6	0
Breaking and cleaning crew	160	11
Total labour	**170**	**13**
Average metres/day	29,6	5,9
Average metres/shift/end	7,4	2,95
Average metres/man/shift	**0,17**	**0,23**

The other potential benefit arising from a successful completion of the 53 level project which was mentioned in the introduction, to wit utilisation of effective techniques in other areas at Kopanang, has also been realised.

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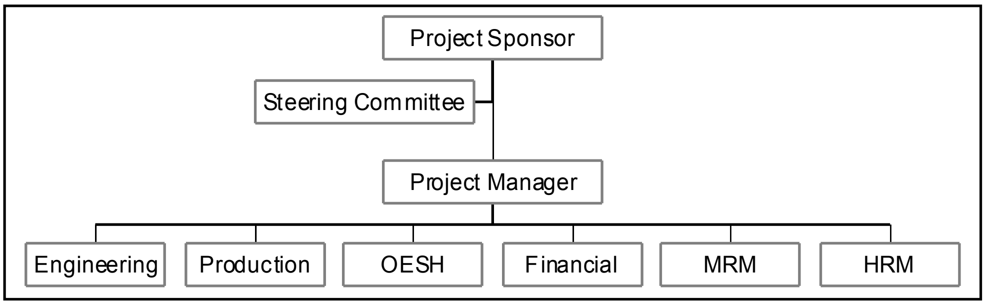
Appendix 1

Project management structure



The project sponsor, being the manager responsible for capital, has the roles of setting priorities, conflict resolution and the provision of leadership and guidance. Project scope and change management are the main tasks of the project manager. In addition to the discipline heads as depicted, additional resources are provided by designated subordinates (a total of 9 people) and by contractors in the areas of hydropower technology implementation, rail construction and upgrading and pipe infrastructure upgrading.

The steering committee consists of the General Manager, the Production Manager, the Financial Manager, the estimator, and the ESH manager.