The Development of Beatrix 3 Shaft and its Hydropower

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Beatrix Mine PTY

SYNOPSIS

Beatrix 3 Shaft (#) utilizes various new mining initiatives that have developed from a ‘three activity’ plan, derived from a specific vision. The largest of these initiatives is the implementation of hydropower, which is putting the claims of the technology to the test. The implementation of hydropower on Beatrix has successfully begun; however, no pure hydropower solution is yet possible. All the hydropower systems in place are functioning well, and are now being managed to offset the high capital outlay. The use of drill rigs and jigs is linked to the more efficient production required to cover this cost, as well as to fulfill other aspects of the 3# vision.

This paper details the current position of the relatively new Beatrix 3# in its implementation of hydropower and related equipment. It discusses the main problems, successes, future targets and future development. This paper stresses the mining processes and their impact, rather than the technical nature of the work being done.

Other initiatives derived from the activity plan include a test monorail system, extensive high quality track work and cemented crosscuts, as well as other improved engineering systems.

INTRODUCTION

Beatrix Gold Mine is situated at the southwestern margin of the Wits’ golden arc, 40km from Welkom. It is a shallow operation, operating at an average depth of 900m, while the new 3# will average depth 1 250m. The shallower shafts use a scattered mining method and use normal pneumatic mining with rail bound transport. No 3# currently operates between 1 100m and 1 350m deep. Beatrix is a relatively low grade operation, making the location and efficiency of mining panels critical to gold output.

Beatrix 3# is a planned expansion to the existing 1# and 2#, to allow an extra 30 000m² production per month by 2008. This will help to maintain the overall mine output. In the 1993 feasibility for the shaft, hydropower was not considered as a power source. On later review, it was decided to implement hydropower – and make a concerted effort to discard compressed air entirely – due to improved energy cost and efficiency.

Sinking of 3# began in July 1996, and was completed in 2001, although the shaft is still in the start up phase. Extensive use of contractors was made to assist the development up to December 2002, when the mine took over all work. Compressed air is still being used in 50% of the stoping, and in some development ends, as hydropower pipes are still being installed in the lower levels.

Geologically, the 3# reef has a very flat dip between 6° and 10°.

The depth of mining and the rock strength has created the first serious rock mechanics constraints in layout at Beatrix. Panels can be no longer than 27m, with small, in-stope pillars left on strike. On a larger scale, the area immediately surrounding the shaft was mined out first, leaving 4 satellite shaft pillars. Mining in the shaft area has just been completed, and backfill is being placed.
Hydropower is planned as the only energy source (barring electricity) for 3#. The concept of hydropower was first properly developed for the mining industry in the 1980’s, with commercial drills reaching viability in the early 1990’s. It is now more than 10 years later, and hydropower should perhaps no longer be called a ‘new’ development. No 3# implemented the hydropower system at a substantial capital investment in order to realise the technical benefits.

Due to the cost of installation and equipment, only new shafts can be fully hydropower equipped. These shafts number less than 10, and have been large and risky undertakings. Some have been successful, others not. Unfortunately, no shaft has rid itself completely of compressed air reticulation – an expensive holdover to the old system.

1) Hydropower is the term used to describe the use of piped, pressurized water as an energy source for various machines. Typical end user pressures range from 16-18Mpa.

THE VISION BEHIND 3 SHAFT

In order to effectively achieve the required boost in output over the coming years, four key vision elements have been determined:

- Safety must improve to beyond international standards;
- Gold volumes produced need to be increased to reduce overhead costs, increase the resource and for better economic benefits;
- Production costs must be lowered to remain competitive;
- The cost reduction is linked to a reduced pay limit, increasing the life of mine and the number of jobs available.

The attainment of these visions will come about via three activity types. These activities are Benchmarking, Blueprinting and Reverse Engineering. All three activity types are related, and depend on each other.

Benchmarking is the comparison between the practices and efficiencies of Beatrix and competitors in order to find areas of potential improvement at Beatrix. Potential is being realised by improving practices, methods and implementing technology - all leading to better mining team work standards and quality. Benchmarking sets the targets in the Blueprinting process and assists with Reverse Engineering.

Blueprinting is the segregation of the mine into different components (such as horizontal engineering, stoping, environmental services, etc) so that each can have its subdivisions (labour, stores, explosives, etc) inspected and costed. These are compared to current efficiency and method in the components, allowing an effective cost profile to be generated. New methods and practices are (to be) implemented to arrive at the targeted cost.

Finally, Reverse Engineering is the manner in which the new methods and practices used in Blueprinting are arrived at. Current practice is looked at, and modified to match the required state. The modifications come in the form of changes in infrastructure, technology, process redesign, labour practices and so on.

The new systems detailed below are as a result of the actions described, and serve to fulfill the vision of 3# Beatrix.
HYDROPOWER PROMISES

The various papers written about hydropower have been upbeat and optimistic, particularly when combined with rigs and basic machines. Some of the more commonly presented advantages are listed below:

- Hydropower equipment is considerably less noisy than pneumatics, and the noise generated is of a higher frequency, which more easily stopped by ear plugs.
- Drills operate at a rate much faster than pneumatic drills.
- Less vaporization of water and no use of oil improve the working atmosphere.
- Cold hydropower water creates a microclimate that saves on cooling costs.
- Rig use allows accurate drilling, which leads to less explosive induced damage, leading to less falls of ground and less scaling.
- Rigs are operated largely by 1 man, who is removed from the face (where most fall of ground (FÖG) accidents occur), and who does not need to hold the drill proper (avoiding noise and vibration induced illnesses). The operator suffers less fatigue.
- Water powered rocker shovel (‘boesman’) loading is silent and more rapid than its compressed air counterpart.
- Water energy can be free (or at least very cheap) with the help of gravity to build up required operating pressures.

Almost all these advantages have come about at 3#, with few exceptions. The technical quality of hydropower is standing up to its promises. The valuation of the cost saved by many of these effects is not easy (such as the saving on hearing loss), and many are only a means to a saving (such as the faster drilling rate). Where possible, these have been detailed in their respective sections.

Some pitfalls related to hydropower also exist. Most will be common to all hydropower users; the main issues noted / identified at 3# are:

- Hydropower pipes are very expensive. The larger bore pipes are imported, and the Rand fluctuations make this risky – and still more costly. Large lag times from order to receipt also occur.
- Equipment is considerably more expensive than its air counterparts. This means parts are more costly too. Hoses in particular, are an expensive consumable. Equipment is usually heavier than matching air units.
- Hydropower equipment is a more advanced technology than pneumatics. This means less internal tolerances so hydropower water needs to be of a good quality, equipment treatment and storage needs to be careful (machines do not take well to the ‘hammer repair’ method) and specific operating procedures need to be followed. Not only does this require technical items such as water filtration plants, it also requires a behaviour change from the workers. As this does not happen overnight, initial maintenance and repair of end user equipment is costly.
- Training crews on the new system takes a considerable amount of time.
- Drilling at double the usual rate is good, but if hydropower is not implemented to take advantage of this, all that has been put in place is an expensive way of letting the crews knock-off early. Implementation of the system may (in Beatrix 3#’s case, does) need new layouts, crew sizes, scheduling, water handling systems, equipment monitoring systems, workshops, and so on. A measurable extra gain in production or reduction in costs must be obtained, to make hydropower worth while. A key element in 3#’s cost saving was the reduction in crew size.
required, which would allow more crews to be created and so more reef could be mined at any one time.

These problems have been, or are being, tackled by Beatrix personnel. Again, these issues are further detailed in their respective sections.

THE BEATRIX 3# SYSTEM

The shallow depth of 3 shaft’s workings led to the selection of a hydropower system with a surface booster pump system. The rest of system is relatively simple and consists of two 300mm Nominal Bore (NB) pipes down the shaft, to an ever narrowing string of pipes on each level. Final pipe dimensions at the face are 50 NB.

The current system serves 6 levels from 1092m to 1342m deep. The gravity feed is assisted by surface pumps that generate an extra 6.5 MPa of pressure (see Illustration 1). The system, with pressure regulating valve (PRV) stations on the lower levels, gives a constant and reliable 17 – 18 MPa of pressure to the working face equipment.

The aim at 3# is to make hydropower the sole means of mechanical energy in the shaft, with one exception; compressed air to supply refuge bays, as required by law. Hydropower stopes and development ends still have some air operated equipment. To date no effective solution has been found for charging up with ANFO prill and hole desludging. Current solutions involve water driven air compressors feeding modified air equipment. Initial indications are that the equipment will need improvement to match its air counterparts.

Hydropower, from a purely engineering point of view, generates a range of long term savings to offset a high initial capital cost. The clearest benefit is the cheapness of the power source and the efficiency with which it operates. The elimination of the dual water and compressed air system means the mine now only carries one, well installed and well managed, system.

At 3#, the cold water used in the hydropower system generates 10.1MW of cooling capacity, which is an important factor in the mine environmental control, particularly as the ventilation systems, as initially designed, were built for only 40% of the expected production.

Illustration 1
Surface Booster Pumps
At 3#, development is still close to the station, with only two levels developed sufficiently to allow stoping. All main development comprises of twin 3.5m x 4.0m (haulage and return airway (RAW)) ends, as determined mainly by ventilation requirements, which have to handle current double shift blasting and, later on, sufficiently cool boundary stoping so that efficiencies are not compromised. Cross-cut spacing is 120m.

As the levels are equipped with hydropower pipes, work with pneumatic hand held equipment is being phased out. Thus, developing is being done with hydropower rigs and handheld hydropower machines with the balance being done with hand held pneumatic machines and electro hydraulic rigs.

6 hydropower drill rigs are currently in use, with more being implemented as the need arises. Drill rig crews are made up of 5 face workers– 2 rig operators and 3 construction workers. In a double shift, double end blasting system, 3 people do the tramming and cleaning in each shift.

In the case of a rig, the blasting cycle is simple. Subsequent to cleaning with a hydropower loader, the support rig is trammed in, and permanent roofbolts installed. The support rig is removed, and the drill rig put in place. Finally, after drilling, the drill rig is removed and the face is charged up.

Double shift blasting is used in the development work. In general, a crew will clean one end while drilling and blasting another, although the capability does exist – and is used by several crews – to complete the full cycle in one shift in one end. Some areas are working on triple shift blasting. These areas will be expanded when the supporting battery bays and fitter shops are complete, which will allow more locomotives per level.

Some twin ends have advanced 80m (haulage and RAW together) off one drill rig in a month, with +70m advances achieved on consecutive months. The average advance for a single face is 35m/month, with a maximum, to date, of a 50m single face advance in a month. The advance rate of the ends is steadily climbing as problems are ironed out. One of the more serious problems being overcome is the length of hole drilled versus the achieved advance. Rounds were being drilled of 2.8m giving an average advance of 2.0m per blast. This was due to the use of hydro powered ‘hole desludgers’, which were not effectively cleaning the toe of the hole. Current practice entails a
cartridge primer pushed into the hole, creating a longer effective break. Once the system is refined and the hole desludgers improved, the cartridge will be left out and holes drilled to 3.1m length.

Aside from the initial capital cost of the rig, the operating cost of the rig is not remarkable.

The use of the rig has changed the nature of the work in the development ends. Where most activity used to occur at the face, this is now almost secondary to the ancillary work being done behind the rig. The holes drilled are accurate and in a pre-set pattern, leaving less up to the rig operators’ discretion, so less direct supervision is needed. Aside from the pilot holes, once the rig is set up, it does not need to be moved. As no one is at the proper face, this allows the miner to concentrate on better management of his work place, such as indirect safety aspects, equipping, store control, tramming, and so on.

The use of the drill rig does have some problems, which are detailed below:

- The tramming of the various rigs/units takes a substantial amount of time. Tramming spurs are needed to prevent having to push the rigs (as in this case) almost to the station.

- Initial operation caused drill steel damage through the excessive application of force by the drills to the face. Damage was in the form of sheared shanks and steel bent beyond recovery from the hole. Better operator coaching has largely solved this problem.

- The rigs are considered to now be fairly reliable, but operators needed to be further trained on part replacement, so that downtime is minimized. Operator experience has largely resolved this.

Hand held hydropower drilling ends have 3 rock drills, and the crews are made up of 5, multitasking, ‘hydropower operators’, who drill, blast and equip the end. 3 other people tram and clean with the hydropower loader (see Illustration 2) and two locomotives. They normally clean 2 ends per shift, depending on the advance rate and location of the end. The development is done in much the same manner as pneumatically developed ends; only the faster drilling rate allows longer rounds to be completed with less people. Average face advance for these ends is 1.8m per blast, and is set to increase.

Illustration 2
Hydro powered Rocker Shovel
Initially, high maintenance costs were experienced, but these have dropped substantially, so that store and repair costs are not far greater than a pneumatic system. This has come about with workers learning and applying the correct procedures in handling the equipment, so that the lives of the machines between services have been prolonged.

**THE MONORAIL RAISE CLIMBER**

Subsequent to discussion with the HPE (Hydropower Engineering) company, it was decided to implement a monorail mounted raise climber in a single raise line. This was to test the benefits of having a rail mounted hydro powered drill rig, these being an expected better advance, easier equipping and a smaller work crew.

The machine is hydropower driven, and comprises of 4 segments that run on a toothed track hung closely to the hanging wall. The front segment is a single boom hydropower rig, which is used to drill the face with a 2.1m round. The second segment is the operator’s cab, followed by a ‘hose roller’ that winds in or out the hydropower hose as the climber moves. The last component is a load carrying tray, for the equipment necessary to perform other work. The climber has proven to be reliable, with a few serious breakdowns. The lack of spares on site is seen as a problem, but this is not unusual for what is essentially a prototype.

The monorail will be left in place when the raise has holed, and the equipment used to start ledging and equipping. The rails can be left in place as they are ‘blast on’ rails. The boom will be swung to the side and will drill the initial ledging round. The load tray, which is able to carry a winch, will be used for exactly that and other equipment. As current ledging and equipping costs are high, and the duration long, the monorail should improve the process.

The development of the raise is done by a 3 man crew, who perform all the operations and equipping (cleaning is done by a night shift crew).

Subsequent to the entry exam, a hydropower handheld machine drills roofbolt holes, and the roofbolts installed. The necessary rail segments are installed by attaching it to the ‘2-1-2’ roofbolt pattern. The rail segments can be installed at a range of gradients to accommodate the changing reef behaviour. Subsequent to installation, the rig is moved forward and drilling begins. The machine operator remains at the face while the others extend the pipes. Charging up with ANFO is done with compressed air. Before blasting, the rig is parked at the bottom of the raise, out of the way and ready for the next shift (see Illustration 3).

Current face advances are 35m – 40m per month.

The advance rate and the savings generated by the re-deploying of 2 people (compared to 1# and 2#) do not yet compensate for the large capital investment required, but the project has just begun, and more savings are expected, particularly from the equipping aspect. In addition to this, the use of a rig to drill the initial ledging rounds is seen as an important safety boosting opportunity – the center gully sidewalls (the ledged raise) and hanging wall are expected to be less blast damaged. This is important considering the life and extent to which a center gully is used. This is over and above the immediate safety aspects of the rig, which includes the removal of the worker from the face, the area most frequently affected by falls of ground.

**THE RAIL NETWORK**

Part of the potential cost savings identified through Reverse Engineering was in the field of horizontal engineering. While costs can be saved here, there is also an awareness that mining is a logistical operation, and that good haulages are critical for effective mining. Fewer, higher payload trains on a well installed network are being created to increase efficiencies in the tramming process. The quality of rail and the limited number of locomotives and trips will also save costs in less direct ways, such as reduced maintenance, reduced wheel damage, fewer derailments, etc.
To ensure effective tramming, the track work at 3# is being upgraded to a high standard. Main haulages have graded ballast with a wide gauge rail and a substantial drain wall. The rails have been laid so that corners are smooth, elevations are correct and rail ends meet with a sub 5mm gap. Cross-cuts are being cemented in, making it much easier to keep them clean and drained. This also helps improve the general condition of material stored in the cross cut and keeps the area neater. Main haulages and cross cuts are being illuminated, creating a clear safety advantage (see Diagram 2 and Illustration 4).

![Illustration 3](image)

**Illustration 3**
Front Drill Section of HPE’s Hydro powered Raise Climber

To dovetail with these changes, new hopper systems are being implemented. A fleet of battery locomotives is going to tram a combination of conventional and 10 ton ‘spillage-free’ hoppers. The larger hoppers will be trammed in spans of nine, with a locomotive on either end. The idea will be to empty an entire box hole in one or two draws (see Diagram 3).

The net effect of these changes is to eliminate time consuming derailments, reduce the need to constantly lash clean crosscuts and ensure higher tramming velocities with less total trips required. This will be especially valuable in the long term. In addition to this, is an intangible behavioural element brought about by the greatly improved appearance of the working areas – a professional appearance is more likely to promote professional work standards. Other future possibilities being assessed are trolley line locomotives and centralized draw points and boxholes with higher capacities.

![Diagram 2](image)

**Diagram 2**
Class 2 Long Term Rail Installation
The stoping operations at 3# got off to a challenging start – the mining of the reef in the immediate vicinity of the shaft required special precautions. Compressed air was used in that area, so a changeover to hydropower is now occurring. Currently, hydropower crews generate approximately one half of the production. Some other areas have a hybrid cleaning system – scraper assisted water jet cleaning, or more correctly, water jet assisted scraping. The balance of the operation will move to hydropower when the crew training is complete, about mid 2004.
Stoping layouts are similar to most narrow reef metalliferous mines, and are scattered in nature. Cross-cuts are developed from the footwall drives to reach just below the reef plane. From the cross cuts, raises are developed, from which breast stoping is done. The shallow dip of the reef makes interlevel spacing only 50m, with long stope backs.

The layout and support pattern plan for a standard stope is shown in Diagram 4.

The stope panels vary in length – from 15m to 30m – due to various rock mechanics reasons related to the proximity of the shaft. On average a panel is 25m long (pillar to pillar). Small pillars are left on the up dip side of each panel. Two extreme ‘forms’ of stope panel can be used to explain the operation.

The first is a short stope face of 15m, in which drill jigs are used (see Illustration 5). The drill jigs are hydro powered drills mounted on simple frames (or elevated rails) installed between support units. The frame allows for accurate and easy drilling. The use of hydropower means the face drilling is very rapidly completed, and that only one rock drill operator (RDO) is required.

Stoping crews comprise of eight (8) day shift workers (with a shared centre gully driver) and two (2) night shift workers (with a shared centre gully driver).

Subsequent to cleaning, the jig frame is installed (the frame can be installed in the top end of the panel while cleaning is still being completed). One RDO is used to drill 1.5m deep holes in the face. A large portion of the blast is thrown into the gully using a shottube system of blasting, which is a more accurate blasting system than pyrotechnics, and complements the better, jig drilled holes. Cleaning is done using a water cannon only. Face cleaning rates vary, and take at best, between 4 to 6 hours. Faster instances have been recorded, but are rare. This is due to the very flat dip of the reef at Beatrix. Currently, the use of a water cannon saves on the requirement of a face winch, but no labour saving ensues (see Illustration 6).
Future mining plans include the implementation of double shift blasting in the stopes. This has already been attempted, but bottlenecks in the flow of ore prevented its effective use. In later mining phases, when more raise lines are available and thus less stopes are operated in each line, the double shift blasting will be re-instated. The impact of the flat reef has introduced cleaning time as another problem here, but various solutions are being looked at. The implementation of double shift blasting has extensive cost saving possibilities, the main aspect being that the number of panels can be almost halved, while the production stays the same.
Other stopes generally have a face length of between 25m and 30m long, and are operating similarly to stopes in the neighboring 1 and 2 shafts, except for the use of shock tube blasting. Stope crews are 10 people on day shift and 2 or 3 people on night shift.

Pneumatic equipment is used, with the shocktube system to throw blast. Currently, cleaning times have shown no improvement, and with the use of a face scraper and water cannon, labour compliment actually increases to very little benefit.

The cleaning times in both instances are substantial limitation in the current system. Due to the shallow dip, rock movement is not gravity assisted, so only water is used to move the rock. The shorter panels are at throw blast and water jetting time limits, while the longer panels are at scraper assisted water jetting limits when it comes to the cleaning time frame. Productivity cannot be increased using longer faces or longer rounds, as it just generates more broken ore – which impacts on the cleaning time. Some panels with experienced water cannon operators have shown cleaning times where moving on to a double shift is possible, so work is being used as a learning point for other areas.

The current stoping layouts are being examined, and small scale testing of various layouts and combinations of equipment is being done, to find the best system. The best layout will then be used as a standardizing template. This is essentially a ‘hands on’ format of the Reverse Engineering process.

Some hydropower equipment has given problems, but generally the equipment is good and the supply of spares is not problematic. The only fundamental design problem is the blast hole cleaner and ANFO loader. The new ANFO loading system has only recently been through initial practical assessment. The loader is driven by compressed air produced by a water driven compressor, a separate, mobile cylinder.

Workers appreciate the hydropower equipment – particularly the cleanliness of it, but complain of the weight of some of the equipment. The miners and the majority of production supervisors also support hydropower.
The stoping crews have, individually, undergone a week of spirit and team building and training termed ‘Bompodi’. This served to create a greater cultural understanding – of both the company and the workforce, a greater work directed pride, and, subsequently, a more self directed team. The results of the training and the hydropower technology have shown themselves in the stoping production results (see Graph 1). The stoping crews completed their Bompodi training in February 2003; subsequent to this, the production indices have moved positively.

![Graph 2](image)

**Graph 2**

Stoping Production Face Advance and Crew Advance

The developing crews are going to start the training in the near future.

The table below gives a snapshot of current and target operational indices (Table 1) for Beatrix as a whole and 3# separately.

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<th>FUTURE (2008)</th>
<th>UNITS</th>
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<td>1, 2 and 3 Shaft</td>
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<td>1, 2 and 3 Shaft</td>
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<td>Injury frequencies rate</td>
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<td>200</td>
<td>15% drop p.a.</td>
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<td>0</td>
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Table 1

Performance Indices for Beatrix Gold Mine
MAINTENANCE

The high initial costs of maintenance warrant a special mention. Beatrix 3#, as is recommended in various papers from the hydropower equipment suppliers, outsourced the maintenance of its equipment to the suppliers. Initially, problems were had with mechanical reliability and spare parts, but this was partly to be expected under the circumstances of a new shaft with untrained crews. Hydropower equipment is also considerably more expensive and sensitive than air equipment, so maintenance can be costly. However, with good care, a hydro powered drill can generate far more face holes than a conventional drill before being serviced.

Water quality at 3# is not yet up to hydropower standard – water is being pumped from 1#, which is not filtered with hydropower considerations in mind. Refrigeration and filtering plants are slated to be constructed soon. The water is dosed, and while it does not have a very high solid particle count, the final result has a relatively high chloride content. This has led to internal component corrosion, and specific problems, such as a higher frequency of drill rig drive chain snaps, as the water runs over the chain.

Labour has not yet truly appreciated the sensitivity of the equipment to dirt and rough handling. Initial maintenance was characterized by drills that had been damaged by being struck or left lying in water and mud pools, or connected up to dirty hose ends.

Costs during this period led the shaft to build its own repair stations on site, managed and operated by the suppliers. These carry their own supply of parts. Aside from this, exists equipment to cut and make hydropower hoses to the required length and, in the future, workshops for most machines, and a valve test station. Existing workshops have helped reduce costs by 60% and reduced the turnaround time of items they repair.

Maintenance costs have fallen considerably since the implementation of on site repairs, but this trend is also due to other factors. Personnel have improved their treatment of the equipment, and poor handling now constitutes about half of the greatly reduced, overall maintenance work. A peculiar finding is the number of normally operating drills that are sent to the surface for maintenance. This is due to poor fault finding procedures – again a training issue.

Large valves have been reliable, with only 3 repairs needed to date. These 3 instances have been due to uncommon causes – gloves or rocks found in the valve!

Maintenance of equipment is logged and a feedback system is in place, so that suppliers can modify equipment if needed and source common problem areas. Suppliers also have their own full time personnel visiting areas underground to look at improving equipment use and life.

The compliment of engineering personnel is important. Hydropower is a more technically advanced system, and while it may reduce the labour complement on the mining face, it requires an increase in the engineering and support complement. Equipment standing time has been dropping, as the reliability of equipment goes up and the training and experience of the users improves. In order to further assist this trend, the mine is going to expand its number of fitters while the supply companies are going to supply their own fitters for major breakdowns.

SAFETY

Over the last 18 months, only 5 accidents directly related to hydropower have been recorded. 3 of these were treat and returns, one lost day injury and 2 serious injuries – a fractured toe and a fractured finger.

The low accident rate indicates the inherently safe nature of hydropower. Of the few accidents which occurred, only one was related to water – a treat and return; the others were more ‘cause neutral’ – generally pinching by moving equipment.
What has been noted by its ‘non existence’, are fall of ground (FOG) incidents on rig operations. While it has been found that rigs do not necessarily create a more competent hangingwall, they do effectively remove the operator from the face and stop hand collaring. This safety consideration alone has been suggested as making the hydropower installation worthwhile.

There is an informal consensus on 3# that the hydropower equipment is definitely better when it comes to noise, atmosphere, cleanliness and coolness. This generates savings in various forms, ranging from reduced hearing loss compensation to higher output due to a cooler work face. The value of these ‘intangibles’ is not easily determined, but what is noticed, is a ‘mood’ improvement across the shaft. Along with the cemented cross-cuts and sections of professionally laid track, hydropower helps generate a more modern, pleasant and safe feel to the operation.

**HUMAN RESOURCES**

Various issues have come up with regard to labour. Of primary concern, and impact to production, are the training and the unity of work crews. Most crews are a new combination of workers, which are moved around often while the shaft normalises. The cost of this in lost production is hard to estimate in black and white, but is considered to be substantial.

Associated with this, good training (and experience) for hydropower crews is important. In order to furnish this, training is done over 3 weeks – where workers are multi-skilled, with the extra ‘Bompodi’ team building week on completion of formal training.

**FUTURE PLANS**

Plans to address the current problems and future work expansion are in place. Some of the highlights are listed below:

- New stoping layouts, which will not differ drastically from present layouts, are being looked at. This will be used to optimize the use of hydropower. Double shift blasting is being considered.
- The fleet of drill jigs in use is being expanded.
- Development end rounds are going to be examined to help generate a more effective blast.
- Training will be continued and completed.
- Drill allocation will be more closely monitored.
REFERENCES


7. The on site employees of Novatek, Sulzer and HPE, personal communication, May/June 2003

Many of the production, engineering and support personnel at Beatrix 3#, personal communication, May/June 2003.