Water requirements for the recovery of diamonds using grease technology

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T e c h n i c a l   N o t e

Synopsis

South Africa is running out of fresh water and is looking at ways to improve water usage.

This report addresses how a diamond mine in Gauteng has improved the utilization of its water resources. In the past, water from the local river was deemed the most suitable to use in the grease recovery plant but subsequent tests on the water from the slimes dam have shows that this water source is in fact more suitable for diamond recovery. Utilizing the slimes dam water provides a more stable water source than the local river while also reducing the impact of the mine on the water resources in the area.

Introduction

The recovery of diamonds from an ore can be compared to finding a needle in a haystack. A viable kimberlite deposit can have a grade as low as 10 carats per hundred tons (cpht), which equates to 2 parts per 100 000 000. A viable alluvial deposit could have grades as low as 1 cpht since only minimal crushing is required. Such a grade equates to 2 parts per 1 000 000 000.

A diamond mine

The flow sheet of a diamond mine includes extracting the ore from either an alluvial or a kimberlite deposit. In a kimberlite deposit, the ore is crushed using primary (jaw or gyratory) crushers. This crushed material is scrubbed to remove the clays associated with kimberlites and a large percentage of the nonviable fine (–1.5 mm) material. The material is passed through secondary (cone) crushers with a 'top size' setting of 32 mm or 25 mm, depending on the expected top size of diamond, the mine expects to recover. The material is then screened, sized and passed though a dense medium separation (DMS) circuit to remove all material with a density less than 3.0 g/ml. The majority of alluvial and kimberlitic material has a density less than 3.0 g/ml and the DMS circuit removes between 98% and 99% of the material to tailings. The DMS concentrate is then passed onto the recovery section where, due to the increased grade of the ore, security is increased.

If there is a magnetic component in the ore, this will report to the DMS concentrate since magnetic materials usually have a density greater than 3.0 g/ml. Magnetic separation can be used to further concentrate the ore by removing another 40% of the DMS concentrate to the magnetic fraction. The diamonds, which are heavy and non-magnetic, are contained in the non-magnetic fraction. This fraction is then sent to either an X-ray machine or a grease recovery plant or both. The +8 mm material coming out of the recovery plant is then sent to re-crush (tertiary crushing) to ensure that no diamonds are locked up in large particles. This material then joins the crushed ore for reprocessing through the DMS and recovery plant. A block diagram showing the progress of ore through a diamond plant is given in Figure 1. The mass retention of the ore, at each stage is given by the percentages associated with each stream.

In the block diagram in Figure 1, the total concentrate comprises 0.000043% of the ore. This equates to concentrating the ore 2 000 000 times. If the ore had a grade of 10 cpht, the occurrence of diamonds in the concentrate would be about 1 in 25, and this final product is hand sorted in the sort house.

Water and slimes dam

South Africa is running out of fresh water and is looking at ways to improve water usage. One area where water can be better utilized is in the hydrometallurgical plants of the mines[1]. This report addresses how a diamond mine has improved the utilization of its water resources.

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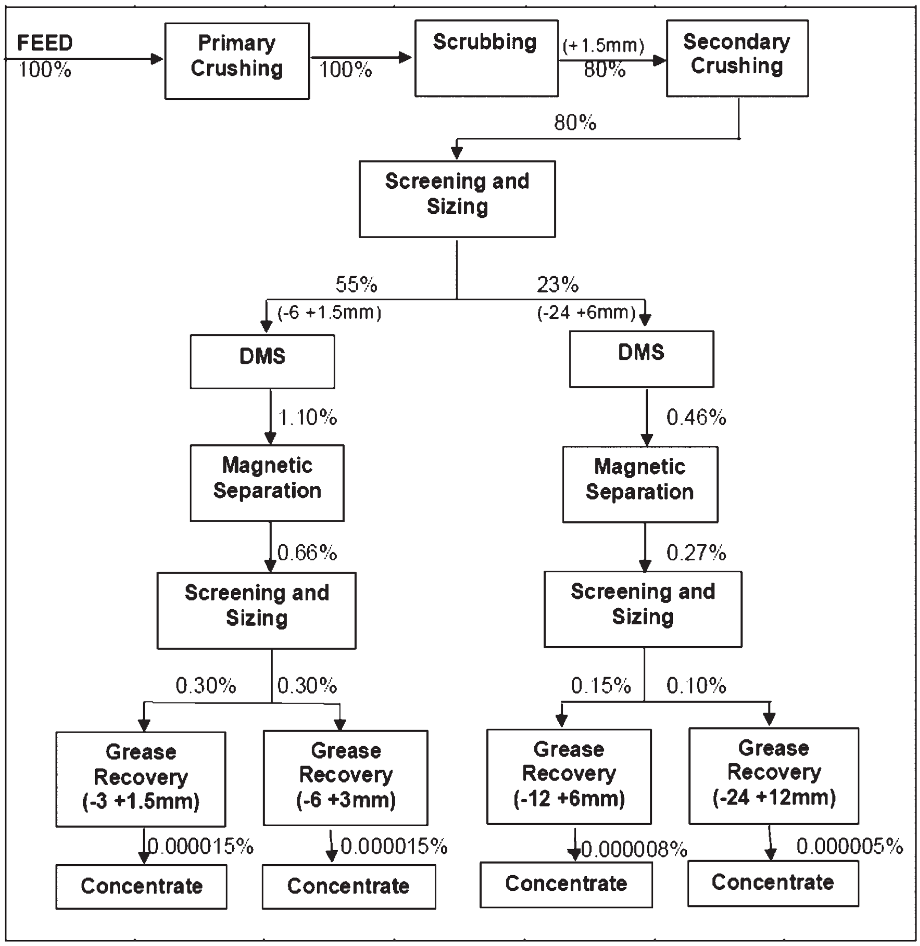


Figure 1—The flow of material in a diamond plant showing the percentage mass reduction at each stage

In 2004, the diamond mine was facing a water shortage for its mining operation, leaving the mine with no source of clean water for the grease recovery plant. However, the mine did have a large source of 'dirty' water in its slimes dam.

The life of a mine depends on how much water the slimes dam can hold. In order to increase the life of mine, the slimes dam capacity has to be continually increased and, in some cases, a new location for a slimes dam has to be sought. By using the water from the slimes dam in the plant, the life of mine is increased indefinitely since any new water reaching the slimes dam would be minimal and this excess would be removed through evaporation.

Hydrophobicity

To assess what water characteristics are important for diamond recovery on grease one needs to determine what is happening at the water-diamond interface. At the water-diamond interface, the force of attraction on a water molecule from a neighbouring water molecule is greater than the force of attraction from the diamond surface. This causes the water molecule to move away from the diamond and remain with the other water molecules. These forces of attraction and repulsion between the adjacent water molecules and diamond–water interfaces are noticed by the bending of the water around the hydrophobic diamonds, as shown by Figure 2.

At the water-gangue particle interface, the force of attraction by the gangue material is greater than that of the neighbouring water molecule, thus the gangue material is able to pull the water molecule away from the neighbouring water molecules and become wet. The degree of bending at the diamond-water interface is dependant on two major factors:

- The hydrophobicity of the diamond surface and
- The forces of attraction between adjacent water molecules.

All the diamonds used in this investigation were un-acidized to represent exactly what the grease recovery section would have to treat. The diamonds were all found to be hydrophobic with varying degrees of hydrophobicity. The force of attraction between adjacent water molecules within a specific water source can be inferred by measuring the surface tension of the water source. Factors that affect the surface tension of a water source are pH, conductivity, dissolved solids and suspended solids.

Scope

The diamond mine needed to quantify the diamond losses when water from the slimes dam was used in an emergency for grease recovery. The slimes dam water was tested for its

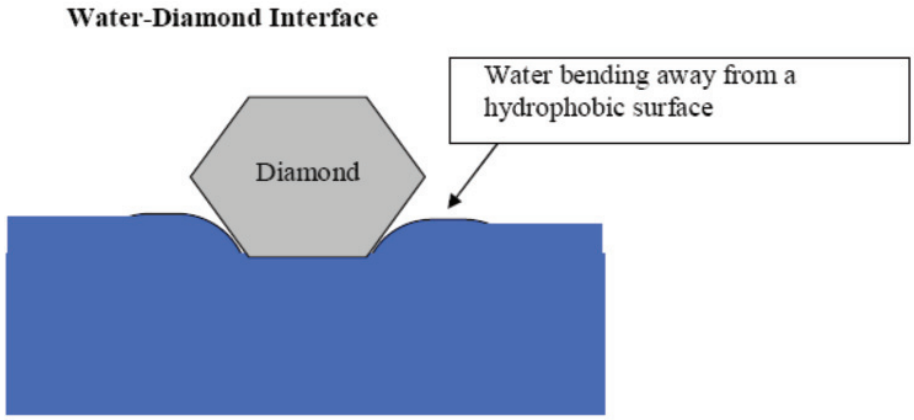


Figure 2—A sketch showing the effects of the forces of repulsion at the water-diamond interface

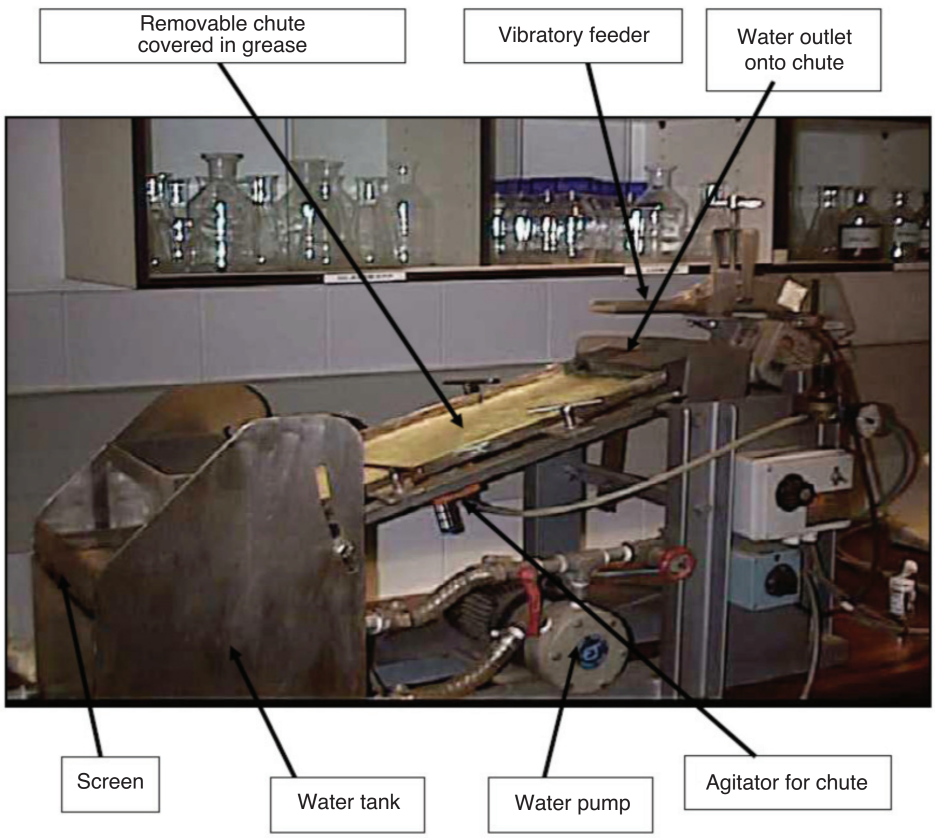


Figure 3—The grease recovery testing jig

appropriateness to use in grease recovery technology. Water characteristics such as surface tension, pH and conductivity all affect the capability of the water to wet or not to wet the diamonds. The purpose of this investigation was to characterise the slimes dam water for use in grease recovery in conjunction with the water from the local river and a sample of filtered water from the slimes dam.

Equipment

The characterization tests comprised water analysis from Anglo Research Laboratories (ARL) and practical tests carried out with diamonds on a laboratory grease jig, as seen in Figure 3. The grease jig has a water tank and pump, which enables each water source to be circulated in a closed circuit. The jig has two chutes for smearing with grease and these can be interchanged when necessary. The chute is equipped with an agitation motor, which causes a disturbance to material adhering to the grease. This agitator is used to disturb any material adhering to the grease (diamonds), so causing them to move down the chute. The jig is equipped with a feeder with an adjustable height setting to simulate mining conditions as closely as possible.

Materials

The materials that were used in the test work were:

- A total of 30 (+4 mm) un-acidized rough diamonds selected randomly from the mine
- A total of 10 (+4 mm) hydrophobic tracers
- A degreaser to clean the diamonds and tracers
- A sample of petrolatum and 2305 micro-wax from Sasol. These two substances were melted and mixed in a ratio 4:1 respectively to make the grease for applying to the chute.
- A total of 20 litres of water from each of the three water sources to be evaluated.

Experimental procedure

Water characterization tests

The three water sources to be tested were first stirred so that any settled solids were disturbed and placed in suspension. This was to ensure that the water samples were all homogenous mixtures. A 1-litre sample from each of the three water sources was then collected and sent to the ARL for analysis.

Diamond recovery evaluation tests

To evaluate the effects of the water source on diamond recovery, 15 litres of the water was placed in the water tank in the grease jig. The diamonds were divided into 6 groups of 5 diamonds each and placed in 6 petri dishes. A total of 5 hydrophobic tracers were then placed in each petri dish with the 5 diamonds, as seen in Appendix A. The diamonds and tracers were then submerged in water from the water source presently being evaluated by filling the 6 petri dishes with the water.

The grease components were then placed in the correct ratio in a metal pan and melted at 95°C in the oven. The molten mixed grease was then poured onto the chute where it was allowed to cool. Once the grease was cool the grease had to be lightly scraped to remove the waxy crust that had formed on top of the grease mixture. The water pump on the grease jig was then switched on to allow the water in the tank to circulate over the grease chute.

The first batch of 5 diamonds and 5 tracers was then placed on the feeder and fed onto the grease chute. The water pump was switched off to stop the water circulating so that the distribution of the diamonds and tracers could be measured. The water pump was then restarted and the agitation motor started. The system was operated in this manner for 2 minutes after which the agitation motor was stopped and the water pump stopped. The new distribution of the diamonds and the tracers was then measured. Again the water pump was restarted and the agitation motor was allowed to run for another 2 minutes, after which the distribution of the diamonds and tracers were recorded again. In each test the agitation sequence was carried out 3 times. Photographs of the diamond and tracer distribution before and after the final agitation are shown in Figures 4 and 5. These photographs were taken during tests of the water from the slimes dam.

On completion of each test, the diamonds and hydrophobic tracers were removed from the grease chute and cleaned with a degreaser.

Grease contamination tests

The grease under the feed chute is continually being contaminated with fine hydroscopic particles. These fine particles are usually inconsequential particles and do not negate the grease recovery process. However, heavy particles such as ferrosilicon can adhere to the grease since the water carrying capacity is too low to wash it away. Material with a high content of heavy fines such as spinels (with a density of 4.1 g/ml) and ilmenites (with a density of 4.5–5.0 g/ml) can also adhere to the grease. In such situations, the grease becomes coated with heavy fines or is 'blinded' to any hydrophobic material falling on the contaminated grease.

An important parameter to measure when evaluating the three water sources for use in a grease recovery process was the degree of grease contamination from the different water sources. For each water source a fresh grease sample was placed on the chute and the amount of grease contamination was evaluated at the end of the set of tests. The time taken to complete a set of tests on a water source was approximately 1 day.

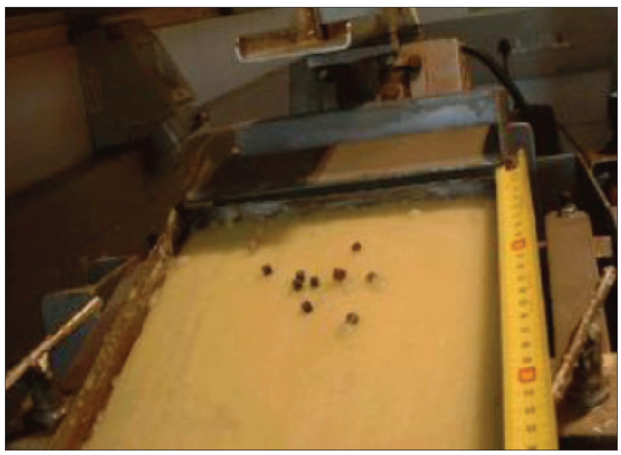


Figure 4—Distribution of diamonds and tracers before agitation

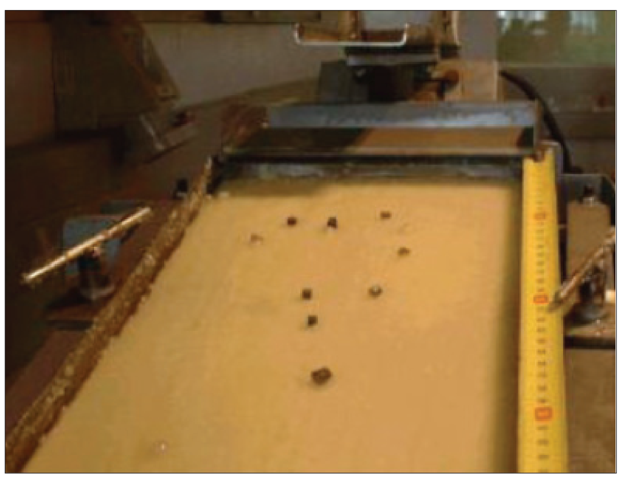


Figure 5—Distribution of diamonds and tracers after agitation

Experimental results

Diamond recovery results

The results of the tests carried out with diamonds and tracers on the two water sources are seen in Appendix B. A summary of the results obtained from the tests are given in Table I.

Results of the water characterization tests

The water analysis obtained from the ARL is documented in Table II. The water sources are ranked from left to right according to their appropriateness for use in the grease recovery plant, the slimes dam water having the highest rank and the filtered water having the lowest rank.

Results of the grease contamination tests

In all three cases, the amount of contamination from the water sources was negligible, as seen by Figures 6 and 7. The amount of grease contamination from the three water sources could be quantified since the particles adhering to the grease were too small and could not be removed. All the grease contamination occurred at the top end of the chute, where the water from the weir first impacts onto the grease.

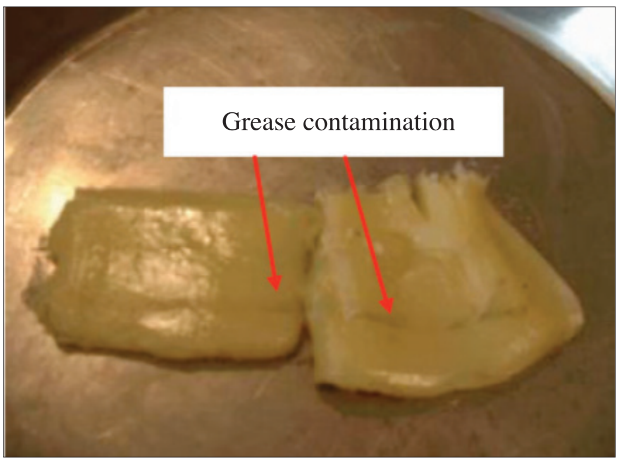


Figure 6—Contaminated grease from river water on the left and the slimes dam water on the right

Figure 7—Contaminated grease the filtered dam water

Discussion

Diamond recovery

The results in Table I indicate that the water from the slimes dam is more suitable for the recovery of diamonds in the grease plant than the water from the local river. The results also show that the slimes dam water, left untreated, had the highest diamond recovery with the least amount of movement of the diamonds when the jig is agitated. These results indicate the diamond-water contact angle for the water from the slimes dam are the smallest and that this water source is repelled the most by the diamond surface.

The results from Table II show that the water surface tension from the slimes dam was in fact the strongest of the three water sources. The pH of the water also affects the surface tension of the water and was also found to be the highest for the three water sources. Soaps and settling agents destroy the surface tension of water, and it is expected that some form of settling agent was used in the filtered water in order to obtain such a clean water source.

Slimes dam

Determining that the water from the slimes dam can be used in the grease plant, significantly extends the life of the diamond mine. The mine was using vast quantities of water from the local river that had to be disposed of in the slimes dam and the dam was close to maximum capacity. In future designs of diamond recovery mines, being able to use processed water and significantly reduced the design capacity

Table I

Water rankings for use in grease recovery technology based on the diamond data

Ranking	Water source	Diamond recovery (%)	Average movement (mm)
1st	Slime dam	99.2%	102.0
2nd	River water	98.3%	154.5
3rd	Filtered dam water	93.3%	166.9

Table II

The water characterization results from the ARL

	Slimes dam water	River water	Filtered dam water
pH at 25°C	9.2	8.3	8.6
Conductivity ms/m at 25°C	243	47	133
Total dissolved solids (mg/l)	1554	232	858
Total suspended solids (mg/l)	8630	51	<10
Turbidity NTU	4080	25.7	8.4
Colour/clarity(Pt-Co)	Int.	192	15
Surface tension (dynes/cm)	72	62	60

for the slimes dam. This should provide any future mine that uses grease recovery technology huge benefits since the costs of fresh water would be significantly reduce and planning for the life of the slimes dam would no longer be a concern.

Grease contamination

The amount of grease contamination from the slimes dam was negligible. The high quantities of suspended solids in the water did not settle out of the water but stayed in suspension. Settled clays were also dropped onto the grease but they were rapidly washed away by the water from the slimes dam. Kimberlitic clays are generally of a low density and stay suspended in the water source. As long as no flocculants or settling agents are used, these clays should not contaminate the grease.

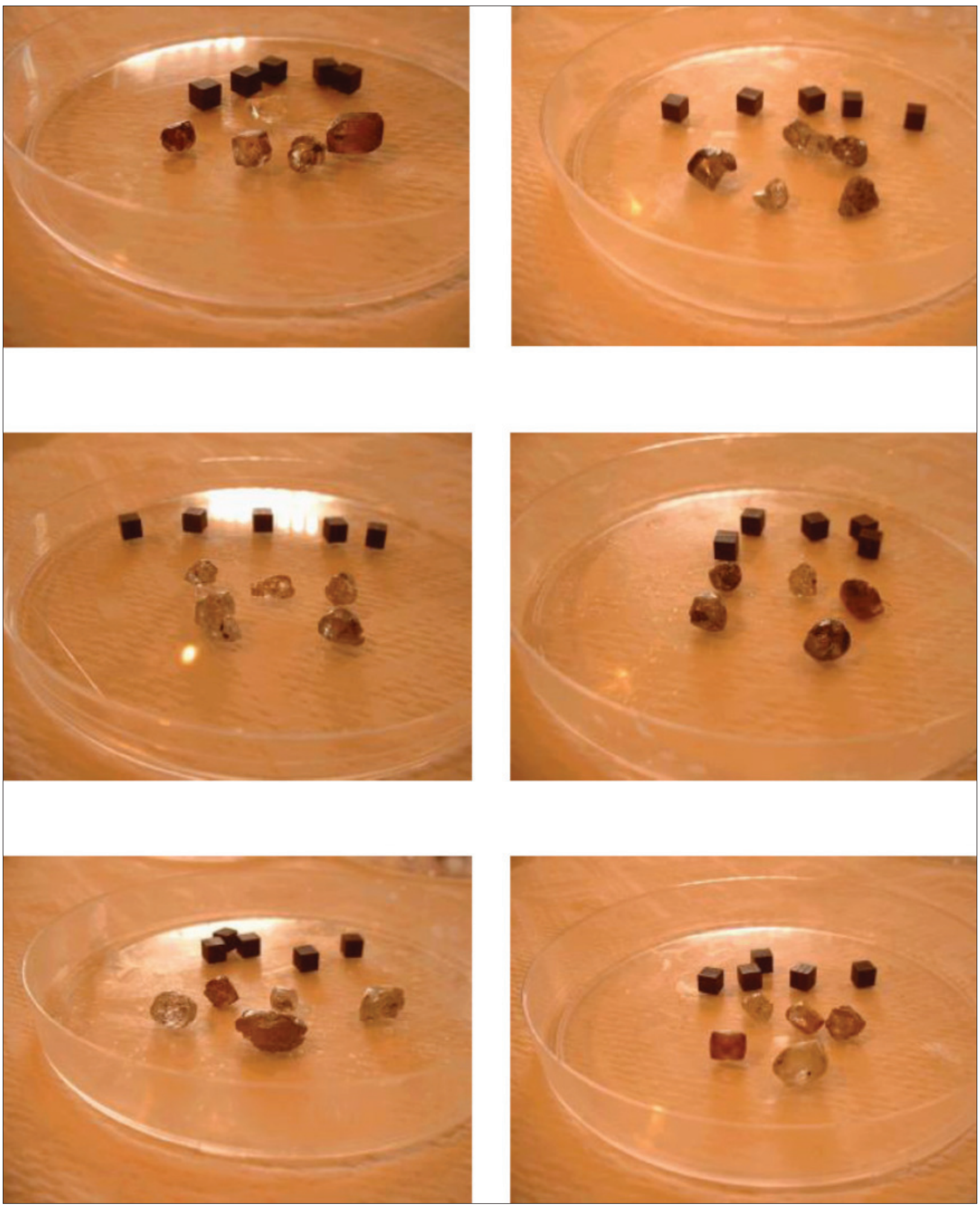
Conclusion

Using water from the slimes dam is beneficial to the recovery of diamonds on grease. Making use of water from a slimes dam or even using the mine's processed water significantly reduces the impact of the mining operation on the water supply of the area. In the past it was thought that the requirement for the recovery of diamonds on grease was with fresh clean water. The mine has subsequently changed this philosophy and changed the water in the grease plant to water from the slimes dam.

References

1. *Mining Weekly*, Creamer Media, Water & Mining Rising Concern, pp. 11–17 August 2006, vol 12. no. 30, pp 8–9. ◆

Appendix A



Appendix B

		Diamond Distribution and Movement					Average
	Recovered	D 1	D 2	D 3	D 4	D 5	Movement
		(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
Slimes Dam Water							
Feeder test 1	5	78	103	59	176	60	
2 min Agitation	5	170	160	144	242	146	77.2
4 min Agitation	5	201	161	151	269	146	90.4
6 Min Agitation	5	204	162	155	290	146	96.2
Test 1		**126**	**59**	**96**	**114**	**86**	**87.9**
Feeder test 2	5	45	74	63	59	61	
2 min Agitation	5	45	99	66	82	203	38.6
4 min Agitation	5	45	99	67	82	245	47.2
6 Min Agitation	5	45	175	67	82	290	71.4
Test 2		**0**	**101**	**4**	**23**	**229**	**52.4**
Feeder Test 3	5	59	53	97	56	93	
2 min Agitation	5	75	213	250	60	112	70.4
4 min Agitation	5	75	214	265	60	131	77.4
6 Min Agitation	5	75	214	272	60	136	79.8
Test 3		**16**	**161**	**175**	**4**	**43**	**75.9**
Feeder Test 4	5	47	58	60	70	84	
2 min Agitation	5	282	178	228	70	202	128.2
4 min Agitation	5	385	191	229	70	203	151.8
6 Min Agitation	5	385	200	229	70	204	153.8
Test 4		**338**	**142**	**169**	**0**	**120**	**144.6**
Feeder Test 5	5	53	89	60	83	112	
2 min Agitation	5	77	283	165	98	273	99.8
4 min Agitation	5	203	315	165	98	380	169.8
6 Min Agitation	4	220	lost	165	98	385	174.2
Test 5		**167**	**311**	**105**	**15**	**273**	**147.9**
Feeder Test 6	5	41	76	76	48	53	
2 min Agitation	5	240	93	193	59	220	102.2
4 min Agitation	5	242	93	194	59	220	102.8
6 Min Agitation	5	248	93	194	59	221	104.2
Test 6		**199**	**17**	**117**	**11**	**167**	**103.1**
Diamond Recovery	99.2%				Average Diamond Movement		102.0