APPLICATION OF WHITTLE 3D PIT OPTIMIZER TO A MULTI-SEAM COAL DEPOSIT

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ABSTRACT

Geologically the Sapan Dalam Coal deposit of Indonesia consists of multi-seams with variable thicknesses (0.10 - 3.5 m) and quality parameters. The complex nature of the deposit coupled with limited exploration data made it difficult to create a realistic geological model. With the available geological information, a gridded seam model was created using GEMCOM suite of mine design modules. Attempts to create an optimum pit with WHITTLE 3D pit optimizer proved unsuccessful since the pit optimizer has been developed purposefully for regular fixed block economic models. The gridded seam model was further converted to a partial block model before the WHITTLE 3D could be used to optimise the pit. The optimum "Whittle pit" was further smoothed by a base control technique in order to obtain a realistic pit.

INTRODUCTION

The geology of Sapan Dalam coal deposit of Indonesia consists of steeply dipping multi-layers and narrow seams. The deposit has been proved by twenty seven diamond drilled holes. Traditionally, the company's mine plans have been based on a manual interpretation of the geological information. The manual technique hardly provides the flexibility to make immediate changes to mine plans as more geological information is made available. With an aid of a commercial mine planning software, the economic viability of the deposit was evaluated using the company's current mining and cost parameters. This paper discusses how GEMCOM Service Inc. (Gemcom, 1992) suite of mine planning modules and WHITTLE 3D (Whittle, 1992) pit optimizer were used to design an optimum

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pit for the multi-seam coal deposit in Indonesia (Milawarma, 1995). The mine planning modules used in this case study were PC-XPLOR, GEO-MODEL, GEM-SOLID and PC-MINE. The stages of this exercise included block model preparation, pit optimization, pit sequencing and production scheduling (Figure 1).

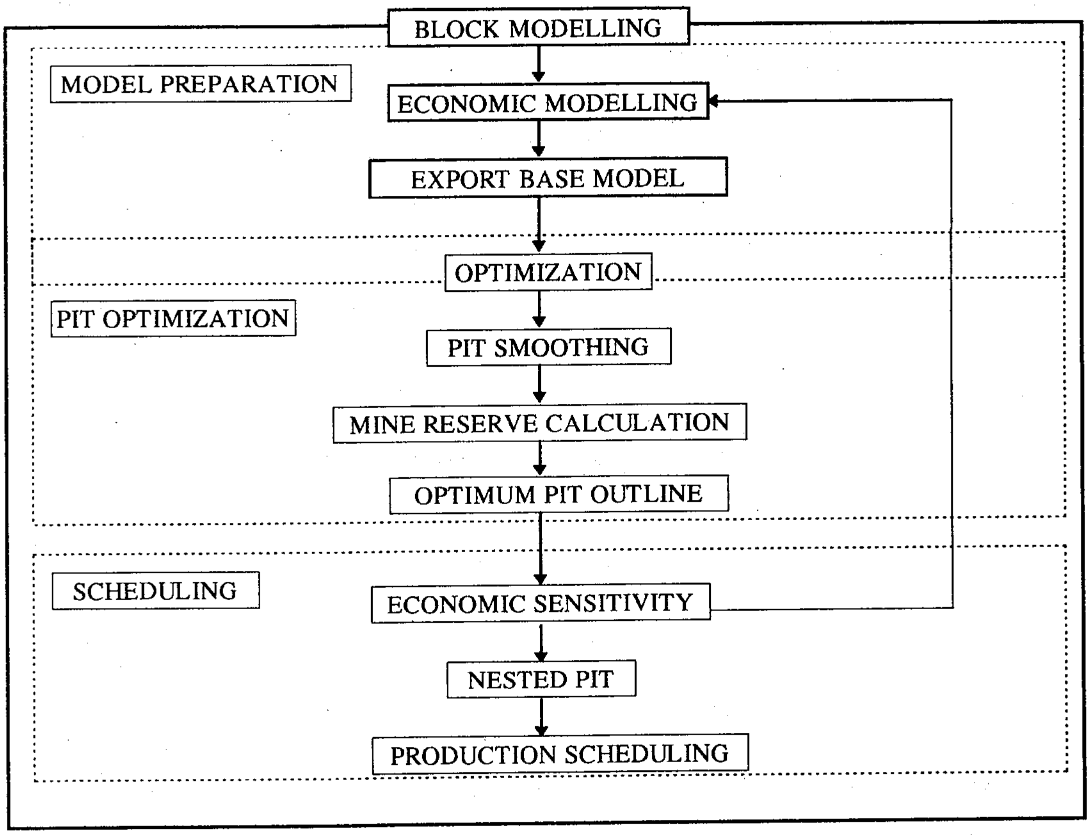

Figure 1 : Mine planning and design stages of Sapan Dalam Coal Deposit

Owing to complex nature of the multiple seam, the base geological block model was created using the gridded seam modelling technique. A standard regular or fixed block was avoided because of the difficulty in obtaining an accurate coal tonnage within a block unless the block size was smaller than the coal thickness. Unfortunately, the available version of WHITTLE 3D pit optimizer was limited to a regular fixed block model. This meant that the base block model of the Sapan Dalam coal deposit had to be converted from the gridded seam model to a regular or a fixed block before the WHITTLE 3D could be used to develop an optimum pit. After converting the gridded seam model to a regular block, two economic block models were created for both domestic and export coal markets.

BASE GEOLOGICAL MODEL

Twenty seven exploration drill holes from the Sapan Dalam area and seventeen control drill holes from nearby area, Kandi and Tanah-Hitam were the main sources of geological information. The lengths of drill holes vary between 20 and 158 metres. The coal deposit consists of ten different coal layers with seam thicknesses varying between 0.1 and 3.5 meters and complicated by four major faults. The four major faults in the area and the locations of the twenty seven drill holes are shown in Figure 2. The available exploration drilled holes are divided into North-West and South-East areas by the faults. The drill holes spacings vary between 50 to 200 metres in North-West area, and between 100 and 200 metres in the South-East area. The overall model area is characterized by three parallel faults in the NNE direction and one fault in the NNW direction.

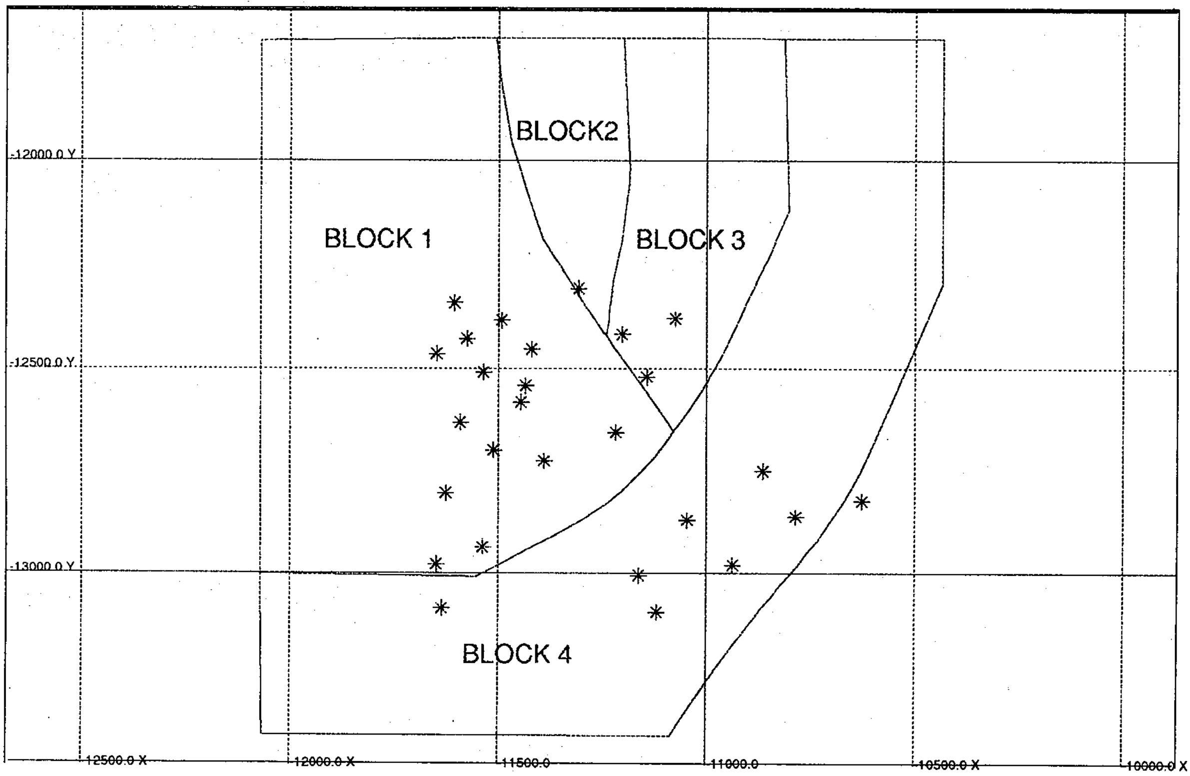

Figure 2 : Locations of fault block zones and drill hole in Sapan Dalam area

The four fault blocks in Figure 2 were created by drawing imaginary lines from the faults to the map edges to isolate each block. These four fault polygons were used to control the geological model. A combination of fault-block and restore-surface technique was used to create a geological model of the coal deposit. The four blocks were modelled independently and then combined into one main geological block model.

The geological complexity of the deposit influenced the sizes of the blocks in the geological model. A smaller block size was not practical owing to the limited amount of exploration data in such a large area. In addition, smaller blocks will also require an excessive disk storage space and a longer computing time on a standard IBM compatible 486 PC. Furthermore, the PC-MINE module which was used in the mine planning exercise limits the number of blocks in a model as follows:

- the maximum number of rows or columns or level is 256,
- the combined maximum number of rows and levels is such that (number of levels) *x* (number of rows) must not exceed 32,760 or the total number of blocks in the block model must not exceed 32,660 x 256 blocks (i.e 8,386,560 blocks).

The PC-MINE program dictated that a block size could not be smaller than 10m *x* 10m *x* 1m for the proposed mining area. Therefore, the number of blocks for the Sapan Dalam area was restricted to 3,554,496 blocks, i.e. 132 *x* 132 *x* 204 blocks (Eastern blocks *x* Northern blocks *x* Number of benches) and a block dimension of 10m *x* 10m *x* 1m (Length *x* Width *x* Thickness). Figure 3 shows the extend of the modelled area.

After creating a gridded seam model, the base model was converted to a partial block model; PC-MINE module has an option to create a partial fixed block model from a gridded seam model. A partial block model is a regular or fixed block in which all the blocks have the same dimensions but each block can be assigned two different materials - coal and waste. The partial block modelling uses both a gridded seam model and a polygon control to allocate rock type to each block. If a block is located below or is on a given surface grid and is inside a given polygon, the block is assigned a rock type which has been defined in the polygon, otherwise the whole block is treated as air block or a predefined (default) block.

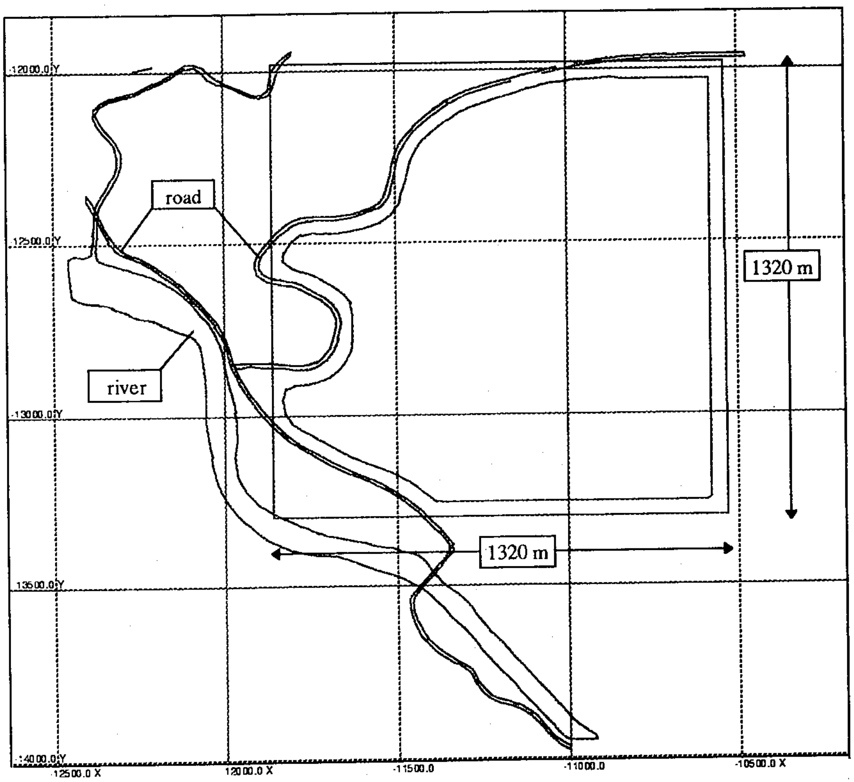

Figure 3: Sapan Dalam mining area for pit optimization

There are three options for assigning a block if a grid cuts through a model block :

- include the whole block
- include the whole block if more than half is below the grid
- exclude the whole block

In the partial block modelling, the PC-MINE starts from the uppermost surface (the initial surface topography) to the lowermost grid through subsequent grids. The PC-MINE module also searches for a fraction of block within the polygon (Fp) and a fraction of block below surface (Fs) and then accumulates these fractions into a percentage of coal in each block. In calculating coal tonnage inside a block, the PC-MINE module uses this percentage of coal within a block. Finally, the base model was exported to WHITTLE 3D format with appropriate cost parameters. The economic parameters used to determine the ultimate optimum pit were based on the coal market price(Case 1 of Table 1) and domestic coal consumption rate (Case 2 of Table 1). The coal price and cost parameters were based on the company annual report 1993/1994 (US$ 1.00 is equivalent to Rp 2,150 local Indonesian currency) and are summarised in Table 1.

Table 1 : Cost parameters for economic block modelling

ECONOMIC PARAMETER	CASE 1	CASE 2
A. Coal Price (US$/tonne)	29.00 (f.o.r)	32.63 (f.o.b)
B. Waste Stripping Cost: ($/m^3)	2.179	2.179
1. Drilling	0.25	0.25
2. Blasting	0.17	0.17
3. Fixed Load and Haul	0.567	0.567
4. Surface Hauling (2000 m)	1.192	1.192
C. Coal Mining and Processing Cost:		
1. Coal Mining		
a. Fixed Load and Haul (US$/m^3)	0.29	0.29
b. Surface Hauling (US$/tonne/100 m)	0.0244	0.0244
2. Coal Handling and Processing: (US$/ton)	1.065	4.97
a. Processing	1.00	1.00
b. Transport	0	3.65
c. Port and Handling	0	0.19
d. Surveyor	0.065	0.13
D. Over-head and Administration: (US$/ton)		
1. Head Office	9.5	9.5
a. G & A	5.5	5.5
b. Depreciation	1.53	1.53
c. Equipment	0.64	0.64
d. Tax	1.83	1.83
2. Mine Office	2.93	2.93
a. G & A	1.71	1.71
b. Depreciation	0.46	0.46
c. Equipment	0.11	0.11
d. Tax and Exploitation Fee	0.65	0.65

In Case 1, coal is used for domestic market without the coal-port and other transport facilities from mine site at a price of US$ 29 per tonne. In Case 2, coal is used for both export and domestic markets, and accounts for the transport costs from mine-site to the coal port; a f.o.b coal price of US$ 32.63 per tonne was assumed.

ULTIMATE PIT OPTIMIZATION

Pit optimization of the Sapan Dalam block model was carried out in the steps illustrated in Figure 4.

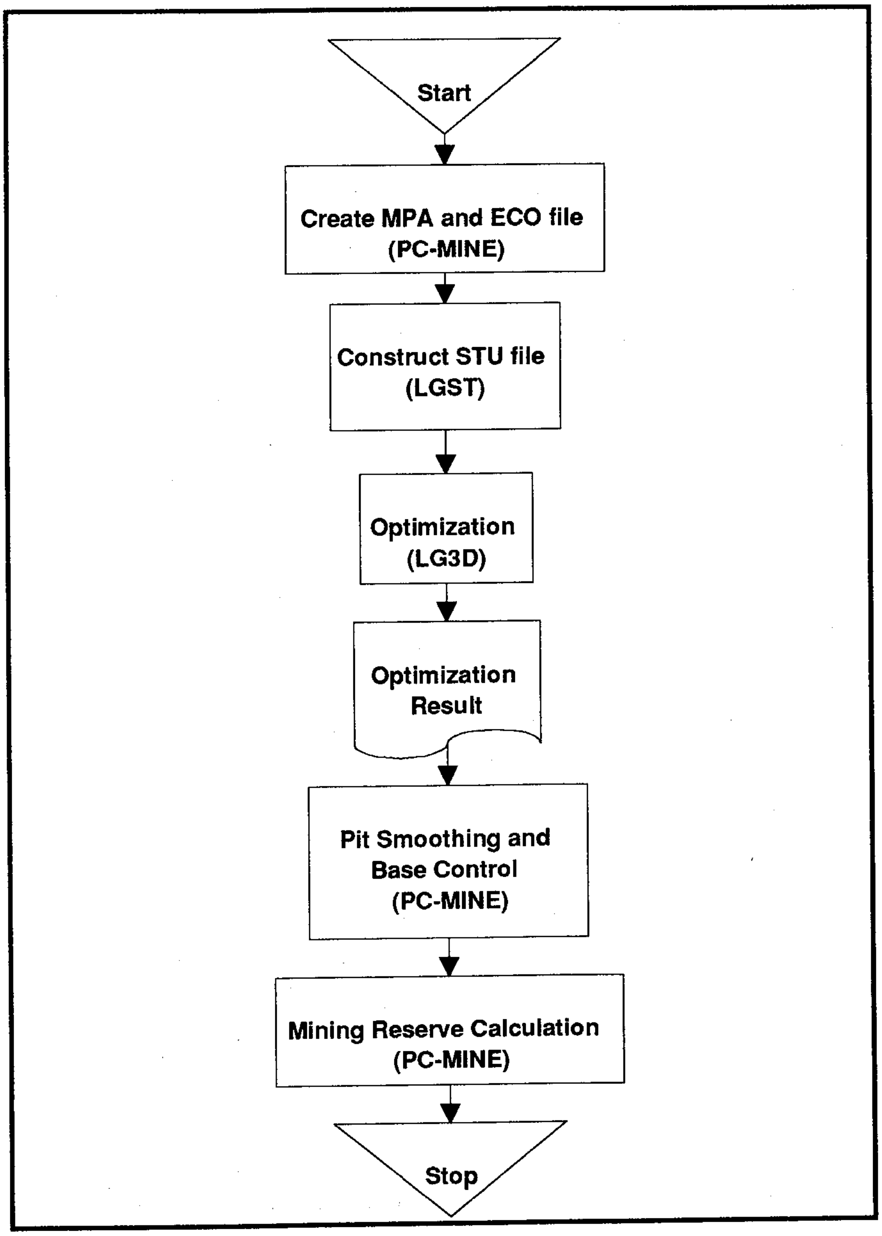

Figure 4 : Sapan Dalam Optimization Stages

The model parameter files defined the general information of the base model including the following:

- the dimension of a block in X, Y and Z directions is 20m *x* 20m *x* 12m after reblocking,
- the number of blocks in X, Y and Z directions is 66 *x* 66 *x* 17 after reblocking,
- an active block indicator 3 defined only blocks that appear in the economic file are considered; and air flag 1 defined an air block,
- the default value of a waste block is -10464 for a hundred percent waste block,
- the number of sub-regions is 1,

- the lowest and highest bench limits in X, Y and Z directions are 1 - 66,
- 1 - 66 and 1 - 17, respectively (in terms of number of blocks),
- the number of slope angles is 4, and the maximum number of benches for structure calculation is 6,
- the bearing clockwise of slope angle is 0, 90, 180, 270 from Y positive with average slope angle 40 degree in all directions,
- the number of mining phase is 1, which meant that an intermediate pit outline is mined to the ultimate pit outline,
- the reblocking factors in X, Y and Z directions are 2, 2, and 12, respectively.

The LGST module of the pit optimizer examines each block in the base model and writes out to the structure file (*.STU) those arcs appropriate to block and rejects arcs that go outside the model. The structure files contain the structure arcs calculated from the block proportion, the region limit, the bearings and slopes as defined in model parameter file. The arcs are stored as lists toward each block from below. The LG3D module of the pit optimizer then writes out the lists of the blocks that must be mined in a result file (*.RES) for given mining and economic parameters.

RESULTS

As depicted in Table 2, Case 2 resulted in 4731 ore blocks (positive blocks) and 3865 waste blocks (negative blocks), and the optimum pit in Case 2 gave a higher total economic value than Case 1. From Figure 5, the optimum pit generated by the optimizer is not realistic for subsequent pit design. This is because the optimum pit by the optimizer overmined through the actual bedrock layer because of a relatively high reblocking factor used in generating the economic files. The PC-MINE module was further used to generate a realistic pit (Figure 6). The PC-MINE uses a moving weighted average method to smooth surface topographies of block generated by other packages, including the WHITTLE 3D.

	CASE 1	CASE 2
Blocks read:	24139	24135
air (zero)	87	52
ore (+ve)	6630	6704
waste (-ve)	17422	17379
Blocks accepted	24139	24135
Structure arcs read	817140	817140
Apply to blocks in the Model	192522	192946
Passes	86	128
Arcs checked	16556892	24697088
Arcs added	16624	17904
Run results:		
Arcs checked	16556892	24697088
Arcs added	16624	17904
Blocks to be mined	7137	8596
Total value (US$)	21,183,450	24,724,380
Blocks written:	7137	8596
ore (+ve)	4234	4731
waste (-ve)	2903	3865

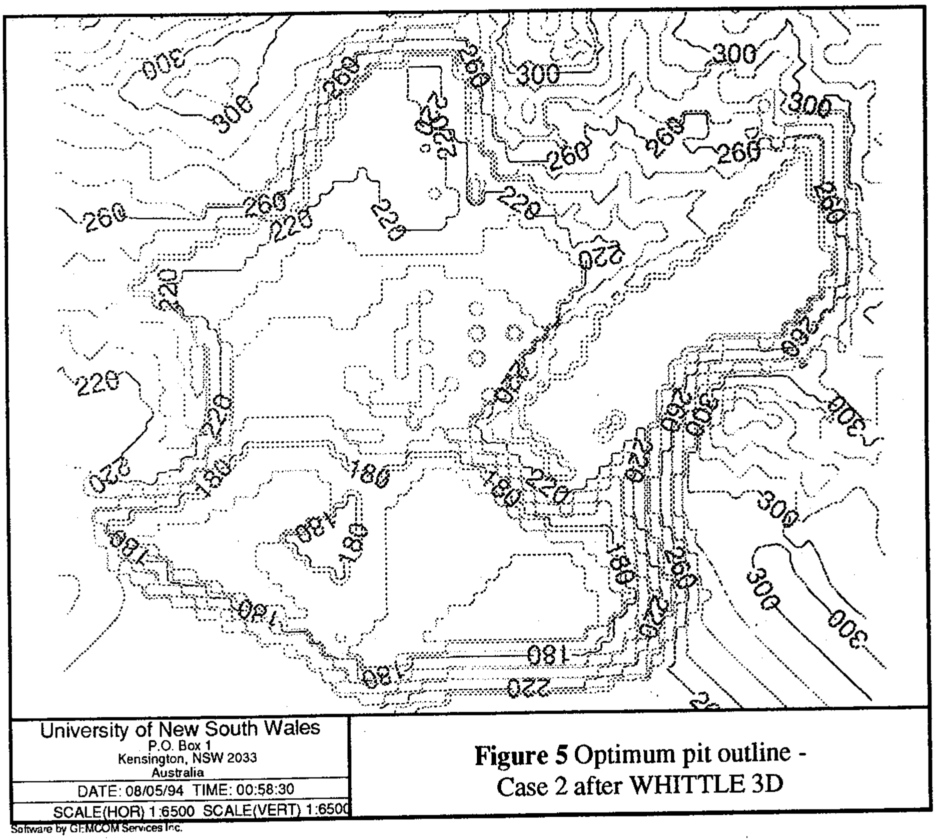

Figure 5 Optimum pit outline - Case 2 after WHITTLE 3D

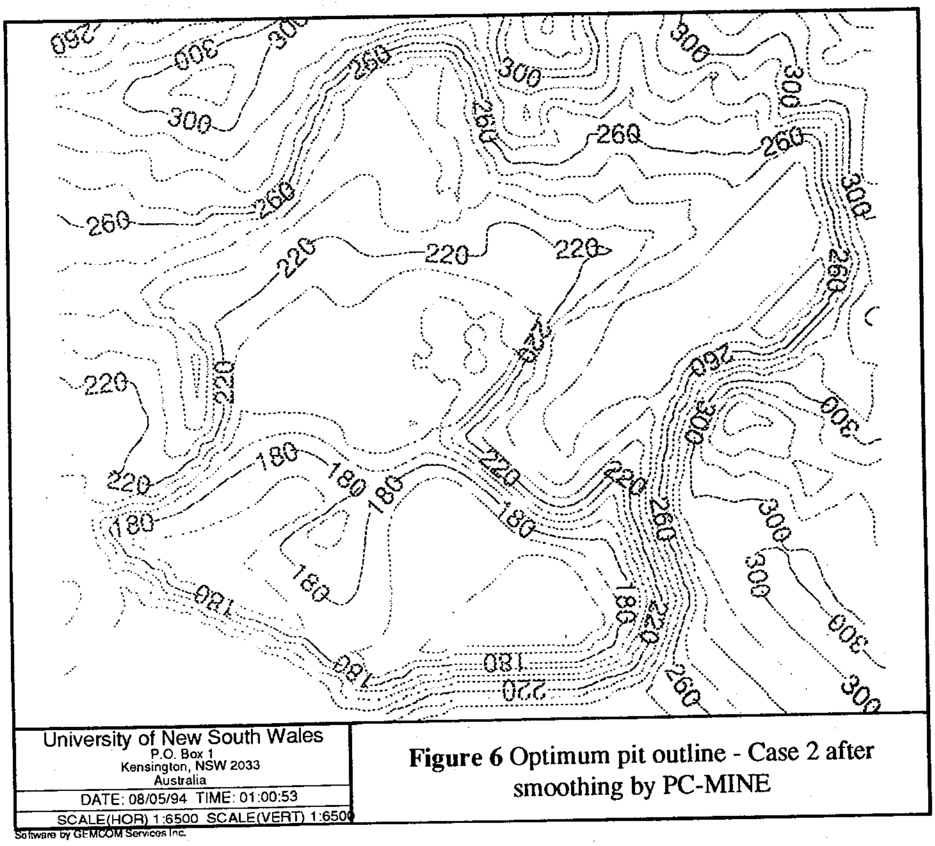

Figure 6 Optimum pit outline - Case 2 after smoothing by PC-MINE

CONCLUDING REMARKS

The pit optimization of the Sapan Dalam coal deposit was conducted on a partial block geological model converted from a gridded seam model. The optimum pit outlines obtained from the WHITTLE 3D pit optimizer had to be adjusted to the pit base to avoid overmining the bedrock layer. The use the PC-MINE waste fill routine was very apt given the complexity of the Sapan Dalam coal deposit. Eight economic models were further generated with the pit optimizer to produce eight nested pits for pit sequencing and production scheduling. Using the pushback generation approach, the nested pits were used to schedule medium term mine production.

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