Commissioning and Operating Experience with Gekko's Gold Ore Treatment Plants

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ABSTRACT

In the past year, two very innovative gold ore processing plants have been designed, built and commissioned by Gekko Systems Pty Ltd. The first plant in Vietnam utilizes conventional crushing and ball milling followed by gravity concentration (Inline Pressure Jig (IPJ) and Falcon concentrator), flotation, intensive leaching (GFIL), the first industrial scale use of AuRIX®100[1] ion exchange resin and a cyanide destruction circuit. The second plant, in Australia, uses a 3 stage crushing circuit to crush the gold ore to minus 1mm, followed by gravity concentration utilising a rougher, scavenger, cleaner circuit of IPJ's and a Falcon concentrator. A direct smeltable gold concentrate is produced as well as a lower grade concentrate for future intensive leaching or sale. Both plants were designed and built within very tight time frames and budgetary constraints. The experience gained during the plants' design, commissioning and operation are discussed.

INTRODUCTION

Gekko Systems (Gekko) is a leader in the development of innovative technology for gravity recovery and intensive cyanidation. It provides low cost and metallurgically optimal solutions for its customers. It has also led the trend away from whole ore cyanidation (CIP/CIL) towards gravity/intensive cyanidation (GIL) and gravity/flotation/intensive cyanidation (GFIL) plants. These types of plants offer low capital costs, low environmental impact and maximum return to investors (Rob J Longley et al, 2002). Key to this type of flowsheet is the application of a continuous concentrate unit, such as the InLine Pressure Jig (IPJ), which is designed to produce high gold gravity recoveries at a coarse grind (Sandy Gray, 2003). When combined with other gravity devices, and/or

[1] AuRIX®100 is the registered trademark of Cognis Corporation and is exclusively licensed to Gekko Systems Pty Ltd.

flotation, and intensive cyanidation, using the Gekko InLine Leach Reactor (ILR), very high overall recoveries can be achieved.

In 2004, Gekko launched a new range of products called Gekko Modular Systems. The idea was to provide off the shelf, complete solutions for the separation and recovery of complex and free gold as well as the pre-concentration of diamonds. A series of modules were designed that incorporated Gekko manufactured as well as outsourced equipment. Gekko now offers modules ranging from feeding and conveying to crushing, gravity recovery, flotation, intensive cyanidation, refining and detox (see Figure 1).

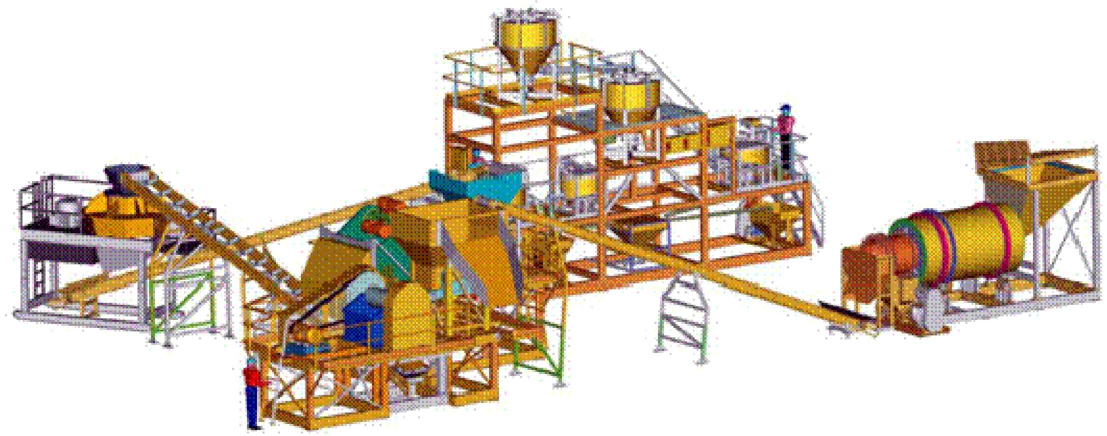

Figure 1: 3-D model of Gekko modular alluvial gold plant built for SMT in Sudan

Gekko modular systems offer particular benefits for small, remote high grade deposits or low grade deposits requiring pre-concentration. Gekko believes that the key drivers for many projects are capital and operating cost reduction. It is for this reason that the main aim of the flow-sheets designed by Gekko is to produce a plant with both low capital and operating costs. This can be achieved on ore bodies that respond well to pre-concentration by gravity or a combination of gravity and flotation. Pre-concentration reduces the footprint and installed power requirements. Other benefits include fast delivery, mobility and ease of transport, ease of assembly and operation and flexibility.

Gekko modular plants have been installed at numerous sites worldwide. Recent installations include:

- SMT's Belugwa Alluvial Hard Rock Gold Plant in Sudan
- DES's Boungou Diamond Separation Plant in Central Africa
- Bendigo Mining's New Moon Bulk Sampling Plant in Australia
- Olympus Pacific Minerals' Bong Mieu Hard Rock Gold Plant in Vietnam
- Ballarat Goldfields' Ballarat East Gold Processing Plant in Australia

This paper will focus on these last two installations.

BONG MIEU

The Bong Mieu gold mine has recently been brought into production by Toronto based Olympus Pacific Minerals Inc. The Bong Mieu mine is the first foreign gold mine in Vietnam to be brought to production since the 1940's and follows successful drilling in historical goldfields mined for over 1500 years.

The process plant (see Figure 2) has a nominal capacity of 500 tonnes of gold ore per day with a potential future increase to 800 tonnes per day. The Bong Mieu plant has been supplied by Gekko on a turnkey basis with the flowsheet developed after laboratory scale testing of ore materials in Ballarat and Perth. The flowsheet includes: Crushing circuit (provided by others), Ball milling, InLine

Pressure Jigs, Falcon concentrator, conventional flotation cells, a continuous InLine Leach Reactor, the Gekko Resin Column, electrowinning and a cyanide destruction circuit (H_2O_2).

Figure 2: Bong Mieu processing plant

The plant was supplied in 5 modules to reduce construction time. All modules were wet commissioned before leaving Gekko's Ballarat factory. The plant items were shipped in 40' sea containers to the port of Danang and then road transported to the Bong Mieu mine site about 90km south.

A crew of Gekko fabrication and technical specialists worked with local operating staff to assemble and commission the plant. Despite a severe monsoon season the plant construction was completed in December 2005, less than 9 months after earthworks began, and the first gold was poured on February 15, 2006. The plant was built on budget at an overall cost of USD$4.5M. Since then the ramp up to full production rates has been hampered by commissioning and operational issues, which are being resolved.

Gekko also organised the purchase of two Dominion ball mills which were formerly used at the closed Ballarat East gold plant operated by Valdora Minerals some years ago. Both mills have been installed in Vietnam with the second mill ready to go for a future upgrade in the plant capacity.

The start-up and production of gold, via the Gekko Resin-Column, demonstrates that this treatment route is an alternative to the traditional CIP/CIL process. The system used by Gekko is a novel way of using AuRIX®100 resin in combination with its continuous InLine Leach Reactor (Gray, 2005).

Testwork and Flowsheet Design

The flowsheet for Bong Mieu was developed after laboratory scale testing of Bong Mieu Run of Mine Ore at Gekko's laboratory in Ballarat and at Ammtec in Perth. Gravity amenability and flotation testing indicated a high gold recovery; +90% gold in approximately 10% mass, as shown in Figure 3.

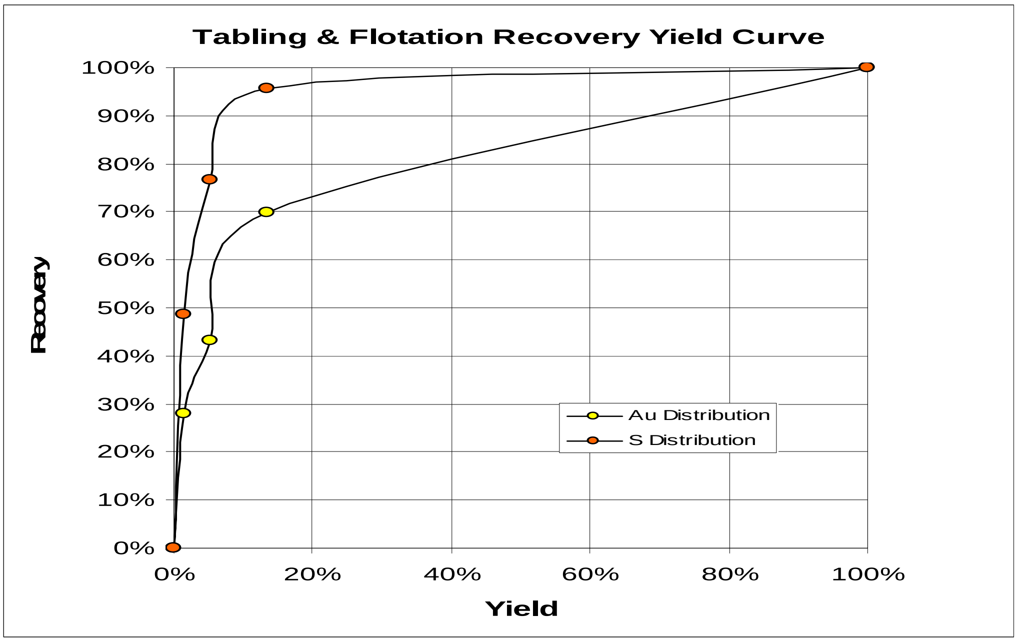

Figure 3: Tabling (gravity) and flotation results for Bong Mieu ore

Based on these results, the process was designed with the following major design criteria:

Mill throughput	500 tpd (expandable to 800 tpd)
Head grade	4 g/t
Gravity recovery – mass%	9%
Gravity recovery – gold%	81.4%
Flotation recovery – mass%	2%
Flotation recovery – gold%	10.4%
Overall recovery to concentrate – mass %	11%
Overall recovery to concentrate – gold %	90.6%
ILR concentrate leach recovery – gold%	94%
Overall recovery	86%

Crushed ore at a P80 of 12mm is milled in the ball mill in closed circuit with two 10” cyclones to a target P80 of 75um (see Figure 4). An IPJ1500 operates in the cyclone underflow to produce a rougher concentrate which is upgraded in a cleaner IPJ1000. The cyclone overflow reports to a Falcon SB750 for free gold scavenging before being floated in a bank of flotation cells. The flotation concentrate is added to the IPJ concentrate and is fed continuously at a rate of 2.5tph to an ILR5000 where it is leached in a moderate 0.1% NaCN solution.

The pregnant solution is separated from the solids in a settling cone and reports to a Gekko Resin Column using AuRIX®100 ion exchange resin in four stages (described in more detail later). The barren solution is mixed with the underflow from the settling cone and is re-thickened in a small thickener. The thickener overflow is recycled to the ILR whilst the thickener underflow at approximately 70% solids is detoxified using hydrogen peroxide.

The flotation tailings and ILR tailings are stored in separate tailings dams.

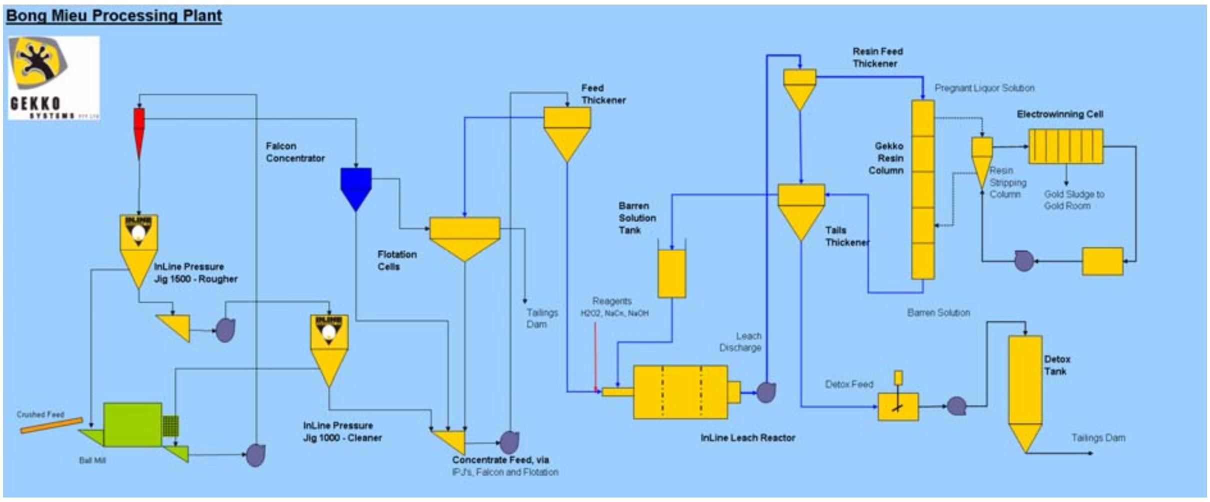

Figure 4: Bong Mieu Processing Plant Flowsheet (Post-Crushing)

The Gekko Resin Column

The Bong Mieu plant is the first full-scale gold operation to use AuRIX®100 ion-exchange resin and the Gekko Resin Column. The Gekko Resin Column (Gray, 2005) is a multi-stage, counter-current, pulsed reactor developed specifically for the absorption of gold from low-density slurries (<10% solids). The reactor consists of a series of four compartments loaded with AuRIX®100 resin (test work has shown that four stages is optimal for gold absorption). The column stages are separated by 400 µm aperture wedge-wire screens which hold the resin in place. Slurry flows down the column and resin is educted up in stages every 8 hours. Loaded resin (at up to 12 000 gAu/t) is educted from the top of the column to a resin strip column. It is then stripped in a simple process using a 40 g/L caustic, 70 g/L sodium benzoate, 200 ppm NaCN solution heated to 55-60 deg C. The gold loaded strip solution is pumped through an electrowinning cell for gold recovery and the return solution recycled back to the strip column. The barren slurry from the bottom of the resin column is pumped to a security screen ahead of the thickener. Barren resin is introduced to the bottom of the column to ensure that all gold in the slurry is scavenged and a low tails grade is achieved. The column is pulsed using a diaphragm to ensure that there is no blinding in the screens, there is intimate contact between the slurry and the resin and that the solids are kept fluidized so that they aren't held-up within the column. A schematic of the Gekko Resin Flowsheet is shown in Figure 5.

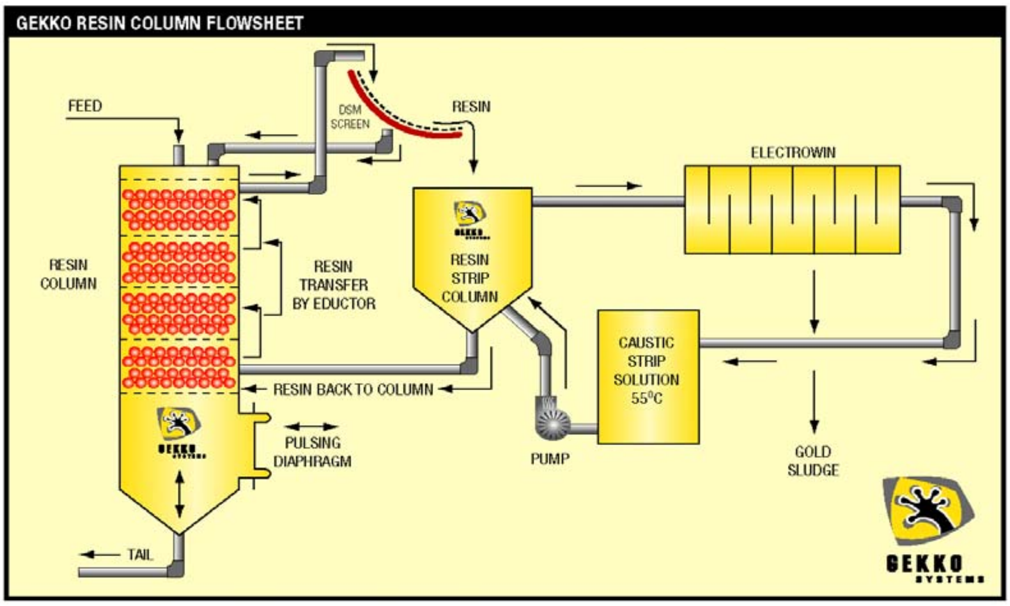

Figure 5: Gekko Resin Column and Strip circuit schematic as used at Bong Mieu

The first full-scale use of resin and the Gekko Column produced some challenges which Site personnel and Gekko have had to overcome. Screening of the feed to the column was found to be inefficient due to surging and near-size particles entering the column. These particles ended up being caught between the wedge wire screens separating the stages in the column and caused blockages and a reduction in throughput. This problem was overcome by replacing the wedge-wire screens with woven wire screens (which have a shorter life span, though still comparable to woven wire screens used in CIL plants) which increased the volumetric throughput capacity of the column.

Also, it was decided to replace the screening of the feed with a counter-current decant (CCD) system to ensure near size material wouldn't report to the column. Since the two modifications were put in place, blockages in the column have been eliminated.

Resin and leach solution chemistry was an unexpected issue at Bong Mieu. In initial testwork the elution accelerant sodium benzoate was not found to be required as the resin could be efficiently stripped within the designated 8 hour cycle without it. However, inefficiencies in the electrowinning cell (primarily caused by the anodes and cathodes being wired up incorrectly in the first instance) limited the barren resin grade achieved in the strip cycle to 1 000 g/t. This, in effect, increased the barren solution grade leaving the resin column. Seventy g/L sodium benzoate was added to the elution liquor and the cell re-wired subsequently reducing the barren resin grades to less than 200 g/t.

After 6 months operation, the resin was analysed and found to contain a significant amount of iron. Iron absorption onto resin is unexpected as the pH of the leach liquor precludes absorption of iron cyanides. Analysis of the resin by the manufacturers, Cognis Corporation, found the iron had precipitated onto the resin as an iron alkyl phosphate which resulted from the use of Di-thio phosphate (DTP) in the flotation circuit post commissioning (only PAX was used in test work and process design). Acid washing of the resin with hydrochloric acid has been found to be needed to remove this precipitate. The site has also chosen to review its use of DTP in the flotation circuit.

Despite the challenges faced at the Bong Mieu site and with using new technology (Gekko Resin Column) the commissioning and start-up has gone well and the design recoveries and throughputs are expected to be achieved in the near future. This is a reflection of site personnel, Gekko and Cognis working together to resolve issues as they arose.

BALLARAT EAST

Ballarat Goldfields

Ballarat Goldfields NL (BGF) is a gold producer based in Victoria, Australia. BGF has consolidated all of the gold holdings in the town of Ballarat which is a historic gold mining district that produced over 12 million ounces before its premature closure around the time of the first world war.

After a comprehensive geological model of the entire field was constructed in 2004, and following a pre-feasibility study based on this model, underground development at Ballarat East recommenced in December 2004. The mine is planned to have a life of 21 years ramping up to an average production rate of approximately 200 000 ounces per annum (800 000 tonnes per annum at 8.5 g/t).

Metallurgical Testwork

During the pre-feasibility stage, gravity test work was undertaken by Gekko into the best method to process the BGF ore which historically contained a significant amount of coarse gold. The testwork involved crushing and grinding the ore to various grind sizes before tabling on a Wilfley table. A summary of the test work undertaken up until early 2004 is given in Table 1 (Ballarat Goldfields NL, 2004).

Table 1: Summary of metallurgical test work on Ballarat East ore

Test Work Program	Gold Recovery
Progressive grind (1.0mm to 106um) testwork for sample grade of 24 g/t	
Recovery to concentrate at mass yield of 0.9%	79.0%
Recovery to concentrate at mass yield of 2.9%	92.9%
Recovery to concentrate at mass yield of 8.6%	98.4%
Recovery to concentrate at mass yield of 25.1%	99.0%
Single pass tabling testwork at 100% passing 600 micron	
Recovery to concentrate at mass yield of 0.9%	79.0%
Recovery to concentrate at mass yield of 3.2%	91.5%
Recovery to concentrate at mass yield of 9.7%	95.6%
Single pass tabling testwork at 100% passing 300 micron	
Recovery to concentrate at mass yield of 1.1%	72.0%
Recovery to concentrate at mass yield of 4.1%	80.7%
Recovery to concentrate at mass yield of 12.1%	83.2%
Recovery to concentrate at mass yield of 21.4%	84.3%
Single pass tabling testwork at 100% passing 106 micron	
Recovery to concentrate at mass yield of 0.1%	20.0%
Recovery to concentrate at mass yield of 2.1%	48.1%
Recovery to concentrate at mass yield of 6.7%	53.2%
Recovery to concentrate at mass yield of 22.3%	56.3%
Cyanide leaching of gravity concentrate	
With oxygen addition	98.8%
No oxygen addition	97.7%

The testwork showed the ore had a very high amenability to a continuous gravity recovery device such as an IPJ. The results also indicated that the ore was grind sensitive in that finer grinds were detrimental to gravity recovery as shown in the yield/recovery curves in Figure 6.

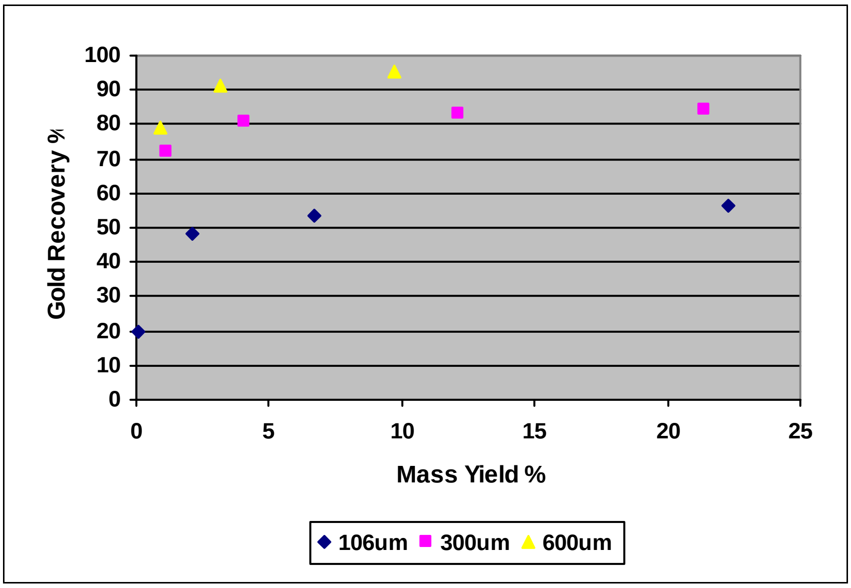

Figure 6: Affect of Grind Size (P100) on Gravity Recovery for BGF Ore Sample

Further test work was carried out by Gekko in early 2005 using an impact mill to prepare the sample. The sample was analysed using QEMSCAN and found to consist of 50% Feldspar, 20% Quartz, 17% Mica/Clays, 5% Arsenopyrite and 4% other Silicates with minor Pyrite. After impact milling to a P80 of 1.2mm, the QEMSCAN Bulk Mineral Analysis (BMA) indicated that the arsenopyrite was over

80% liberated (see Figure 7). Gravity amenability testing of this sample gave 91% gold and 50% arsenopyrite recovery to concentrate in 8% mass yield at a grind size of 1.2mm.

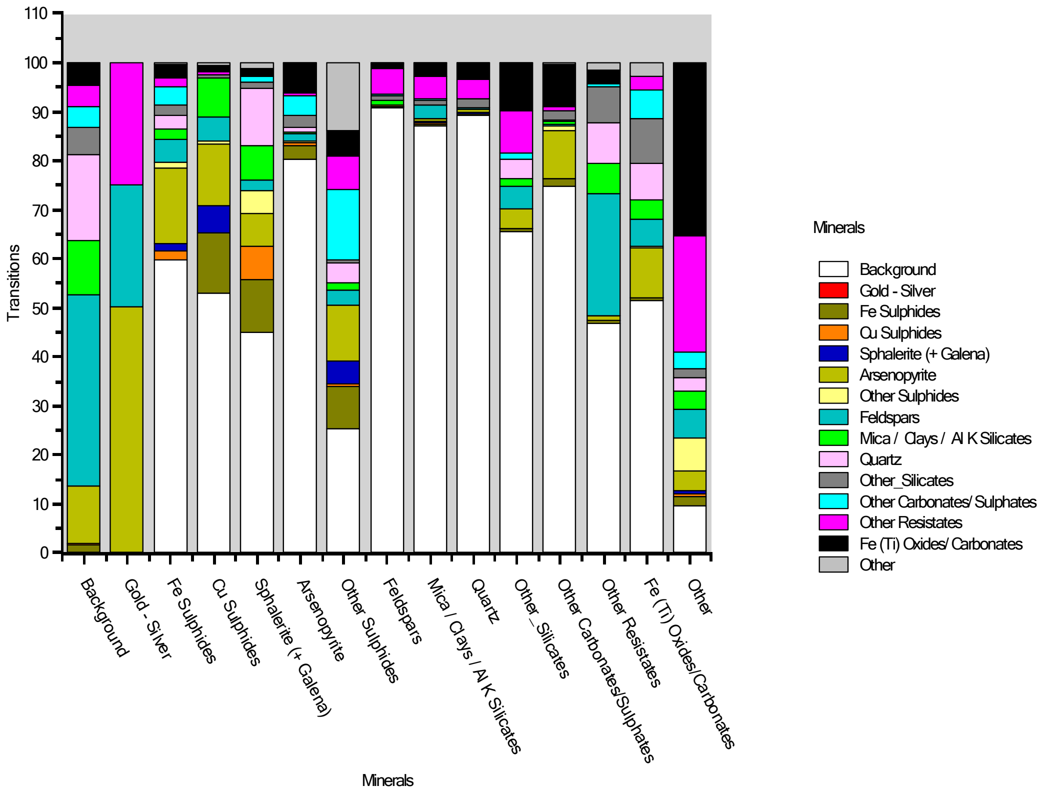

Figure7: QEMSCAN Bulk Mineral Associations of BGF ore after Impact Milling to a P80=1.2mm

Based on the gravity testwork, a target grind of 1.0mm was conservatively chosen and was expected to result in over 90% gold recovery to concentrate.

Crushing and comminution testwork were also carried out on the ore with the results summarised in Table 2.

Table 2: Crushing and comminution testwork results on BGF ore

Parameter	**Result**
Ave Impact Work index	2.4 kWh/t
Unconfined Compressive Strength – Quartz	42 MPa
Unconfined Compressive Strength – Waste	38 MPa
Abrasion Index	0.3745
Rod Mill Work Index	14.1 kWh/t
Ball Mill Work Index	14.9 kWh/t
SAG Mill – Dwi value	2.5
SAG Mill – Axb	105.98
T10@1 kWh/tonne	58.15
Auspactor VSI amenability test	Type 1-2 (very soft ore)
Tornado VSI single pass test	+30% minus 1.18 mm

The UCS, SAG milling and VSI tests all indicated the ore was very soft. Based on these results, Vertical Shaft Impact milling was chosen as the preferred comminution method.

Process Design

In early 2005, BGF set the following guidelines for the process plant design:

Throughput	75 tph (annualised at 600,000 tpa)
Head grade	8.5 g/t (longterm)
Target grind	P100 = 1.0mm, P80 = 850 um
Mass pull to concentrate	5%
Gold recovery to concentrate	90%
Arsenopyrite recovery to conc	50%

The challenges to be met by the Gekko design team included:

- noise emissions to be kept to a minimum due to the close proximity of neighbours
- initially dayshift only operation of the entire plant due to ore production constraints
- dayshift only primary/secondary crushing to reduce future noise reduction requirements
- low capital costs
- very fast design/construction/commissioning schedule (March to December 2005)
- plant to be easily expandable to 800,000 tpa
- plant to be constructed at the Woolshed Gully site next to the decline/office complex, bounded by access roads and on a site with a steep gradient (30 degrees)
- stagewise construction to optimise capital expenditure
    - stage 1: nominal 75 tph, crushing and gravity only plant operated dayshift only, 5 days a week
    - stage 2: addition of an intensive leaching circuit to increase gold recovery from the gravity concentrate
    - stage 3: 24 hr a day, 7 days a week operation at a nominal 600,000 tpa
    - stage 4: optional flotation circuit to increase gold recovery to 94%
    - stage 5: increase throughput to 800,000 tpa

In a very tight design period, Gekko incorporated all of the above into the final process described below. Earthmoving commenced in July 2005 and plant construction was completed by November 2005. First gold was poured on 22 December 2005.

Processing Plant Design and Construction

Site Preparation

As stated previously, the processing plant had to be built into the existing 30 degree slope next to the decline portal, underground workshops and office complex (see Figure 8). To enable this to be completed and to minimise the amount of earthmoving, the slope was terraced into two benches 7 metres apart (see Figure 9). The crushing circuit and coarse ore bin were located on the bottom bench and the gravity circuit, gold room, ROM pad, leaching (future) and reagent mixing facilities (future) were located on the upper bench.


Figure 8: Proposed plant site to the left of the underground diesel workshop

Figure 9: Benching at the BGF construction site

Locating the equipment in this way enabled all the "noisiest" equipment to be located lower on the side of the hill thus providing increased noise suppression.

Even with the terraced approach, approximately 200 000 bcm of material had to be relocated.

Primary/Secondary Crushing

Equipment selection was an iterative process based on the final product size and throughput required. In the end, the circuit selected included:

- Fixed 400mm grizzly over a 50 tonne hopper
- Vibrating grizzly feeder scalping at 80mm
- Secondhand Jacques jaw crusher 42" x 30" operating at a closed side setting (CSS) of 80mm
- Self-cleaning cross belt magnet and metal detector to protect the secondary crusher

- Hawk 8'x 20' single deck vibrating screen fitted with 35mm aperture panels (later changed to 25mm)
- Secondhand Allis 60" Hydrocone with a175mm throat opening and 19mm CSS
- Nominal 500 tonne capacity coarse ore bin.

The jaw and cone crushers were installed in a three metre recess in the bottom bench (see Figure 10). This had the quadruple benefit of reducing noise emissions from these components, lowering the ROM pad in respect to the surroundings so as to reduce noise from the ore trucks and loader, enabling noise suppression buildings to be easily fitted at a later date if needed and enabling the coarse ore bin to be located closer to the ROM pad which reduced the footprint of the crushing circuit. The recess has a driveway access for a forklift, backhoe or utility for ease of cleaning and maintenance.

Figure 10: Jaw and cone crusher installed in a 3 metre recess to reduce noise emissions

Screening and Tertiary Crushing Circuits

The major issues to be faced in this section included determining the best way to achieve the fine crush/coarse grind of 1.0mm and being able to achieve an acceptable size separation at the finer end of conventional screening. Test work indicated that impact crushing technology would be suitable for this ore and, fortunately, Gekko had some experience with Vertical Shaft Impactors (VSI) at an alluvial plant in Sudan which it had constructed and commissioned in early 2005. It was recognised that the VSI would be at the limit of its capability but testing by two suppliers indicated it could produce approximately 30% of -1.0 mm product per pass through the crusher due to the very soft nature of the ore. Allowing for this circulating load, and sizing the VSI and vibrating screens to suit, resulted in a much cheaper comminution system than an equivalent milling circuit and with better control of the product size to avoid over-grinding.

The tertiary crushing and screening circuit consists of:

- Vibrating feeders at the base of the coarse ore bin
- Hawk secondary screen 8'x20' with 5mm apertures
- Auspactor VS200RR Vertical Shaft Impactor
- Hawk double deck tertiary screen 8'x24' with 2.2 and 1.0 mm apertures
- Warman pumps to pump the undersize from the secondary screen to the gravity circuit and the undersize of the tertiary screen to the water recovery circuit

The aperture on the secondary screen was a compromise between ensuring coarse gold in the ore is exposed to the gravity circuit as soon as possible (the VSI was not expected to effect any size reduction in the malleable gold "nuggets") and ensuring the gravity circuit wasn't exposed to a high circulating load caused by a large percentage of material passing through the secondary screen and bypassing the crusher.

To recover nuggets greater than 5mm, a full-aperture metal detector commonly used in the food industry was installed on the VSI discharge conveyor. During testwork in the "factory", this type of detector was found to be capable of detecting gold pieces down to 3mm. On detection of metal, the metal detector would activate a diverter gate which would divert the ore containing the nugget to a separate stockpile for hand sorting. Unfortunately the high moisture content of the ore and the abundance of metallic trash (copper wire, aluminium detonator caps, etc) have meant the detector produces too much diverted ore to be sorted successfully. Further work is required in this area.

Gravity Circuit and Water Recovery

The gravity circuit was designed based on Gekko's experience with using IPJ's in the recirculating loads of milling circuits. Whilst there is no mill in the BGF circuit, the design of the tertiary circuit has allowed a circulating load of approximately 300% to be established through the gravity circuit.

The gravity circuit runs in closed circuit with the VSI and consists of rougher and scavenger InLine Pressure Jigs (3xIPJ2400's as roughers and 3xIPJ2400's as scavengers) feeding concentrate to a cleaner IPJ1500 that produces a concentrate stream of approximately 4% of the mass (5% design) as shown in Figure 11. Mass pull is variable depending on the sulphide loading in the circuit.

Figure 11: BGF Gravity Circuit

The cleaner concentrate reports to two Inline Spinners (ISP's) in parallel to recover coarse gold. Currently both the ISP concentrates and tails are pumped to the gold room, where very coarse gold is removed via Wilfley and Gemeni tables. The gravity sulphide concentrate (table tails) is currently being stockpiled on site for later processing.

The cleaner IPJ tailings reports to the secondary vibrating screen for re-processing through the gravity circuit. The scavenger IPJs' tailings report to the tertiary screen where the +1.0mm fraction is fed with the +5mm secondary screen product to the VSI for comminution. The -1.0mm product is pumped to a bank of Warman 10” Cavex cyclones for water recovery with the overflow used in the dirty water system. The underflow at approximately 50% solids reports to a Falcon SB1350 to scavenge the final plant tailings before they are pumped to the tailings dam.

The “dirty water” recovered from the cyclone overflow is used as spray water on the secondary and tertiary screens and as hutch water for the IPJ’s. Re-use of this water significantly reduces the requirements for clean water and allows lower %solids to be used in the gravity circuit to aid recovery.

In the Goldroom, a Wilfley Table is used to produce a rough concentrate out of the ISP tailings for further upgrading on the Gemeni Table. The ISP concentrates and Wilfley Table concentrate are upgraded over the Gemeni to produce a direct smeltable gold concentrate.

Other

The plant control incorporates fully automated startup and shut down with complete process control carried out through an Allen Bradley Device Net system with a RS View SCADA system. The fast commissioning was due to the simple design of the overall circuit and the complete integration of the control system.

Metallurgical control is carried out in Gekko’s Ballarat laboratory until a metallurgical and assay laboratory is built on site. Due to the coarse grind size of the streams being tested and the coarse, nuggety nature of the gold, all assays are carried out using a Mineral Process Control PAL1000 (Pulverise and Leaching) machine. One kilogram samples are placed in the PAL1000 to reduce the nugget affect. The tailings from the PAL1000 have been assayed by fire assay and show <0.05 g/t remains in the final tail residues whilst the PAL1000 leaves behind upto 1.0 g/t in the sulphide concentrate residues. In both cases the PAL1000 is reporting over 90% of the gold contained in the sample and is considered a fair trade off considering the advantage of assaying 1.0 kg samples.

Commissioning

Primary and Secondary Crushing

The primary and secondary crushing circuit has achieved throughputs of up to 300 tonnes/hour giving it a nominal capacity in excess of 1.2 million tpa operating on a dayshift only basis. The vibrating screen aperture was reduced during commissioning as there was insufficient load on the cone crusher which allowed slabby material to pass between the bowl and mantle of the cone. This slabby material was causing chute blockages downstream.

The open circuit design of the secondary crushing circuit was driven by the lack of real-estate in which to install the circuit and the relative insensitivity of the tertiary crusher to oversize. In retrospect, the slabby material produced by the jaw crusher has created the issues described earlier and a closed circuit would have produced a more controlled product.

Tertiary Crushing and Screening

Both the secondary and tertiary screens are operated with water sprays to ensure undersize material is passed through the panels. This had the detrimental affect of producing a high moisture feed to the VSI which has in turn meant water sprays had to be fitted to the underside of the crusher to prevent blockages. Whilst wear information is still being gathered, it is expected the wear in the VSI will increase due to the presence of so much water in the circuit.

The tertiary screen apertures were conservatively selected at 1mm to produce a P80 of 600um despite the test work indicating the P80 of the product could be 1mm and still maintain high recovery. This was to ensure maximum recovery at start-up and allow a gradual coarsening of the grind to determine the affect on recovery once the plant was running efficiently. This finer than designed product has put extra pressure on the VSI and reduced throughput from the design 75 tph to approximately 55 tph. Trials were undertaken in March 2006 to determine the throughput versus grind size relationship for the circuit and it was found that throughputs in excess of 75 tph could be achieved at a final grind size of 850um. However, the short lengths of the trials meant the affect on recovery couldn't be determined and as the supply of underground ore is still ramping up and there is no throughput pressure on the treatment plant, the circuit was returned to its original configuration in order to maximise recovery.

In general the VSI has performed exceptionally well with low noise emissions and good throughput versus grind size performance. The VSI has also produced an ideal product for gravity recovery as shown in Figure 12. The VSI has broken the sulphides on their grain boundaries producing cubic and orthorhomboidal crystals which recover well in the IPJ's.

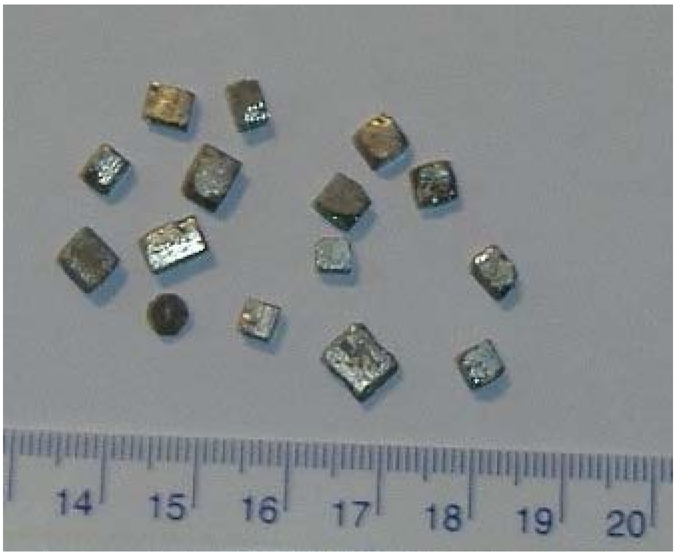

Figure 12: Arsenopyrite crystals recovered in the IPJ concentrate post VSI crushing.

The feed rate to the tertiary crushing circuit is controlled by a cascade loop linked to the VSI amps. This link was installed in early 2006 and has resulted in a 20% increase in plant throughput.

Gravity Circuit

To minimize gold losses during the commissioning phase, the decision was made to commission the plant on low grade ore. The grade varied between 1.0 and 2.0 g/t which restricted gold recovery of the plant. A summary of the test work carried out on the Ballarat East ore showed a definite relationship between head grade and gold recovery to concentrate as shown in Figure 13.

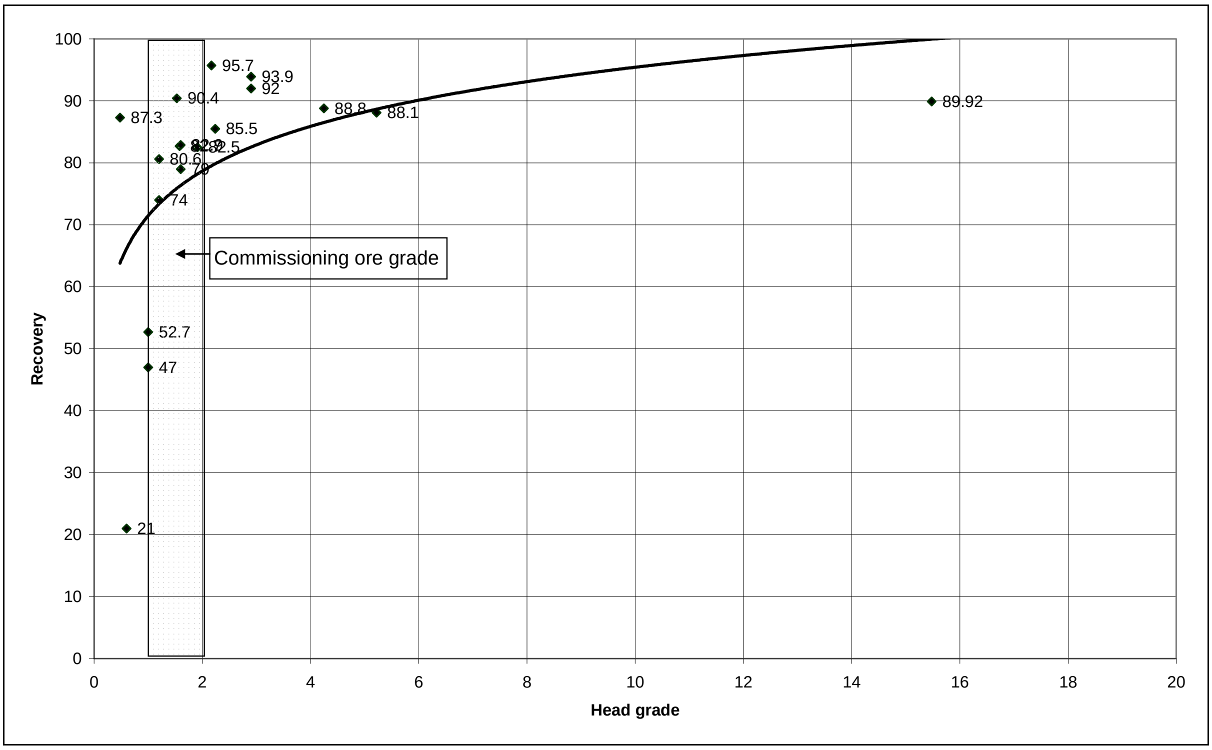

Figure 13: Gold Recovery to concentrate versus head grade for Ballarat East Ore

A survey of the gravity circuit during the commissioning on low grade ore is summarised in the results given in Table 3.

Table 3: Gravity circuit survey (low grade commissioning ore)

Stream	Weight %	Au g/t	Au Dist%	As %	As Dist%
Est. Bullion		0.20	18%		
Table Tail	1.9%	24.9	43%	5.6%	91%
Final Tail	98.1%	0.43	39%	0.011%	9%
Calc Feed		1.09		0.11%	

Whilst gold recovery was limited by the low grade of the commissioning ore it is in line with the predicted data given in Figure 13. Recovery is expected to increase with the increase in feed grade once commissioning is completed. The recovery of arsenopyrite was excellent at 90% and is almost double that expected from the test work. The liberation of the arsenopyrite by the VSI at a much coarser size than could be tested in the laboratory has produced this “better-than-design” result.

The upgrading of the gravity concentrate by tabling in the Goldroom has been troublesome due to the coarse nature of the sulphides recovered by the jigs making separation from the gold on the table difficult. Ideally the concentrate should be leached and this is planned in the Stage 2 upgrade of the circuit. The goldroom has an allowance for a series of electrowinning cells to be installed at a future date for that purpose.

Final tailings residues to date at around 0.2 – 0.4 grams of gold per tonne (gAu/t) have been well below design (0.70 gAu/t). Investigation of the gold distribution in the tailings product shows insignificant gold in the fractions above 500 µm, indicating exceptional liberation and recovery and the ability to increase grind size even further. Gravity recovery of arsenopyrite is very high due to the unique liberation circuit that ensures over-grinding does not occur and the heavy minerals are recovered from the circuit as soon as they are liberated.

Ongoing work is being carried out in all areas of the plant to gain a better understanding of the metallurgy of the ore and the recovery system.

Future

The layout of the tertiary crushing circuit allows for a second VSI to be added when high circuit availability is required. Also, a comparison of the VSI with a High Pressure Grinding Rolls (HPGR) will be carried out in the middle of this year to compare metallurgical and operating efficiencies for both units before the final decision is made to expand the circuit. The plant has been engineered for the inclusion of a Polysius MAGRO sized HPGR for the trial (see Figure 14). Depending on the outcome of these trials either a second VSI or the HPGR may be fitted into the circuit.

Figure 14: Vertical Shaft Impactor (VSI) and space for second VSI or HPGR

Stage 2 of the process plant is planned to incorporate an intensive cyanidation plant installed to maximise the recovery of gold from the sulphide concentrate stream (see Figure 15). Significant test work has been carried out on the actual concentrates to ensure the downstream process will be at least as efficient as the primary recovery circuit. All leach residues will be subjected to detox to ensure very low levels of cyanide are discharged to the tailings disposal facility. Every effort will be made to ensure the design allows for compliance with the International Cyanide Code.

To date the development of the BGF process plant is running to schedule and no foreseeable problems lie ahead in achieving the initial goals set at the beginning of the development. Given that the plant is located in the equipment supplier's home town, Gekko have provided a broader service than normal. This has included site preparation and construction management and an operations and project management team (run by the Gekko subsidiary Spinifex Projects) to operate the BGF processing plant.

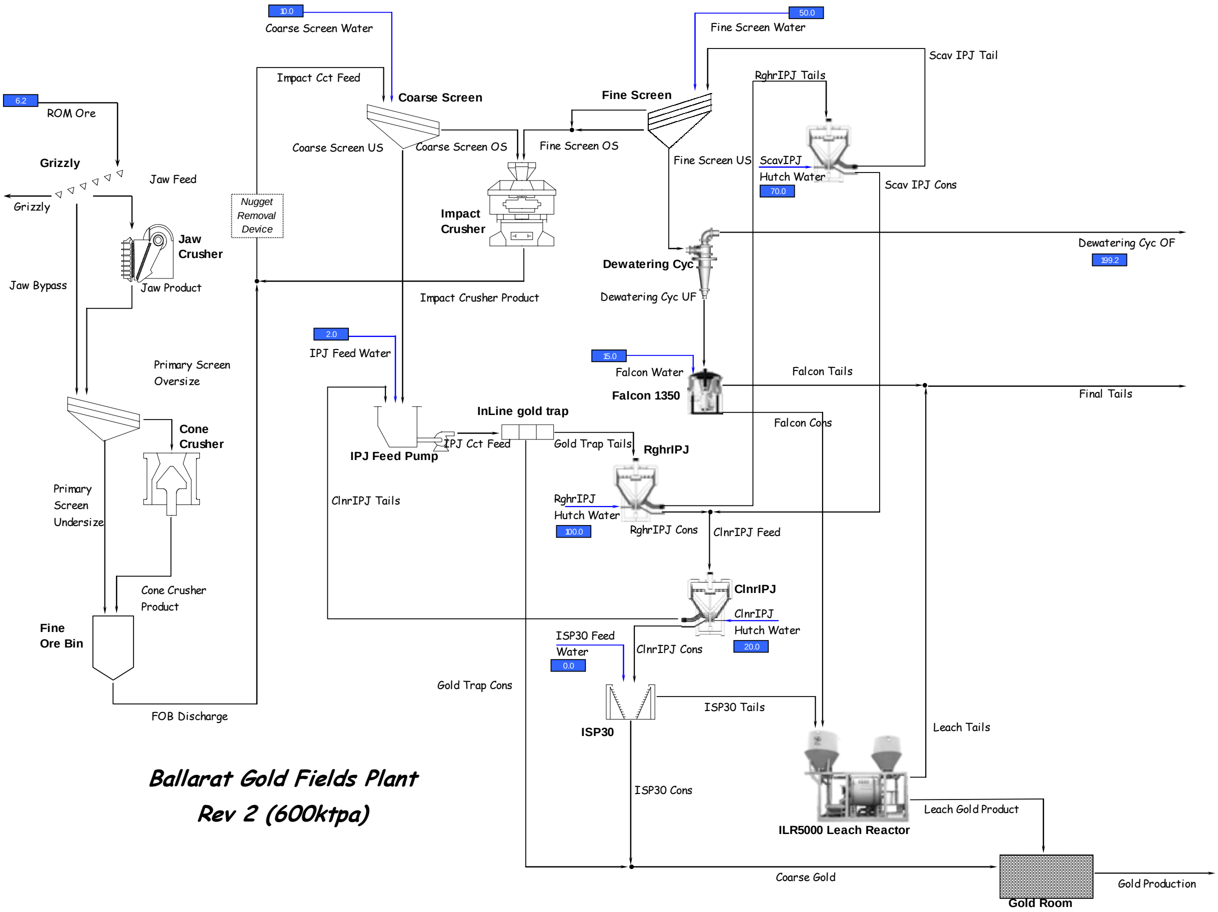

Figure 15: LIMN® model of the overall BGF Circuit (stages 1 and 2)

CONCLUSIONS

This paper provided an overview of Gekko's capabilities with regards to modular systems for the recovery of gold. Two case studies, detailing two very different plants, were provided. The first, on the Bong Mieu plant in Vietnam provided details on the test work and development of a new gravity/flotation/intensive leaching plant as well as the subsequent commissioning and start-up.

Further details were also provided on Gekko's first full-scale application of the Gekko AuRIX®100 Resin column.

The second case study, on BGF's Ballarat East plant, detailed the test work and development of a 3 stage crushing and gravity recovery plant. Details on the commissioning and start-up of the plant were provided.

Both of these plants were designed and constructed within very tight timeframes and budgets. Both were built and installed on time and on budget and are producing gold. Gekko modular systems have provided a cost effective and timely solution.

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