A clear quantification of the costs of these consequences can be useful in targeting unit operations where improvements through either reducing or eliminating the causal effects would make significant savings in the overall mining operational costs.

A model for quick or 'on-the-spot' estimates of the unit operational costs would be very useful for mines, thus enabling a timely decision towards minimising operational costs. This may be achieved by quick decision on alternatives included in 'timely decision' in order to reduce the anticipated extra costs in downstream operations. The alternatives include:

a) Controlled drilling aiming at reducing hole deviations.
b) Re-planning of blasting patterns
c) Re-drilling of problem areas.
d) Combination of one or more of the above alternatives.

## 5.1 Methods Used in Cost Estimation of Extra Costs Due to Consequences of Hole Deviations

In estimating cost of consequences associated with hole deviations, the cost items for the consequences (Table 5.1) were identified. The unit costs of items were obtained from various sources, including equipment manufacturers, accounts section of ZCCM-Nkana Division and London metal exchange (LME) market. The unit prices were based on the price levels of 1998.

To estimate the cost, the quantity of cost items was multiplied by the unit cost. The quantities of cost items were determined during stope and raise pilot drilling and subsequent operations. All unit costs and calculations are in US dollars.

Examples of procedures of some calculations are shown below:

a) Number of extra 165mm buttom bits used multiplied by the cost of one bit

b) Number of extra magnum 365 explosives used multiplied by the cost of one case of explosives

c) Estimating costs of extra drilling using unit cost may be calculated as follows:

If to drill one metre costs US$***X***, and

Planned metres drilled (per stope) = ***Y***

Actual metres drilled = ***W***

Cost of extra drilling = US$ ***X***(***W-Y***)

Or, if total extra metres drilled are known, then the actual total cost may be estimated as shown in Figure 5.1.

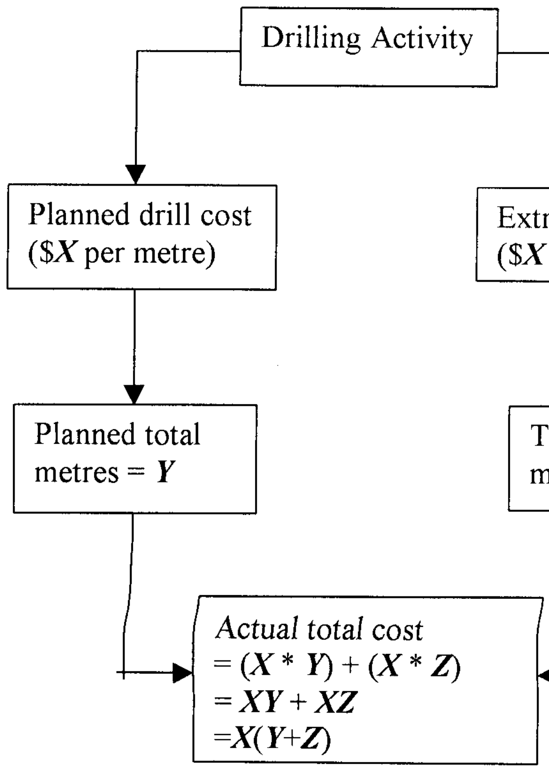



Figure 5.1 Drilling Cost

d) Loss of production due to delay or down time.

If the normal production rate is 700 tonnes of ore per seven-hour shift and due to delays, 700 tonnes of ore is produced in eight hours, then the production efficiency has dropped to 7/8 x 100 = 87.5%

Or, if one machine is making revenue of US$***X*** in five hours.

∴ Five machines will make revenue of US$***X*** x by 5, in five hours.

If one hour is lost, then more than six machines will be required to make the same revenue of US$5***X***. This can be illustrated as follows:

Let 5 vehicles be planned to work 5 hours each. This would amount to 25 production hours. If 1 hour is lost totally for the 5 vehicles, then each vehicle losses 1/5 or 0.2 hours

∴ 5 vehicles X 5 hours = ***Y*** vehicles x (5 hours – 0.2 hr lost per vehicle x 5 vehicles)

25 = ***Y***(5 – 1)

25 = 4***Y***

***Y*** = 25/4 = 6.25

Therefore 'six and a quarter' vehicles will be required to produce the same amount of ore that five vehicles would produce at 100% rated productivity (or 5 effective hours each). The operating costs for extra vehicles will be the extra cost due to down time.

## 5.2 Cost Estimation

### 5.2.1 Estimating Extra Costs for Stope Drill Holes

#### 5.2.1.1 Manual Calculations

***Chamber***

Planned estimated cost of drill bits = No. of bits x unit cost (*Appendix B, Table D*)

= 1.5 x 274.693 = $412.040

Actual estimated cost of drill bits = 2.0 x 274.693 = $549.386

Extra cost = $137.346

Extra cost percentage = 33.3%

Planned estimated drilling cost = metres drilled x unit cost ($/m)

[Including labour and drill accessories (*Appendix A, B & D; Tables C, E & I*)]

| | |
|---|---|
| | = 1,088.26 x 1.55 = $1,686.803 |
| Actual estimated drilling cost | = 1,246.0 x 1.55 = $1,931.3 |
| Extra cost | = $431.397 |
| Extra cost percentage | = 14.49% |

| | |
|---|---|
| Planned estimated labour cost | = Labour cost/day x number of workers x days |
| | = 8.303 x 8 x 11 = $730.664 |
| Actual estimated labour cost | = 8.303 x 8 x 17 = $1,129.208 |
| Extra cost | = $398.544 |
| Extra cost percentage | = 54.5% |

***Recovery Ring 1***

| | |
|---|---|
| Planned estimated cost of drill bits | = 0.3 x 274.693 = $82.408 |
| Actual estimated cost of drill bits | = 0.5 x 274.693 = $137.347 |
| Extra cost | = $54.939 |
| Extra cost percentage | = 67.0% |

| | |
|---|---|
| Planned estimated drilling cost | = 214.28 x 1.55 = $332.134 |
| Actual estimated drilling cost | = 298.10 x 1.55 = $462.055 |
| Extra cost | = $129.921 |
| Extra cost percentage | = 39.12% |

| | |
|---|---|
| Planned estimated labour cost | = 8.303 x 8 x 2 = $132.848 |
| Actual estimated labour cost | = 8.303 x 8 x 3 = $199.272 |
| Extra cost | = $66.424 |

Extra cost percentage = 50.0%

***Recovery Ring 2***

Planned estimated cost of 165mm-bits = 0.3 x 274.693 = $82.408

Actual estimated cost of 165mm-bits = 0.4 x 274.693 = $109.877

Extra cost = $27.469

Extra cost percentage = 33.3%

Planned estimated drilling cost = 196.69 x 1.55 = $304.695

Actual estimated drilling cost = 270.99 x 1.55 = $420.035

Extra cost = $115.34

Extra cost percentage = 37.85%

Planned estimated labour cost = 8.303 x 8 x 2 = $132.848

Actual estimated labour cost = 8.303 x 8 x 4 = $265.696

Extra cost = $132.848

Extra cost percentage = 100.0%

***Wrecking Rings***

Planned estimated cost of 165mm-bits = 0.2 x 274.693 = $54.939

Actual estimated cost of drill bits = 0.3 x 274.693 = $82.408

Extra cost = $27.469

Extra cost percentage = 50.0%

Planned estimated cost of 127mm-bits = 0.2 x 211.43 = $42.286

Actual estimated cost of drill bits = 0.3 x 211.43 = $63.429

| | |
|---|---|
| Extra cost | = \$21.143 |
| Extra cost percentage | = 50.0% |

| | |
|---|---|
| Planned estimated drilling cost | = 277.38 x 1.55 = \$429.939 |
| Actual estimated drilling cost | = 393.00 x 1.55 = \$609.15 |
| Extra cost | = \$179.211 |
| Extra cost percentage | = 41.68% |

| | |
|---|---|
| Planned estimated labour cost | = 8.303 x 8 x 4 = \$265.696 |
| Actual estimated labour cost | = 8.303 x 8 x 6 = \$398.544 |
| Extra cost | = \$132.848 |
| Extra cost percentage | = 50.0% |

***Estimated Cost of Explosives***

*For VCR Chamber stope.*

Planned estimated cost of slurry = Number of cases x unit cost (*Appendix C, Tables G & H*)

= 575 x 35.55 = \$20,441.25

| | |
|---|---|
| Actual estimated cost of slurry | = 636 x 35.55 = \$22,609.80 |
| Extra cost | = \$2,168.55 |
| Extra cost percentage | = 10.61% |

Planned cost of explosive accessories = \$1,630.012

Actual cost of explosives accessories = \$2,593.532

Extra cost = \$963.52

Extra cost percentage = 59.11%

*For Rib pillar.*

Planned estimated cost of slurry = Number of cases x unit cost (*Appendix C, Tables G & H*)

= 433 x 35.55 = $15,393.15

Actual estimated cost of slurry = 486 x 35.55 = $17,277.30

Extra cost = $1,884.15

Extra cost percentage = 12.2%

Planned estimated cost of magnum = 260 x 33.44 = $8,694.40

Actual estimated cost of magnum = 307 x 33.44 = $10,266.08

Extra cost = $1,571.68

Extra cost percentage = 18.1%

Planned estimated cost of explosive accessories = $158.610

Actual estimated cost of explosive accessories = $290.043

Extra cost = $131.433

Extra cost percentage = 82.87%

*For Crown pillar.*

Planned estimated cost of slurry = Number of cases x unit cost (*Appendix C, Tables G & H*)

= 144 x 35.55 = $5,119.20

Actual estimated cost of slurry = 236 x 35.55 = $8,389.8

Extra cost = $3,270.6

Extra cost percentage = 63.89%

Planned estimated cost of magnum = 87 x 33.44 = $2,909.28

*Actual estimated cost of magnum = 138 x 33.44 = $4,416.72*

*Extra cost = $1,507.44*

Extra cost percentage = 58.62%

*Planned estimated cost of explosive accessories = $52.763*

Actual estimated cost of explosive accessories = $87.217

Extra cost = $34.454

Extra cost percentage = 65.30%

***Other Extra Costs***

a) Delays

The stope was delayed by 13 days due to extra drilling, unblocking of holes and other hole deviation consequences (Sections 4.3.1.4.1; 4.3.1.5.4 and 4.3.1.7.1). Since the stope was supposed to produce approximately 1400 tonnes per day at $2.389 income per tonne (Appendix A, *Table C*):

Therefore, Loss of revenue = 1400 x 13 x 2.389 = $43,479.8 in that particular month.
(SOB shaft has a target of 700 hoisted cars per day i.e. 2,800 tonnes per day)

b) Extra maintenance and service cost

For 13 extra days, mining equipment and accessories had to be maintained and serviced. Using maintenance and service cost in Appendix D, Table I for the month of October:

Estimated cost = Tonnes x Unit cost (US$ per tonne)

= 13 x 1400 x 2.30

= $41,860.00

c) Extra tramming cost

The extra tonnage of waste added to the stope ore tonnage was 17,911 (Table 4.17). This dilution was caused mainly by holes deviating into waste rock.

Estimated extra tramming cost = tonnage x unit cost (US$/tonne)

*(Appendix A, Table C)*

= 17,911 x 1.03

= $18,448.33

d) Extra hoisting cost = 17,911 x 1.68 = $30,090.48

e) Time wastage = 17,911 x 2.30 = $41,195.3

f) Cost of processing extra waste material

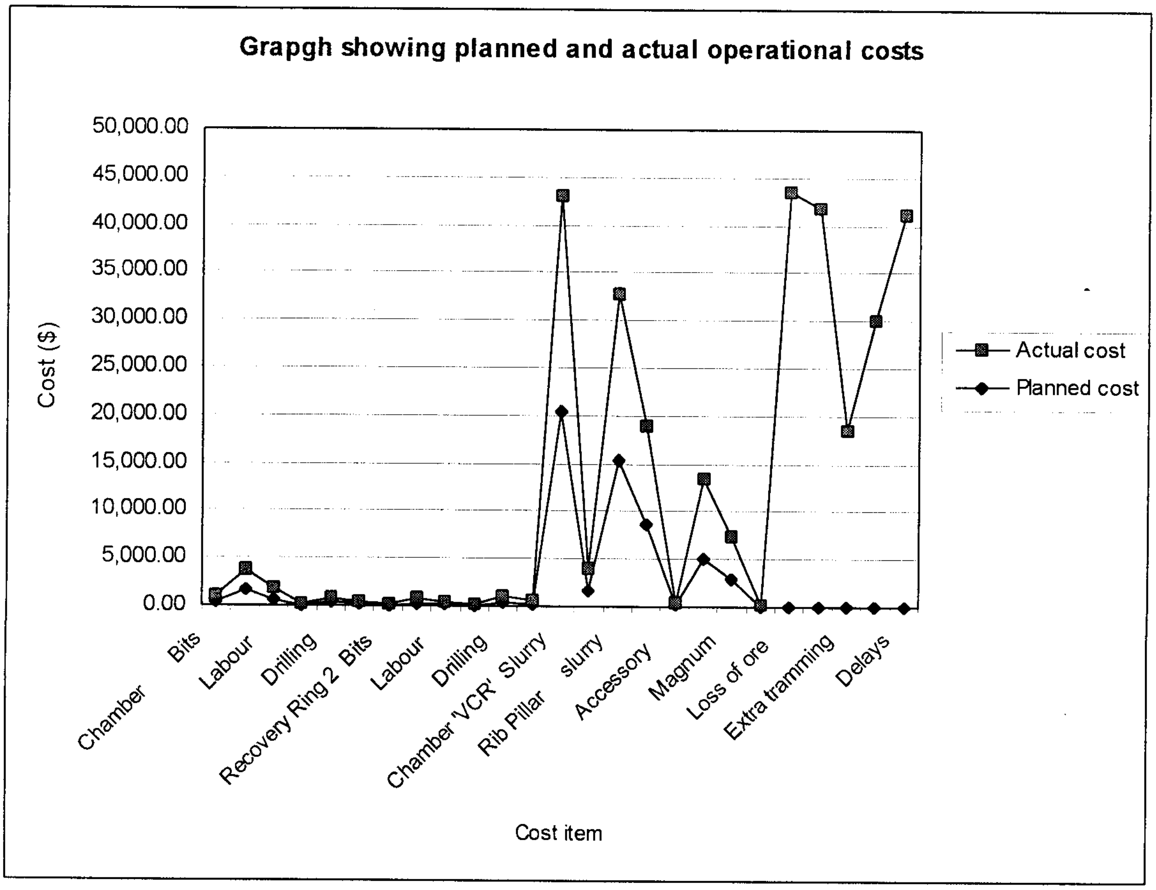
= Tonnes waste x Processing cost per tonne waste

= 17,911 x 4.73

= $84,719.03

Table 5.2 Summary of manually computed costs due to consequences of hole deviations

| | PLANNED | | | ACTUAL | | | | |
|---|---|---|---|---|---|---|---|---|
| **Item** | **Units** | **Unit Cost ($)** | **Total Cost ($)** | **Units** | **Unit Cost ($)** | **Total Cost ($)** | **Extra Cost ($)** | **%** |
| *Chamber* | | | | | | | | |
| Drill bits | 1.5 | 274.693 | 412.040 | 2.0 | 274.693 | 549.386 | 137.346 | 33.3 |
| Drilling | 1088.26 | 1.55 | 1686.803 | 1246.0 | 1.55 | 1931.3 | 431.397 | 14.5 |
| Labour | 88 | 8.303 | 730.664 | 136 | 8.303 | 1129.208 | 398.544 | 54.5 |
| *Recovery 1* | | | | | | | | |
| Drill bits | 0.3 | 274.693 | 82.408 | 0.5 | 274.693 | 137.347 | 54.939 | 67.0 |
| Drilling | 214.28 | 1.55 | 332.134 | 298.10 | 1.55 | 462.055 | 129.921 | 39.1 |
| Labour | 16 | 8.303 | 132.848 | 24 | 8.303 | 199.272 | 66.424 | 50.0 |
| *Recovery 2* | | | | | | | | |
| Drill bits | 0.3 | 274.693 | 82.408 | 0.4 | 274.693 | 109.877 | 27.469 | 33.3 |
| Drilling | 196.69 | 1.55 | 304.695 | 270.99 | 1.55 | 420.035 | 115.34 | 37.8 |
| Labour | 16 | 8.303 | 132.848 | 32 | 8.303 | 265.696 | 132.848 | 100 |
| *Wrecking* | | | | | | | | |
| 165 drill bit | 0.2 | 274.693 | 54.939 | 0.3 | 274.693 | 82.408 | 27.469 | 50.0 |
| 125 drill bit | 0.2 | 211.43 | 42.286 | 0.3 | 211.43 | 63.429 | 21.143 | 50.0 |
| Drilling | 277.38 | 1.55 | 429.939 | 393.00 | 1.55 | 609.15 | 179.211 | 41.7 |
| Labour | 32 | 8.303 | 265.696 | 48 | 8.303 | 398.544 | 132.848 | 50.0 |
| *Explosive-Chamber* | | | | | | | | |
| Slurry | 575 | 35.55 | 20441.25 | 636 | 35.55 | 22609.80 | 2168.55 | 10.6 |
| Accessories | - | - | 1630.012 | - | - | 2593.532 | 963.52 | 59.1 |
| *Rib Pillar* | | | | | | | | |
| Slurry | 433 | 35.55 | 15393.15 | 486 | 35.55 | 17277.3 | 1884.15 | 12.2 |
| Magnum | 260 | 33.44 | 8694.40 | 307 | 33.44 | 10266.08 | 1571.68 | 18.1 |
| Accessories | - | - | 158.61 | - | - | 290.043 | 131.433 | 82.9 |
| *Crown Pillar* | | | | | | | | |
| Slurry | 144 | 35.55 | 5119.2 | 236 | 35.55 | 8389.8 | 3270.6 | 63.9 |
| Magnum | 87 | 33.44 | 2909.28 | 138 | 33.44 | 4416.72 | 1507.44 | 58.6 |
| Accessories | - | - | 52.763 | - | - | 87.217 | 34.454 | 65.3 |
| | | | | | | | | |
| Delays | - | - | - | 18200 | 2.389 | 43479.8 | 43479.8 | 100 |
| Service | - | - | - | 18200 | 2.30 | 41860.0 | 41860.0 | 100 |
| Extra Tramming | - | - | - | 17911 | 1.03 | 18448.33 | 18448.33 | 100 |
| Extra Hoisting | - | - | - | 17911 | 1.68 | 30090.48 | 30090.48 | 100 |
| Time wastage | - | - | - | 17911 | 2.30 | 41195.3 | 41195. | 100 |
| Extra Processing | - | - | - | 17911 | 4.73 | 84719.03 | 84719.03 | 100 |
| | | | | | | | | |
| **TOTAL** | | | **59088.38** | | | **332071.14** | **272982.79** | |



Grapgh showing planned and actual operational costs
50,000.00
45,000.00
40,000.00
35,000.00
30,000.00
25,000.00
20,000.00
15,000.00
10,000.00
5,000.00
0.00
Cost ($)
Actual cost
Planned cost
Chamber
Bits
Labour
Drilling
Recovery Ring 2 Bits
Labour
Drilling
Chamber 'VCR' Slurry
Rib Pillar
slurry
Accessory
Magnum
Loss of ore
Extra tramming
Delays
Cost item

### 5.2.1.2 *Computer aided calculations*

In this section, the calculations, which were done manually in Section 5.2.1.1, are done with the aid of computer. The worksheet package of Microsoft Excel for Windows Release 7.0 was used. This provides an alternative to the rudimental method and also saves as a check. Table 5.3 is an output using this approach.

Table 5.3 Estimating extra costs for stope drill holes

| COST ITEM | Unit Cost | Chamber | Rec. R1 | Rec. R2 | Wreck Rings | Row Total |
|---|---|---|---|---|---|---|
| Drilling | 1.7 | 431.392 | 174.641 | 155.9886 | 238.1598 | 1000.1814 |
| Bits 165mm | 274.69 | 137.35 | 54.94 | 27.47 | 27.47 | 247.22 |
| 127mm | 211.43 | 0.00 | 0.00 | 0.00 | 21.14 | 21.14 |
| Accessories | 1.70 | 0.00 | 682.52 | 71.43 | 34.24 | 788.19 |
| Labour | 66.42 | 398.54 | 66.42 | 132.85 | 132.85 | 730.66 |
| **Sub Total** | | **535.89** | **803.88** | **231.75** | **215.70** | **2787.41** |

| COST ITEM | Unit Cost | Chamber | Rib | Crown | 'Stoping' | Row Total |
|---|---|---|---|---|---|---|
| Explosives | | | | | | |
| Slurry | 35.55 | 2168.55 | 1884.15 | 3270.60 | 0.00 | 7323.30 |
| Magnum | 33.44 | 0.00 | 1571.68 | 1705.44 | 0.00 | 3277.12 |
| Accessories | | 682.52 | 71.43 | 34.24 | 0.00 | 788.19 |
| Time wastage | 2.30 | 0.00 | 0.00 | 0.00 | 41195.30 | 41195.30 |
| Maint/Serv. | 2.30 | 0.00 | 0.00 | 0.00 | 41860.00 | 41860.00 |
| Tramming | 1.03 | 0.00 | 0.00 | 0.00 | 18448.33 | 18448.33 |
| Hoisting | 1.68 | 0.00 | 0.00 | 0.00 | 30090.48 | 30090.48 |
| Processing | 4.73 | 0.00 | 0.00 | 0.00 | 84719.03 | 84719.03 |
| Equipment | 8.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Loss of revenue | 3344.60 | 0.00 | 0.00 | 0.00 | 43479.80 | 43479.80 |
| **Sub Total** | | **2851.07** | **3527.26** | **5010.28** | **259792.94** | |
| **OVERALL EXTRA TOTAL COST = $272,968.78** | | | | | | |

The extra costs estimated using computer-aided method agree with the results *obtained using manual method (Table 5.2 and Table 5.3).*

### 5.2.2 Estimating extra costs for raise pilot hole

#### 5.2.2.1 *Manual calculations*

a) Cost of extra drilling (Raiseborer) = unit cost x metres (*Appendix D, Table I*)

= 39.155 x 3.6

= US$ 140.958

(*for exchange rate see Appendix A Table C for the month of September*)

b) Time wastage (unproductive man-hours)

| No. of Workers | Grade | Mid-point Salary per month ($) | Salary/ Hour ($) | Hours Worked | Total Cost (US$) |
|---|---|---|---|---|---|
| 1 | UG3 | 151.548 | 0.758 | 18 | 13.644 |
| 1 | UG4 | 119.941 | 0.600 | 18 | 10.800 |
| 6 | UG7 | 103.224 | 0.516 | 18 | 55.740 |
| | | | | | = US $80.184 |

c) Maintenance and services.

For 3.5m by 3.5m by 12.0m cross cut and specific gravity (S.G) = 2.56t/$m^3$, this gives:

Tonnage = 376.32 T.

Maintenance and service unit cost = US$2.56 per tonne developed *(Appendix D Table I)*

$\therefore$ Total Cost = 2.56 x 376.32 = $963.379

a) Extra development cost

Average cost of secondary development per metre advanced = US$281 *(Appendix D, Table I)*

For 12m advanced, Total Cost = 281 x 12 = $3372.00

b) Mucking and transportation cost

Cost of mucking and transportation of 376.32 tonnes of waste = 376.32 x US$1.59 *(Table I)*

$\therefore$ Cost = 1.59 x 376.32 = $598.349

c) Accelerated wear of equipment

3m$^3$-250D loader was used to lash unwanted ground.

Cost of loader = US$ 212,000 [ZCCM-Nkana Division]

Loader life span = 25,000 hours

Unit cost = 8.48 $/hour

Time taken to lash the unwanted ground = 18 hours

$\therefore$ Cost = 8.48 x 18 = $152.640

d) Hoisting cost

Cost of hoisting waste at SOB shaft in September, 1998 was estimated at US$1.61 per tonne. Therefore 376.32 tonnes of waste cost: 1.61 x 376.32 = $605.875

e) Man-hours

The cost of labour is included in the element cost (*Tables A and I*)

Table 5.4 Summary of extra costs due to hole deviation consequences

| ITEM | EXTRA COST (US$) | Planned Cost (US$) |
|---|---|---|
| Drilling | 140.96 | |
| Labour | 80.18 | |
| Accessories | 963,38 | |
| Extra develop. | 3,372.00 | |
| Mucking | 598.35 | |
| Equipment | 152.64 | |
| Hoisting | 605.88 | |
| | | |
| **Total** | **5,951.01** | **4,111.80** |

The extra total cost caused by the consequences associated with the hole deviation is estimated at **US $5,951.01** (Table 5.4).

Planned total cost = 105 x 39.16 x 1927 = **US $4,111.80**

∴ Extra cost in percentage = **43.81%**

### 5.2.2.2 *Computer aided calculations*

In this section, the calculations which were done manually in Section 5.2.2.1, will be done with the aid of computer. In this computer program, the cost items are entered with their unit costs. The extra costs due to hole deviations are estimated and the total costs for each item is shown as 'row total' (Table 5.5) The total for each consequence is shown as 'column total' and the overall total cost is shown at the bottom of the table.

Table 5.5 Estimating extra costs for raise pilot hole

| COST ITEM (column A) | Unit Cost (US$) | CONSEQUENCES DUE TO HOLE DEVIATIONS | | | | |
|---|---|---|---|---|---|---|
| | | Develop. | R/Boring | Dev. Into waste/pillar | | Row Total |
| Drilling (R/Boring) | 39.16 | 0.00 | 140.98 | 0.00 | 0.00 | 140.98 |
| Time Wastage | | | | | | |
| Man-hour | 1.47 | 0.00 | 80.85 | 0.00 | 0.00 | 80.85 |
| Maint/service | 2.56 | 963.38 | 0.00 | 0.00 | 0.00 | 963.38 |
| Extra sec. Dev. | 281.00 | 3372.00 | 0.00 | 0.00 | 0.00 | 3372.00 |
| Labour | 1.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mucking/Transp. | 1.59 | 0.00 | 0.00 | 598.35 | 0.00 | 598.35 |
| Hoisting | 1.61 | 0.00 | 0.00 | 605.88 | 0.00 | 605.88 |
| Acc.Wear | | | | | | |
| Loader 250D | 8.48 | 152.64 | 0.00 | 0.00 | 0.00 | 152.64 |
| **Column Total** | | **4488.02** | **221.83** | **1204.22** | **0.00** | |
| **OVERALLL TOTAL COST = $5,914.07** | | | | | | |

The extra costs estimated using computer-aided method agree with the results obtained using manual method (Table 5.4 and Table 5.5).

### *5.2.3 Itemised cost analysis*

A more accurate estimate of overall mining operating cost can be made from summation of items of cost after determining the effect of specific local conditions on each item of operating cost.

This involves breaking the cost of mining operation components into cost elements and units. For example, major operations can be subdivided into smaller operations, and the cost of each item can be analysed and estimated (*Appendix F).*

## 5.3 'MINCOST' Computer Program

Cost analysis, modelling and cost estimation are time consuming and difficult to perform manually because of the laborious statistical calculations involved.

A computer program called 'MINCOST', has been developed to reduce on the above mentioned constraints. The program is based on Figures 2.3 and 5.2; and Table 5.1. It uses concepts developed in this study and applies statistical database functions. The program consists of a number of formulae. The 'MINCOST' automatically calculates the cost of mining operations based on cost items and unit costs, and it gives total cost per item as well as overall total cost.

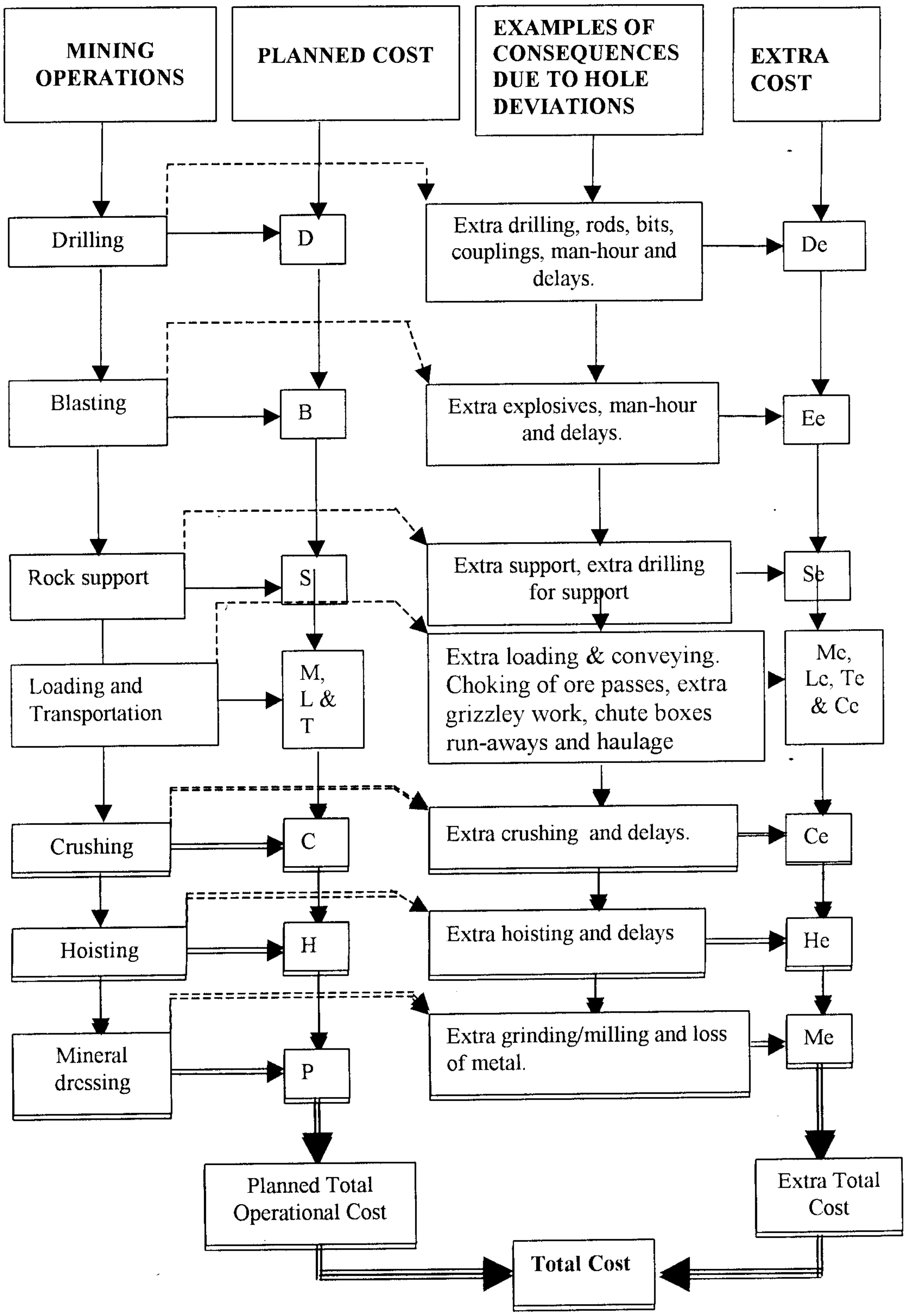



Figure 5.2 Illustrating extra costs associated with hole deviations in mining operations.

The data input of unit operations and cost items is a prerequisite to cost estimation calculations. Variable data input for 'what-if' analysis has been incorporated as an integral part of the program. The 'what-if' analysis data input enables the program to be adaptable to different conditions, operations and consequences. The inflation or depreciation has also been included as a variable input for cost item calculations, and is treated as an absolute cell reference.

### 5.3.1 Concepts used in the 'MINCOST' program

In addition to the concepts stated in Sections 4.3, 5.1 and 5.2, the following concepts have also been incorporated into the 'MINCOST' program.

#### 5.3.1.1 *Dilution*

Dilution is a measure of the amount of waste that adds up to the ore during the process of mining. Dilution may be caused by production holes deviating into waste rock. When these holes are blasted, waste will mix with ore thereby lowering the grade.

There are two major types of dilution:

a) Anticipated, and

b) Unanticipated dilution.

The study is concerned with unanticipated dilution in stopes. Unanticipated dilution in stopes measures the dilution that takes place inside a stope. This is the dilution, which causes the stope average draw grade to be lower than the stope average block grade. Unanticipated stoping dilution for a completed stope can be calculated by dividing the total stope waste less the total planned stope waste sent to the mill by the total stope ore sent to the mill at block grade, thus:

$$\frac{(\text{Stope waste})_{\text{TOTAL}} - (\text{Stope waste})_{\text{ANTICIPATED}}}{(\text{Stope Ore})_{\text{ORE TO MILL AT BLOCK GRADE}}}$$

Alternatively, the total stoping dilution can be calculated by using the *dilution formula* and then adjusting for planned stoping dilution thus:

Total stoping dilution = (BG / RG) - 1

Where: BG is the average stope block grade

RG is its reconciled draw grade.

Figure 5.3 shows the relationship among the three variables, namely; grade, tonnage and cost. The change in any of the variables will affect the others and subsequently change in revenue. This concept has been applied in the 'MINCOST' program.

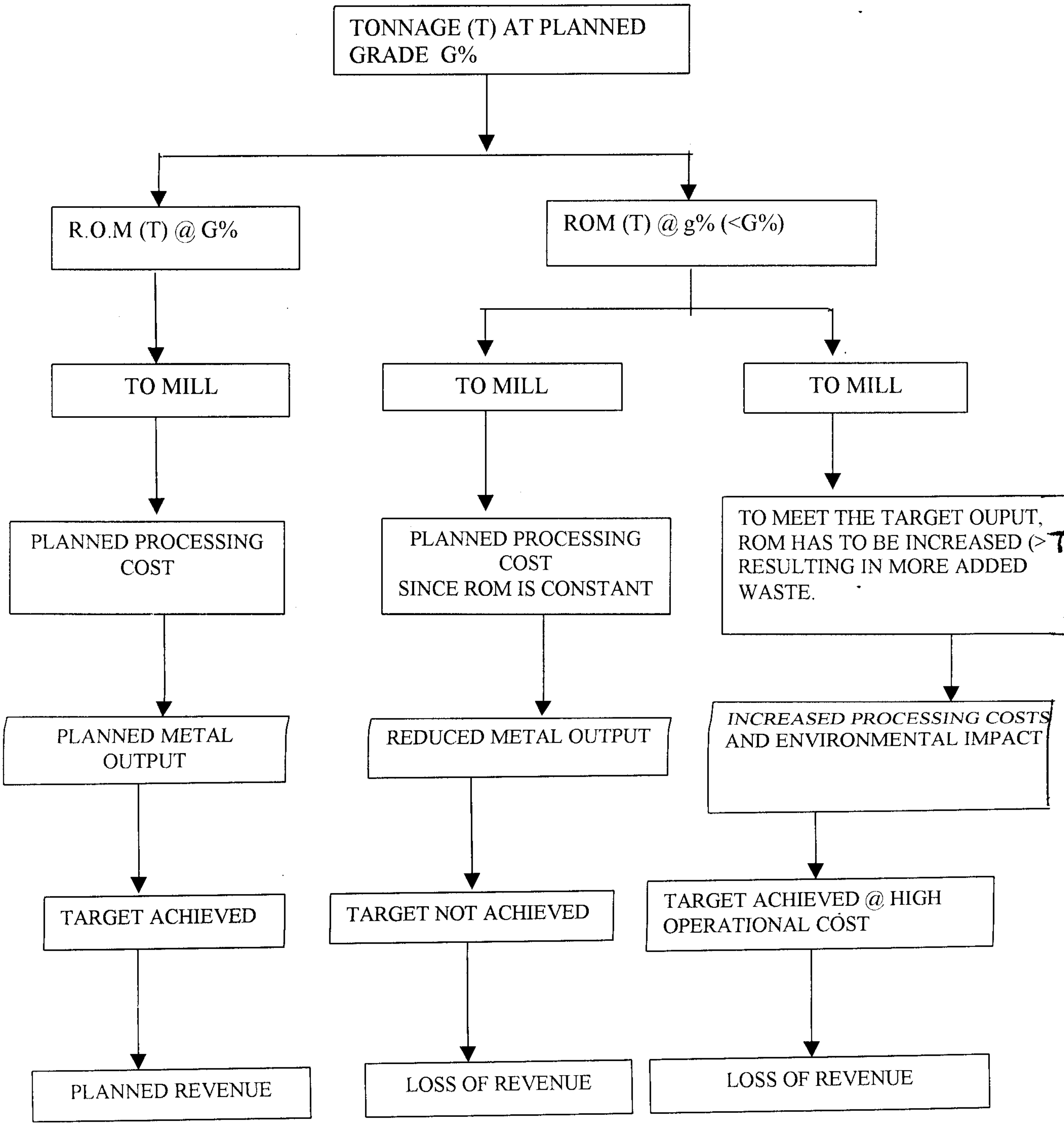



Figure 5.3 Illustrates the effect of grade on R.O.M and processing cost

#### 5.3.1.2 *Recovery*

Recovery or percentage extraction may be defined as the proportion of ore reserve, which is removed from the stope.

$$\text{Recovery} = \frac{\text{Tonnes ore drawn}}{\text{Tonnes ore in block}} \text{ X } 100\ \%$$

It may also be defined as the ratio of ore tonnes milled to ore tonnes removed from the reserves. The recovery is affected by the block grade and the grade at which the ore is trammed. Thus:

$$\text{Recovery} = \frac{\text{Actual Tonnes Trammed x Tramming Grade}}{\text{Scheduled in-situ Tonnes x Scheduled Block Grade}} \text{ X } 100\ \%$$

#### 5.3.1.3 Recovery and Costs

The relationship between stoping recovery and costs has been derived and used in the 'MINCOST' program. To establish the relationship between costs and recovery, the following assumptions are made:

a) The rate of metal production per year is constant at **P** tonnes of contained copper.

b) Stoping dilution is constant.

If the stoping recovery is R%, grade is g and the combined total concentrator, smelter and refinery recovery factor is F, then, to meet the annual metal target of P tonnes of contained copper, the amount of in situ copper needed to break is:

$$10000P / gFR$$

Since production in terms of tonnes of ore and in terms of tonnes contained copper will remain constant, a change in recovery will have no effect on production costs (i.e. lashing, tramming, crushing, conveying/hoisting and post-mining costs). However, the amount of development, stope drilling and charging required will vary according to the recovery. The relationship is inverse i.e. as recovery goes up, the development, drilling and charging requirements go down and vice versa. Assume that the combined cost of development, stope drilling and charging is **c** per tonne of in situ ore, then the cost of producing P tonnes of contained copper per year is:

$$\frac{10000\,P\,c}{gFR} \quad \text{Or} \quad (10000Pc / gFR)$$

If recovery is increased by r**%,** then the cost becomes:

$$10000Pc / (gF\,(R + r))$$

Where $r \geq 0$, and $r \leq (100 - R)$

The associated cost saving is:

$$10000c/(gF)[1/R-1/(R+r)]$$

The cost saving of finished copper production can be calculated using the formula above. **c** can be obtained from Appendices A and D and is the cost of primary development, secondary development, stope drilling, blasting and general expense

#### 5.3.1.4 *Accelerated Wear of Equipment*

Accelerated wear in this study refers to that caused by:

a) Misuse of equipment

b) Misdirection of equipment, and

c) Worn out parts

The concept of depreciation has been used in the "MINCOST' program in estimating cost of accelerated wear of equipment caused by re-drilling, extra rock handling and other repeat jobs in the chain of mining operations.

A provision for depreciation percentage has been included in the 'MINCOST' program (as absolute cell reference) and can be changed to suit the prevailing situation.

#### 5.3.1.5 *Labour and Services*

Extra man-hour and services may be required because of repeat jobs. Repeat *jobs like extra drilling, extra rock handling, secondary blasting to rectify build-ups,* hang-ups and to fragment large boulders, are usually caused by hole deviations.

Labour costs at ZCCM are set and cost per hour can be calculated for repeat jobs. Service costs associated with daily upkeep of drilling rig, consumption of oil, power, engineering services and other consumables can be monitored and by using unit cost *(Appendix B, C and D)* the total cost can be determined.

### 5.3.3 Data Input

The data inputs (Table 5.6) in this 'MINCOST' program includes the data collected from Nkana Division during the study and extra hypothetical data. The hypothetical data were based on the experience and were included to satisfy the program.

Table 5.6 Data Inputs for 'MINCOST' Program.

## DATA

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Loaders | (Cost) = | 212000.00 | 235400.00 | 366000.00 | Life span= | 25000.00 | | |
| Dilution | c: | 3.61 | 0.99 | 2.40 | 0.40 | 0.98 | 0.03 | 1.60 |
| C = | | 10.01 | | C Drifter = | 13639.45 | | | |
| F: | | 0.96 | 0.95 | 0.99 | F = | 0.90 | d = | 1.00 |
| Ore Loss | c: | 1.30 | 3.60 | 4.50 | 0.40 | c = | 9.80 | |
| g = | | 3.00 | F = | 91.00 | r = | 1.00 | R = | 71.00 |
| Waste | c: | 0.98 | 0.03 | 1.60 | 0.40 | d = | 1.00 | |

**Unit Cost**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Drilling ($/m) | Cubex = | 2.14 | Quasar = | 12.06 | L Drifter = | 4.78 | | |
| | R/Borer = | 39.16 | | | | | | |
| Bits | 57mm = | 66.82 | 127mm = | 234.15 | 165mm = | 304.22 | | |
| Rods | 959x42 = | 39.88 | 1759x41 = | 57.60 | 2559x40 = | 58.60 | | |
| | 915 ext = | 29.82 | Coup. = | 20.05 | Adaptor = | 123.68 | | |
| Explosive | ANFO = | 14.39 | Slurry = | 32.38 | Magnum = | 33.42 | | |
| | Access = | (Variable) | | | | | | |
| Ore Dilution | = | 3.69 | T/ Waste | 1.47 | Mucking = | 1.59 | Convey = | 1.61 |
| Ore Loss | = | 5.04 | 250D = | 8.48 | 300D = | 9.42 | 350D = | 14.64 |
| Crushers | = | 1.30 | Hoisting = | 1.61 | Labour = 1.47 | | Supp. = | 0.00 |
| Maintenance | = | 2.56 | Service = | 2.30 | Process = | 4.73 | Others = | 0.00 |

**"What-If" Analysis Data Input**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Depreciation = | | 5% | | | | | | |
| Metres Drilled | Cubex = | 374.00 | Quasar = | 168.00 | L Drifter = | 580.00 | | |
| | R/Borer | 0.00 | J/Hamm= | 720.00 | Others = | 1.00 | | |
| Bits (165mm) | = | 1.00 | Rods = | 1.00 | Coup. = | 2.00 | Adaptor = | 1.00 |
| Ore Tonnage | = | 7862.40 | Waste = | 376.32 | C/Cu = | 204.42 | S/Waste = | 17067.00 |
| Loader hours | = | 18.00 | M/hrs = | 168.00 | 0.00 | 112.00 | | |
| Explosives: | ANFO = | 0.00 | Slurry = | 144.00 | 41.00 | 0.00 | | |
| | Magnum | 87.00 | Access. | 86.42 | 54.80 | 0.00 | | |
| Accel. Wear | | 0.15 | Haulage = | 5.60 | Loco = | 250000.00 | | 18.00 |

### 5.3.4 Execution of the program

Following execution of the program, Table 5.7 shows the output for the planned cost while Table 5.8 shows the output for the estimated extra costs. Note that Table 5.6 (data input), Table 5.7 (planned cost) and Table 5.8 (extra cost) are integral.

Table 5.7 Cost Estimation Computation for Planned Costs

| COST ITEM (US$) | Unit Cost (US$) | PLANNED COSTS | | | | |
|---|---|---|---|---|---|---|
| | | MINING OPERATIONS | | | | |
| | | Stoping | Develop. | R/bring | S/Services | Others |
| Drilling – Cubex | 2.25 | 6824.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Quasar | 12.66 | 3541.00 | 1205.00 | 0.00 | 0.00 | 0.00 |
| LHD Drifter | 5.02 | 2681.00 | 2907.00 | 984.00 | 0.00 | 0.00 |
| Raiseboring | 41.12 | 0.00 | 0.00 | 6543.00 | | |
| Bits 57mm | 70.16 | | 4562.00 | 412.00 | 0.00 | |
| 127mm | 125.86 | 2783.00 | 0.00 | 0.00 | | |
| 165mm | 319.43 | 3794.00 | 0.00 | 1586.45 | | |
| Rods 959x42mm | 41.87 | | 548.00 | 0.00 | | |
| 1759x41mm | 60.48 | | 354.00 | 247.00 | 0.00 | |
| 2559x40mm | 61.53 | | 430.71 | 231 | | |
| 915mm Ext. | 31.31 | | 654.00 | 341.00 | | |
| Couplings R32 | 21.05 | 0.00 | 285.00 | 172.00 | | |
| Pilot Adaptor | 129.86 | | | 276.00 | | |
| Explosives | | | | | | |
| ANFO | 15.11 | 0.00 | 857.00 | 0.00 | | |
| Slurry | 34.00 | 4264.00 | 1282.00 | 0.00 | | |
| Magnum | 35.09 | 2056.00 | 1785.00 | 0.00 | 0.00 | |
| Accessories | 90.74 | 1648.00 | 2467.00 | | | |
| Ore dilution | 3.88 | | | 0.00 | | |
| Ore loss | 5.29 | 0.00 | | 0.00 | | |
| Time wastage | 1.54 | 0.00 | 0.00 | 0.00 | | |
| Loaders | | | | | | |
| 250D | 8.90 | 2490.00 | 1836.00 | 865.00 | 1428.66 | |
| 300D | 10.38 | | | | | |
| 350D | 15.37 | | | | | |
| Mucking | 1.67 | 2845.00 | | 682.00 | 918.00 | |
| Haulage (Locos) | 109.77 | 1960.00 | | 741.00 | 682.00 | |
| Conveyors | 1.69 | 781.00 | | | 519.00 | 0.00 |
| Crushers | 1.37 | 2018.00 | 1203.00 | | 723.00 | 0.00 |
| Rock support | 0.00 | 2073.00 | 1547.00 | 1047.00 | 105.00 | |
| Hoisting | 1.69 | 1962.00 | 1206.00 | 0.00 | 741.00 | 0.00 |
| Mineral dressing | 4.97 | 2065.00 | 1036.00 | 0.00 | 1209.00 | 0.00 |
| Labour | 1.54 | 2784.00 | 1562.00 | 0.00 | 1975.00 | 1406.00 |
| Maintenance | 2.69 | 2310.00 | 1206.00 | 1294.00 | 1720.00 | 978.00 |
| Services | 2.42 | 3076.00 | 2641.00 | 1958.00 | 2097.00 | 791.00 |
| Incidentals/Social | 37.04 | 1643.00 | 749.00 | 549.00 | 439.00 | 0.00 |
| Others | 0.00 | | | 782.00 | | |
| Column Total = | | 53598.00 | 18520.00 | 18710.45 | 12556.66 | 3175.00 |

**OVERALL TOTAL PLANNED COST = $106,560.00**

Table 5.8 Cost Estimation Computation for Extra Costs

| COST ITEM ($) | Unit Cost | EXTRA COST DUE TO HOLE DEVIATIONS | | | | |
|---|---|---|---|---|---|---|
| | | CONSEQUENCES | | | | |
| | | Build-ups | Hang-ups | Poor fragmentation | Extra Dev. | Others. |
| Drilling – Cubex | 2.25 | 840.38 | 0.00 | 840.38 | 377.50 | 0.00 |
| Quasar | 12.66 | 0.00 | 0.00 | 2127.38 | 0.00 | 0.00 |
| LHD Drifter | 5.02 | 2911.02 | 2911.02 | 2911.02 | 2911.02 | 2911.02 |
| Raiseboring | 41.12 | 0.00 | 0.00 | 0.00 | | |
| Bits 57mm | 70.16 | | 912.09 | | 1613.70 | |
| 127mm | 245.86 | | | 491.72 | | |
| 165mm | 319.43 | 319.43 | 638.86 | 319.43 | | |
| Rods 959x42mm | 41.87 | | | 41.87 | | |
| 1759x41mm | 60.48 | | | | 544.32 | |
| 2559x40mm | 61.53 | | 430.71 | | | |
| 915mm Ext. | 31.31 | | | | | |
| Couplings R32 | 21.05 | 42.11 | | 7873.64 | | |
| Pilot Adaptor | 129.86 | | | 129.86 | | |
| Explosives | | | | | | |
| ANFO | 15.11 | 0.00 | | 0.00 | | |
| Slurry | 34.00 | 4895.86 | 0.00 | 1393.96 | | |
| Magnum | 35.09 | 3052.92 | 0.00 | 1922.99 | 280.73 | |
| Accessories | 90.74 | 7841.84 | 0.00 | | | |
| Ore dilution | 3.88 | | | 1458.69 | | |
| Ore loss | 5.29 | 1391.31 | | 51883.09 | | |
| Time wastage | 1.54 | 259.31 | 222.26 | 172.87 | | |
| Loaders | | | | | | |
| 250D | 8.90 | | | 160.27 | 3350.75 | |
| 300D | 10.38 | | | | | |
| 350D | 15.37 | | | | | |
| Mucking | 1.67 | | | 628.27 | 628.27 | |
| Haulage (Locos) | 109.77 | | | 1536.73 | 1975.80 | |
| Conveyors | 1.69 | | | | | -636.17 |
| Crushers | 1.37 | | 185.64 | | | 513.68 |
| Rock support | 0.00 | | | | | |
| Hoisting | 1.69 | | | | | 636.17 |
| Mineral dressing | 4.97 | | | | 1015.25 | 80726.91 |
| Labour | 1.54 | 172.87 | 160.52 | 259.31 | | |
| Maintenance | 2.69 | 48.38 | | 1011.55 | | |
| Services | 2.42 | 43.47 | | 908.81 | | |
| Incidental/Social | 37.04 | | | | | 4148.93 |
| Others | 0.00 | | | | | |
| **Sub Totals =** | | **21818.89** | **568.43** | **76071.84** | **12697.34** | **89572.87** |
| **OVERALL TOTAL EXTRA COST = $200,729.37** | | | | | | |

The program was successfully executed and has given the same results as other methods used.

The 'MINCOST' program has the following advantages over the manual method: it

a) can be used for cost estimation of different mining operations.
b) speeds up the calculations
c) is easy to use
d) is versatile
e) is capable of comparing planned and actual costs of each cost item.

# CHAPTER SIX

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

### 6.1 Conclusions

The study has shown that almost all the production and service holes observed had a certain degree of hole deviation. The linear deviation measured ranged from 0.2m to 9.0m.

The causes of hole deviations were identified to include:

1. Poor rigging and site preparation
2. Defective drilling machines
3. Inadequate drilling accessories (i.e. stabilisers)
4. Insufficient flushing of circulation fluid
5. Change of rock formations
6. Inclined holes
7. Inappropriate application of drilling parameters

This study has established that there is a direct link between hole deviations and many problems faced in the chain of mining operations. The study identified and quantified consequences associated with hole deviations. The results showed that these consequences are major factors contributing to high operational costs.

From the cost estimates, ZCCM-Nkana Division, SOB shaft accrued approximately US$274,000 extra operational cost on one VCR stope and about US$6,000 on one pilot hole for tip raise-bore. The extra operational costs estimated may be representing lower limits of the actual value because of assumptions made, and some unit costs used were the lower or mid-point values. The cost of social services and incidentals accrued during repeat jobs were not included in estimations.

The findings of this study indicate, in agreement with the hypothesis, that hole deviations have negative economic consequences on mining operations.

If the quality of mining production and service holes at the study area is improved, a saving of up to 70% can be achieved. Once this saving is made, ZCCM-Nkana Division, SOB shaft, may compete favourably with other underground and surface mines.

This study indicates that improved hole quality in mining operations can significantly reduce costs of mining and downstream operations.

This study concentrated on VCR, the mining method with largest deviation on average, mainly to demonstrate an approach to linking hole deviations to the resulting economic consequences. However, hole deviation problems encountered in other mining methods are no less important, and should be treated in a similar manner.

## 6.2 Recommendations

### 6.2.1 Areas of operational and managerial improvement

Reduction in the extra mining operational costs is possible. To achieve this at Nkana Division, the following are recommended:

***Steering group***

Management should set-up a steering group to comprise all Nkana Division Mines and appropriately incorporate research institutions. The group would be responsible for carrying out applied research and development work to include, for example:

a) Data collection, analysis and setting of improved parameters for drilling

b) Making recommendations for appropriate equipment

c) Embark on personal sensitization for efficient and cost-effective production in mining operations.

***Drilling machines and accessories***

Drilling machines and accessories should be rehabilitated to high productive levels, or better still, purchase new ones, as most machines and associated accessories were observed to be obsolete. Accurate instruments for setting up rigs and in-hole surveys should also be acquired. The capital invested in drilling machinery and tools can be paid back in a short period, following the high operational costs and the savings which can be made.

*Training*

Drilling operators and supervisors in-charge of drilling should be trained in the following areas:

a) basic principles of drilling and effects of hole deviation on the chain of mining production
b) interpretation of drilling and blasting layouts

***Blasting sequence***

Computer program dealing with 'hole paths' and plotting of production holes at different elevations should be used for all the stope blasting sequences. Any serious deviations should be adjusted accordingly.

***Application of MIMS***

Mincom Information Management System (MIMS) should be fully implemented in order to improve cost controls in mining operations.

### 6.2.2 Further Studies

The study has achieved the intended objectives from the case studies carried out at ZCCM Nkana Division. The study concentrated on areas employing VCR *mining method. Many problems arose during the gathering of data and isolation* of consequences associated with hole deviations. In some cases, continuous monitoring (on 24-hour basis) of the mining process was required in order to

obtain statistically representative data and to ascertain the actual causes of hole deviations, and quantify the consequences. This proved to be an expensive and difficult task for the resources which were available. As a result, not all mining operations affected by hole deviation consequences were fully investigated. Further work is therefore recommended in areas employing other mining methods of extracting ore to provide a basis for comparison with the results obtained in areas employing VCR method. The work will also provide a complete view on the role played by drilling accuracy in the economics of mining operations.

Other areas recommended for future studies include:

a) Developing of a model for isolating consequences associated with hole deviations
b) Identifying parameters affecting drilling accuracy and build a computer model that can predict hole deviations.
c) Study of trajectory deviation for all mining methods.

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# 8.0 APPENDICES

## APPENDIX A

Table A – *Analysis of SOB Shaft Cost [Source: ZCCM, Nkana, 1998].*

| | MAY, 1998 | | | | JUNE, 1998 | | | |
|---|---|---|---|---|---|---|---|---|
| Activity | Actual (K'M) | Budget (K'M) | Var. | Var. % | Actual (K'M) | Budget (K'M) | Var. | Var % |
| Primary Development | 147 | 200 | 53 | 27 | 91 | 180 | 89 | 50 |
| Secondary Development | 132 | 241 | 109 | 45 | 287 | 325 | 38 | 12 |
| Ore Extraction | 366 | 509 | 143 | 28 | 332 | 453 | 121 | 27 |
| Ore/Waste Tramming | 212 | 290 | 78 | 27 | 186 | 281 | 95 | 34 |
| Convey/Crushing/Transport | 160 | 196 | 36 | 18 | 251 | 201 | (50) | (25) |
| Drainage/Pumping | 105 | 115 | 10 | 9 | 181 | 115 | (66) | (57) |
| Ventilation | 25 | 42 | 17 | 40 | 36 | 41 | 6 | 14 |
| Exploratory Drilling | 63 | 105 | 42 | 40 | 74 | 106 | 32 | 30 |
| Mining services/Overheads | 208 | 245 | 37 | 15 | 202 | 196 | (6) | (3) |

| Activity | MAY, 1998 Actual (K'M) | MAY, 1998 Budget (K'M) | Var. | Var. % |
|---|---|---|---|---|
| K/Tonne – Ore to Conc. | 17,910 | 30,207 | 12,297 | 41 |
| K/Tonne – Cu in Ore | 1,411,565 | 2,037,519 | 625,954 | 31 |
| Exchange Rate US$ 1 = K | 1,774 | 1,660 | (114) | (7) |
| Cent/Lb. Ore to Mill | 0.46 | 0.83 | 0.37 | 44.52 |
| Cent/Lb. Cu in Ore | 36 | 56 | 20 | 25 |

| Activity | JUNE, 1998 Actual (K'M) | JUNE, 1998 Budget (K'M) | Var. | Var. % |
|---|---|---|---|---|
| K/Tonne – Ore to Conc. | 17,456 | 24,318 | 6,862 | 28 |
| K/Tonne – Cu in Ore | 1,106,316 | 1,636,619 | 530,303 | 32 |
| Exchange Rate US$ 1 = K | 1,816 | 1,680 | (136) | (8) |
| Cent/Lb. Ore to Mill | 0.44 | 0.66 | 0.22 | 33.60 |
| Cent/Lb. Cu in Ore | 28 | 44 | 17 | 37 |

Table B - Analysis of SOB Shaft Cost [Source: ZCCM, Nkana, 1998].

| | JULY, 1998 | | | | AUGUST, 1998 | | | |
|---|---|---|---|---|---|---|---|---|
| Activity | Actual (K'M) | Budget | Var. | Var. % | Actual (K'M) | Budget | Var. | Var % |
| Primary Development | 113 | 183 | 70 | 38 | 91 | 180 | 89 | 50 |
| Secondary Development | 240 | 355 | 114 | 32 | 287 | 325 | 38 | 12 |
| Ore Extraction | 383 | 455 | 72 | 15 | 332 | 453 | 121 | 27 |
| Ore/Waste Tramming | 294 | 264 | (30) | (11 | 186 | 281 | 95 | 34 |
| Convey/Crushing/Transport | 192 | 184 | (9) | (5) | 251 | 201 | (50) | (25) |
| Drainage/Pumping | 97 | 101 | 4 | 4 | 181 | 115 | (66) | (57) |
| Ventilation | 30 | 39 | 8 | 22 | 36 | 41 | 6 | 14 |
| Exploratory Drilling | 79 | 108 | 29 | 27 | 74 | 106 | 32 | 30 |
| Mining services/Overheads | 366 | 2175 | (149 | (69 | 202 | 196 | (6) | (3) |

| Activity | JULY, 1998 Actual (K'M) | Budget | Var. | Var. % |
|---|---|---|---|---|
| K/Tonne – Ore to Conc. | 22,177 | 29,044 | 6 ,867 | 24 |
| K/Tonne – Cu in Ore | 1,529,356 | 1,966,088 | 436,732 | 22 |
| Exchange Rate US$ 1 = K | 1,823 | 1,700 | (123) | (7) |
| Cent/Lb. Ore to Mill | 0.56 | 0.77 | 0.22 | 28.79 |
| Cent/Lb. Cu in Ore | 38 | 52 | 14 | 27 |

| Activity | AUGUST, 1998 Actual (K'M) | Budget | Var. | Var. % |
|---|---|---|---|---|
| K/Tonne – Ore to Conc. | 23,163 | 29,202 | 6,040 | 21 |
| K/Tonne – Cu in Ore | 1,616,828 | 1,998,532 | 381,704 | 19 |
| Exchange Rate US$ 1 = K | 1,845 | 1,720 | (125) | (7) |
| Cent/Lb. Ore to Mill | 0.57 | 0.77 | 0.20 | 26.05 |
| Cent/Lb. Cu in Ore | 40 | 53 | 13 | 25 |

Table C - Analysis of SOB Shaft Cost [Source: ZCCM, Nkana, 1998].

| Activity | SEPTEMBER, 1998 | | | | OCTOBER, 1998 | | | |
|---|---|---|---|---|---|---|---|---|
| | Actual (K'M) | Budget (K'M) | Var. | Var. % | Actual (K'M) | Budget (K'M) | Var. | Var % |
| Primary Development | 221 | 196 | (25) | (13 | 116 | 198 | 82 | 42 |
| Secondary Development | 347 | 336 | (11) | (3) | 408 | 355 | (53)( | (15) |
| Ore Extraction | 467 | 451 | (16) | (3) | 330 | 503 | 173 | 34 |
| Ore/Waste Tramming | 218 | 260 | 42 | 16 | 146 | 280 | 133 | 48 |
| Convey/Crushing/Transport | 61 | 180 | 119 | 66 | 237 | 194 | (43) | (22) |
| Drainage/Pumping | 114 | 111 | (3) | (3) | 54 | 128 | 74 | 58 |
| Ventilation | 29 | 38 | 9 | 23 | 8 | 52 | 44 | 85 |
| Exploratory Drilling | 82 | 107 | 15 | 14 | 81 | 110 | 29 | 26 |
| Mining services/Overheads | 232 | 278 | 47 | 17 | 373 | 322 | (51) | (16) |

| Activity | SEPTEMBER, 1998 Actual (K'M) | Budget | Var. | Var. % |
|---|---|---|---|---|
| K/Tonne – Ore to Conc. | 25,212 | 29,032 | 3,820 | 13 |
| K/Tonne – Cu in Ore | 1,511,850 | 2,004,162 | 492,312 | 25 |
| Exchange Rate US$ 1 = K | 1,927 | 1,740 | (187) | (11) |
| Cent/Lb. Ore to Mill | 0.59 | 0.76 | 0.16 | 21.61 |
| Cent/Lb. Cu in Ore | 36 | 52 | 17 | 32 |

| Activity | OCTOBER, 1998 Actual (K'M) | Budget | Var. | Var. % |
|---|---|---|---|---|
| K/Tonne – Ore to Conc. | 24,483 | 31,973 | 7,491 | 23 |
| K/Tonne – Cu in Ore | 1,441,662 | 2,278,946 | 837,285 | 37 |
| Exchange Rate US$ 1 = K | 1,966 | 1,760 | (206) | (12) |
| Cent/Lb. Ore to Mill | 0.56 | 0.82 | 0.26 | 31.46 |
| Cent/Lb. Cu in Ore | 33 | 59 | 25 | 43 |

**APPENDIX B**

Table D – Purchase Prices of Drills and Drilling accessories

(Data for equipment price was sourced from different manufacturers and based on the price levels of 1998 at US $1 = ZK1927)

| ITEM | PRICE (US $) |
|---|---|
| Cubex drilling machine | 404,000.00 |
| Quasar drilling machine | 100,000.00 |
| Raise borer – 41R and 43R | 1,221,000.00 |
| Raise borer – 61R | 1,404,150.00 |
| Raise borer drill string – 6ft rod (6inch diameter) | 550.00 |
| Raise borer drill string – 6ft rod (5inch diameter) | 450.00 |
| Raise borer reamer 127mm bit | 379.00 |
| CH drifter | 13,639.45 |
| Ch drifter 3-ft extension rod | 40.10 |
| CH drifter couplings | 27.10 |
| Adaptor | 164.00 |
| CH drifter shank | 105.50 |
| 57mm pilot bit | 90.50 |
| 165mm Cubex bit | 274.69 |

Table E – Drilling Accessories Used at SOB Shaft [Source: ZCCM, Nkana, 1998].

| TYPE | UNIT PRICE ($) | MAY | JUNE | JULY | AUG. | SEPT | OCT |
|---|---|---|---|---|---|---|---|
| 959 x 42mm Rod | 69,398.54 | 31 | 26 | 21 | 28 | 18 | 29 |
| 1759 x 41mm Rod | 100,215.76 | 47 | 34 | 24 | 35 | 32 | 40 |
| 2559 x 40mm Rod | 101,965.00 | 25 | 22 | 11 | 29 | 12 | 19 |
| 127mm Button Bit | 407,427.69 | 1 | 3 | 1 | 2 | 1 | 3 |
| 57mm Cross Bit | 116,273.27 | 23 | 19 | 8 | 13 | 18 | 18 |
| Pilot Adaptor | 215,199.46 | 1 | 3 | 1 | 2 | 1 | 3 |
| 38mm Shank | 115,307.05 | 11 | 7 | 14 | 9 | 5 | 14 |
| 44mm Dia. R32 Coupling. | 34,879.99 | 149 | 160 | 125 | 100 | 183 | 116 |
| 915mm Ext. Rod | 51,888.47 | 149 | 160 | 125 | 100 | 183 | 116 |
| Rockdrill oil (Litres) | 2,879.00 | 1688 | 1777 | 1655 | 1133 | 1120 | 1155 |
| 64mm Button Bit | 370,000.00 | 1 | 3 | 7 | 8 | 9 | 5 |

Table F – Long-hole Drilled Metres Per Machine Type at SOB Shaft.

| | MAY | | | JUNE | | |
|---|---|---|---|---|---|---|
| | Target | Actual | Var. | Target | Actual | Var. |
| L.H.D. – Conv. | 5260 | 6885 | 1625 | 5260 | 7992 | 2732 |
| Cubex | 1280 | 1005 | -275 | 1280 | 1790 | 510 |
| Quasar | 2000 | 0 | -2000 | 2000 | 1757 | -243 |

| | JULY | | | AUG. | | |
|---|---|---|---|---|---|---|
| | Target | Actual | Var. | Target | Actual | Var. |
| L.H.D. – Conv. | 5260 | 6741 | 1481 | 5530 | 4108 | 2732 |
| Cubex | 1280 | 1300 | 20 | 1280 | 184 | -1096 |
| Quasar | 2000 | 1222 | -778 | 2000 | 0 | -2000 |

| | SEPT. | | | OCT. | | |
|---|---|---|---|---|---|---|
| | Target | Actual | Var. | Target | Actual | Var. |
| L.H.D. – Conv. | 6200 | 2403 | -3797 | 3010 | 6916 | 3906 |
| Cubex | 4200 | 103 | -4097 | 1280 | 0 | -1280 |
| Quasar | 3000 | 1243 | -1757 | 2000 | 0 | -2000 |

## APPENDIX C

Table G – Explosive Price List – Kafironda Products [Source: ZCCM, Nkana and Kafironda, 1998].

| EXPLOSIVES | UNIT | PRICE (US $) INC. VAT |
|---|---|---|
| Ordinary ANFO | Bag (25kg) | 15.20 |
| Low Density ANFO | Bag (25kg) | 17.48 |
| Water Gel Slurry P/Plus (110 x 560mm) | Case | 35.55 |
| Water Gel Stubbies P/Plus Pillar Pack | Case | 35.55 |
| Water (power Gel '810') 32 x 200mm | Case | 30.62 |
| Power Gel Stubbie '810' | Case | 32.71 |
| EMULSIONS | | |
| Magnum '365' 32 x 200mm | Case | 36.53 |
| Magnum Buster 38 x 560mm | Case | 33.44 |
| Magnum Buster 45 x 560mm | Case | 33.44 |
| ACCESSORIES | | |
| Safety Fuse (0.6m) | Case | 731.38 |
| Safety Fuse (1.5m) | Case | 500.00 |
| Electric Det. – Instant (1.8m) | Case | 519.22 |
| Cordtex 10 | Case | 433.67 |
| Slow Ignitor Cord | 1m | 0.36 |
| Stemming Cartridges | Case | 6,652.00 |
| Nonel Master Starter | Each | 1.49 |

Table H – Explosive Price List – ZAMDET Products [Source: ZCCM, Nkana and ZAMDET, 1998].

| NONEL | UNIT | PRICE (US$) EXC. VAT. | PRICE (US$) INC. VAT. |
|---|---|---|---|
| Nonel LP 3.6m | Each | 1.22 | 1.43 |
| Nonel LP 4.2m | Each | 1.27 | 1.49 |
| Nonel LP 4.8m | Each | 1.32 | 1.55 |
| Nonel MS 15.0m | Each | 3.31 | 2.71 |
| Nonel MS 21.0m | Each | 2.86 | 3.36 |
| Snaline '0' 2.4m | Each | 1.22 | 1.43 |
| Snaline '17 – 42' 4.8m | Each | 1.58 | 1.86 |
| Nonel B/Con. 4.8m | Each | 1.79 | 2.10 |
| U450-500 15.0m | Each | 2.29 | 2.69 |
| U450-500 21.0m | Each | 2.95 | 3.47 |
| U450-500 30.0m | Each | 3.77 | 4.43 |
| U450-500 48.0m | Each | 6.63 | 7.79 |
| U450-500 60.0m | Each | 7.69 | 9.04 |

Prices as on 4 December, 1998 at US$ 1 = ZK2205.00

## APPENDIX D

Table I – The Average Unit Mining Operational Cost at SOB Shaft. [Source: ZCCM, Nkana 1998]. (*The following elements were cost estimated taking into consideration drilling, blasting, labour, mucking, and services)*

| OPERATION | MAY | JUNE | JULY | AUG. | SEPT | OCT |
|---|---|---|---|---|---|---|
| Primary Dev. ($/metre advanced.) | 887 | 514 | 820 | 700 | 914 | 1372 |
| Secondary Dev. ($/metre advanced).) | 126 | 257 | 254 | 211 | 281 | 420 |
| Ore Extraction ($ /Tonne mined) | 2.60 | 1.95 | 2.60 | 2.94 | 3.41 | 2.34 |
| Tramming ($/Tonne mined) | 1.51 | 1.09 | 1.99 | 2.25 | 1.59 | 1.03 |
| Hoisting ($/Tonne mined) | 1.14 | 1.47 | 1.30 | 1.47 | 1.61 | 1.68 |
| Pumping ($/Tonne mined) | 0.75 | 1.06 | 0.66 | 0.74 | 0.83 | 0.38 |
| Drilling–LHD Drifter ($/metre Dr'd) | 3.38 | 3.63 | 7.67 | 4.33 | 7.11 | 2.59 |
| Drilling – Cubex ($/metre Drilled) | 3.29 | 1.80 | 2.05 | 2.03 | 55.92 | 1.55 |
| Drilling – Quasar ($/metre Drilled) | | | | 59.88 | 12.05 | |
| Raise Boring ($/metre Drilled) | 50.07 | 28.24 | | | | |
| Maint. Cost ($/Tonne mined) | 2.84 | 2.07 | 2.56 | 3.26 | 3.55 | 2.30 |

Table J – Showing Monthly Production Figures at SOB Shaft (1998).

| | MAY | JUNE | JULY | AUG. | SEPT | OCT. |
|---|---|---|---|---|---|---|
| Primary Dev. (metres advanced | 93 | 97 | 76 | 88 | 87 | 43 |
| Secondary Dev. (metres advanced | 589 | 615 | 518 | 618 | 370 | 494 |
| Ore Mill (Tonnes '000') | 79 | 94 | 81 | 71 | 71 | 72 |
| Contained Copper (Tonnes) | 1005 | 1481 | 1174 | 1013 | 1185 | 1220 |
| Contained Cobalt (Tonnes) | 41 | 89 | 74 | 57 | 65 | 62 |
| Copper Grade (%) | 1.27 | 1.58 | 1.45 | 1.43 | 1.67 | 1.70 |
| Cobalt grade (%) | 0.05 | 0.09 | 0.09 | 0.08 | 0.09 | 0.09 |

| | MAY | JUNE | JULY | AUG. | SEPT | OCT. |
|---|---|---|---|---|---|---|
| Waste Broken | 7179 | 9162 | 4568 | 7179 | 6564 | 6533 |
| Waste Hoisted | 2010 | 1650 | 2460 | 2010 | 5387 | 4843 |
| Waste Segregated | 28% | 18% | 54% | 28% | 82% | 74% |

**APPENDIX F - *The Model for Itemised Cost Estimating Method.***

C = D + S + V + M

Where: C = Planned operating cost
D = Development cost
S = Stoping (extraction) cost
V = Cost of services
M = Milling cost

D = Dd + Db + Dt + Dp + Dw

Where: Dd = Development drilling cost
Db = Development blasting cost
Dt = Development transport cost (loading, mucking, hauling etc.)
Dp = Development power cost ( compressed air, electricity, etc.)
Dw = Development support work (roof bolts, grouting, timber work etc.)

2.1. Dd = dbt + drd + dcl + ddm +dac + ddl

2.2. Db = dch + dex + dbl + dbc

2.3. Dt = dlo + dco + dtr + dho + dtl + dtc; and Dw is given as one figure.

Where: dbt = Cost of development drilling bits
drd = Cost of rods
dcl = Cost of couplings
ddm = Drilling machine depreciation
dac = Cost of accessories ( oil, grease, water tubes, taps etc.)
ddl = Cost of development drilling labour
dch = Cost of charging
dex = Cost of explosives
dbl = Cost of charging and blasting labour
dbc = Cost of charging and blasting accessories (charging sticks, stemming material etc.)
dlo = Cost of loading
dco = Cost of conveying
dtr = Cost of tramming
dho = Cost of hoisting ( development rock)
dtl = Cost of transport labour
dtc = Cost of transport consumables (fuel, oil, tyres etc.)

1. S = Sd + Sb + St + Sc + Sw

Where: Sd = Cost of stope drilling
Sb = Cost of stope blasting
St = Cost of rock transportation
Sc = Cost of accessories (chute boxes, grizzlies etc.)
Sw = Cost of stope support work

3.1. Sd = sbt + srd + scl + sdm + sdc + sdl

3.2. Sb = sch + sep + sbl + sbc

3.3. St = slo + sco + str + sho + stl + sgr

Where: sbt = Cost of bits used in stope drilling
srd = Cost of rods
scl = Cost of couplings
sdm = Depreciation of stope drilling machines
sdc = Cost of stope drilling accessories
sdl = Cost of stope drilling labour
sch = Cost of stope charging
sep = Cost of explosives
sbl = Cost of blasting labour
sbc = Cost of blasting accessories
slo = Cost of loading
sco = Cost of rock conveying
str = Cost of tramming
sho = Cost of hoisting
stl = Cost of transport labour
sgr = Cost of grizzlies, rock pass etc.

4.0. V = Ge + Su + Vt + Pl + Pc + En + Hs + Oh

Where: Ge = Cost of geological services
Su = Cost of survey services
Vt = Cost of ventilation services
Pl = Cost of planning services
Pc = Cost of production control services
En = Cost of engineering services
Hs = Cost of health and safety
Oh = Cost of overheads (others)

5.0. M = Co + Sm + Re + Mc

Where: Co = Cost of concentrator work
Sm = Cost of smelting
Re = Cost of refining
Mc = Cost of others (in milling operations)

6.0. Ct = C + Ce

Where: Ct = Total cost
C = Planned cost
Ce = Extra cost

6.1. Ce = De + Se + Ve + Me

Where: De = Cost of extra development

Se = Cost of extra stoping work
Ve = Cost of extra services
Me = Cost of extra milling work

6.1.1. De = Dde + Dbe + Dte + Dpe + Dwe
6.1.2. Se = Sde + Sbe + Ste + Sce + Swe
6.1.3. Ve = Gee + Sue + Vte + Ple + Pce + Ene + Hse + Obe
6.1.4. Me = Coe + Sme + Ree + Mce

Where: Dde = Cost of extra development drilling
Dbe = Cost of extra blasting
Dte = Cost of extra transport work
Dpe = Cost of extra power used
Dwe = Cost of extra support work

Sde = Cost of stope drilling
Sbe = Cost of extra blasting
Ste = Cost of extra transport work
Sce = Cost of extra accessories
Swe = Cost of extra support work

Gee = Cost of extra geological services
Sue = Cost of extra survey services
Vte = Cost of extra ventilation services
Ple = Cost of extra planning work
Pce = Cost of production control services
Ene = Cost of extra engineering services
Hse = Cost of extra health and safety work
Obe = Cost of extra overheads (others)
Coe = Cost of extra concentrator work
Sme = Cost of extra smelting
Ree = Cost of extra refining
Mce = Cost of extra milling (others).

## APPENDIX G

Table K. Showing London Metal Exchange Copper Price

| Month (1999) | Price ($/t) |
|---|---|
| March | 1378.35 |
| April | 1466.00 |
| May | 1511.16 |
| June | 1422.48 |
| July | 1640.00 |
| August | 1647.62 |

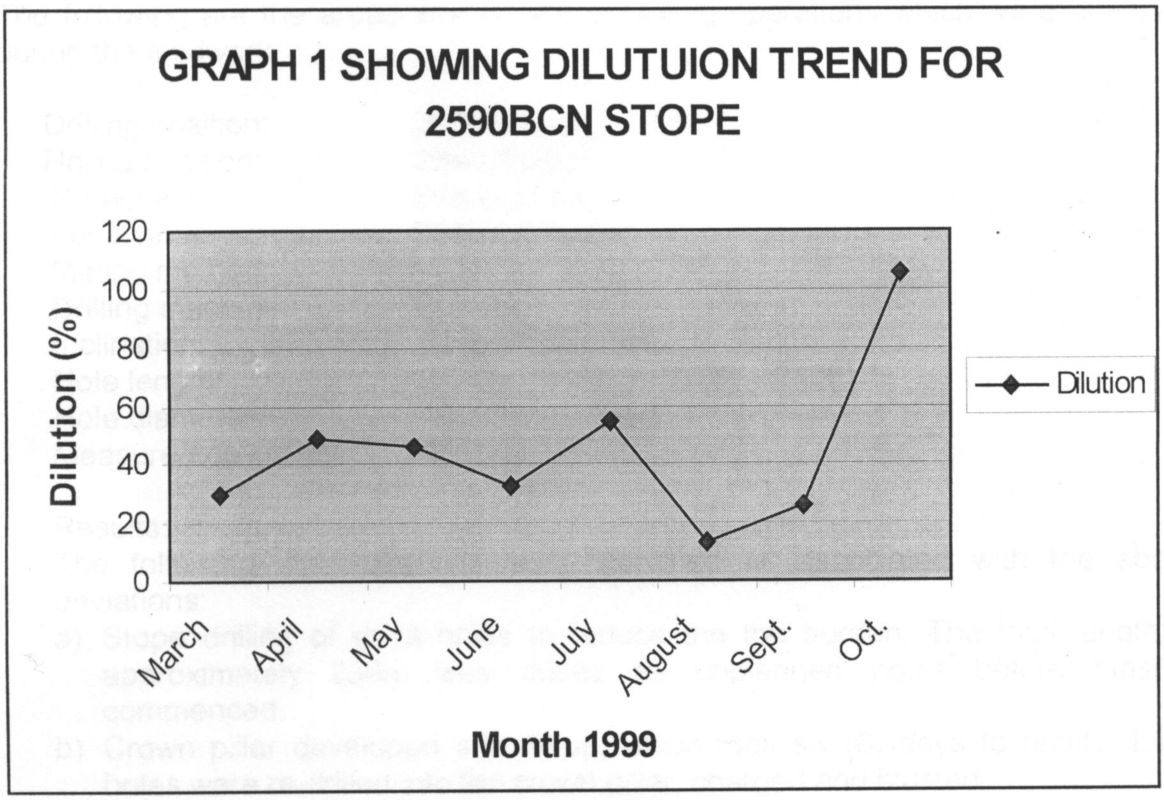
Table L. Showing Market Cobalt Price

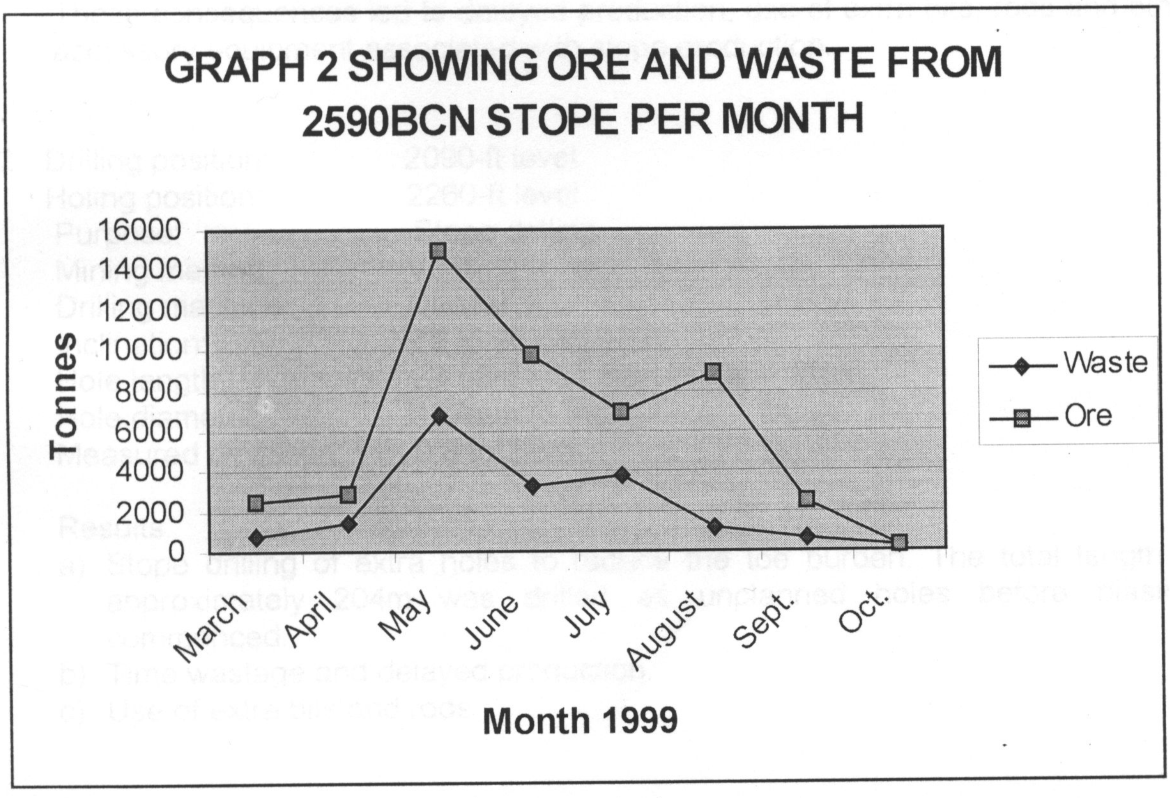
| Month (1999) | Price ($/lb.) | |
|---|---|---|
| | Low | High |
| March | 15.022 | 18.578 |
| April | 13.288 | 16.425 |
| May | 13.713 | 15.863 |
| June | 18.020 | 21.480 |
| July | 17.675 | 20.850 |
| August | 17.486 | 19.900 |

## APPENDIX H - Rock Compressive Strength (RCS)

| RCS (MPa) | CATEGORY |
|---|---|
| < 3 | Extremely soft |
| 3 – 10 | Very soft |
| 10 – 25 | Soft |
| 25 – 80 | Hard |
| 80 – 200 | Very hard |
| > 200 | Extremely hard |

**APPENDIX I**


GRAPH 1 SHOWING DILUTUION TREND FOR 2590BCN STOPE
120
100
80
60
40
20
0
Dilution (%)
Dilution
March
April
May
June
July
August
Sept.
Oct.
Month 1999


GRAPH 2 SHOWING ORE AND WASTE FROM 2590BCN STOPE PER MONTH
16000
14000
12000
10000
8000
6000
4000
2000
0
Tonnes
Waste
Ore
March
April
May
June
July
August
Sept.
Oct.
Month 1999

## APPENDIX J Stope and Service Hole Drilling

The following are the areas and results of drilling operations which were observed during the fieldwork.

1. Drilling position: 2620-ft level
   Holing position: 2840-ft level
   Purpose: Stope drilling
   Location: 2540 BC North
   Mining method: VCR
   Drilling machine: Cubex
   Inclination: 87 to 90 degrees
   Hole length: 31.4m – 64.01m (103ft – 210ft)
   Hole diameter: 16.51cm (6.5 inch.)
   Measured deviation: 0.2 to 2.1m

   Results:
   The following consequences were identified as associated with the above deviations:
   a) Stope drilling of extra holes to reduce the toe burden. The total length of approximately 236m was drilled as unplanned holes before blasting commenced.
   b) Crown pillar developed a build-up, which took six (6) days to rectify. Eight holes were re-drilled into the crown pillar, charged and blasted.
   c) The consumption of explosives was high. The powder factor increased from the planned 0.3 to 1.8.

   These consequences led to delayed production, use of extra bits, rods and other accessory equipment associated with stope production.

2. Drilling position: 2090-ft level
   Holing position: 2260-ft level
   Purpose: Stope drilling
   Mining method: VCR
   Drilling machine: Quasar
   Inclination: 79 to 90 degrees
   Hole length: 33.53m – 51.82m (110ft – 170ft)
   Hole diameter: 127mm (5 inch.)
   Measured deviation: 0.3 to 2.6m

   Results:
   a) Stope drilling of extra holes to reduce the toe burden. The total length of approximately 204m was drilled as unplanned holes before blasting commenced.
   b) Time wastage and delayed production.
   c) Use of extra bits and rods.

3. Drilling position: 2880-ft level
   Holing position: 2740-ft level
   Purpose: Stope drilling
   Mining method: SLC
   Drilling machine: Quasar
   Inclination: 70 to 85 degrees
   Hole length: 18.29m – 42.67m (60ft – 140ft)
   Hole diameter: 6.35cm (2.5 inch.)
   Measured deviation: 0.4 to 1.8m

   Results:
   a) Stope drilling of extra holes to reduce the toe burden. The total length of approximately 316m was drilled as unplanned holes before blasting commenced.
   b) Poor fragmentation - the ground was broken to mostly powder form, which led to loading and hauling problems i.e. runaways and spillage.
   c) The consumption of explosives was high because of concentrated blasting.

4. Drilling position: 2370-ft level
   Holing position: 2510-ft level
   Purpose: Stope drilling
   Mining method: VCR
   Drilling machine: Cubex
   Inclination: 63 to 90 degrees
   Hole length: Approximately 42.67m (140ft)
   Hole diameter: 16.57cm (6.5 inch.)
   Measured deviation: 0.3m to 1.9m. The stope experienced hole closures of four holes

   Results:
   a) Stope drilling of extra holes to reduce the toe burden. The total length of approximately 181m was drilled as unplanned holes before blasting commenced.
   b) Poor fragmentation - the ground was broken to mostly powder form, because the holes, which were initially closed, opened up after few blasting rounds and were charged and blasted. Poor fragmentation led to loading and hauling problems i.e. runaways and spillage.
   c) The consumption of explosives was high because of concentrated blasting.

5. Drilling position: 2880-ft level
   Holing position: 2840-ft level
   Purpose: Stope drilling
   Mining method: SLC
   Drilling machine: Quasar
   Inclination: 58 to 90 degrees
   Hole length: 3.35m – 14.63m (11ft – 48ft)
   Hole diameter: BX
   Measured deviation: The actual holing lengths were 4.57m to 18.29m (15 to 60ft).

Results:

a) *Over-drilling of some holes.*
b) The consumption of explosives was high because of 'over-drilling'.

6. Drilling position: 1810-ft level
   Holing position: 2090-ft level
   Location: 5335 S.
   Purpose: Raise drilling
   Mining method: VCR
   Drilling machine: Robbins 41R Raiseborer
   Inclination: 87 degrees
   Hole length: 85.34m (280ft) - planned
   Hole diameter: 22.86cm (9 inch.) – pilot hole and reamed to 1.83m (6ft)
   Measured deviation: 5m East and 2.4m North of the intended holing point. The raise had trajectory deviation

   Results:
   The raise holed into the main haulage instead of footwall crosscut. This resulted into extra development (slyping) to intercept the pilot hole. The development was 3.0m by 3.4m and 2.6m long.

7. Drilling position: 2840-ft level
   Holing position: 3140-ft haulage
   Location: 5335 S.
   Purpose: Ventilation raise drilling
   Drilling machine: Robbins 61R Raiseborer
   Inclination: 68.5 degrees
   Hole length: 105m (344.5ft)
   Hole diameter: 22.86cm (9 inch.) – pilot hole and reamed to 1.83m (6ft)
   Measured deviation: 9.0m South and 3.5m west of the intended holing point.

   The raise was wrongly collared, instead of using 65-degree inclination, 68.5 degrees was used resulting in collaring deviation.

   *Results:*
   A camera survey was carried out and time was lost in trying to allocate the hole toe point. In-hole camera survey results showed that apart from collaring deviation, the hole had also trajectory deviation. A 3.5m by 3.5m crosscut was developed in waste in an effort to intercept the pilot hole. The cross cut, which was 12m long, missed the hole. When the pilot hole was deepened, it holed into water drive, 9m away from the intended point.

   Consequences:

a) delays in putting up the raise
b) extra man-hour

c) extra services and accessories
d) extra development, and
e) accelerated wear of equipment

8. Drilling position: 2840-ft level
Holing position: 3140-ft level
Purpose: Tip raise drilling
Drilling machine: Robbins 61R Raiseborer
Inclination: 58 degrees
Hole length: 108m (354.3ft) - planned
Hole diameter: 22.86cm (9 inch.) – pilot hole
Measured deviation: 3.5m

Results:
a) Extra development – 3.5m by 3.5m and 4m-long drive was developed to expose the pilot hole
b) Delayed the reaming (to 1.83m diameter) of the raise
c) Delayed production of 2590BCN stope.

9. Drilling position: 3920-ft level (Mindola mine)
Holing position: 4100-ft level
Purpose: Stope drilling
Location: 3620 North
Mining method: VCR
Drilling machine: Cubex
Inclination: 65 degrees west.
Hole length: Approximately 53m (174ft)
Hole diameter: 16.57cm (6.5 inch.)
Measured deviation: 0.3m to 1.2m. The stope experienced hole closures.

Results:
a) a). Stope drilling of extra holes to reduce the toe burden. The total length of approximately 121m was drilled as unplanned holes before blasting commenced.
b) b). Accelerated wear of the drill string.
c) Extra drilling accessories were used.

10. Drilling position: 3920-ft level (Mindola mine)
Purpose: Geological exploration
Location: Horizontal diamond hole number DDH 443
Drilling machine: Rotary Diamond drill
Inclination: 2 degrees
Hole length: Approximately 502m
Hole diameter: BX
Measured deviation: +35 degrees (measured by in-hole camera survey).

Results:
The following consequences were identified as associated with the above deviations:
a) Missed the aquifer.
b) Delayed de-watering of the area
b) Extra work of carrying out in-hole camera survey and delays in interpreting correct geological information.

## APPENDIX L Quantification of Consequences associated with Hole Deviations

### *Chamber Rings*

| | |
|---|---|
| Planned total metres: | 1,088.26 |
| Actual total metres drilled: | 983.00 (excluding extra holes) |
| Unplanned metres drilled: | 263.00 |
| Total actual metres drilled: | 1,246.00 |
| Expected life span of 165mm button bit: | 730m [ZCCM, Nkana Division...1998] |
| Actual life span (as observed): | 653m |
| Estimated number of bits to be used: | 1,088.26/730 = 1.49 $\approx$ 1.5 bits |
| Actual number of bits used: | 1,246/653 = 1.90 $\approx$ 2 bits |
| Planned drilling days: | 11 (2 shifts per day) |
| Actual drilling days: | 17 days |
| Number of workers: | 4 per shift |

### *Recover Ring 1*

| | |
|---|---|
| Number of planned holes: | 9 |
| Number of extra (unplanned) holes: | 3 |
| Planned total metres: | 214.28 |
| Unplanned metres drilled: | 83.82m |
| Total actual metres drilled: | 298.10m |
| Expected life span of 165mm button bit: | 730m [ZCCM, Nkana Division...1998] |
| Actual life span (as observed): | 653m |
| Estimated number of bits to be used: | 214.28/730 = 0.29 λ 0.3 |
| Actual number of bits used: | 298.1/653 = 0.46 λ 0.5 |
| Planned drilling days: | 2 (2 shifts per day) |
| Actual drilling days: | 3 days (due to extra holes and machine movements) |
| Number of workers: | 4 per shift |

### *Recovery Ring 2*

| | |
|---|---|
| Number of planned holes: | 9 |
| Number of extra (unplanned) holes: | 2 |
| Planned total metres: | 196.69m (165mm diameter holes) |
| Actual metres drilled: | 270.99m (165mm diameter holes) |

| | |
|---|---|
| Estimated number of165mm-bits to be used: | 196.69/730 λ 0.3 |
| Actual number of 165mm-bits used: | 270.99/653 λ 0.4 |

| | |
|---|---|
| Planned drilling days: | 2 (2 shifts per day) |
| Actual drilling days: | 4 days (due to extra holes and machine breakdown) |
| Number of workers: | 4 per shift |

### *Wrecking Rings*

| | |
|---|---|
| Number of planned holes: | 13 |
| Number of extra (unplanned) holes: | 5 |
| Planned total metres: | 277.38m |
| Actual total metres drilled: | 393.00m (measured total length) |
| Unplanned metres drilled: | 114.5m (84.6m for down holes and 29.9m for up holes) |

| | |
|---|---|
| Estimated number of 165mm-bits to be used: | 141.43/730 ≈ 0.2 |
| Actual number of bits used: | 224.70/653 ≈ 0.3 |

| | |
|---|---|
| Estimated number of 127mm-bits to be used: | 135.95/620 ≈ 0.2 |
| Actual number of 127mm-bits used: | 168.30/560 ≈ 0.3 |

| | |
|---|---|
| Planned drilling days: | 4 (2 shifts per day) |
| Actual drilling days: | 6 days (due to extra holes and low pressure) |
| Number of workers: | 4 per shift |

## APPENDIX M Examples of 'MINCOST' Calculations.

To determine Cubex machine drilling unit cost for 'MINCOST' applications, the following formula was used:

Cost = Current Operating unit cost x Depreciation/inflation % + Current Operating unit cost

To determine unit cost for ore dilution, the following formula was used

**W = [P x (D/100) / [(g/100) x F],** simplified to
**cP*d* / gF** i.e. **c*d* / gF** per tonne of finished copper production.

Where: c = 10.01 *(see 'MINCOST' data input)*
d = 1.00
g = 3.00
F = 0.90, and
Depreciation./Inflation = 5% (Absolute cell reference)

To determine unit cost for ore loss, the following formula was used

**[10000Pc / gF (1/R – 1 / R + r)]** or
**10000c/(gF)[1/R-1/(R+r)]**

Where: c = 9.80 *(see 'MINCOST' data input)*
g = 3.00
F = 91.00
R = 71.00, and
r = 1.00

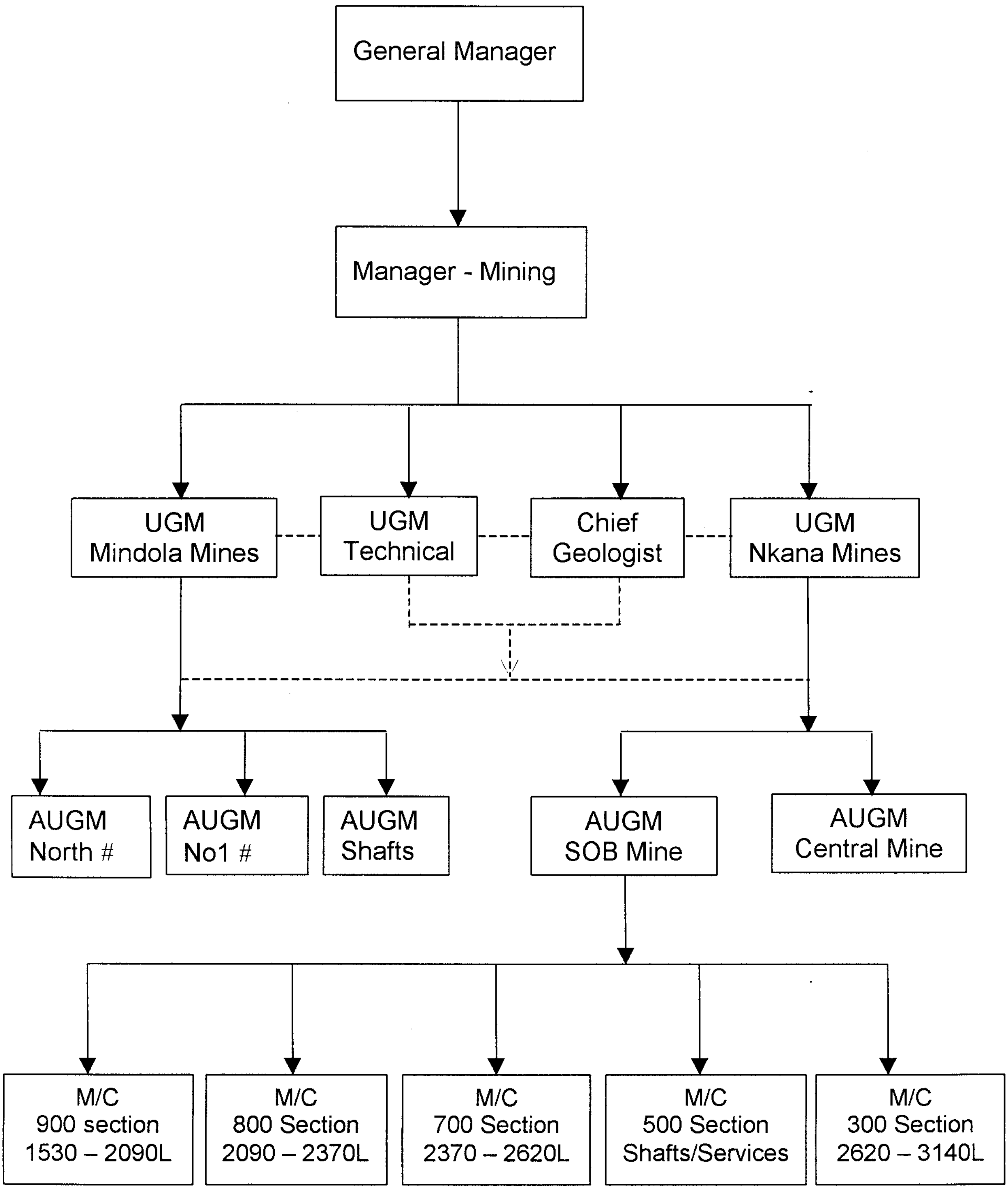
To determine unit cost for equipment i.e. loaders, the following formula was used:

Unit cost = Cost of loader/life of loader in hours

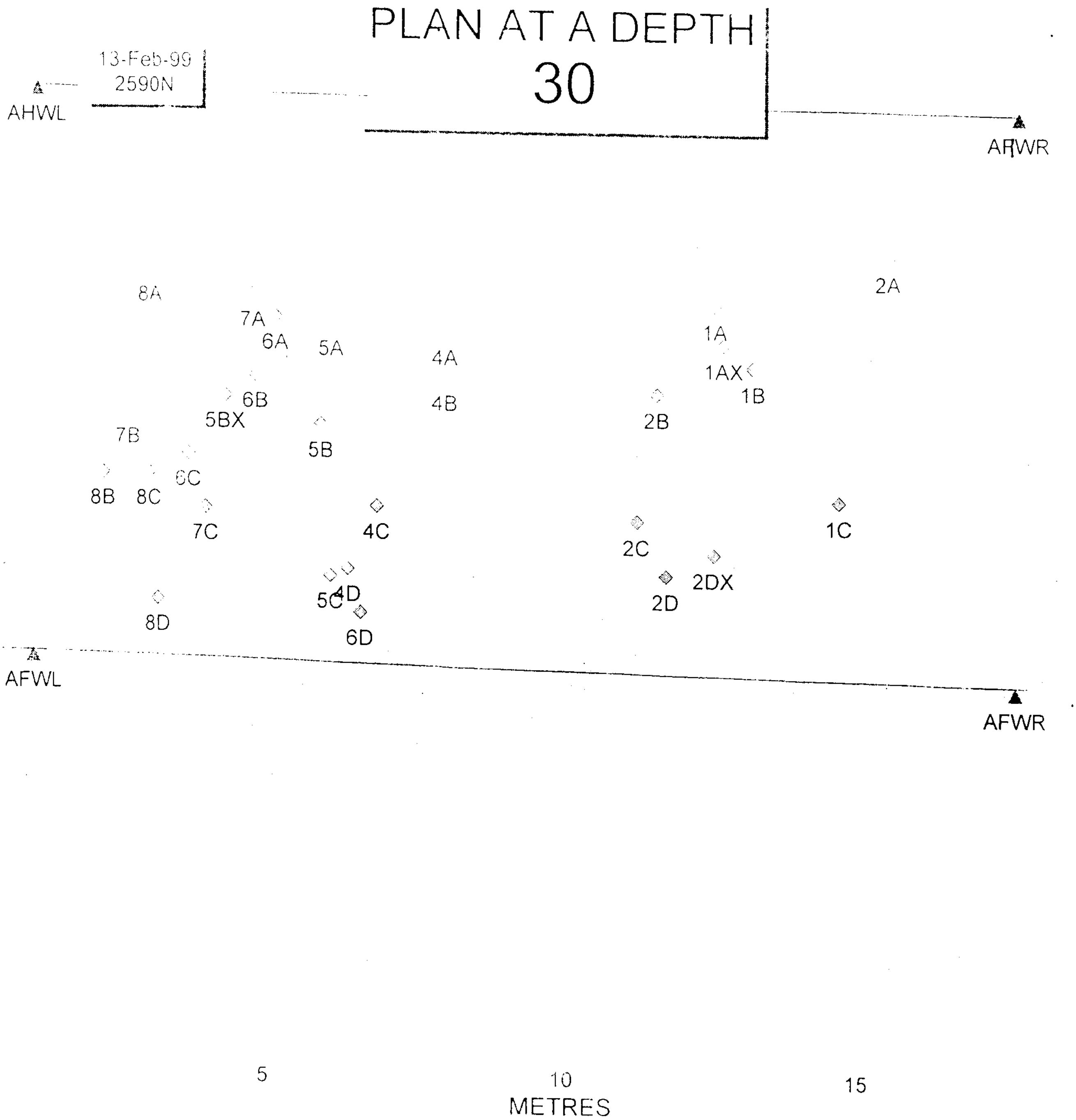
Where: Cost of loader = US$212,000
Life of loader = 25,000 hours

Similar principle was used for other loaders.

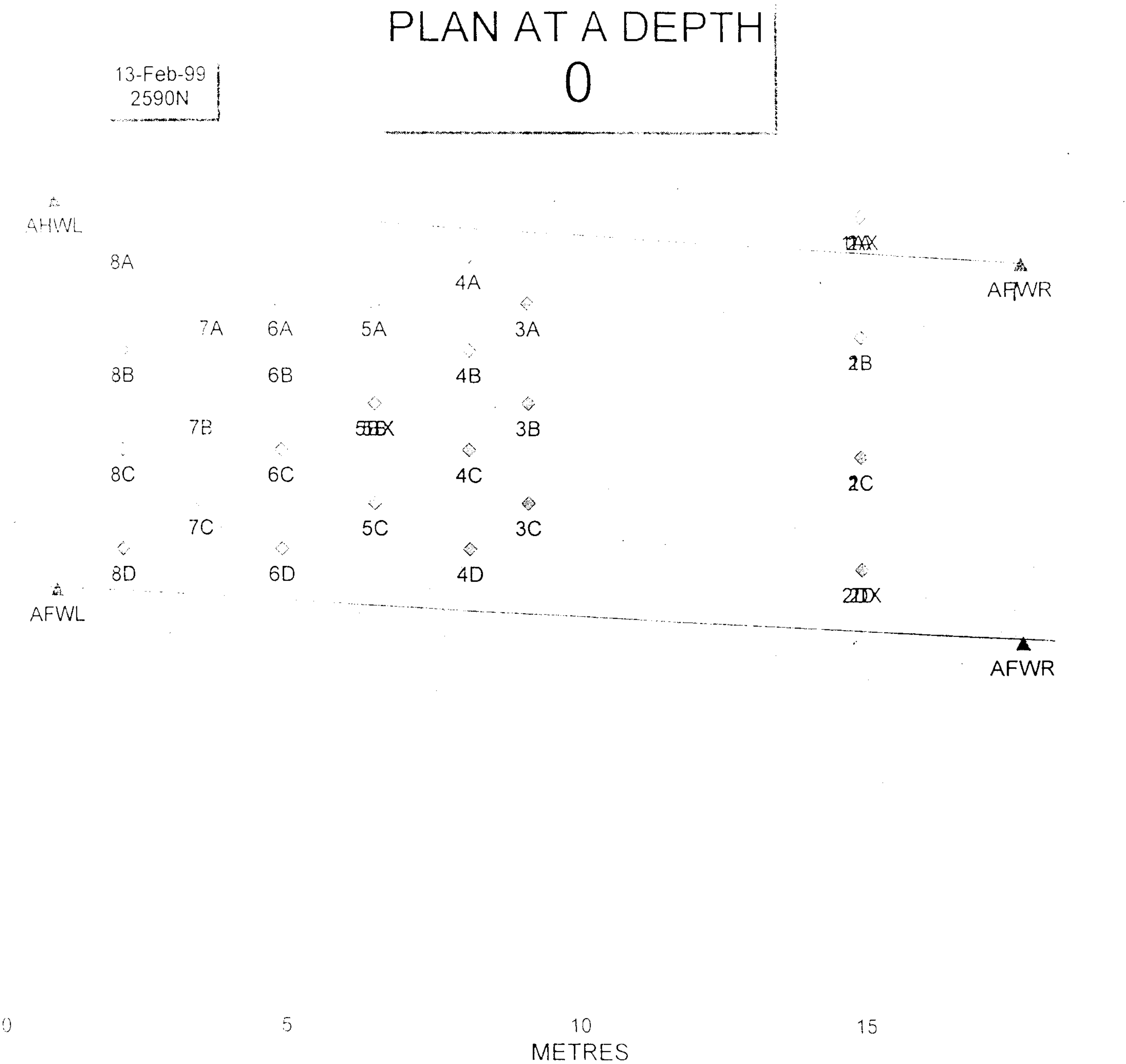
**Appendix N** Structure of the Mining Department at Nkana Division and SOB Mine Sections



Appendix O: Location of holes as monitored by the computer program



Appendix O : Location of holes as monitored by the computer program



Appendix P: Plate showing types of fragmentation

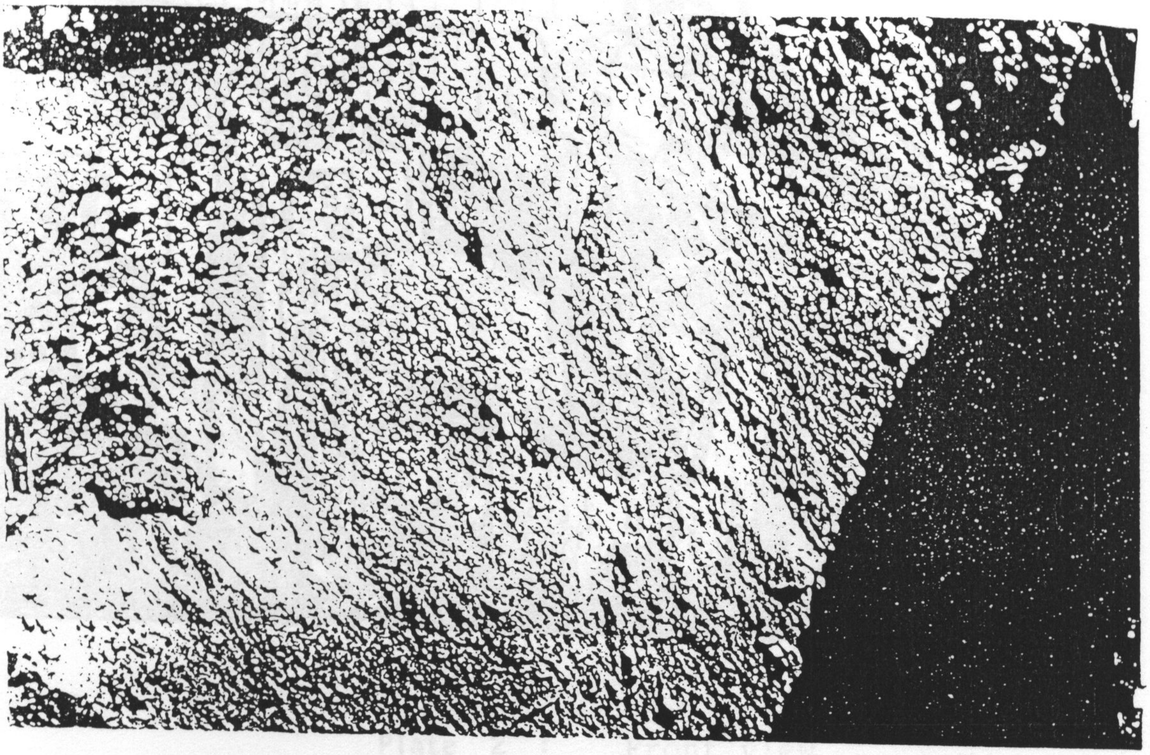


Plate 4: Powder fragmentation

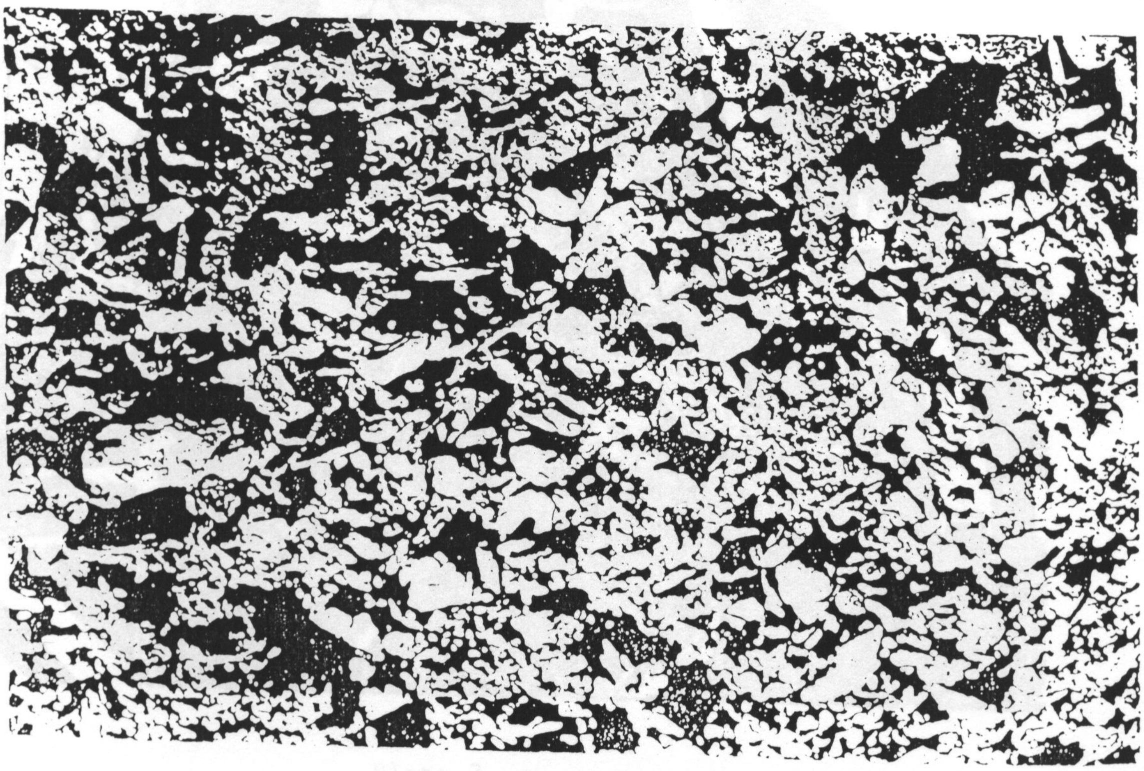


Plate 5 : Fine fragmentation

Appendix Q : Worn - out cubex ITH drill used for stope drilling

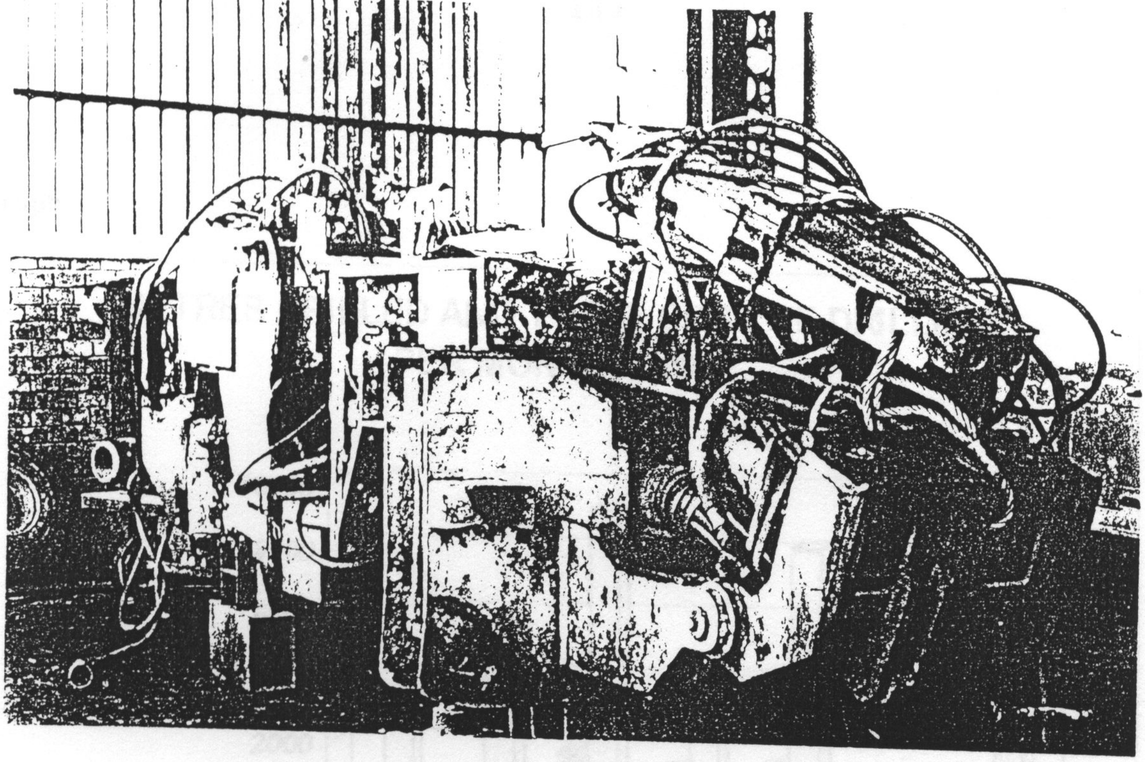


**Plate 2 :** Front view

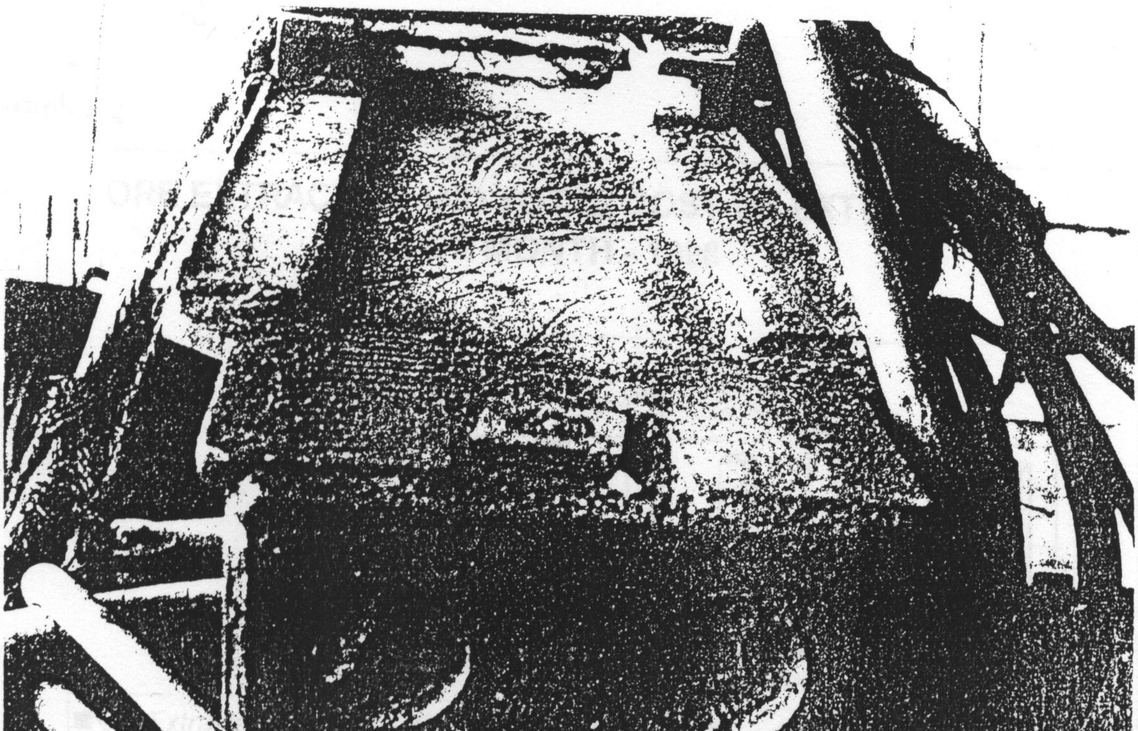
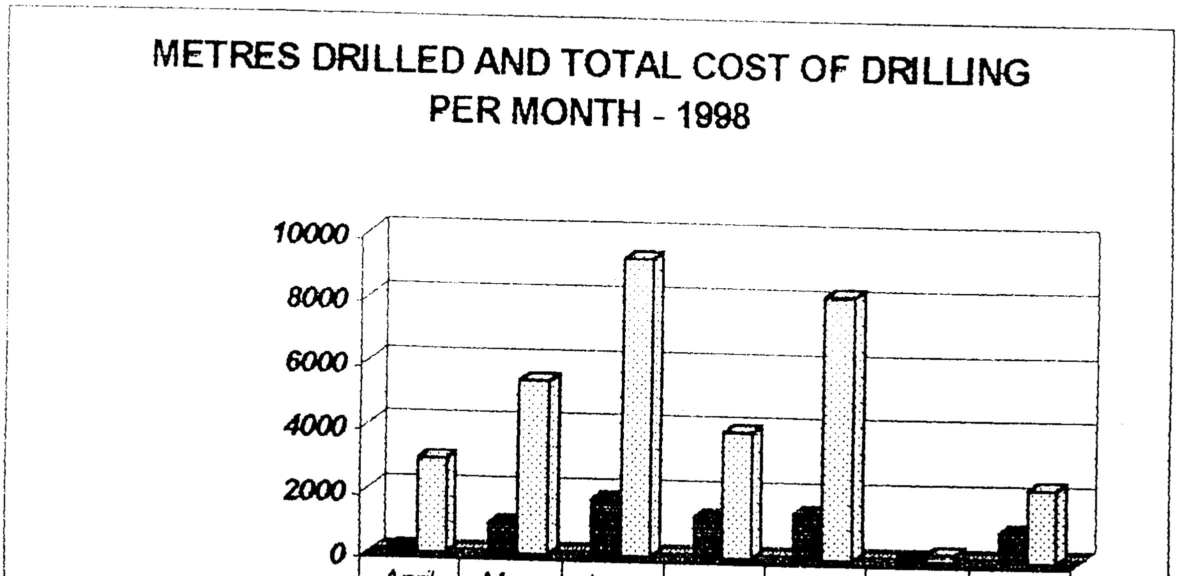


Plate 3 : Rear view

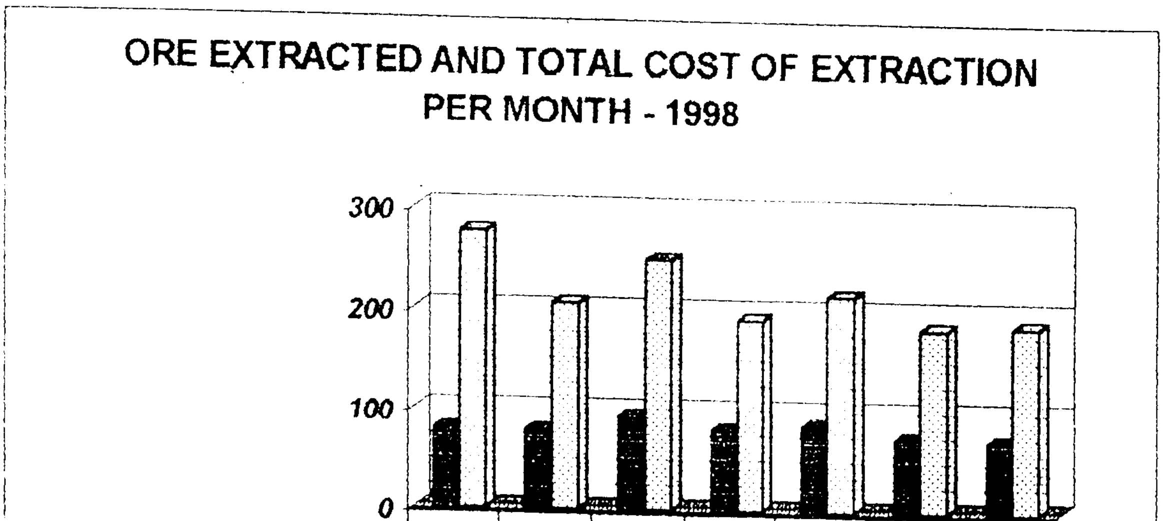
Photo by S. Kangwa

Graph 3




| | April | May | June | July | Aug | Sept | Oct |
|---|---|---|---|---|---|---|---|
| ■ Metres Drilled (m) | 184 | 1005 | 1790 | 1300 | 1458 | 103 | 978 |
| □ Total Cost (US$) | 2990 | 5427 | 9308 | 3965 | 8238 | 250 | 2337 |

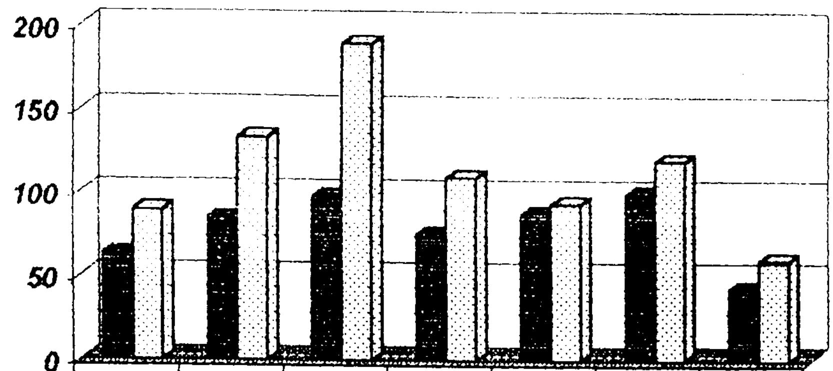
Graph 4




| | April | May | June | July | Aug | Sept | Oct |
|---|---|---|---|---|---|---|---|
| ■ Ore Extracted (Tonnes '000) | 80.2 | 79.2 | 93.9 | 81 | 86.3 | 73.3 | 71.8 |
| □ Total Cost (US$ '000) | 277 | 206 | 250 | 192 | 216 | 184 | 188 |

Graph 5

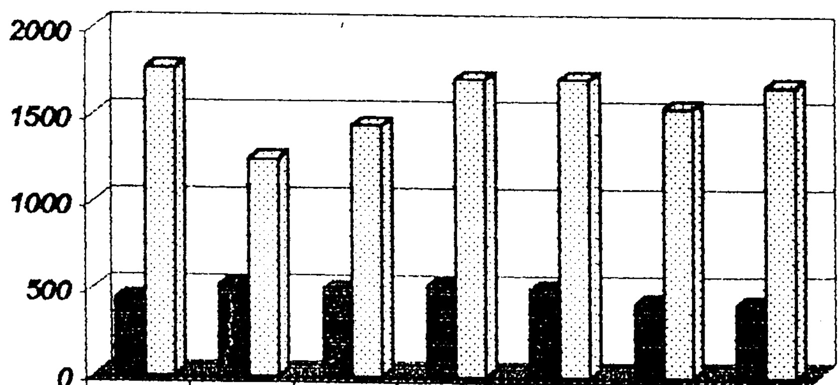
**PRIMARY DEVELOPMENT PERFORMANCE AND TOTAL COST OF DEVELOPMENT PER MONTH - 1998**




| | April | May | June | July | Aug | Sept | Oct |
|---|---|---|---|---|---|---|---|
| ■ Metres Advanced (m) | 63.8 | 85.1 | 97.4 | 75.6 | 87.2 | 99.5 | 43 |
| □ Total Cost (US$ '000') | 90 | 133.2 | 189.3 | 109.5 | 93.7 | 119.7 | 60.5 |

Graph 6

**SECONDARY DEVELOPMENT PERFORMANCE AND TOTAL COST OF DEVELOPMENT PER MONTH - 1998**




| | April | May | June | July | Aug | Sept | Oct |
|---|---|---|---|---|---|---|---|
| ■ Metres Advanced (m) | 441.9 | 522.8 | 500.5 | 517.5 | 506.7 | 422.1 | 414.3 |
| □ Total Cost (US$ '00') | 1772 | 1250 | 1446 | 1713 | 1713 | 1549 | 1670 |