The Effect of Minimum Mining Width on NPV
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Abstract

This paper describes the application of an automated procedure to provide minimum mining width adjustments to Four-X pit outlines. The cost of applying the minimum mining widths can be measured by the change in NPV of the resultant pit shell.

The effects of minimum mining width and other control features are explored in a test case and are extrapolated to a set of rules for use in practical push-back operation.

Introduction

The push-backs and final pit outlines used by Four-X for its life-of-mine simulations obey the required pit slopes but do not necessarily conform with the practical requirements of mining. There may be insufficient space for mining equipment, uneven pit floors due to small drop cuts, inconvenient small irregularities in the pit wall, and sharp corners.

Although it was never expected that Four-X would produce a detailed design, if only because it doesn't include haul roads, the nearer it approaches the detailed design the more accurate and useful are the simulations, and the easier it is to produce the detailed design.

A new module, FXMW, has been developed which addresses these problems by modifying the normal Four-X push-backs. The resultant file can be analysed in the same way as a normal Results File, and the outlines can be fed back into the user's mining package. FXMW also works with Four-D.

Method

The user specifies the ultimate pit and a series of pit numbers to push back to. FXMW then groups the required pit shells together and gives a push-back number to each block. Thus, if there are three mining phases, every block within the pit will have a number from 1 to 3, with the blocks having a 1 representing the first push-back.

The user specifies a minimum mining width and FXMW converts this to a minimum number of blocks in the X and Y direction. This rectangular definition is known as a "template" and is used to control the application of the minimum mining width.

Associated with this template is a mining tolerance expressed as the number of blocks in the template which need not meet a specific criterion, such as belonging to a particular push-back. This feature allows more natural push-backs to be generated. If the tolerance is set to zero, then the push-backs become more rectangular and the pit expansion tends to become greater.

FXMW works on each bench in turn, from the bottom of the pit upwards. This means that, except on a floor of the pit, it can only reduce the push-back number of a block. Increasing the push-back number of a block, and thus mining it later, might make the pit slope steeper than required.

After each bench is processed, any changes are extended to the top of the pit using the block relationships from the Structure File which was used during optimization. If the outer pit expands, it either picks up information from the Results File or, if it is not in the Results File, then waste material is assumed.

The user can control the size of the template, the mining tolerance and seven other smoothing features. The effects of these other smoothing options are discussed below.

Drop cuts which are too small are removed

Any contiguous group of blocks from a particular push-back which is surrounded by blocks which are mined later or not at all (they are at the bottom of the pit) define a drop cut. In FXMW, blocks are regarded as contiguous if they share a side. Thus the “A” blocks in Figure 1 form a contiguous group, but the “B” blocks do not.

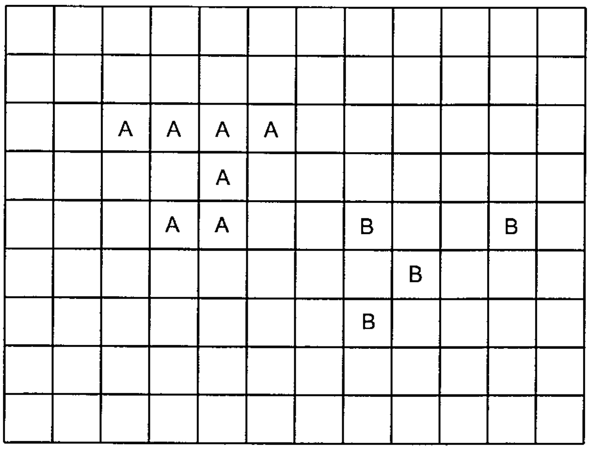

Figure 1

If a drop cut contains fewer than a user-specified number of blocks, it is removed. If it is surrounded by blocks which are not mined by any push-back, the drop cut blocks are removed from the pit. If the drop cut is surrounded by blocks which are to be mined, the blocks are given a higher push-back number, that is, their mining is delayed. Different numbers of blocks can be specified for each of the two cases.

The outer edge of the pit is tidied

If the user allows it, any small protrusions on the outer edge of the pit are tidied. In this context, a small protrusion is one into which the “template” will not fit, even allowing for the mining tolerance.

If the outer edge has to be tidied, it will be tidied in a manner that minimises the adjustment on the next bench level. In other words, if there is a choice on how to expand, the program will choose the region that causes less subsequent change to the next bench.

The remaining steps are carried out on each push-back from the last to the second.

Inaccessible blocks are dealt with

Any block in the push-back which cannot be covered by a template lying, except for the tolerance, entirely within the push-back, is defined as inaccessible. The next inner push-back is then extended to cover these blocks.

This means that narrow regions in a push-back are removed by extending the previous push-back.

Figure 2 illustrates what happens with a template which is three blocks by three blocks and where the tolerance is zero. A small portion of push-backs 1, 2 and 3 are shown, and the blocks marked with a cross are changed to push-back 1, thereby joining 1 to 3.

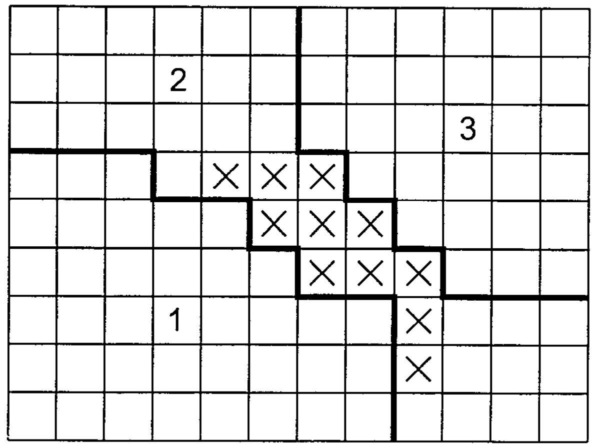

Figure 2

The resultant push-backs after this operation are shown in Figure 3.

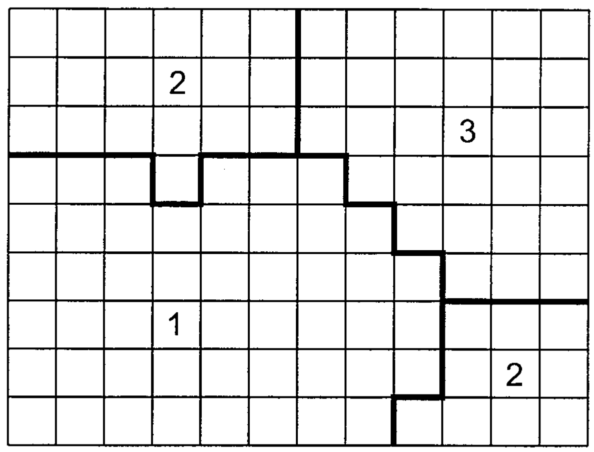

Figure 3

The obvious anomaly of the single block, or stump, sticking into push-back 1 is dealt with later when stumps and holes are tidied up.

If the block tolerance is set to 1, the result is the same. If it is set to 2 or more, the push-backs are unchanged.

We experimented with round, rather than rectangular templates, but these do not work as well as rectangular ones with a tolerance.

The outer edge of the previous push-back is tidied

This is done in a similar way to the tidying of the outer pit outline.

Any small walls are given a lower push-back number

A wall is a contiguous group of blocks belonging to a particular push-back which has a later push-back, or the side of the pit, on one side of it and an earlier push-back on the other side. If the number of contiguous blocks is less than a user specified minimum, then the blocks will be reassigned to the lower push-back and will be processed sooner. In both the cases illustrated in Figure 4, the wall would be assigned to push-back 1.

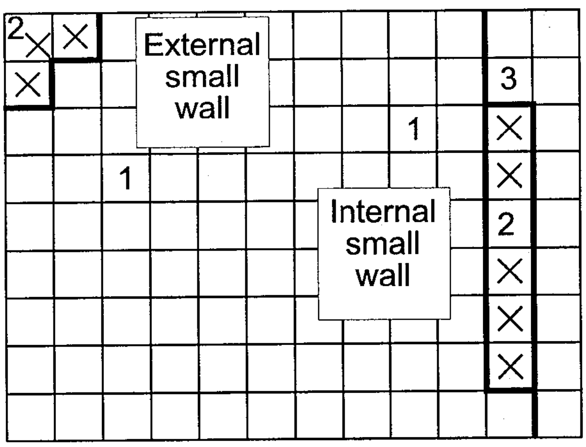

Figure 4

Small stumps are removed

A "stump" is a row of blocks belonging to a higher numbered push-back protruding into an otherwise straight wall of blocks. It is small if its length is less than the template width or template height as appropriate. Stumps are removed by decreasing the push-back number.

The stump shown in Figure 5 would become part of push-back 1, thereby providing a smooth wall to mine.

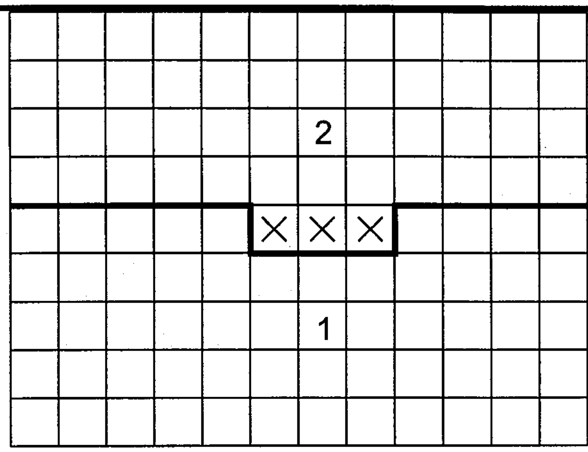

Figure 5

Small holes are removed

A "hole" is a row of blocks belonging to a lower push-back sticking into an otherwise straight wall of blocks. A hole is small if its length is less than the template width or template height as appropriate. Small holes are removed by assigning the blocks within them to a higher push-back but this can only be done if the blocks had earlier been given a lower push-back number. The hole shown in Figure 6 would become part of push-back 2, thereby providing a smooth wall to mine.

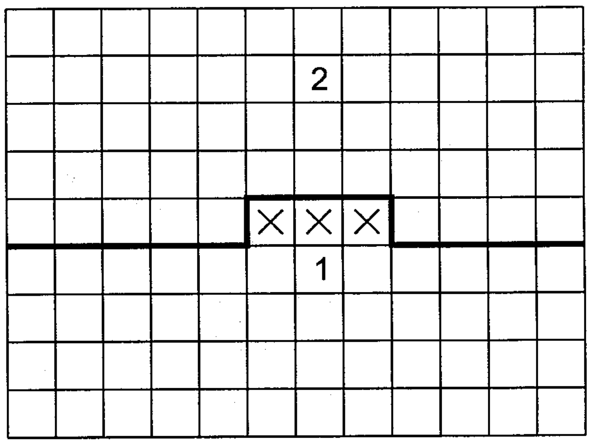

Figure 6

Corner blocks are removed

Corner blocks in a ninety degree corner may be removed. There are two cases to consider. The first case, marked with a cross, is where the push-back effectively expands. This will be carried out unconditionally if the user allows corner smoothing. The second case, marked with a cross and an asterisk (*) will only be made if the corner block belonged to a higher push-back before the bench adjustment was started.

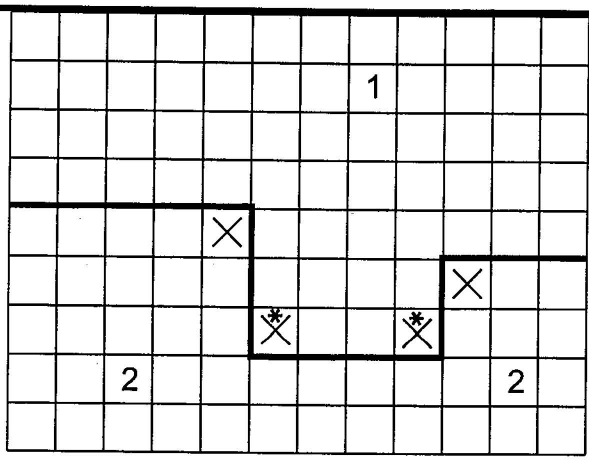

Figure 7

Example

The cost of applying the minimum mining width and smoothing strategies can be measured by the change in NPV of the resultant pit shell when re-analysed through the analysis program. The impact of these changes will depend on the grade tonnage distribution and is likely to be greater for projects that have large differences between their best case and worst case schedules. This is because some waste stripping is brought forward. In general, the impact will also increase as the mining width increases.

The following test case is based on a gold/silver deposit. It consists of a long thin ore body that forms two pits for the economic scenario under consideration. The block size is 10m x 10m, thus a 20m mining width is a 2 x 2 template with a tolerance of 1 block and a 30m mining width is a 3 x 3 template with a tolerance of 2 blocks.

The best and worst case schedules, depicted in Figure 8, show a large variation in NPV so that the selection of the push-backs will be important. The maximum mining rate is 2m tonnes per annum which indicates an initial push-back in the vicinity of pit 5 or pit 6.

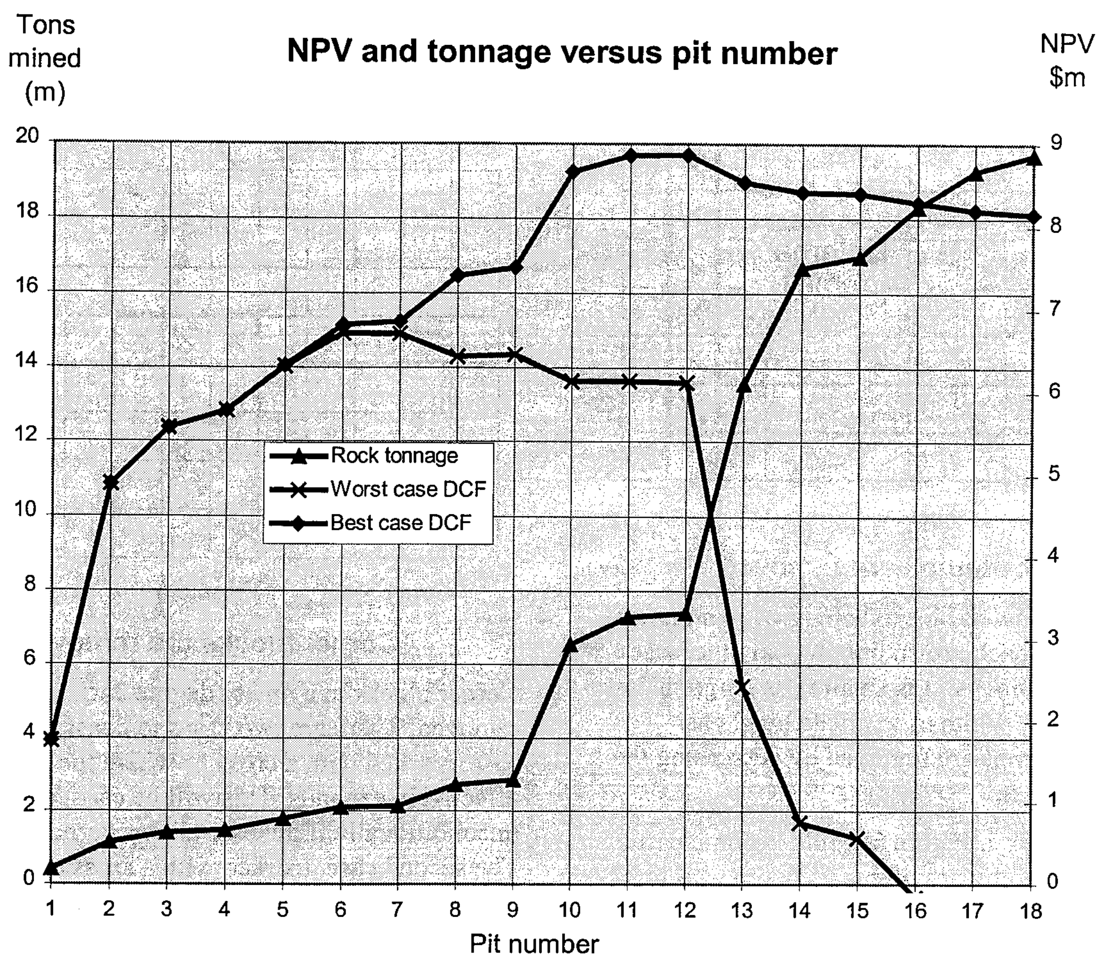

Figure 8

As the user has control over all the smoothing options in FXMW, it is possible to do a series of runs on a project and measure the impact of each option. While it is not necessary to do this, it does give you a measure of the relative effects of each option on the final NPV. You can also assess whether the design simplification is worth the cost.

Assuming that the pit is to be mined with a maximum of three push-backs the best specified schedule in this case is 5 9 11. The next best is 4 9 11. When FXMW is run the second alternative gives a considerably better smoothed result than the first.

The results of a series of runs, varying each option, for mining widths of 20m and 30m are tabulated below.

Description	% change in NPV
20m mining width (allow expansion of outer shell) Case A	-3.5
Case A and allow removal of stumps holes & corners Case B	-4.1
Case B and remove small walls < 5 blocks	-4.4
Case B and remove small walls < 10 blocks	-4.8
Case B and int drop cuts < 5 blocks	-7.2
Case B and int drop cuts < 10 blocks	-11.7
Case B and remove small walls and int drop cuts < 5 blocks	-7.1
Case B and remove small walls and int drop cuts < 10 blocks	-11.7
30m mining width (allow expansion of outer shell) Case A	-17.1
Case A and allow removal of stumps holes & corners Case B	-17.7
Case B and remove small walls < 5 blocks	-17.6
Case B and remove small walls < 10 blocks	-17.6
Case B and int drop cuts < 5 blocks	-21.9
Case B and int drop cuts < 10 blocks	-22.4
Case B and remove small walls and int drop cuts < 5 blocks	-21.1
Case B and remove small walls and int drop cuts < 10 blocks	-22.4

The cost of allowing for the removal of small stumps, small holes and smoothing the corners is, in general, very small compared to the costs associated with maintaining minimum mining width.

The costs associated with the removal of small walls will tend to increase with the number of blocks excluded. Intermediate drop cuts show a similar effect, however, it is quite common when both options are taken together to get a penalty less than the penalties associated with each smoothing option. In the above case for the 30m mining option, the cost of applying both intermediate drop cuts and isolated walls is no more than the cost of intermediate drop cuts.

Intermediate drop cuts can be deferred as a smoothing option and the only costs associated are the discounted cash flow time delays. Drop cuts in the pit floor can be removed and possibly mined at the end of the project. The costs associated with drop cuts on the pit floor have not been detailed here. The program will highlight which blocks are removed and the associated ore content. However, someone then has to remember to go back and schedule them. In many cases these blocks are valuable and are worth mining.

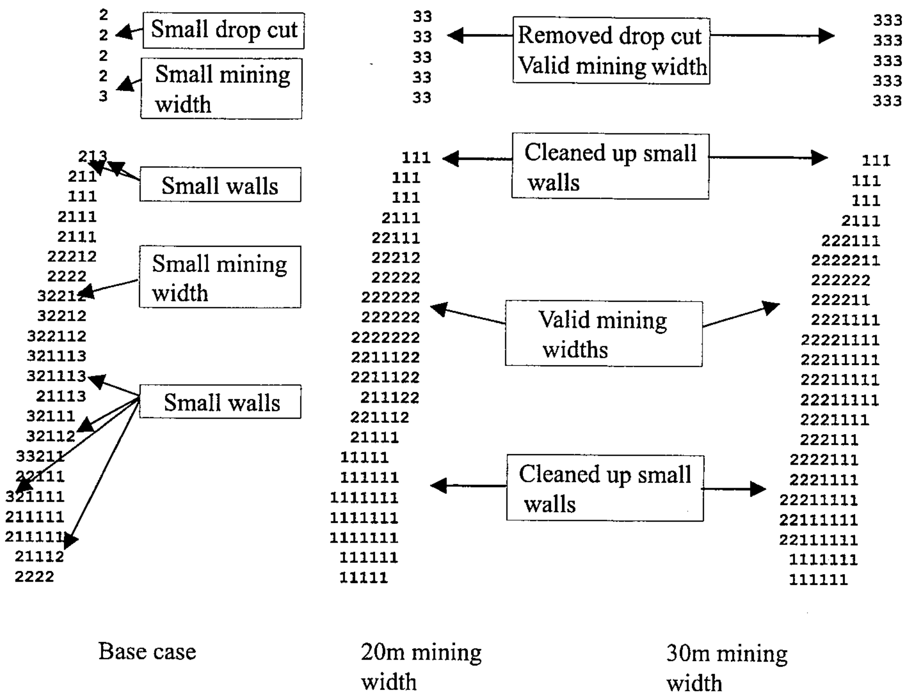

Figure 9: Typical bench detail

Figure 9 shows a particular bench before and after smoothing. The mining width has been applied within the tolerances allowed and isolated walls and small intermediate drop cuts have been removed. There are no stubs or holes in the above example. It is interesting to note how the different mining widths lead to different scheduling solutions.

Conclusions

The objective was to provide practical push-backs, that satisfy mining width requirements, and are easy to implement and require little user intervention. The heuristic is coded to minimise the modifications to the optimal outline. Since the resultant push-back is in the form of a Results File, the impact on the final NPV can be assessed. The final NPV will represent a more realistic project value as it takes into account the reduction in NPV caused by bringing waste stripping forward and possible extra mining due to pit expansion to meet minimum mining width conditions.

Sometimes there can be several scheduling options that produce approximately the same raw NPV value but produce vastly different results when smoothed. This again is a function of a project's sensitivity to the mining schedule and it is important for the user to check the value before and after to measure the impact.

In general, it will be best to create a base case consisting of the minimum mining width plus removal of stumps, holes and corners and then experiment with the effects of small wall and drop cut removal.