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KALGOORLIE CONSOLIDATED GOLD MINES

FLYROCK MODEL CALIBRATION UPDATE

1. SUMMARY

This report provides an update on the current state of flyrock control in the Kalgoorlie Consolidated Gold Mines Super Pit, and its significance for proposed blasting operations in the Golden Pike Cut-Back. The report includes data obtained from a previous study in 2004, and further data obtained from observations of current blasting practice that were taken during the period July to October 2006.

The 2004 study was based on observations of flyrock resulting from routine blasting operations that were suitable for use with a 400 metre blast clearance area. Analysis of this data resulted in recommendations for blasting specifications and controls that were suitable for use with a 200 metre clearance area.

The 2006 study was based on observations of flyrock resulting from blasting on both void and non-void areas, when using blasting procedures and checks that had been revised following the 2004 study. The observations showed a substantial improvement in flyrock control since 2004.

The blasting specifications and procedures used for blasting in non-void areas, when using a stemming height of 4.1 metres, resulted in a maximum flyrock throw distance of 45 metres, and a mean flyrock distance of 14.7 metres. When stemming height is increased to 5 metres, the maximum flyrock throw distance is reduced to 26.7 metres, and the mean flyrock distance reduced to 8.7 metres

The blasting specifications and procedures used for blasting in void areas, when using a stemming height of 4.1 metres, resulted in maximum flyrock distances for two blasts exceeding 50 metres (70 metres and 80 metres), and mean flyrock distances of 24.2 metres. When stemming height is increased to 5 metres, the maximum flyrock throw distance is reduced from 80 metres to 47.3 metres, and the mean flyrock distance reduced to 14.4 metres.

It is common to use a factor of safety of 4 x maximum throw to establish clearance distances for personnel, and this would require a clearance distance of 200 metres for a maximum throw of 50 metres. The 2006 study showed that current blasting practice, with 5 metre stemming heights, results in maximum flyrock distances that are compatible with a 200 metre clearance zone. With current improved loading practice, the proposed 200 metre personnel clearance distance has a factor of safety of 200 metres/27 metres = 7.4.

2. FLYROCK OBSERVATIONS - 2004

The flyrock from normal blasting operations was observed and the maximum throw recorded for the period 24th October to 2nd November 2004. The maximum throw was the maximum distance beyond the blast footprint, not the maximum throw from the collar of any hole.

The observations were analysed and the findings were presented in a report prepared by Adrian Moore and Alan Richards entitled 'Golden Pike Cut-Back Flyrock Control and Calibration of Predictive Model', dated 30th November 2005.

Analysis of the observations is summarised in **Table 1**.

The data was separated into oxide zone, sulphide zone and transitional categories. Blasts, where the flyrock distance was in excess of 50 metres, were also investigated and recorded in detail. The maximum flyrock distance for blasts where the maximum throw was less than 50 metres was not recorded.

3. FLYROCK OBSERVATIONS – 2006

Following the 2004 study the loading process, especially the design stemming height procedural check, was reviewed and improved checking systems were developed and implemented.

The flyrock observation methodology used in 2004 was repeated again between July and October 2006 to evaluate the effect of the improvement program and to recalibrate the flyrock model. A significant observation during this period was the effect of voids on flyrock control. The flyrock data was categorised into void or non-void areas.

During the period 18th July to 10th October 2006 the flyrock from 42 blasts was observed and recorded in detail. The flyrock distance from all blasts were noted, which permitted an average distance to be determined.

The blasting specifications for all the recent blasts were consistent, being 165 mm diameter holes, using Energan 2660 (1.3 s.g.) with a 4.1 metre stemming height. The flyrock from two of the 27 blasts in void areas in this period exceeded 50 metres (being 80 metres and 70 metres, respectively). In areas without significant voids, the maximum throw was 45 metres from the 15 blasts observed.

The flyrock observations are summarised in **Table 2**.

Table 1 – Summary of flyrock throw observations - 2004

Date	Blast	Maximum Throw (m)	Rock type	Mechanism	Hole Diameter (mm)	Explosive Type	kg/m	k Cratering q = 45^{o}
29/10-29/11/04	various	<50	sulphide	-	-	-	-	<16.0
			trans/oxide	-	-	-	-	<20.6
29/10/04	150-1902	80	sulphide	face burst	165	2660	27.8	20.2
	100-1306	80	oxide			2640	25.6	27.5
	120-2214	60	sulphide		115	ENERGAN	11.7	30.6
03/11/04	140-2202	**250-450***	sulphide	cratering	165	2660	-	-
05/11/04	110-317	70	oxide	cratering and rifling		ANFO	17.1	33.5
12/11/04	150-1904	85	sulphide	rifling		2640	25.6	22.0
17/11/04	140-2201	65		cratering		ANFO	23.5	20.2
24/11/04	140-2203	95					27.8	22.0
30/11/04	140-2205	30 (50 vertical?)		cratering and face burst		2660	27.8	17.4
02/12/04	110-1309	90 (80-100 vertical?)		cratering			27.8?	21.4

* *secondary breaking toe or boulders – severely overpowered*

Table 2 – Summary of flyrock throw observations - 2006

Date	Blast No.	Maximum Throw (m)	Maximum Height (m)	Mechanism			Voids	Type of Blast
				Cratering	Rifling	Face Burst		
18/07/06	200-132	50	50	✓			✓	
	200-1317	Nil			✓		x	
	210-1305	Nil					x	
21/07/06	190-1902	Nil					x	
	200-1313	30	30	✓		✓	x	
	Toe 200MB	Nil					✓	
	210-1304	80*	40	✓			✓	
23/07/06	200-1316	Nil					x	
26/07/06	430-1211	30		✓			✓	
	210-1303	Nil		✓			✓	Pre-split
27/07/06	210-1308	25					x	Pre-split
28/07/06	210-1306	20		✓			✓	
29/07/06	440-1202	40		✓	✓		✓	
	210-1309	35	15	✓			✓	
30/07/06	210-1301/02	Nil	30	✓		✓	x	
01/08/06	190-1901	45	45	✓	✓		x	
02/08/06	210-1307	Nil					✓	
07/08/06	210-1310	40	20		✓		✓	
08/08/06	140-1329	Nil			✓		✓	
09/08/06	440-1203	35		✓	✓		✓	
15/08/06	210-1311	20	15	✓			✓	
17/08/06	210-1318/19/24	40	25	✓	✓		✓	
19/08/06	210-1325/26	40		✓			x	+ Pre-split
20/08/06	210-1314	25		✓	✓	✓	x	
	440-1205	20		✓			✓	
25/08/06	210-1315	Nil						
	200-1903	20			✓		x	
29/08/06	440-1206	70*	35	✓			✓	
30/08/06	210-1316	Nil					x	+ Pre-split
01/09/06	210-1313	20		✓			✓	
04/09/06	210-1317	15					x	
08/09/06	200-1606/07	20				✓		
	220-1302	20			✓		x	
09/09/06	440-1208	10					✓	
10/09/06	210-1320	Nil					✓	
11/09/06	220-1303	10			✓		✓	
20/09/06	220-1305	30			✓		✓	
22/09/06	440-1210	15			✓		✓	+ Pre-split
25/09/06	220-1309	15			✓		✓	
	200-1920/21	30		✓	✓		✓	
28/09/06	440-1211	25			✓		✓	+ Pre-split
10/10/06	450-1203	15		✓			✓	

– Total blasts:	42
– Total blasts with voids:	27
– Total blasts without voids:	15
– Blasts >50 metre throw:	2
– Maximum throw-blasts in void areas:	80 metres
– Maximum throw-blasts in non-voids areas:	45 metres
– Mean throw-blasts in void areas:	24.2 metres
– Mean throw-blasts in non-void areas:	14.7 metres

3. MODEL CALIBRATION

The flyrock observations were analysed using the flyrock model:

$$L_{max} = \frac{k^2}{9.8} \cdot \left(\frac{\sqrt{m}}{S.H.}\right)^{2.6} \qquad [1]$$

where:

where:	SH	=	stemming height (m)
	m	=	charge mass/metre (kg)
	k	=	a constant
	L_{max}		maximum throw

3.1 Non-Void Areas

- Maximum throw: 45 metres
- Average throw: 14.7 metres
- Charge mass: 27.8 kg/metre
- Stemming height: 4.1 metres
- Substituting in [1]: $$L = \frac{k^2}{9.8} \cdot \left(\frac{\sqrt{27.8}}{4.1}\right)^{2.6} \qquad [2]$$

  k_{max}: 15.1

  k_{mean}: 8.6

3.2 Void Areas

- Maximum throw: 80 metres
- Average throw: 24.2 metres
- Charge mass: 27.8 kg/metre
- Stemming height: 4.1 metres
- Substituting in [1] gives: k_{max}: 20.1

  k_{mean}: 11.1

Comparing the effect of the void areas to the non-void areas, if k_{max} = 15.1, the effective stemming height is equivalent to 3.4 metres, ie. 0.7 metres less than design. This shows the increased difficulty in maintaining control over confinement in void areas.

For 25 of the 27 blasts with $L_{max} \leq 50$, k_{max} = 15.9.

4. COMPARISON WITH PREVIOUS FLYROCK OBSERVATIONS

Prior to the implementation of tighter quality assurance operating procedures for hole loading, the maximum throw exceeded 50 metres for 28% of blasts and the maximum throw was 95 metres. This compares with 2 out of 42 (5%) blasts exceeding 50 metres with the maximum throw of 80 metres.

The oxide zone has no voids and the stemming height is increased to 5 metres on the Golden Pike Cut-Back to limit airblast. ANFO can be used more frequently because the blastholes are more likely to be dry. To be conservative, it is assumed that 1.3 s.g. explosive will be used exclusively.

For non-void areas in the oxide zone, the predicted throws using Energan 2660 are:

- Maximum throw $= \left(\frac{15.1}{9.8}\right)^2 \cdot \left(\frac{\sqrt{27.8}}{5}\right)^{2.6} =$ 26.7 metres
- Average throw $= \left(\frac{8.6}{9.8}\right)^2 \cdot \left(\frac{\sqrt{27.8}}{5}\right)^{2.6} =$ 8.7 metres

In the unlikely event that voids are encountered:

- Maximum throw: 47.3 metres
- Average throw: 14.4 metres

If ANFO is used, the maximum throws become:

- Non-voids maximum throw: 14.2 metres
- Non-voids average throw: 4.6 metres
- Voids maximum throw: 25.1 metres
- Voids average throw: 7.7 metres

Table 3 lists the recommended minimum clearance distances for plant and equipment (factor of safety '2') and personnel (factor of safety '4') for void and non-void areas, together with oxide zone (5 metre stemming height) and sulphide zone (4.1 metre stemming height) blasts.

Table 3 – Recommended minimum clearance distances

		Stemming Height (m)	Maximum Throw (m)	Clearance to Plant (m)	Clearance to Personnel (m)
Void Areas	**oxide**	**5**	**47**	**94**	**188**
	sulphide	4.1	80	160	240
Non-Void Areas	**oxide**	**5**	**27**	**54**	**108**
	sulphide	4.1	45	90	180

5. DISCUSSION

The blasting specifications and procedures currently used for blasting in non-void areas, when using a stemming height of 4.1 metres, resulted in a maximum flyrock throw distance of 45 metres, and a mean flyrock distance of 14.7 metres. When stemming height is increased to 5 metres, the maximum flyrock throw distance is reduced to 26.7 metres, and the mean flyrock distance reduced to 8.7 metres.

The blasting specifications and procedures currently used for blasting in void areas, when using a stemming height of 4.1 metres, resulted in maximum flyrock distances for two blasts exceeding 50 metres (70 metres and 80 metres), and mean flyrock distances of 24.2 metres. When stemming height is increased to 5 metres, the maximum flyrock throw distance is reduced from 80 metres to 47.3 metres, and the mean flyrock distance reduced to 14.4 metres.

It is common to use a factor of safety of 4 x maximum throw to establish clearance distances for personnel, and this would require a clearance distance of 200 metres for a maximum throw of 50 metres. The 2006 study showed that current blasting practice, with 5 metre stemming heights, results in maximum flyrock distances that are compatible with a 200 metre clearance zone.

Circumstances in the Golden Pike Cut-Back are more favourable than those in the general open pit area due the absence of voids, and in these circumstances a greater degree of control is possible. With an increase in stemming height to 5 metres in the oxide zone to limit airblast, the maximum throw can be reduced to 27 metres.

With current improved loading practice, the proposed 200 metre personnel clearance distance has a factor of safety of 200 metres/27 metres = 7.4. To throw a rock 200 metres, the issue of clearing the bund aside, the stemming height must be inadvertently reduced to 2.3 metres using 1.3 s.g. explosive.

The current quality assurance procedures have proven effective in limiting the stemming height to that designed with a small tolerance, and this has demonstrated that KCGM have developed procedures that will permit blasting in the Golden Pike Cut-Back to be safely carried out using a 200 metre clearance zone.

6. CONCLUSIONS

Current practice (2006), using strict control over explosive loading and stemming practice in areas without voids, has resulted in a maximum flyrock throw of 45 metres when using a 4.1 metre stemming height, which will be reduced to 26.7 metres when using a 5 metre stemming height.

Current practice (2006) in void areas has resulted in a maximum flyrock throw of 80 metres when using a 4.1 metre stemming height, which will be reduced to 47.3 metres when using a 5 metre stemming height.

Circumstances in the Golden Pike Cut-Back are more favourable than those in the general open-pit area due the absence of voids and, in these circumstances, a greater degree of control is possible.

It is common to use a factor of safety of '4' x maximum throw to establish clearance distances for personnel, and this would require a clearance distance of 200 metres for a maximum throw of 50 metres. The 2006 study showed that current blasting practice, with 5 metre stemming heights, results in maximum flyrock distances that are compatible with a 200 metre personnel clearance zone. With current improved loading practice, the proposed 200 metre personnel clearance distance has a factor of safety of 200 metres/27 metres = 7.4.

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