Gravity Gold 2010

Coarse Gold Separation at Bendigo Mining's

Kangaroo Flat Operation

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ABSTRACT

Bendigo Mining operates a 600,000 tpa comminution, gravity, flotation and leaching processing plant for the recovery of gold from their Kangaroo Flat Operation, in the Bendigo goldfields. The free gold and gold bearing sulphides present are typically coarse grained, and hence are highly amenable to gravity recovery. Plant operating data is consistently showing that over 78% of the feed gold is recovered in a circuit, consisting of InLine Pressure Jigs, InLine Spinners followed by free gold tabling and intensive leaching of tabling tails. The circuit receives coarse crushed product from high pressure grinding rolls and the grinding mill discharge, which allows material to be re-circulated through the gravity process until the particles are small enough to enter the flotation circuit.

A plant audit was completed on 26th November 2009 designed to give an indication of the overall operational characteristics of the gravity circuit including single pass efficiencies of associated equipment. The techniques, results and challenges of such a survey are discussed.

INTRODUCTION

Bendigo Mining Limited (BML) has been active in exploration around the Bendigo area since the 1980's. Early miners in the area had recognized the difficulty in representative sampling and BML progressed to processing bulk samples from their underground exploration decline in 2002. They processed samples of around 150 tonnes by crushing and splitting 7 tonne duplicate sub samples. Each duplicate was hammer milled to -1mm and passed through a gravity circuit consisting of two InLine Spinners. Concentrates produced and tails assays were used to estimate total grade. One of the key outcomes noted was that liberation of much of the free gold occurred at 1 to 2 mm.

Trial ore parcels of up to 3000 tonnes were also processed through the New Moon 9 tph pilot gravity plant consisting of ball mill, InLine Jigs, InLine Spinners, tables and InLine Leach Reactor. Gravity recoveries of 75%-85% were consistently achieved.

Environmental constraints for the Kangaroo Flat site led the flowsheet development away from whole ore leaching. Early testwork indicated comparable recoveries from gravity and whole ore leaching to gravity / flotation / intense leach of flotation concentrate.

In 2004 the pilot plant facilities were converted to flotation and gravity tails were reclaimed, attritioned and subjected to flotation to prove up laboratory test results.

The processing plant at Kangaroo Flat was designed and constructed by Ausenco along these lines, and commissioned by BML in mid 2006. It incorporates traditional two stage crushing and HPGR tertiary crushing, followed by gravity recovery methods (gold trap, jigs, and centrifugal concentrators) within a milling circuit, and then flotation on the cyclone overflow. The gravity concentrates produced are upgraded in the gold room using an additional centrifugal concentrator, shaking tables, followed by intensive leaching of the tails. The flotation concentrates are treated using the CIL process.

Continuing with the theme of grade reconciliation and further understanding of the Bendigo geology the plant matches throughput with exploration and mining. The plant runs on a day shift only basis at design rates to process 2000 to 5000 tonne ore blocks as defined by the geology and produced from mining operations and development.

Extensive operational data has shown that on average 78% of the gold in the ore is recovered by the gravity equipment. A plant audit was completed in late 2009 to determine the characteristics of the gold and sulphides being recovered from the recovery equipment.

PROCESS DESCRIPTION

A simplified flowsheet is given in Figure 1. The process description describes current operating practices.

Figure 1: Simplified Processing Plant Flowsheet

Ore is delivered by truck from the underground mining operation and stored in individual ore block piles on the ROM pad. A front-end loader transfers the ore to a two stage crushing plant, where crushed ore (P100 25 mm) is stored in a 1500 t steel bin. The ore is then reclaimed at the rate of 75 t/h and conveyed to the HPGR, which crushes the ore, in closed circuit with the mill feed screen to P_{100} 4 mm. A coarse gravity gold trap is incorporated into the feed box of the screen and has been effective in recovering coarse nuggets. The screen oversize (+4 mm) is directed back to the HPGR, while the screen undersize reports to the ball mill discharge sump, as new feed, where it is combined with mill discharge and ISP tails.

From the mill sump the coarse slurry (P80 850 µm, 58% solids) is pumped to a bank of three parallel IPJ2400s, two duty and one standby. The jigs are setup with 4 mm screens and 8 mm lead shot ragging to a depth of 3 layers. Operating at a pressure of 70 kPA, the jig tails are transferred to a gravity preparation screen approximately 4 m above the IPJ's while the concentrates report to the ISP feed box. Other operating parameters of the IPJs at the time of the survey were: Pulse rate 130 Hz, Stroke rate 8mm and Hutch water flow rate of 40 m3/hr.

The ISP system consists of two parallel trains of 2 x ISP30's (rougher and scavenger). The current dump time for the ISP's is 15 mins. The spinner tails flow to the mill discharge sump, while the concentrates are collected in a dewatering cone and are periodically pumped to the gold room.

At the gravity preparation screen, the IPJ tails are screened, where the +2mm is directed to the mill feed, while the -2mm slurry is available to be fed to a Falcon concentrator SB2500 (off-line at time of audit). The Falcon tails flow to the cyclone feed sump, and the concentrate is sent to the ISP concentrate dewatering cone.

The cyclone cluster consists of 3 x 500mm flat bottomed Cavex cyclones, with 1-2 operating and 1 in standby, which controls the grind size at a P80 of approximately 250 µm. The cyclone underflow (approx. 74% solids) is directed to the ball mill feed chute, while the cyclone overflow (approx. 27% solids) gravitates to the float feed thickener, before being pumped to the flotation circuit.

The thickened flotation concentrate and ILR tails slurry are combined and passed over a trash removal screen, prior to entering the CIL circuit. After leaching the slurry is treated in a detoxification system to reduce the cyanide concentration to below permitted limits. The loaded carbon undergoes acid treatment, before the gold is recovered using the Zadra elution process.

In the gold room, heavies caught in nugget traps in the plant are hand sorted to recover gold nuggets, while the sorting rejects and accumulated ISP concentrates are screened. The oversized material is milled and process through a small ISP and tails returned to the screen. ISP concentrates and the screen undersize are processed using tables to recover free gold, via calcining and direct smelting. The tails from the gold room are sent to a continuous ILR in series with an electrowinning cell, which maximises the recovery of any remaining leachable gold. CIL and ILR EW precipitates are smelted with fluxes into doré bullion.

The reagent area includes facilities for the offloading, mixing, storage and distribution of flotation collector, activator, frother, flocculent, hydrated lime, sodium hydroxide, sodium cyanide, sodium metabisulphite, copper sulphate and hydrochloric acid.

PLANT SURVEY

The survey was designed to give an indication of the overall operation of the gravity circuit including single pass efficiencies of associated equipment. As the mineralization is very challenging to sample from an exploration perspective[1], it was recognized that any sampling and assay methods used in the survey, should be more rigorous than usual. Steady state is rarely achieved due to the "nugget effect" of the Bendigo ore and it was deemed that a single "snapshot" would not suffice and a short term survey was adopted.

In theory the size of the samples required for "accurate" gold analyses can be calculated. For Bendigo's relatively coarse gold particles this is extremely large. As the process streams are somewhat more representative to sample than drill core and due to economics and practicality and to ensure reasonably steady operation, the survey was limited to a one hour period. Sample frequency was planned to allow reproducible sampling and minimize the bias affect of a faulty cut on the overall sample while still maintaining a manageable quantity of sample. Sample sizes were limited to a 20 L buckets.

The timing for the survey was set by the companies' method of processing an entire ore block over 6-8 dayshifts, in order to accurately determine the grade of the material. The survey was completed on the second day of the campaign, four hours after starting dayshift operation. The ore block being processed on the day, was sourced from one of the main reefs in the mine.

In order to effectively cut and sample the 13 streams, purpose built samplers were used. A team of six people were then required to collect the samples, with lots collected at intervals of 10 minutes. The buckets were sealed and sent to the Gekko Systems laboratory, where the wet and dry weights were measured, which allowed the solids density to be calculated for each stream. The dry sample weights ranged between 10-30 kg.

Few process plants have been designed with sampling in mind and Kangaroo Flat is no exception. Several modifications were required and some streams could not be sampled at all. An important factor hampering this survey was the lack of flow meters in the sampled streams. Due to time constraints and inaccuracies in measuring flow rates by hand, the flow rates of some streams were back calculated from assay values.

Assay Methods

Due to the difficulties in assaying high grade / coarse gold material, three methods were used to determine the head grade of the samples collected.

<u>Size Analysis</u>

All the samples collected were subject to a four kilogram wet screen size analysis using the following screen sizes: 53, 75, 106, 150, 212, 300, 425, 600, 850, 1180, 1700, 2360 and 3000 µm. For all size fractions above 300 µm (75 µm on IPJ/ISP streams), the entire size fractions were put through an intensive cyanidation leach step, followed by a solution Au assay, then residue washing, drying, pulverizing and FA50. Where the individual screen weights were too small, adjacent size fractions were combined.

<u>Screen Fire Assay</u>

Due to the elevated levels of coarse gold present; particularly in streams within the circulating loads around the mill and gravity units, the head grades of those samples were also determined using the screen fire assay method.

A one kilogram sample was used for the assay, which involves a wet screen at 75 µm, followed by a fire assays to extinction on the oversize and a FA50 on the undersize. The head grade is then determined from the weight distribution and grades of each fraction.

<u>Bulk Leach</u>

A modified bulk leach extractable gold (BLEG) assay was conducted on selected streams, followed by a FA50 (BLEG). The leach conditions used were: 24hrs, 2%NaCN, 30% solids, 1 g/t Pb(NO3)2 and O2 addition at start.

Survey Assay Data

The solids densities and grind size of the process streams sampled are tabulated in Figure 2. All streams are within normal process densities ranges expected, which implies that the samples collected were representative of the process stream sampled. The crush size of the mill feed which is generated by the HPGR is a P_{80} of 2517µm and P_{20} of 160 µm. The cut size of the flat bottomed cyclone was P_{80} of 276µm, however over 25% of the cyclone underflow, consisted of material below this size, reflecting the inefficiency of this type of cyclone. The circulating load of the grinding mill is calculated to be 150%.

Figure 2: %Solids and Grind size measured in process streams

Figure 3: Assay method comparison

The assay data from the size analysis is compared to the other two methods used in Figure 3. The main points raised in the analysis of the data are:

- The cyanide leaching step employed in the size analysis and bulk leach assays, resulted in between 56 - 96% of the contained gold dissolving into solution. This has considerably improved the accuracy of the final FA on the residue, as the remaining gold levels were low and it is assumed that any coarse free gold present had been leached.
- The screen fire assay returned a lower gold content compared to the other two methods, on the higher grade samples. This could be due to the smaller sample size used (1 kg compared to 4 kg), and the fact that between 50-75% of the gold reported to the undersize, which may have reduced the accuracy of the sampling for the final FA step.
- The screen fire assays results, show that 26.6% of the Au in the mill feed sample occurred in the size ranges above 75 µm, and this increased to an average of 47.7% in the samples collected around the gravity and grinding circuit. The figures also show that the majority of the coarse gold present was recovered by the IPJ, as the oversize gold content dropped from 47% in the IPJ feed to 7% in the IPJ Tails.
- The leachable gold content in the streams collected around the IPJ were: 73.6% in the IPJ feed, 96.4% in the IPJ Concentrate and 67.4% in the IPJ Tails. This shows that the IPJ is preferentially recovering free gold.

The Gold, Sulfur and Arsenic assays in the streams are summarised in Figure 4.

Figure 4: Assay data for each stream

The mill feed assays are lower than expected, and as its Arsenic content is higher than both the cyclone overflow and float feed sample, it is suspected that the sample collected is not representative of the stream. A mass balance produced from the survey data (refer to Table 1), indicates that the mill feed grade is 12.6 g/t. The accuracy of this number is highly dependent on the estimated mass flow in the IPJ concentrate, which proved to be difficult to measure. Our confidence level of the number used (6% mass pull) is +/-25%.

The survey indicated that the gravity gold and sulfur recovery is 91.3% and 6.7%, respectively, while the overall plant recoveries were 98.7% and 96.6%. The calculated ISP concentrate grade is 6,321 ppm Au, which represents an upgrade ratio of 502.

Table 1: Overall Plant Mass Balance

<u>IPJ Data</u>

Based on the estimated mass flowrates and grades, the IPJ single pass recovery is 32% for Gold and 16% for Sulfur. However when the calculation is based on the recovery at each particle size range the recoveries increase to 53% and 27% respectively.

Figure 5, displays the trend in recoveries to the IPJ concentrate, over each size range. The gold recovery is shown to steadily drop from approximately 90% to 20%, as the particle range falls from 2360 to 75 µm. Overall the IPJ was effective at recovering gold above 212 µm. In the screen range, 850 - 1180µm, a spike in the feed grade, led to a drop in the gold a recovery for this fraction. Given the higher recoveries on fractions either size, we can assume that this is a rogue sample.

The sulphur recovery trend generally follows the gold recovery characteristic, except that in the coarse range above 425 µm, the recoveries are averaging only 40%.

The recovery characteristics of the IPJ can be attributed to its setup. The lead ragging used, results in a separation of the heavies (gold) from the lights (sulphides and gangue), which is seen by the higher gold recoveries measured.

Figure 5: Total Metal % in feed reporting to IPJ concentrate

ISP Data

Based on the estimated mass flowrates and grades, the ISP single pass gold and sulphur recovery is estimated to be 43% and 32% respectively. A closer look at the gold grades measured in each fraction in Figure 6 shows that a rogue tails sample with elevated levels of gold in the coarser fractions reduced the overall recovery. Overall the recovery in all particle sizes was similar, demonstrating that the ISP is effective at recovery values from all particle ranges above 53 µm.

Figure 6: ISP Feed and Tails -Gold grade by size distribution

Cyclone Data

A summary of the survey data collected around the cyclone is shown in Table 2, while in Figure 7 the proportion of gold and sulphur in the cyclone feed reporting to the cyclone underflow is shown. The data shows approximately 88% of the Gold and Sulphide minerals present in the feed are re-circulating back to gravity and then grinding circuit. In the size fractions above 75 µm, over 90% of the Au and 85% of the S values entering the cyclone report to the underflow stream. This confirms that a portion of the values being liberated by additional grinding are eventually being recovered in the gravity circuit.

Table 2: Cyclone Mass Balance Summary

Figure 7: Total Metal % in feed reporting to Cyclone Underflow

CONCLUSIONS

As with any single snap shot of plants performance, it is important to accept, that some unexpected results will be produced. This is especially so on a plant that processes coarse gold. Overall most of the data collected on the samples, was in line with expectations, which confirmed that the samples were representative.

All three of the gold assay methods used produced valuable data. For instance the screen fire assay data, showed that the oversize gold content in the IPJ feed was 47% of the total, which dropped to just 7% in the tails. This demonstrates that the jigs are effective in removing the majority of the free gold present in a single pass.

The survey indicated that the gravity Gold and Sulphur recovery is 91.3% and 6.7%, respectively, while the overall plant recoveries were 98.7% and 96.6%. The IPJ single pass recovery was estimated to be between 32 – 53% for Gold, and 16 – 27% for Sulphides. Overall the IPJ was very effective at recovering valuables at particle sizes above 212 µm. The ISP used to upgrade the IPJ concentrate, in a single pass through two units, recovered 43% of the Golda and 32% of the Sulphides.

With over 88% of the Gold and Sulphur in the cyclone feed, reporting to back to the gravity and grinding circuit, the importance of installing gravity units within in a circulating load in shown.

ACKNOWLEDGEMENTS

Bendigo Mining Limited’s assistance in carrying out the survey and preparation of this paper and permission to publish is acknowledged. The staff of Gekko Systems laboratory who accomplished a challenging number of additional tests over a short period is also acknowledged.

REFERENCES

1. Johansen, G.F., (205), “Sampling and Blending Conference”, Sunshine Coast, QLD, 9-12 mAy 2005
2. McLean, E.J., (2007), “Process Design Aspects at Bendigo Mining’s Gold Operations”, The Ninth Mill Operators’ Conference, AusIMM, Fremantle, 19-21 March 2007

FIGURE CAPTIONS

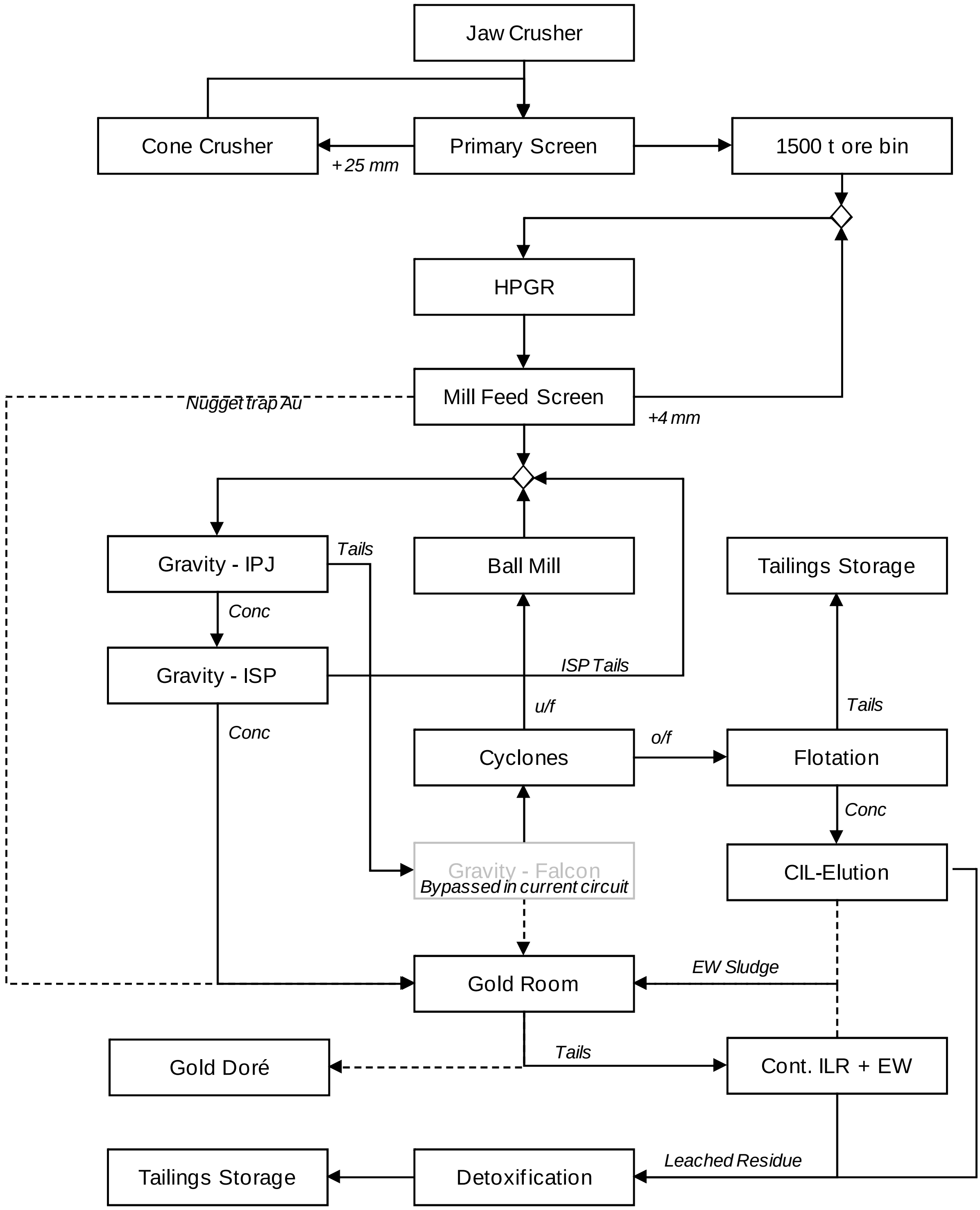

Figure 1: Simplified Processing Plant Flowsheet

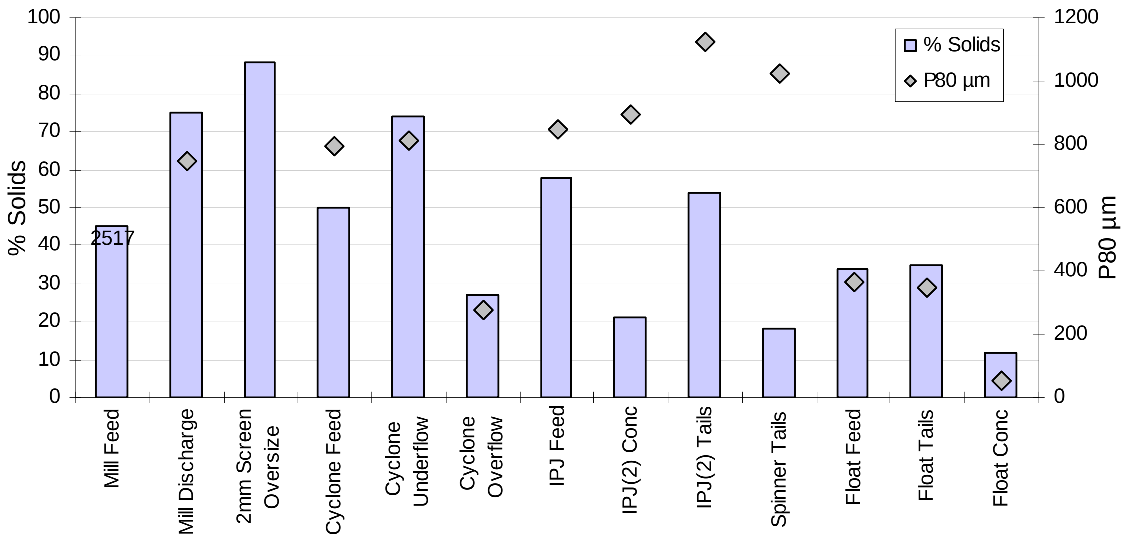

Figure 2: %Solids and Grind size measured in process streams

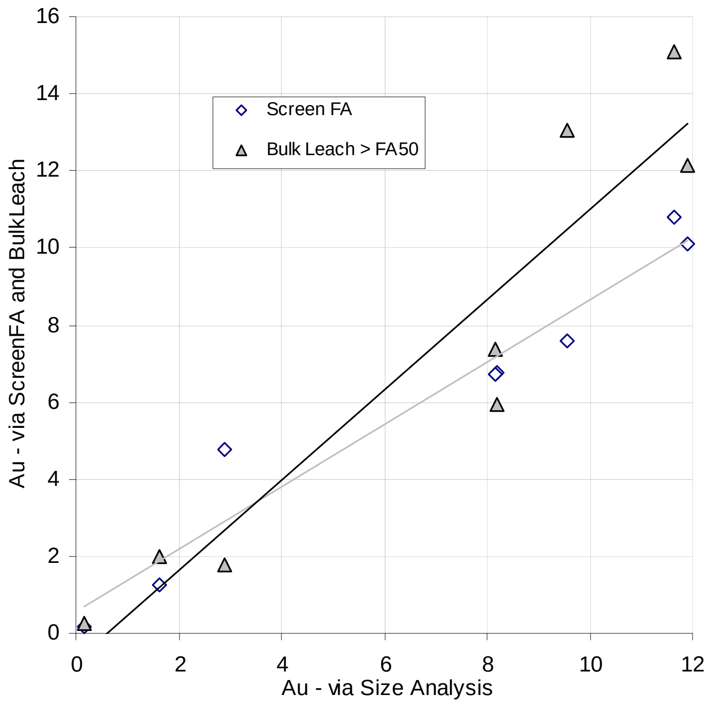

Figure 3: Assay method comparison

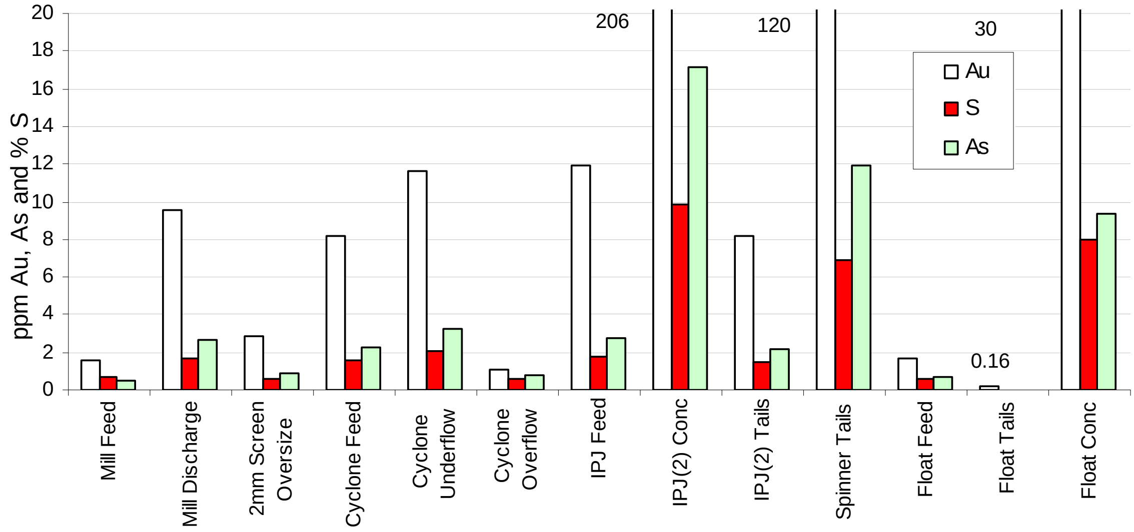

Figure 4: Assay data for each stream

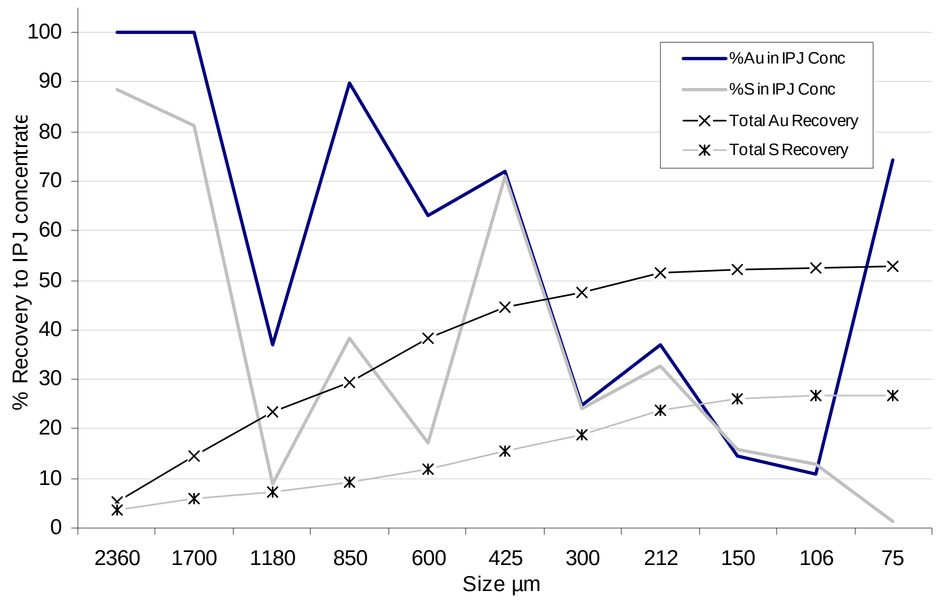

Figure 5: Total Metal % in feed reporting to IPJ concentrate

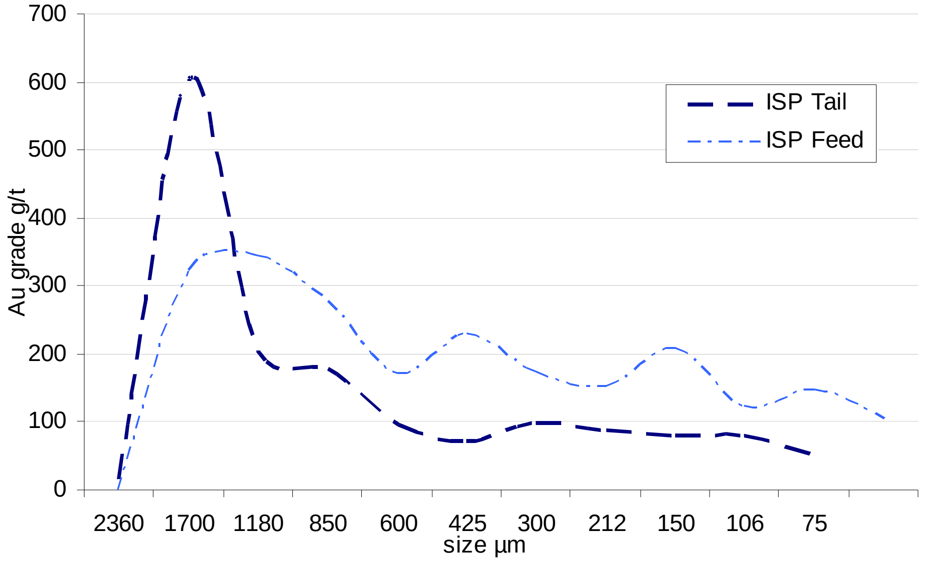

Figure 6: ISP Feed and Tails -Gold grade by size distribution

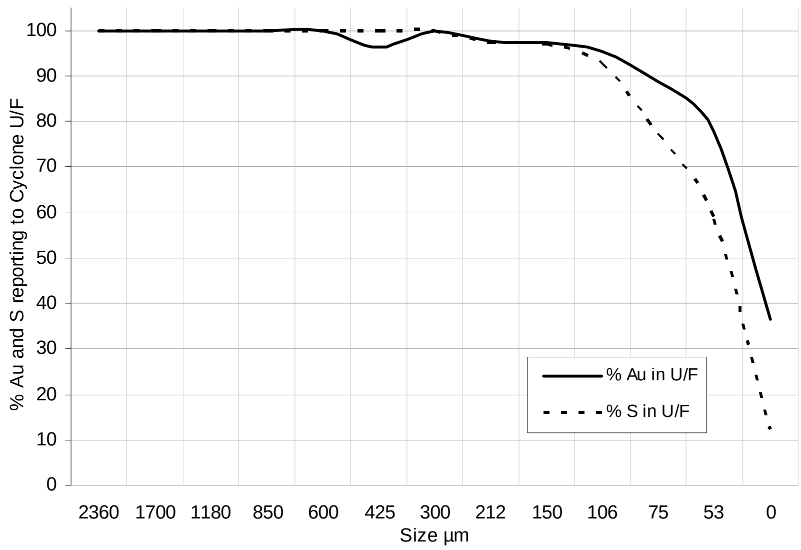

Figure 7: Total Metal % in feed reporting to Cyclone Underflow

TABLE CAPTIONS

Table 1: Overall Plant Mass Balance

	Mill Feed	ISP Concentrat	Float Feed	Flotation Concentrate	Flotation Tails
Solids flowrate, t/hr	70	0.13	69.9	5.4** – 1.2***	64.4** – 68.7***
Au Passing, g/hr	885	809	76.2	60.6	10.1
S Passing, t/hr	0.42	0.03	0.39	0.35	0.01
Grade, g/t Au	12.6*	6,321*	1.09	29.8	0.16
Grade, % S	0.6	21.7*	0.56	8.0	0.02

*Calculated assay
** Tonnage calculated from Sulphur balance
*** Tonnage calculated from Gold balance

Table 2: Cyclone Mass Balance Summary

	Cyclone Feed	Cyclone Underflow	Cyclone Overflow
Au Grade, g/t	8.2	11.6	1.1
S Grade, g/t	1.6	2.1	0.6
% Solids	50	74	27
P80 µm	795	813	276
P50 µm	405	385	103
Au Dist'b %		78	22
S Dist'b %		77	23