Multiple Ore Body Systems (MOBS)
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Introduction

Early in 1996 a study was undertaken at the WMC St Ives operations with the prime objective to:

"Maximise Net Present Value of the operation."

The emphasis of this study was to focus on the global resource amenable to open pit mining, rather than individual deposits. Whittle Four-D was used to optimise the global resource and schedule the tonnes and grades to maximise the NPV of the project. Future use of the Opti-Cut software is planned to allow a cut-off grade policy to be formulated, once a final schedule has been established, further increasing the NPV.

Although Whittle software is well established within the mining industry, it has not previously been used to handle such a complex multi deposit model. Six potential open pit areas are included in this study.

The strategies and techniques used during the study are presented in this paper. Compilation of the model file and parameters file are described in detail, including Whittle log files with annotations and comments as applicable.

Preparing the Model

Over a period of time, using Datamine software, seven models were built for ore resource calculations. The current study includes all seven deposits, however, two have been combined, resulting in six areas being included in the current Whittle block model. The deposits will be referred to as Models A to F. All the original models have different block sizes and RL origins, making the construction of the combined model difficult.

Block sizes in the X Y Z dimensions had to be standardised and this was achieved by using the FDRB (reblocking) Whittle module. All models were reblocked to a standard 10 x 10 x 10 block size, by combining or splitting blocks. By retaining multiple 'parcels' (original smaller blocks) per block, the selectivity in the original models was retained. Details of the original and subsequent 're-blocked' versions of the models are listed in table 1.

Rock type names used within each individual model had to be simplified and standardised, to cope with the Whittle limit of 25 rock type to process method combinations. The name changes were performed in a text editor (jot). Identification of differing deposits within the larger model was accomplished by using abbreviated area names to form part of the rock type name. Oxide or fresh rock types also formed part of the name as this could be used to control the processing costs that would be applied during optimisation and analysis. Ore categories of measured, indicated and inferred resources were lost. Details of the ore categories could be obtained by optimising the original block models for individual deposits once the overview had been formulated. Extrapolated ore was included in model B to prevent the optimisation bottoming on NO data rather than negative data. Other deposits were not checked to see if the optimisation would terminate on a lack of data. Future checks will have to be done when final designs are being performed, otherwise the optimisation will define INTERIM pits which will expand as additional information becomes available, causing potential problems with surface infrastructures (waste dumps, roads etc.) in the future.

Table 1   Datamine models used to construct the Whittle block model

Model	Parm	Blk Size x	Blk Size y	Blk Size z	No Blks x	No Blks y	No Blks z	Coords x	Coords y	Coords z
modc.mod		5	10	5	105	75	80	383300	525300	-100
modc3.mod	modc3.par	10	10	10	53	75	40	383300	525300	-100
modb10.mod		10	10	10	70	80	30	376000	541200	0
modba.mod	modba.par	10	10	10	70	80	30	376000	541200	0
moddo.mod		10	20	5	120	60	80	381400	534995	-50
modd3.mod	modd3.par	10	10	10	120	120	40	381400	534995	-50
mode2.mod		5	5	5	80	140	27	375400	543600	150
mode3.mod	mode3.par	10	10	10	40	70	14	375400	543600	150
modf.mod	modf.par	5	20	5	170	50	72	374600	540000	0
modfa.mod	modfa.par	5	20	5	170	50	72	374600	540000	0
moda.mod	moda.par	10	10	5	170	120	100	4600	10800	-100
moda1.mod	moda1.par	10	10	10	170	120	50	4600	10800	-100

To facilitate the option of using the 'worst case' schedule during analysis, the surfaces of all the individual models had to have the same bench level in the final combined model. As the models were created independently, the individual models contained different RLs for their origins. To create the combined model, offsets from the combined model origin for each individual model were used allowing a uniform surface to exist over the entire combined model (refer to table 2 for vertical block offsets).

Table 2   Vertical off-sets used when combining 10x10x10 block models together.

Mid RL			modf1.mod modf1.par Model F		moda1.mod moda1.par Model A		modd3.mod modd3.par Model D		mode3.mod mode3.par Model E		modba.mod modba.par Model B		modc3.mod Model C
395	50			50	Air								
385	49			49	Air								
375	48			48	Air								
365	47			47	Air								
355	46	36	Air	46	Air								
345	45	35	Air	45	Air	40	Air						
335	44	34	Air	44	Air	39	Air						
325	43	33	Air	43	Air	38	Air						
315	42	32	Air	42	Air	37	Air						
305	41	31	Air	41	Air&Rck	36	Air & Rock						
295	40	30	Air	40	Rock	35	Rock			30	Air	40	Air
285	39	29	Rock	39	Oxide	34	Rock	14	RckMin	29	Rock	39	R&Pit
275	38	28	Rock	38	Fresh	33	RckMin	13		28	RckOre	38	RPit&O
265	37	27	RockOre	37		32		12		27		37	RPit&O
255	36	26	RockOre	36		31		11		26		36	RPit&O
245	35	25	RockOre	35		30		10		25		35	Base Pit
235	34	24	RockOre	34		29		9		24		34	
225	33	23	RockOre	33		28		8		23		33	
215	32	22	RockOre	32		27		7		22		32	
205	31	21	RockOre	31		26		6		21		31	
195	30	20	RockOre	30		25		5		20		30	
185	29	19	RockOre	29		24		4		19		29	
175	28	18	RockOre	28		23		3		18		28	
165	27	17	Waste	27		22		2		17		27	
155	26	16		26		21		1		16		26	
145	25	15		25		20				15		25	
135	24	14		24		19				14		24	
125	23	13		23		18				13		23	
115	22	12		22		17				12		22	
105	21	11		21		16				11		21	
95	20	10		20		15				10		20	
85	19	9		19		14				9		19	
75	18	8		18		13				8		18	
65	17	7		17		12				7		17	
55	16	6		16		11				6		16	

45	15	5	15	10	5	15
35	14	4	14	9	4	14
25	13	3	13	8	3	13
15	12	2	12	7	2	12
5	11	1	11	6	1	11
-5	10		10	5		10
-15	9		9	4		9
-25	8		8	3		8
-35	7		7	2		7
-45	6		6	1		6
-55	5		5			5
-65	4		4			4
-75	3		3			3
-85	2		2			2
-95	1		1			1

Four-D FDRB log file

Reblocking the individual 10x10x10 models into a single combined model

```
PrintFile                     #sup1
RunMode                       1
Number_of_Files               6
PrimaryParametersFile         sup
Change_the_size?              y
X_size                        170
Y_size                        510
Z_size                        42
PrimaryModelFile              modf1
X_offset                      403
X_offset                      0
Y_offset                      403
Z_offset                      10
SecondaryParametersFile1      moda1
SecondaryModelFile1           moda1
X_offset                      0
Y_offset                      0
Z_offset                      0
SecondaryParametersFile2      modd3
SecondaryModelFile2           modd3
X_offset                      0
Y_offset                      200
Z_offset                      5
SecondaryParametersFile3      mode3
SecondaryModelFile3           mode3
X_offset                      120
Y_offset                      200
Z_offset                      25
SecondaryParametersFile4      modba
SecondaryModelFile4           modba
X_offset                      20
Y_offset                      321
Z_offset                      10
SecondaryParametersFile5      modc3
SecondaryModelFile5           modc3
X_offset                      111
Y_offset                      321
Z_offset                      0
Reblock?                      N
Max_parcels                   5
Mining_cost_formula?          N
Processing_cost_formula?      N
Polygon?                      N
NewModelFile                  #sup1
Write_new_Param_File?         y
NewParametersFile             #sup1
```

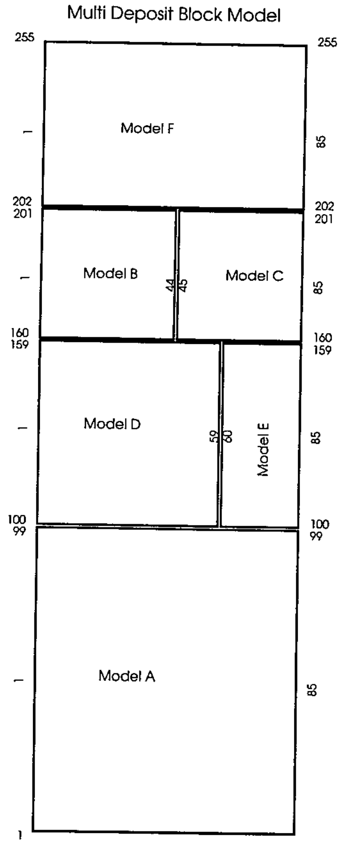
The resultant model file is very large, containing over 3.5 million blocks. This would use a large amount of computing resources and would take a significant time to optimise. As the primary aim of the study was to investigate multiple scenarios with the combined model it was considered prudent to create larger blocks that would result in a smaller model and thereby improve computational speeds. A 20x20x20 block was considered practical for the purpose of the scale of the study (number of blocks is now below 0.5 million). The number of 'parcels' per block was still set at 5 to retain a practical selectivity of original mining blocks. The Whittle Four-D FDRB module was used to reblock the model.

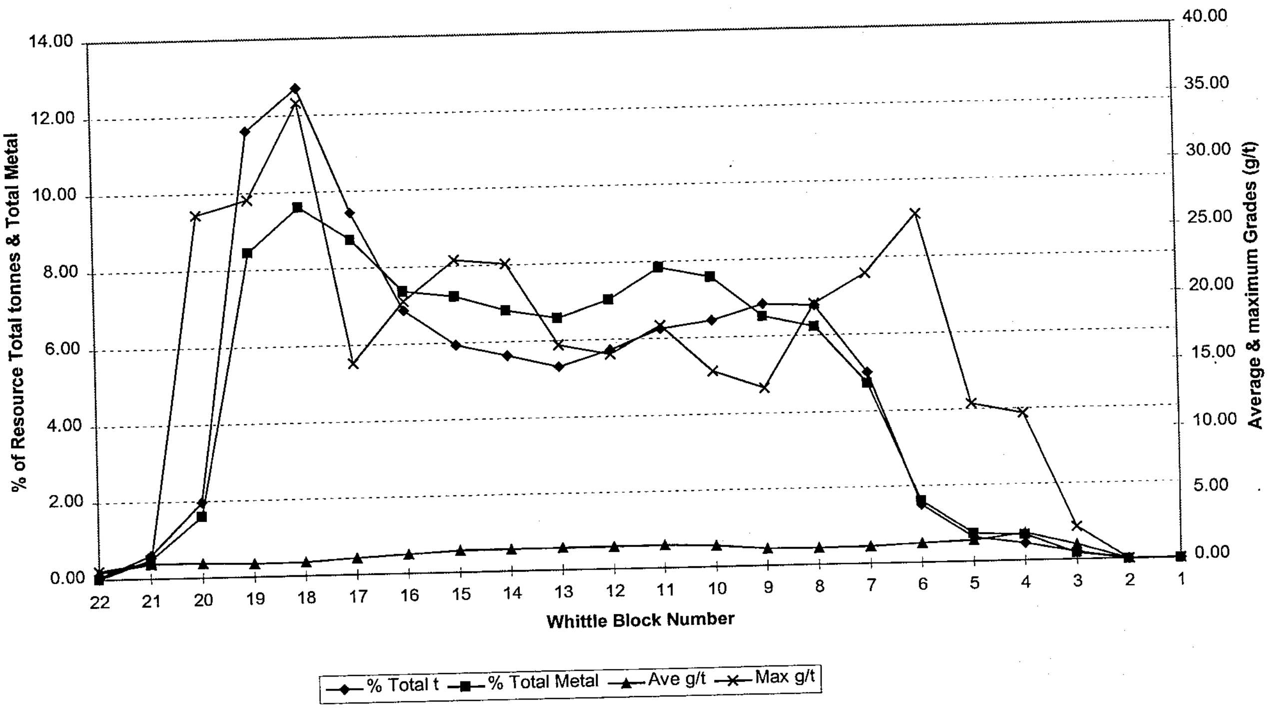
Four-D FDRB log file

Reblocking the 10x10x10 blocks into 20x20x20

```
PrintFile                      #sup2
RunMode                        1
Number_of_Files                1
PrimaryParametersFile          sup1.par
Change_the_size?               N
PrimaryModelFile               sup1.mod
Reblock?                       y
XReblock                       2
YReblock                       2
ZReblock                       2
Max_parcels                    5
Mining_cost_formula?           N
Processing_cost_formula?       N
Polygon?                       N
NewModelFile                   #sup2
Write_new_Param_File?          Y
NewParametersFile              #sup2
```

Multi Deposit Block Model





Whittle to Datamine conversion

To import Whittle result files back into Datamine, it has to be remembered that the models have been reblocked outside the original Datamine models.

Each deposit can be separated from the large model using the polygon intersection facility in FDRB. Once it has been separated from the others, each area has its own result and parameters file. Originally each deposit had its own local coordinates, which were lost when they were combined into the larger model. To import the pit shells back into Datamine the original origin coordinates in each parameters file has to be altered to allow the shell to be correctly imported back.

	Result File	parameters	X (East)	Y (North)	Z (RL)
Model A	3moda.res	3moda.par	4600	10800	-100
Model D	3modd.res	3modd.par	381400	532995	-100
Model E	3mode.res	3mode.par	374200	541600	-100
Model B	3modb.res	3modb.par	375800	537990	-100
Model C	3modc.res	3modc.par	382190	522090	-100
Model F	3modf.res	3modf.par	374600	535970	-100
Model Block Size			20	20	20
Model No Blocks			85	255	25

Pit shells from the individual result file can be imported back into Datamine using the Datamine FDIN module.

Adding the mining costs

Mining costs for each deposit are based on current mining tenders which have been modified for specific functions in each areas.

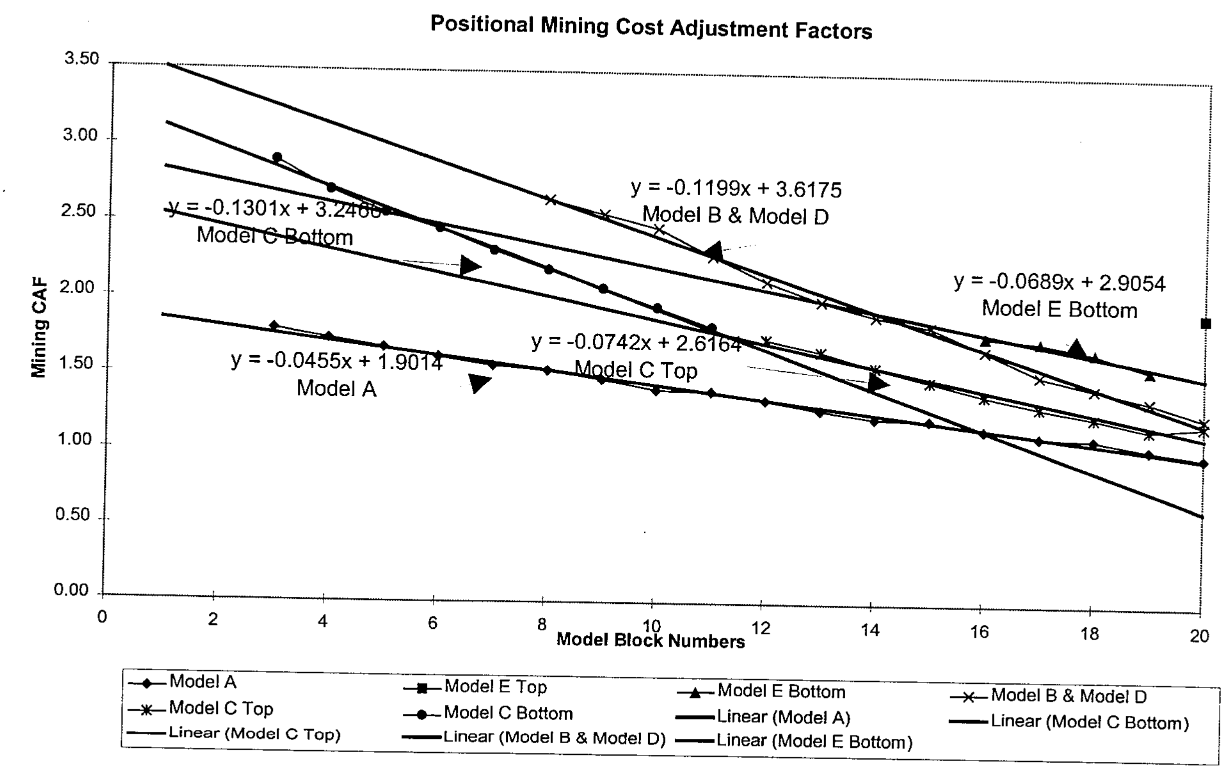
Whittle's mining cost structure has a prime mining cost CostM ($/t) attributed to a reference block, all other mining costs are relative to the reference block and carry a Positional Cost Adjustment Factor (Mining CAF).

The reference block for the model was taken to be at the surface of Model A. All other deposit mining costs are regularised back to the reference block. To calculate the positional CAF's, average mining costs were derived for each of the benches at each deposit. Using the reference position, the mining CAF's were calculated. Positional mining CAF's were then added to the model using FDRB.

Positional Mining Cost Adjustments

Base Bench	Mid Bench	Whittle Bench	Ave Model A	Ave Model E Top	Ave Model E Bottom	Ave Model B Model D	Ave Model C Top	Ave Model C Bottom
280	290	20	1.00	1.93		1.26	1.21	
260	270	19	1.05		1.58	1.37	1.18	
240	250	18	1.11		1.68	1.45	1.26	
220	230	17	1.12		1.75	1.53	1.32	
200	210	16	1.17		1.78	1.69	1.40	
180	190	15	1.23			1.85	1.49	
160	170	14	1.24			1.91	1.58	
140	150	13	1.29			2.01	1.68	
120	130	12	1.35			2.14	1.75	
100	110	11	1.41			2.30		1.83
80	90	10	1.41			2.48		1.95
60	70	9	1.48			2.57		2.08
40	50	8	1.54			2.66		2.20
20	30	7	1.56					2.32
0	10	6	1.62					2.46
-20	-10	5	1.68					2.57
-40	-30	4	1.74					2.71
-60	-50	3	1.80					2.90
	-70	2						
	-90	1						

There is a limit to the formula size which FDRB can use to insert the CAF's into the block model. Trend lines were fitted to any of the straight line sections (refer to Positional CAF Mining diagram), and this was then used in the positional cost formula in the log file.



FDRB Log file (sup3caf.lor) was used to add the positional mining cost adjustment factors into the block model. Testing for the X and Y block position within the model allowed each area to have the CAF's added in the Z direction.

```
PrintFile                   #sup3
RunMode                     1
Number_of_Files             1
PrimaryParametersFile       sup2
Change_the_size?            N
PrimaryModelFile            sup2
Reblock?                    N
Max_parcels                 10
Mining_cost_formula?        y
OK_to_write_all_blocks?     Y
Formula                     r(iy,&
! Model A
Formula                     r(iz,(1.9014-(0.0455*iz)),20.5,1.00)&
Formula                     ,100,&
Formula                     r(ix,&
! Model D
Formula                     r(iz,(3.6175-(0.1199*iz)),20.5,1.00)&
Formula                     ,60.5,&
! Model E
Formula                     r(iz,(2.9054-(0.0689*iz)),19.5,1.93)&
Formula                     ),160.5,&
Formula                     r(ix,&
! Model B
Formula                     r(iz,(3.6175-(0.1199*iz)),20.5,1.00)&
Formula                     ,50.5,&
! Model C
Formula                     r(iz,(3.2466-(0.1301*iz)),11.5,(2.6164-(0.0742*iz)))&
Formula                     ),201.5,&
! Model F
Formula                     r(iz,(3.6175-(0.1199*iz)),19.5,1.00))
Processing_cost_formula?    N
Polygon?                    N
NewModelFile                #sup3
Write_new_Param_File?       Y
NewParametersFile           #sup3
```

Parameters file

The following section has printouts of sections of the parameters file plus comments extracted from the Whittle print files. This procedure was documented and annotated to explain the reasoning that has contributed to the building of the parameters file.

```
Input parameters File    - sup32.par
Line type 1 & 2
```

```
Contents of the parameters File -
  1      20.00      20.00      20.00 374600.00 535970.00    -100.00
  2        85        255         21
The parameters as understood by the program -
 * XYZ block dimensions            -          20.00 by    20.00 by    20.00
 * XYZ model dimensions in blocks -             85 by      255 by       21
 *                  Total blocks -           455175
 * X-coordinate of the model framework origin is  374600.00
 * Y-coordinate of the model framework origin is  535970.00
 * Z-coordinate of the model framework origin is    -100.00
```

Block sizes are selected to be 20x20x20 to enable the model to optimisations quickly for numerous economic scenarios. Within the block, 'Parcels' of different rock types exist and allowing mining selectivity of the original model to be retained. The concept that large blocks equate to diluted ore is a misapprehension.

Model dimensions had to be sufficiently large to enable the individual deposits to be separate and not interfere with each other.

The model framework origin is from the primary model [ie. Model F deposit] which was expanded to form the framework of the combined model.

Line type 3

```
Contents of the parameters File
  3        1        6              1        0   1          2.00
The parameters as understood by the program -
 * Active blocks indicator          -      1
 * Number of Sub Regions within the model
 * Positional mining cost factors will be used
```

```
* Positional processing cost factors will not be used
* Rejected tonnages and metal will be reported
* Restart dumps occur every      -      2.000 hours
```

These are mainly on/off switches used by Whittle programs. These switches do not contribute to the efficiency of the optimisations.

Model Sub-regions line type 4, 5 & 6

```
Contents of the parameters File
! Model F
   4        1       85        1        99       1       21
   5        1        6    21600
   6      0.0     47.5
! Model D
   4        1       59      100       159       1       21
   5        1        6    21600
   6      0.0     44.0
! Model E
   4       60       85      100       159       1       21
   5        1        6    21600
   6      0.0     44.0
! Model B
   4        1       54      160       201       1       21
   5        1        6    21600
   6      0.0     44.0
! Model C
   4       55       85      160       201       1       21
   5        1        6    21600
   6      0.0     44.0
! Model F
   4        1       85      202       255       1       21
   5        1        6    21600
   6      0.0     44.0
The parameters as understood by the program -
Line type 4 defines the sub-region in terms of block numbers
Line type 5 defines
       - the number of slope directions in the sub-region
       - Number of benches to consider when generating the structure vectors -   6
       - Default rock tonnage for this sub-region -      21600
Line type 6 defines
       - Bearing
       - Slope angle
```

Pit slopes of 35 degrees above 40m depth and 45 degrees below 40m depth were used for all deposits.

The slope data for each sub-region is summarised in the following table.

Deposit	Xmin	Xmax	Ymin	Ymax	Zmin	Zmax	Bearing	Slope
Model A	1	85	1	99	1	21	0.0	47.5
Model D	1	59	100	159	1	21	0.0	44.0
Model E	60	85	100	159	1	21	0.0	44.0
Model B	1	54	160	201	1	21	0.0	44.0
Model C	55	85	160	201	1	21	0.0	44.0
Model F	1	85	202	255	1	21	0.0	44.0

Line type 12

```
Contents of the parameters File
  12     0    0    0    0    4    2    2    0                 $
The parameters as understood by the program -
Global values -
 * Decimal places for -
                   Block tonnes of rock -        0
                   Total tonnes of rock -        0
                   Block units of metal -        0
                   Total units of metal -        0
                   MCOSTM values        -        4
                   Grades               -        2
                   Small dollar amounts -        2
                   Large dollar amounts -        0
```

Formatting requirements for Whittle printouts.

MCostM (= CostM/Price) number of decimal places controls the accuracy to which the price can be back calculated during analysis (FDAN).

Line type 13

```
Contents of the parameters File
  13      21600      1.000      1.000         0    1    3
```

```
The parameters as understood by the program -
 * General default rock tonnage  -       21600
 * Mining dilution factor        -       1.000
 * Mining recovery factor        -       1.000
 * Cost ratio for selling/mining -       0.000
 * Air blocks are considered in the optimization
 * All air blocks are included in the Results File
```

General default rock tonnes are not applicable as full models are exported from Datamine.

Mining dilution and mining recovery factors were not used during these optimisations. Dilution is recognised as being included in the regularised blocks constructed in the original Datamine block models. These blocks have been exported to Whittle and are of sufficient dimensions to represent simulated mining units (SMU's). Reblocking of the original models 'parcels' are maintained so that the final 20x20x20 model still retain the characteristics of the original SMU's.

Mining recoveries are not used.

Selling cost ratios are not used.

Air blocks are used in the optimisation as this forces the structural arcs to be connected through 'air'. This is required when the current topography is steeper than the proposed new pit wall slopes.

All air blocks are included in the results file which is necessary to import the pit shells back into Datamine.

MCostM Values. Line type 14

```
Contents of the parameters File
  14      0.0000
  14      0.0311     0.0004     0.0327
  Numerous Line Type 14 listing ranges or single values for MCostM
  14      0.2488
  14      0.2765
  14      0.3110
The parameters as understood by the program -
MCOSTM values -

               Seventy four single McostM (CostM/Price) ratios
               were used to cover a very wide range of prices,
               and allow a large number of shells to be generated
```

The MCostM values control the pit shells calculated by the optimisation. MCostM is the ratio of Cost of Mining divided by price (MCostM = CostM / Price).

Calculation of the MCostM value was done in a spread sheet and imported back into the parameters file:

Rock types defined within models Line type 15

```
Contents of the parameters File
  15  MEOX           1.000          0     1.000
  15  MEFR           1.000          0     1.000
  15  MBOX           1.000          0     1.000
  15  MBFR           1.000          0     1.000
  15  MBEZ           1.000          0     1.000
  15  MFOX           1.000          0     1.000
  15  MFFR           1.000          0     1.000
  15  MAFR           1.000          0     1.000
  15  MDOX           1.000          0     1.000
  15  MDFR           1.000          0     1.000
  15  MCOX           1.000          0     1.000
  15  MCFR           1.000          0     1.000
The parameters as understood by the program -
Rock type details -
                  Rock        Mining        Rehab     Throughput
```

Type	Adjust	Ratio	Adj factor
MEOX	1.000	0.000	1.000
MEFR	1.000	0.000	1.000
MBOX	1.000	0.000	1.000
MBFR	1.000	0.000	1.000
MBEZ	1.000	0.000	1.000
MFOX	1.000	0.000	1.000
MFFR	1.000	0.000	1.000
MAFR	1.000	0.000	1.000
MDOX	1.000	0.000	1.000
MDFR	1.000	0.000	1.000
MCOX	1.000	0.000	1.000
MCFR	1.000	0.000	1.000

All rock types within the model are defined.

Deposit	Oxide & L Seds	Fresh	Endowment
Model E	MEOX	MEFR	
Model B	MBOX	MBFR	MBEZ
Model F	MFOX	MFFR	
Model A		MAFR	
Model D	MDOX	MDFR	
Model C	MCOX	MCFR	

No rock cost adjustments, rehabilitation costs or mill throughput factors are used.

Processing Rock types. Line type 16

```
Contents of the parameters File
  16  Mill MEOX      PRORAT    1.000      Constant
  16  Mill MEFR      PRORAT    1.000      Constant
  16  Mill MBOX      PRORAT    1.000      Constant
  16  Mill MBFR      PRORAT    1.000      Constant
  16  Mill MBEZ      PRORAT    1.000      Constant
  16  Mill MFOX      PRORAT    1.000      Constant
  16  Mill MFFR      PRORAT    1.000      Constant
  16  Mill MAFR      PRORAT    1.000      Constant
  16  Mill MDOX      PRORAT    1.000      Constant
  16  Mill MDFR      PRORAT    1.000      Constant
  16  Mill MCOX      PRORAT    1.000      Constant
  16  Mill MCFR      PRORAT    1.000      Constant
The parameters as understood by the program -
 Processing data for open pit mining -
```

Process Code	Rock Type	Cost Ratio	Recovery Fraction	Threshold Grade	Minimum Cut-off	Maximum Cut-off
Mill	MEOX	PRORAT	1.000	Constant		
Mill	MEFR	PRORAT	1.000	Constant		
Mill	MBOX	PRORAT	1.000	Constant		
Mill	MBFR	PRORAT	1.000	Constant		
Mill	MBEZ	PRORAT	1.000	Constant		
Mill	MFOX	PRORAT	1.000	Constant		
Mill	MFFR	PRORAT	1.000	Constant		
Mill	MAFR	PRORAT	1.000	Constant		
Mill	MDOX	PRORAT	1.000	Constant		
Mill	MDFR	PRORAT	1.000	Constant		
Mill	MCOX	PRORAT	1.000	Constant		
Mill	MCFR	PRORAT	1.000	Constant		

This section of the parameters file is the main section to be altered between the various economic scenarios.

For each Rock Type previously defined there exists two possible treatment methods.

1. Mill, inferring the standard CIP/CIL extraction system.
2. Heap, which relates to a heap leach system where ore is crushed, agglomerated, stacked and leached.

Processing cost ratio is the cost of processing divided by the cost of mining (PRORAT = CostP/CostM). The cost of processing includes all 'ore' related costs, such as transport, grade control, treatment, and admin & general costs. The PRORAT is a stable ratio for a scale of operation, but, if the scale of the operation is changed, then the ratio will change and the model will have to be re-optimised. Although the shape of the optimum shell will change by changing the PRORAT the optimum shell is defined by the MCostM ratio (CostM / Price). Analysing the mineralisation that exists within a shell is dramatically influenced by the cost of processing (CostP) which determines which ore is accepted or rejected to the waste dump.

Recovery fraction is the mill recovery of gold. It was found that a relationship existed between the head grade and the tail grade in the current mill. A constant has been determined and this has been used instead of a constant mill recovery fraction.

Head Grade - Constant = Recovered Grade.

This results in a recovery curve based on the head grade and the constant (Whittle calls this the threshold method).

Minimum and maximum cutoff grades are not used during optimisation but are used to achieve Mill or Heap leach tonnage requirements during analyses.

Optimisation Scenarios

Seven treatment scenarios were formulated and these reflected differing mill sizes and the possibility of additional heap leaching.

Three optimisations were run for the primary CostP's for the three differing mill sizes. From the result files, seven analyses were conducted to evaluate the various mining and treatment scenarios. These analyses were imported into excel spreadsheets and then summarised.

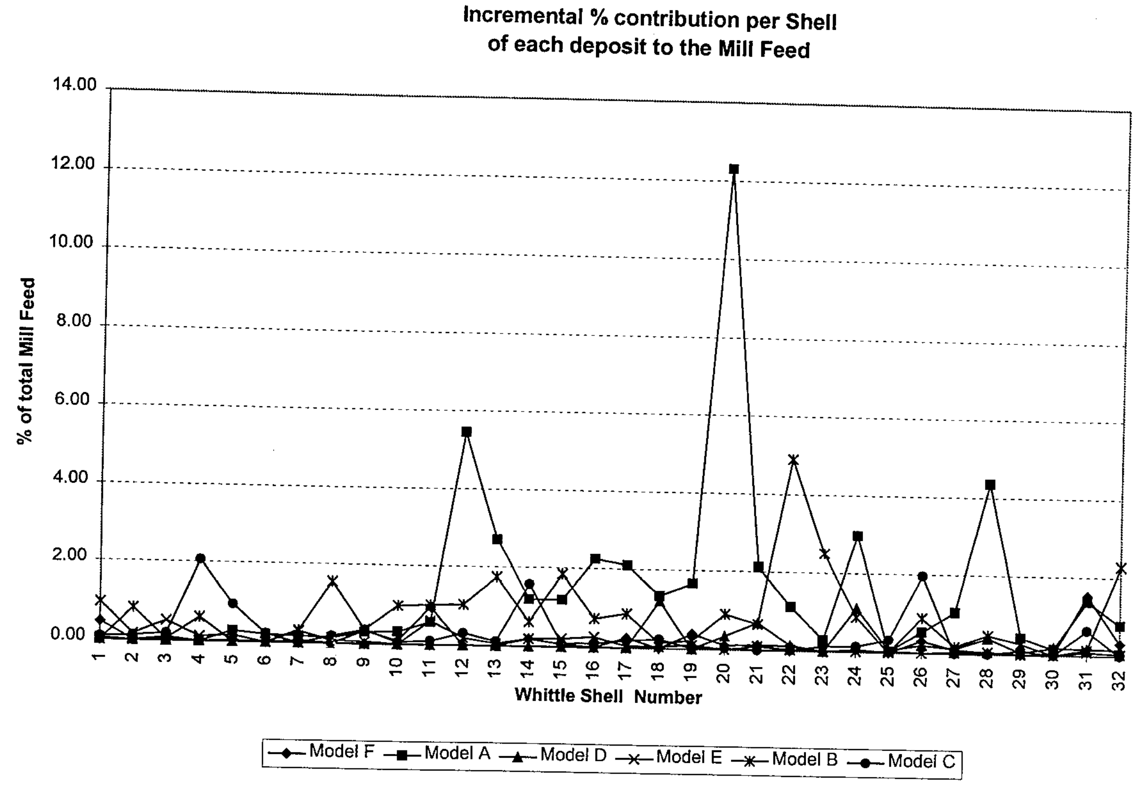
Scheduling

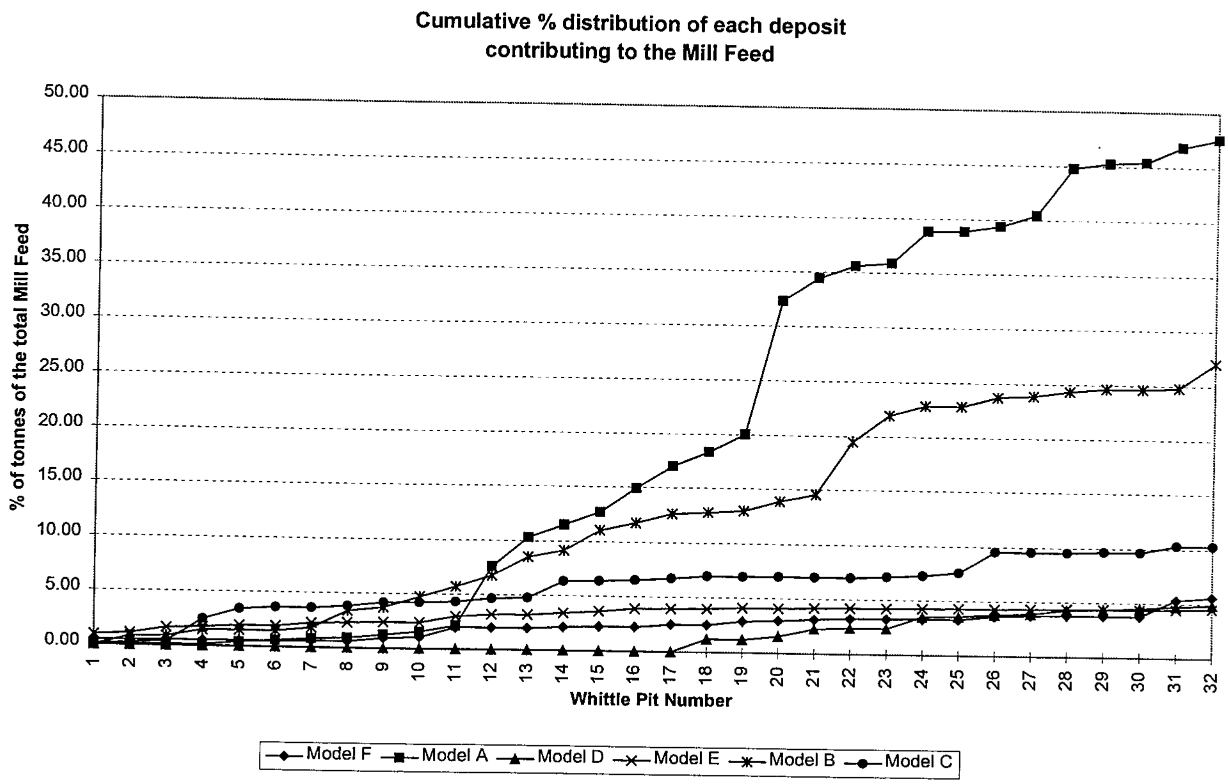
Scheduling of the optimal pit was based on selecting interim pit shells which corresponded to a one year production requirement. This was the initial attempt to create a global schedule for the cut backs which would maximise the NPV of the project. Utilising the FDAN module, the advance of one cut back compared to another was tested. Tests were done from a single bench difference to a possible 5 bench difference. It was concluded that minimal additional profit could be made beyond a 3 bench (60m face) between cutbacks.

Significant features are now becoming obvious in the analyses of all the pitable deposits.

- To maximise the NPV, the optimisation process selects blocks that have the highest grade / lowest strip ratio and which can be mined early in the schedule.
- The NPV per year decreases as the shells become larger and strip ratios increase.
- Cost/oz progressively increase as the shells become larger.
- Exploration schedules can be formulated to replace ore mined, or substitute the higher cost/oz ore.
- Reducing the mining and processing costs would allow more resources to be converted into the reserve category.

The strategy of the current scenario was to simulate the required pit tonnes for an expanding mill scenario. No capital was included in these analyses as it is important to quantify what cash flows the ore bodies can generate.





The optimised 'Best case' selects blocks that will maximise the NPV, but this is not necessarily a good practical schedule. In order to rationalise the erratic extraction of blocks from the various deposits, a mining rationalisation has to be imposed into the Whittle result file that will force a reasonable practical extraction sequence. This is accomplished by using a 'pitlist'.

Whittle FDRB module can extract the X Y Z coordinates of a Block and the Pit shell it belongs to. This is referred to as a pitlist.

FDRB log file sup32pit.lor used to extract the pitlist from the result file:

```
PrintFile                  sup32pit
RunMode                    4
PrimaryParametersFile      sup32.par
Change_the_size?           N
PrimaryResultsFile         sup32.res
Mine_out?                  N
Strip_off_outer_pits?      N
Reblock?                   N
Polygon?                   N
PitListFile                sup32
Write_new_Param_File?      n
```

This list has to be modified to force a more practical mining sequence in the result file to be analysed. To accomplish this, a small QBASIC program was written that would take an existing pitlist and convert it into a newlist. It reads a data file that defines each mining area and converts the old pit numbers into new pit numbers.

```
        QBASIC Pitlist.bas
        program used to convert Pitlist into a Newlist (requires a Data file)
        CLS
        DIM D(50, 7)
        PRINT : PRINT
        PRINT " Program to change the Pit Shell No's in Pit List File "
        PRINT : PRINT
        INPUT " Data File Name "; DatFile$
        PRINT : PRINT
        INPUT " Input      Pit List File Name "; mod$
        PRINT : PRINT : PRINT
        PRINT : PRINT : PRINT
        INPUT " Output New Pit List File Name "; pref$
        PRINT : PRINT : PRINT
        OPEN DatFile$ FOR INPUT AS #1
        OPEN mod$ FOR INPUT AS #2
        OPEN pref$ FOR OUTPUT AS #3
        L% = 1
        DO WHILE (NOT EOF(1))
        LINE INPUT #1, b$
        y$ = MID$(b$, 1, 1)
        IF y$ = "!" THEN 50
        D(L%, 1) = VAL(MID$(b$, 2, 9)): REM X1 EastMin
        D(L%, 2) = VAL(MID$(b$, 11, 10)): REM X2 EastMax
        D(L%, 3) = VAL(MID$(b$, 21, 10)): REM Y1 NorthMin
        D(L%, 4) = VAL(MID$(b$, 31, 10)): REM Y2 NorthMax
        D(L%, 5) = VAL(MID$(b$, 41, 10)): REM P1 PitFrom
        D(L%, 6) = VAL(MID$(b$, 51, 10)): REM P2 PitTo
        D(L%, 7) = VAL(MID$(b$, 61, 10)): REM P3 NewPit
        L% = L% + 1: REM Line Counter
50      LOOP
        DO WHILE (NOT EOF(2))
        LINE INPUT #2, A$
        East = VAL(MID$(A$, 2, 3))
        North = VAL(MID$(A$, 5, 3))
        RL = VAL(MID$(A$, 8, 3))
        Pit = VAL(MID$(A$, 13, 3))
        NPit = 0
        IF Pit = 74 THEN GOTO 5000
        FOR A% = 1 TO L% - 1
        IF East >= D(A%, 1) AND East <= D(A%, 2) AND North >= D(A%, 3) AND North <= D(A%, 4) THEN 1107
ELSE 1200
1107    IF Pit >= D(A%, 5) AND Pit <= D(A%, 6) THEN NPit = D(A%, 7)
1200    NEXT A%
4900    East$ = STR$(East)
        North$ = STR$(North)
        RL$ = STR$(RL)
        Pit$ = STR$(Pit)
        IF NPit = 0 THEN NPit = Pit
        NPit$ = STR$(NPit)
        PRINT East$; ","; North$; ","; RL$; ","; NPit$
        PRINT #3, East$; ","; North$; ","; RL$; ","; NPit$
5000    LOOP
9999    CLOSE #1
        CLOSE #2
        CLOSE #3
        SYSTEM
```

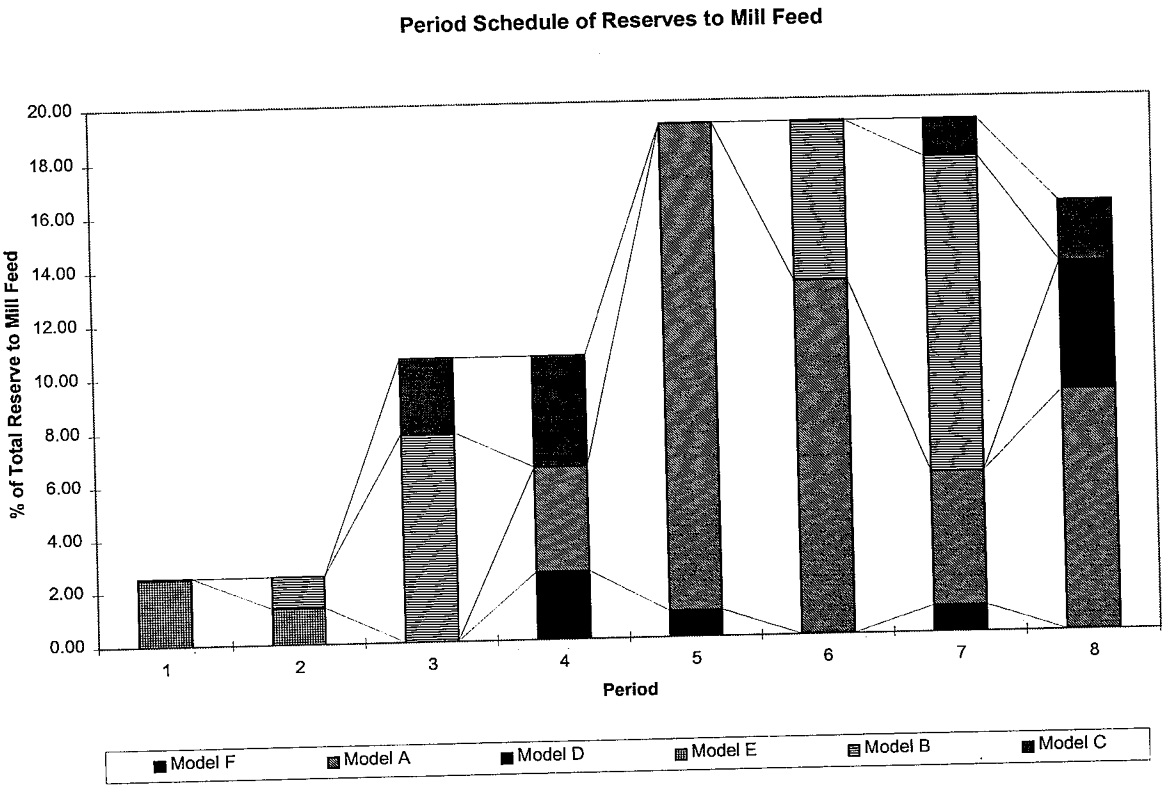
The Data file used by pitlist.bas was created using a text editor.

```
Data File pitlist.dat used as the control file in QBASIC pitlist.bas
!        1         2         3         4         5         6         7
!234567890123456789012345678901234567890123456789012345678901234567890
!     XFrom        XTo      YFrom        YTo   PitFrom     PitTo    NewPit
! Model A
          1         85          1         99         1        12        12
          1         85          1         99        13        20        20
          1         85          1         99        21        29        27
! Model D
          1         59        100        159         1        29        28
! Model E
         60         85        100        159         1         9         1
         60         85        100        159        10        29         2
! Model B
          1         44        160        201         1        13         5
          1         44        160        201        14        29        22
! Model C
         45         85        160        201         1        14         6
         45         85        160        201        15        25        25
         45         85        160        201        26        29        29
! Model F
          1         85        202        255         1        11        11
          1         85        202        255        12        19        19
          1         85        202        255        20        29        27
```

When the pitlist has been modified, a model file and a new pit list are combined, using FDRB to form a new result file that can be analysed. Several trial and error runs were made modifying the pitlist.dat file to allow grouping of the deposits shells to take place and minimise the affects of changes to the 'best' NPV.

```
FDRB log file sup32a.lor used to take a model file plus a pitlist file and create a new result file.
PrintFile                    #sup32a
RunMode                      5
Number_of_Files              1
PrimaryParametersFile        sup32.par
Change_the_size?             N
PrimaryModelFile             sup3.mod
SecondaryParametersFile1     sup32.par
PitListFile1                 sup32a
Reblock?                     N
Max_parcels                  5
Mining_cost_formula?         N
Processing_cost_formula?     N
Polygon?                     N
ResultsFile                  #sup32a
Write_new_Param_File?        Y
NewParametersFile            #sup32a
```

The final result, from modifying the pitlists and running analyses, was a schedule that reflected an expanding mill scenario and simulated a reasonable practical extraction sequence.



Comparison of Whittles 'best' and the rationalised schedule, resulted in a decrease in profit of 0.8% for an undiscounted profit to 6.7% for a discounted profit.

Conclusion

Optimisation of a single pit identifies the optimal shell that can be profitably extracted. This process can be repeated for any number of individual deposits, however the mining sequence for the extraction of the individual pits has not been optimised.

As operations expand and the supply of ore is derived from multiple pits, it is becoming increasingly important to rank the priority of the pits and schedule their output to maximise the overall benefits to the operation. This study addressed the question at the WMC St Ives operations and found that, by combining all the independent deposit models into a combined model and using Whittle Four-D to optimise it, the benefits of scheduling the operation could be quantified.

Hind sight is always the best sight and it can now be seen that careful forward planning can save considerable time. Individual model construction for ore resource calculations could easily be organised to have consistent block sizes and work from a common origin for the framework. Costs can be accumulated to be task orientated thereby allowing standardised costs to be used throughout a study, and allowing comparisons to be made of industry best practices.

This type of study produces numerous files and it is important to leave an 'audit trail' so that the various side tracks that the study has taken can be reconstructed. Consequently all procedures were 'logged' using the facilities in the Whittle programs.

No final comparison to a 'hand held' method was made as none was done, however comparison to Whittles 'best' indicates that a near maximum NPV can be achieved. Utilising the Whittle Four-D programs, multiple ore bodies can be ranked, and subsequently scheduled, to maximise the NPV of a project.

Thanks are due to the WMC St Ives mine planning department for their assistance and diligence during the study of the operations.

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