Cut-Back Analysis and Resultant Financial Benefits in Pit Optimisation – Endeavour 22 Porphyry Cu-Au Deposit

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Abstract

The Endeavour 22 Porphyry Sulphide Cu-Au deposit is one of two Cu-Au deposits to be mined at by open pit at North Parkes in Central NSW. For strategic reasons, the orebody (>14Mt) is to be mined at an annual rate of 1.1 Mtpa with a mine life in excess of 13 years. This specific condition together with other fixed parameters (unit value of product; cost quartile compared to other world producers; etc) ensured that a careful Discounted Cash Flow (DCF) analysis was performed.

An initial optimisation produced a best case DCF (the target for subsequent analysis) and the worst case DCF that varied by 20%. The difference providing encouragement that an improvement in the Net Present Value (NPV) of the deposit could be achieved.

Initiating the cut-back study with the two pits corresponding to the worst case DCF and best case DCF, a stepwise analysis using FDAN and Four-D log files to select different pit sequences was carried out. In each case the DCF data output as a SSO file was parsed into an Excel spreadsheet where it was analysed and graphed to compare with the other cut-back scenarios.

Limiting factors in the optimisation where the current Oxide Pit (oxide Au/Cu-Au) and an operational constraint of a distance of 35-40m required between each cut-back. The Whittle pit shells were viewed in a general mine package GUI (Guide) to enable the distances between the pit shells to be measured, thereby ensuring the that the operational constraints were met.

The delaying of waste stripping and the early mining of the high-grade central core favoured smaller starter pits but the presence of the existing pit required a pragmatic solution to the cut-back sequence.

The cut-back analysis led to a three-pit cut-back scenario, which increased the worst case DCF to within 7% on the best case pit DCF. The financial benefit of the pit cut-back analysis was an increase in the NPV of several millions of dollars which represented approximately a 21% increase in the NPV of the project.

Preparation

The preparatory steps prior to undertaking an optimisation are critical to achieving a satisfactory result from the pit optimisation (FDOP) and any subsequent analysis (FDAN) of the results. Therefore, a systematic approach to preparation of the input data into the relevant Whittle Four-D programs is essential. In the case of the Endeavour 22 pit optimisation this preparation was extensive. The relevant steps undertaken are outlined below:

Initial Preparation

- Establish resource model limits
- Increase model limits for 'mining' model
- Determine whether the surfaces used in 'mining' model extend to the increased model limits:
    - Topographic surface

  * Current pit surface
  * Base of weathering (BOW), and
  * Base of oxidation (BOX).
- Identification of rock and ore types
- Assignment of densities
- Recognition of geotechnical domains/ mining sub-regions
- Calculation of COSTM and COSTP together with mining and processing CAF's.

Preparation of Datamine 'Mining' Model

The general mining package (GMP) used to create a 'mining' model was Datamine. The individual steps in the preparation of the model were recorded in a macro (4D_MODEL.MAC) and were as follows:

- Prepare 'mining' model prototype
- Fill model below an arbitrary surface and assign a background density
- Use topographic digital terrain model (DTM) to set density to null in air cells
- Use Base of Weathering DTM to set densities between BOW and BOX
- Use Base of Oxidation DTM to set densities below BOX
- Use current pit DTM to set density to null in those cells within current pit
- Add resource model to 'mining' model
- Set mandatory Four-D fields (TTONNES, OTONNES, METAL, ORETYPE, MAF and PAF) in 'mining' model (4DMOD.M)
- Assign ore types to ORETYPE field as required, and
- Output 'mining' model to Four-D model file (E22_3.MOD) and parameter file (E22_3.PAR) using Datamine Whittle Four-D interface (FDOUT).

Whittle Four-D Preparation

Prior to the running of any Whittle Four-D programs, a number of parameters were determined before they could be incorporated into the Four-D parameter file. The Datamine process FDOUT generates a parameter file which includes the cell/block size and the real world coordinates of the model origin. The parameters, which were determined, are as follows:

- Determine from the Datamine 'mining' model prototype the number of cells in the X (easting), Y (northing) and Z (RL) directions
- Create a table for converting real world coordinates into block indices for X, Y and Z directions
- Ascertain geographical extents of geotechnical domains and convert these extents in block indices for the mining sub-regions
- Calculate the default tonnage for each of the mining sub-regions
- Calculate the MCOSTM for the range of revenue values (US$0.50/lb to US$1.40/lb in increments of US$0.02/lb)
- Identify the rock type codes (OXID, TRAN, SULP) which are used in the Datamine 'mining' model and Four-D model
- Assign processing methods (MILA – OXID; MILB – TRAN and MILC – SULP) to rock types (ore types)
- Calculate the CRATIO (COSTP/COSTM) for different processing methods
- Determine the mill recovery for each processing method, and
- Ascertain the minimum cut-off grade for each processing method.

During the current phase of mining a number of pit wall failures (Plate 1) had occurred, therefore, particular attention was paid to the overall slope angle recommended for each of the weathering domains. As there was a pronounced asymmetry in both the BOW and the BOX, it was necessary to create a total of eight (8) mining sub-regions to accommodate the slope regimes required.

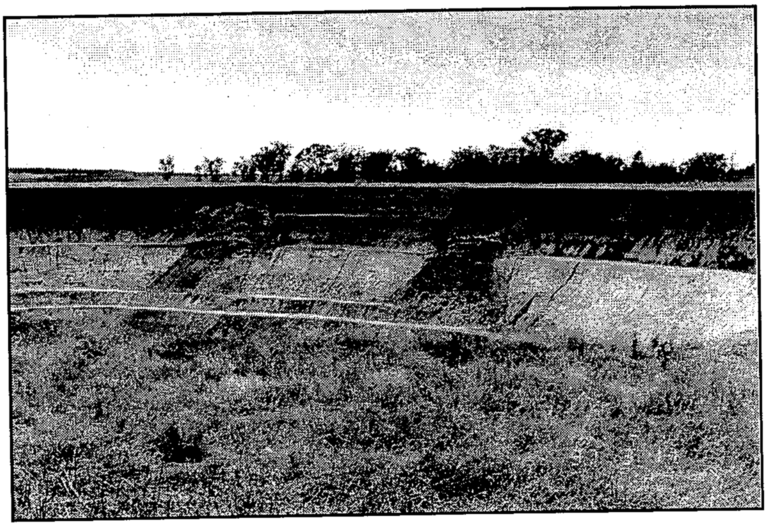


Plate 1 – Wall Failure in Current Endeavour 22 Pit

Whittle Four-D Optimisation

On completion of the data preparation for Whittle Four-D, firstly the parameter file (E22_3.PAR) was compiled using the parameter-editing program (FDED) prior to the running of the structural arc generation program (FDST).

FDED Program

The parameter file (E22_3.PAR) prepared by the Datamine process FDOUT was edited using the Whittle Four-D FDED program. In the entering of data into the parameter file, particular attention was paid to the identification of the block indices for the mining sub-regions.

With a complex set of horizontal and vertical boundaries for the mining sub-regions, it was imperative that the correct block indices were input and that the parameter file was validated.

FDST Program

The structure arcs generation program (FDST) was run using the logging function, to enable the program to be run in a iterative mode. If the average slope errors were too large to be acceptable, then it became necessary to either alter the number of benches for arc generation or combine two vertical sub-regions as one sub-region. This results, when one sub-region may contain an insufficient number of blocks to achieve reasonable slope errors. The FDST print file was inspected to review the minimum, average and maximum slope error for each mining sub-region.

The situation was further complicated with Endeavour 22 as the resource model was a geostatistical panel model with blocks 20m (X or E) x 20m (Y or N) x 5m (Z or RL). This provided further problems because it was difficult to achieve low slope errors because of the height of the panel compared to its length and breadth. This is especially the case if the vertical extent of the sub-region contains a small number of panels.

FDOP Program

The pit optimisation program was run using logging mode to provide a permanent record of the input into the program. A FDOP print file was generated to provide bench schedules for each pit to enable an audit to be carried out by comparing them with the bench inventory calculated in Datamine of the relevant Whittle outer-face pit.

CUT-BACK ANALYSIS

A series of steps were used to carry out the cut-back analysis with the Whittle Four-D analysis program featuring as the principal tool in the study together with Excel to analyse and graph the SSO output data and GUIDE to view the subsequent Whittle outerface pits. The steps carried out in the cut-back analysis are outlined below.

Initial FDAN Run

A first pass of the Whittle Four-D analysis program (FDAN) was run using finite input criteria for COSTM ($/tonne), price for metal (AU$/lb NSR), discount rate (10%) and mill thorough put (1.1Mtpa) to determine the optimal pit.

Initial FDAN Run with SSO Output

The initial FDAN run was re-run using a spreadsheet output definition file (E22_3.SSD) and a corresponding spreadsheet output file (E22_3B.SSO). The SSD file is listed below:

```
Gra Pit/FI Price Rock/TG Tran/TI Tran/GG Sulp/TI Sulp/GG Strip
Gra Metal/UI Metal/UO Opvalue/CB Opvalue/CW
Gra Opvalue/DB Opvalue/DW
```

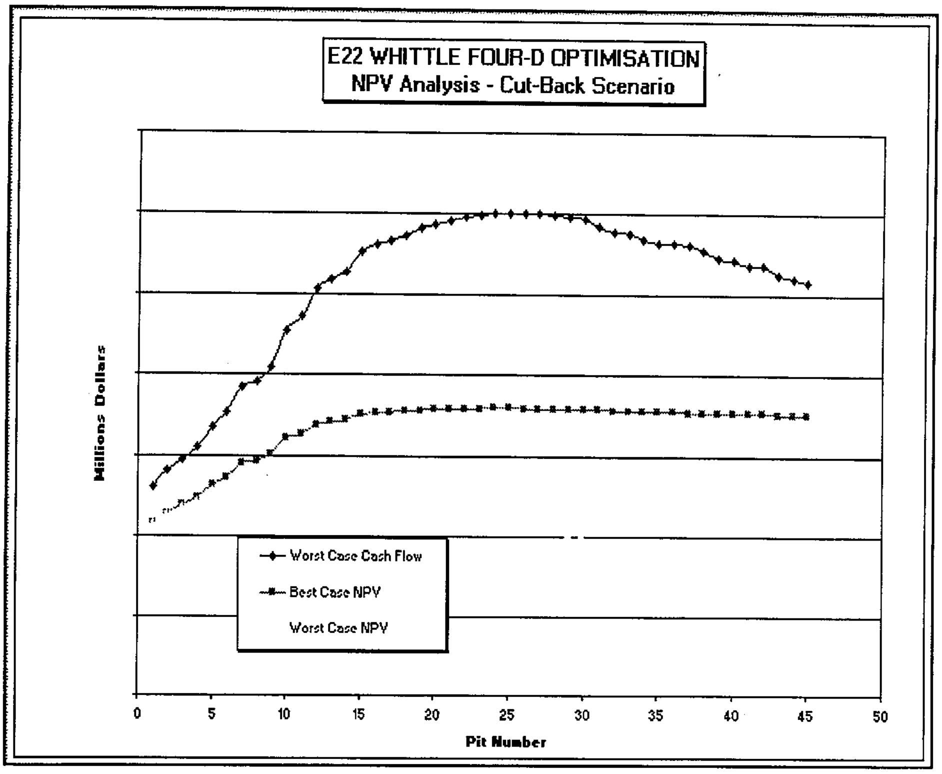
The FDAN log file (E22_3B.LOA) is listed below:

```
PrintFile               e22_3b.pra
ParametersFile          e22_3.par
ResultsFile             e22_3.res
Output_spreadsheet_data? Y
SS_Definition_File      e22_3.ssd
SS_Output_File          e22_3b.sso
Run_Descn               E22 Run 3B;COSTM=$*.**;A$**.**/lb NSR;1.1mtpa;10% Discount.
Timecost_Ovr?           N
Initial_capital         0
COSTM                   *.**1
PRICE                   **.**
PIT                     1-1-45
DISCOUNT                10
ROCK/L                  0
MILA/L                  1.1m
MILB/L                  1.1m
MILC/L                  1.1m
METAL/L                 0
Modify_params?          N
Specified_schedule?     N
Worst_case?             Y
Best_case?              Y
OK?                     y
Another_request?        n
Full_print?             n
```

The FDAN SSO file (E22_3B.SSO) was parsed into an Excel spreadsheet. A graph was prepared using the following fields:

- pit number
- worst case cash flow
- best case NPV, and
- worst case NPV.

The graph displayed below indicates the large difference between the worst case NPV and best case NPV. These curves suggest that there is potential improvement in the NPV if a cut-back sequence was adopted. The subsequent FDAN runs were aimed at an improvement in the NPV by iterative testing of a number of pit cut-back scenarios.



[1] Data including COSTM and unit value of metal (AU$/lb) have been replaced by asterisks because they are commercially sensitive.

Iterative FDAN Runs with Specified Cut-back Schedules

The spreadsheet definition file (E22_3S.SSD) used for the iterative FDAN runs is listed below:

```
Gra Pit/FI Price Rock/TG Oxid/TI Oxid/GG Tran/TI Tran/GG
Gra Sulp/TI Sulp/GG Strip Opvalue/DS
```

The FDAN runs were carried out using a log file that specified that a specific schedule was required and the pit cut-back sequence was edited in the file each time before the log files were run. An example of one of the cut-back FDAN log files is listed below:

```
PrintFile                #e22_3d.praParametersFile          e22_3.parResultsFile
e22_3.resOutput_spreadsheet_data? YSS_Definition_File       e22_3s.ssdSS_Output_File
e22_3d.sso
SS_Output_File           #e22_3d.sso
Run_Descn                E22 Run 3D;COSTM=$*.**;A$**.**/lb NSR;1.1mtpa;10% Discount;11,16,25
Timecost_Ovr?            N
Initial_capital          0
COSTM                    *.**
PRICE                    **.**
PIT                      1-1-45
DISCOUNT                 10
ROCK/L                   0
MILA/L                   1.1m
MILB/L                   1.1mMILC/L                   1.1mMETAL/L                0Modify_params?
Specified_schedule?      y
Push-Backs               11 16 25 45
Lag                      0
Worst_case?              N
Best_case?               n
OK?                      Y
Another_request?         N
Full_print?              N
```

An example of the spreadsheet output (E2_3D.SSO) from the FDAN log file (E22_3D.LOA) is listed below:

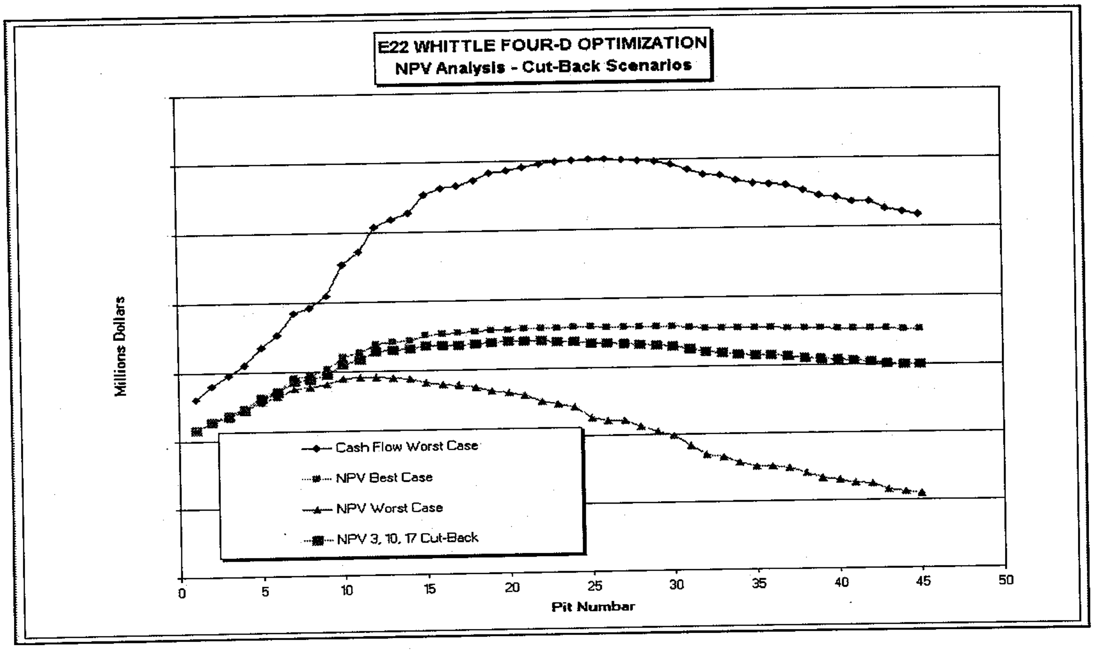
E22 Run 3D; COSTM=$*.**[2]; A$**.**/lb NSR;1.1Mpa; 10% Discount; Pits 11,16,25

	Grand totals:										Pit	Price
	Rock	Oxid	Oxid	Tran	Tran	Sulp	Sulp	Strip	Opvalue			
/FI		/TG	/TI	/GG	/TI	/GG	/TI	/GG		/DS		
1	**.**	4152037	7593	1.07	469785	1.35	3168799	1.29	0.14	********		
2	**.**	4766674	7922	1.06	487590	1.33	3579375	1.26	0.17	********		
3	**.**	5188835	8578	1.06	513459	1.3	3933504	1.23	0.16	********		
4	**.**	5793185	8578	1.06	539900	1.28	4283646	1.21	0.2	********		
5	**.**	6954742	10088	1.03	609917	1.23	4892408	1.18	0.26	********		
6	**.**	7718239	10110	1.03	635058	1.21	5403517	1.15	0.28	********		
7	**.**	9256127	10219	1.02	675315	1.18	6436221	1.1	0.3	********		
8	**.**	9587438	10285	1.02	681703	1.18	6653636	1.09	0.31	********		
9	**.**	10702057	10285	1.02	705420	1.17	7283268	1.07	0.34	********		
10	**.**	13972468	10416	1.02	754215	1.13	9085267	1.02	0.42	********		
11	**.**	15426069	10416	1.02	754531	1.13	9816907	1.01	0.46	********		
12	**.**	19091129	10416	1.02	772400	1.13	11441489	0.98	0.56	********		
13	**.**	20153591	10416	1.02	772400	1.13	12004289	0.97	0.58	********		
14	**.**	21244742	10416	1.02	772874	1.13	12427729	0.96	0.61	********		
15	**.**	25048125	10416	1.02	776827	1.12	13949969	0.95	0.7	********		
16	**.**	26650236	10416	1.02	776827	1.12	14550289	0.94	0.74	********		
17	**.**	27386978	10416	1.02	787927	1.12	14745393	0.94	0.76	********		
18	**.**	28743632	10416	1.02	787927	1.12	15246553	0.93	0.79	********		
19	**.**	31288062	10416	1.02	787927	1.12	16232793	0.92	0.84	********		
20	**.**	32429130	10416	1.02	787927	1.12	16637473	0.92	0.86	********		
21	**.**	34288680	10416	1.02	787927	1.12	17213673	0.91	0.9	********		
22	**.**	37343182	10416	1.02	787927	1.12	18119513	0.9	0.97	********		
23	**.**	38953378	10416	1.02	787927	1.12	18575113	0.9	1.01	********		
24	**.**	40481914	10416	1.02	787927	1.12	19017313	0.9	1.04	********		
25	**.**	45776701	10416	1.02	787927	1.12	20451113	0.88	1.15	********		
26	**.**	46951924	10416	1.02	787927	1.12	20764673	0.88	1.18	********		
27	**.**	47160833	10416	1.02	787927	1.12	20802193	0.88	1.18	********		
28	**.**	50085466	10416	1.02	787927	1.12	21520433	0.88	1.24	********		
29	**.**	51991223	10416	1.02	787927	1.12	21874193	0.88	1.29	********		
30	**.**	54333390	10416	1.02	787927	1.12	22442353	0.87	1.34	********		
31	**.**	58876522	10416	1.02	787927	1.12	23372313	0.87	1.44	********		
32	**.**	62741426	10416	1.02	787927	1.12	24109313	0.86	1.52	********		
33	**.**	63812825	10416	1.02	787927	1.12	24315673	0.86	1.54	********		
34	**.**	66585551	10416	1.02	787927	1.12	24886513	0.86	1.59	********		
35	**.**	68535987	10416	1.02	787927	1.12	25232233	0.86	1.63	********		
36	**.**	68745947	10416	1.02	787927	1.12	25269753	0.85	1.64	********		
37	**.**	69400277	10416	1.02	787927	1.12	25398393	0.85	1.65	********		
38	**.**	71576185	10416	1.02	787927	1.12	25786993	0.85	1.69	********		
39	**.**	73835288	10416	1.02	787927	1.12	26231873	0.85	1.73	********		
40	**.**	74744150	10416	1.02	787927	1.12	26411433	0.85	1.75	********		
41	**.**	76305066	10416	1.02	787927	1.12	26649953	0.85	1.78	********		
42	**.**	76542201	10416	1.02	787927	1.12	26682113	0.85	1.79	********		
43	**.**	79135693	10416	1.02	787927	1.12	27092153	0.84	1.84	********		
44	**.**	80146984	10416	1.02	787927	1.12	27282433	0.84	1.85	********		
45	**.**	81137665	10416	1.02	787927	1.12	27459313	0.84	1.87	********		

The resultant spreadsheet output files (E22_3D.SSO to E22_3K.SSO) contain the field Opvalue/DS which is the NPV of the nominated pit schedule.

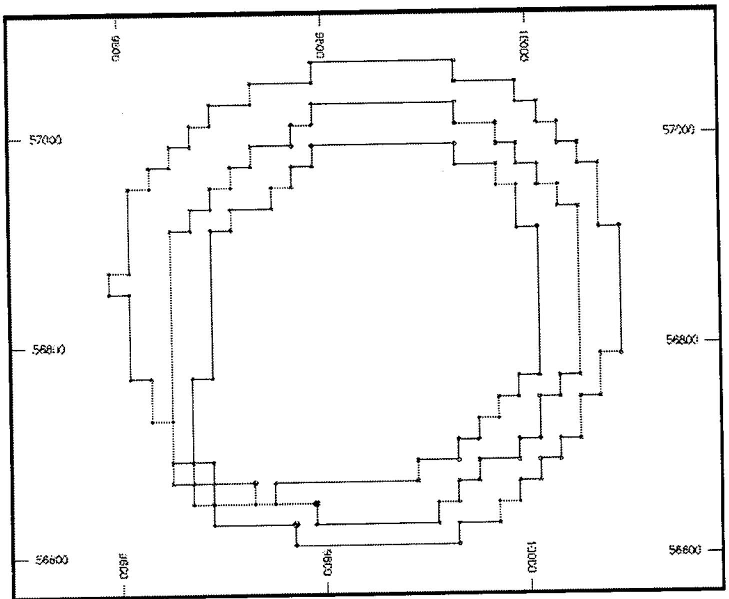
The scheduled NPV values were placed in a spreadsheet together with the worst case cash flow, best case NPV and worst case NPV from the E22_3B.SSO FDAN run. A graph was produced to display the improvement in the NPV from the various cut-back schedules. As a result of the cut-back analysis an improvement in NPV of several millions of dollars was achieved, this represented approximately a 16% increase in the NPV of the project.

[2] Data including COSTM, unit value of metal (AU$/lb NSR) and discounted scheduled value have been replaced by asterisks because they sensitive commercially.



Preparation of Whittle Outer-face Pits

The parameter file (E22_3.PAR) and results file (E22_3.RES) are used as input into the Datamine process FDIN and the Datamine file generated is a model file (PITS.M) of all 45 pits produced by the optimisation. The Datamine process BLKPER can then be used to create a series of perimeters for selected pits. The pit perimeters (WHIT3.P, WHIT10.P and WHIT17.P) for each cut-back sequence was prepared in this manner then evaluated in Guide.



The Guide command 'query-line' (ql) is used to measure the distance between the pit shells to ensure that they meet the operational constraints for a suitable cut-back sequence. The final step is to run a Datamine macro (INVENT.MAC) to produce a bench inventory for each pit.

A summary inventory for the cut-back sequence is prepared and this inventory is compared with the bench inventory for the corresponding pit in the FDOP print file. This provides a crosscheck of the tonnage and contained metal between the two major components of the cut-back study.

Conclusions

The methodology used in cut-back analysis proved to be very successful. This is a direct result of a number of functions or procedures that are reaffirmed below:

- the use of the various Datamine processes to produce an accuracy representation of the deposit in the form of a block model and an easy interface with Whittle Four-D
- the use of FDAN log files to produces a series of cut-back pit sequences
- the use of the spreadsheet definition files (*.SSD) and the resultant spreadsheet output file (*.SSO)
- the use of parsing function in Excel which readily imports the spreadsheet output files
- the ease in which multiple series graphs are generated in Excel
- the use of the import function in Datamine of the Four-D results file to produce a model of the pit sequence
- the transformation in Datamine of the pit model into perimeters of the various pits in the sequence, and
- the ability to view the perimeters for each pit in Guide and to interrogate the distance between the pit shells.

The most satisfactory outcome of the cut-back analysis was the improvement in the NPV of several millions of dollars which represented approximately a 21% increase in the NPV of the project.

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