

A Comparison Between Whittle 4-D & Whittle 4-X Harry Warries

Qualifications: MSc Mining Engineering, Delft University of Technology, The Netherlands.
MSc Computer Science, University of Bradford, UK.

Membership: Aus. IMM.

Experience: Roche Bros.; Hamersley Iron, Australia.

Currently: Senior Mining Engineer, Resource Services Group, Perth, Western Australia.

1. Abstract

This paper deals with the greater flexibility allowed in open pit optimisation with the advent of Whittle Four-X, in particular with multi element deposits. The case study used in this paper compares the Whittle Four-D and the Whittle Four-X derived results using a mineral deposit that contains two economical products.

2. Introduction

One of the methods used to deal with a multi element deposit in Whittle Four-D is the equivalent metal/grade method. Without going into too much detail, simply, using one of the elements as the

primary/reference element, this method converts all the metal/grade contents of the individual elements concerned into a single element metal/grade. An example of an equivalent grade calculation using a simple conversion formula is described below:

$$EQG = Gr_E11 + Gr_E12 * Pr_E12 / Pr_E11$$

Where :EQG = Equivalent Grade

Gr_E11 = Grade for Element 1 [%]

Gr_E12 = Grade for Element 2 [%]

Pr_E11 = Price for Element 1 [\$/t]

Pr_E12 = Price for Element 2 [\$/t]

For the grades and prices tabled below:

ELEMENT	GRADE [%]	PRICE [\$/T]
1	2	2
2	0.2	10

$$\text{then EQG} = 2 + 0.2 * 10 / 2$$

$$= 2 + 1$$

$$= 3\%$$

The above example is a very simplified scenario. A more complex scenario would be where different mill recoveries were applicable for the elements concerned. The equivalent grade formula would be:

$$EQG = Gr_E11 + Gr_E12 * [Pr_E12 / Pr_E11] * [R_E12 / R_E11]$$

Where: EQG = Equivalent Grade

Gr_E11 = Grade for Element 1 [%]
Gr_E12 = Grade for Element 2 [%]
Pr_E11 = Price for Element 1 [\$/t]
Pr_E12 = Price for Element 2 [\$/t]
R_E11 = Mill Recovery for Element 1
R_E12 = Mill Recovery for Element 2

For the same example given previously, but with the following recoveries:

$$R_E11 = 90\%$$

$$R_E12 = 80\%$$

$$\text{then, EQG} = 2 + 0.2 * 10 / 2 * 0.8 / 0.9$$

$$= 2 + 0.89$$

$$= 2.89\%$$

The equivalent grade method can become complex and confusing, especially if there are different prices (prices expressed in different units), costs and recoveries. Further complexities occur when different product streams, complex pricing structures (which incorporates product penalty rates,

net smelter returns etc) are included in the equivalent grade calculation.

Some of the more basic problems associated with the equivalent grade method are listed below:

1. The ratio between the prices of the different elements is fixed. In other words a change in price of the primary element results in a change in price of *all* elements. To assess the true impact of a different pricing scenario you would have to recalculate the equivalent grade in your general mine planning package, export it to Whittle Four-D and run the pit optimisation again.
2. The Whittle Four-D calculated cut off is a cut off for the equivalent grade.
3. Any grades reported by Whittle Four-D are equivalent grades. One needs to import the Whittle Four-D results into a general mine planning package for example, to determine the grades of all elements within a pit shell.

With Whittle Four-X these problems have been resolved.

3. The basics of Whittle Four-X

Figure 3.1 is an example of a typical Whittle Four-X parameter file. The figure highlights the principal changes that have been incorporated into a Whittle Four-X parameter file. The key parameters of interest are printed in bold, and these are:

- i) Waste mining cost (line type 13).
- ii) Revenue factor (line type 14). This is simply a scaling factor.
- iii) Product price for the respective elements (line type 20).
- iv) Processing cost (line type 25).
- v) Element data (line type 26), such as element processing cost per unit and recovery.

In essence, all parameters are specified by element. Furthermore, explicit costs and prices are used in the parameter file

It is of note that two important (Whittle Four-D) line types have changed, namely line type 14 and line type 16. Line type 14 is the MCOSTM range, which has been replaced by the Revenue Factor whilst line type 16 is the C-Ratio which has disappeared all together as a result of the above described changes.

FIGURE 3.1
A TYPICAL FOUR-X PARAMETER FILE

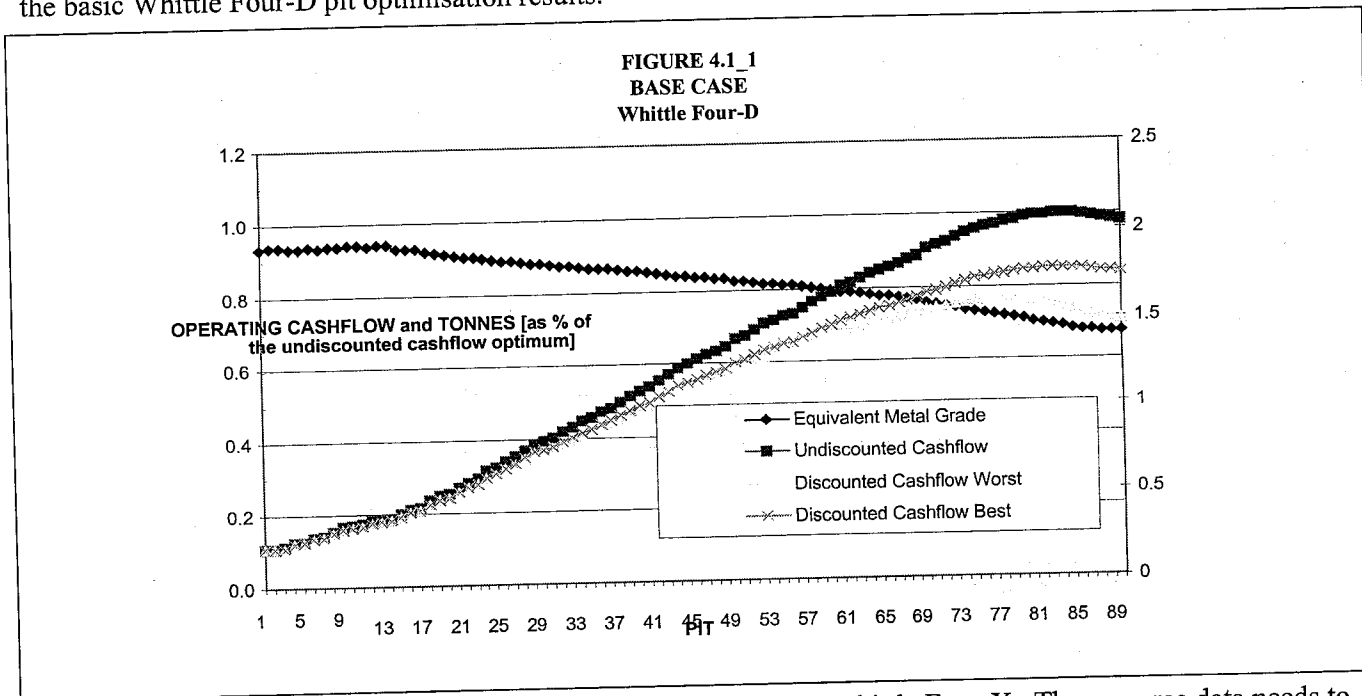
1	10.00	20.00	2.00				
2	74	63	41				
3	1	1		1	1	1	2.00
4	1	74	1	63	1	41	
5	2	41	0				
6	0.00	50.00					
6	180.00	50.00					
12	1	0	2	0	4	3	2
13		0	1.000	1.000		1	2
14	0.2500	0.0175	1.9825				
20	EL1	2	1	0.000		10.0	
20	EL2	3	2	0.000		50.0	
21	ORE	1.000	0.000	1.000			
25	MILL ORE	15.00					
26	EL1	C	0.000	0.900			
26	EL2	C	0.000	0.800			

The fact that the MCOSTM and the C-Ratio have been made redundant is significant and should not be discarded as being trivial. It allows for Whittle Four-X to be more transparent. Everyone understands real costs and product prices. Not everyone is comfortable with the MCOSTM being described as the inverse of the product price divided by the cost of mining. Some of the mystique that surrounds the mechanism of the pit optimisation has thus become less daunting.

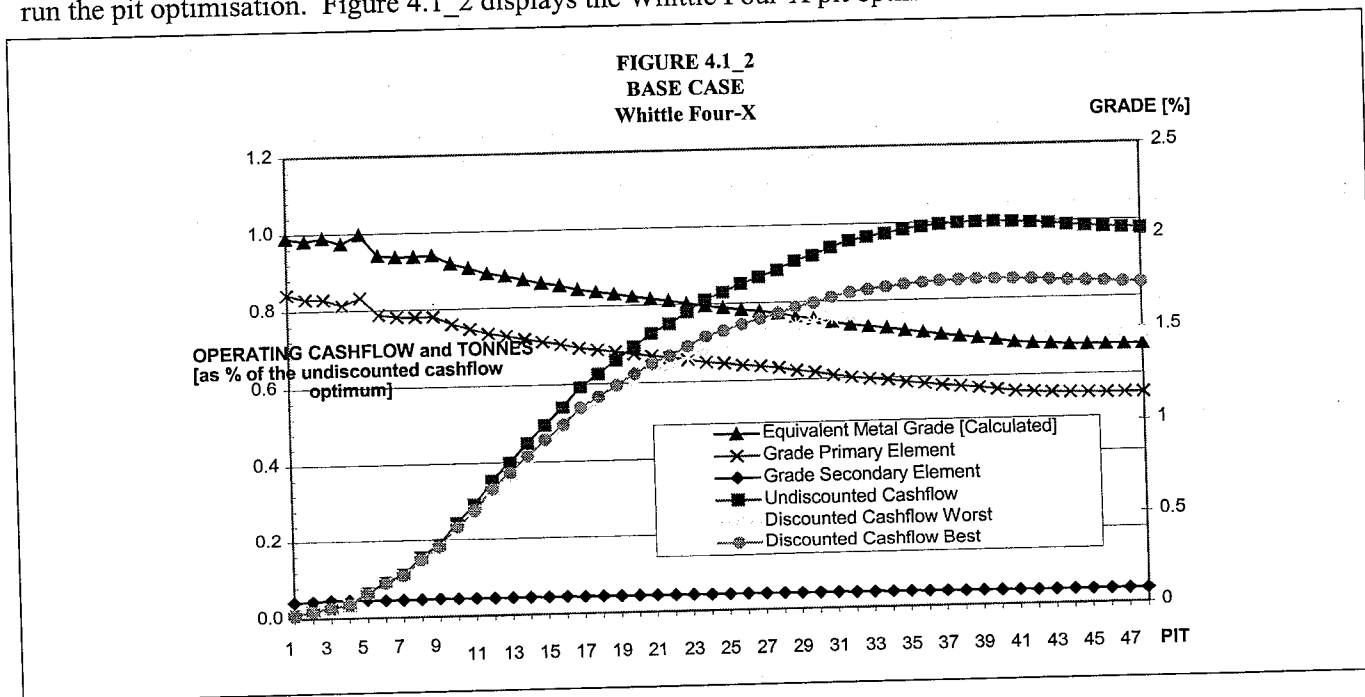
4. Case study

4.1 A Comparison of the Basic Pit Optimisation Results in Whittle Four-D and Whittle Four-X.

The mineral deposit used in this case study contains two elements/products of economic interest. Initially Whittle Four-D, using the equivalent grade method, was used to run a pit optimisation. Figure 4.1_1 displays the basic Whittle Four-D pit optimisation results.



The resource model file used in Whittle Four-D can not be used in Whittle Four-X. The resource data needs to be exported from your general mine planning package for the different elements separately. Subsequently, the two resource model files were combined within Whittle Four-X using FXRB. Whittle Four-X was then used to run the pit optimisation. Figure 4.1_2 displays the Whittle Four-X pit optimisation results.

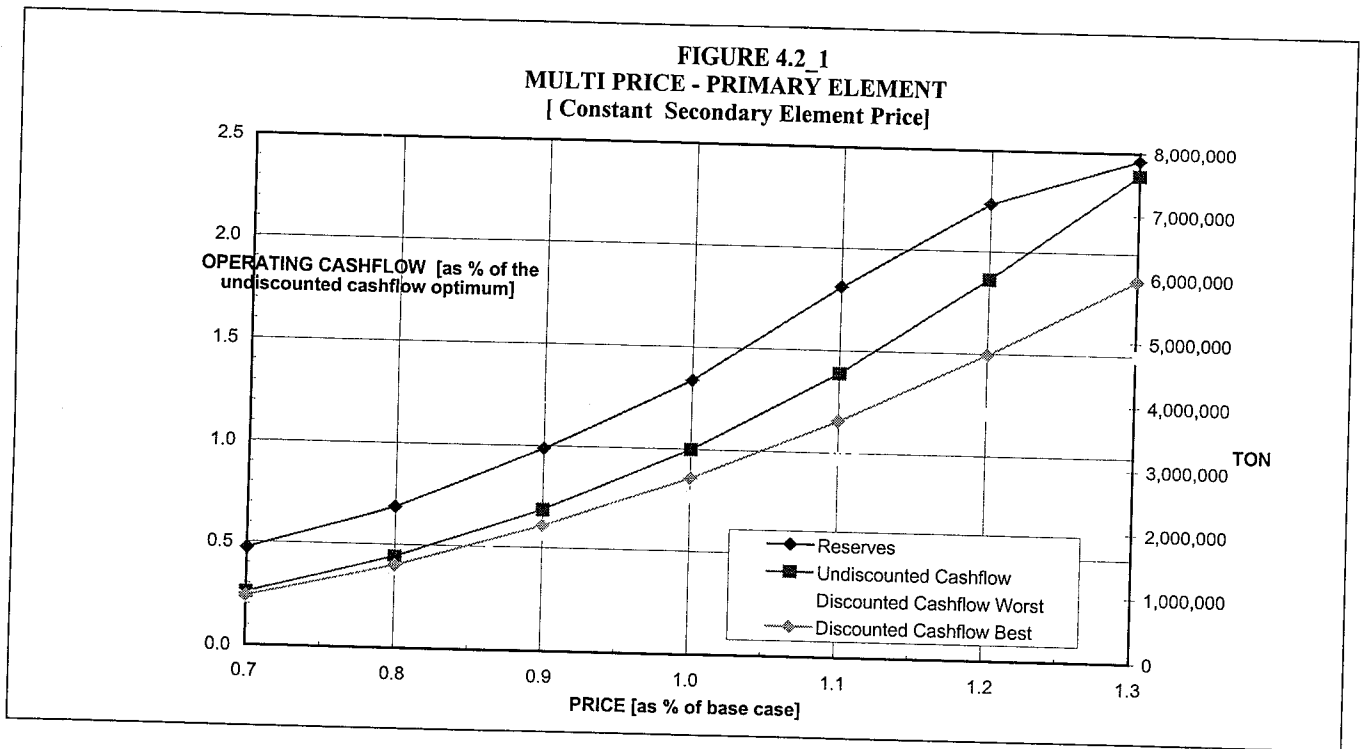


The results of the Whittle Four-D pit optimisation are virtually identical to the Whittle Four-X optimisation results. The difference between the Whittle Four-D derived optimum and the Whittle Four-X derived optimum is approximately 0.1%. In addition, Figure 4.1_2 displays the ability of Whittle Four-X to report the *actual* grades for *all* elements concerned.

4.2 Assessing the Effect of a Change in Price of the Individual Elements Concerned

Figure 4.2_1, Figure 4.2_2, Figure 4.2_3, and Figure 4.2_4 illustrate the ability of Whittle Four-X to calculate the true effects of a price change of the individual elements. The flexibility and power of Whittle Four-X is clearly demonstrated in these figures. Through one FXAN run the effect of a range of prices of one of the elements can be assessed. In fact, the effect of a range of price combinations of the different elements can be assessed in just one FXAN run.

Figure 4.2_1 displays the effect of a range of prices of the primary element on the different cashflows and the reserves.



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Figure 4.2_2 displays the effect of a range of prices of the primary element on the reserves and the associated grades.

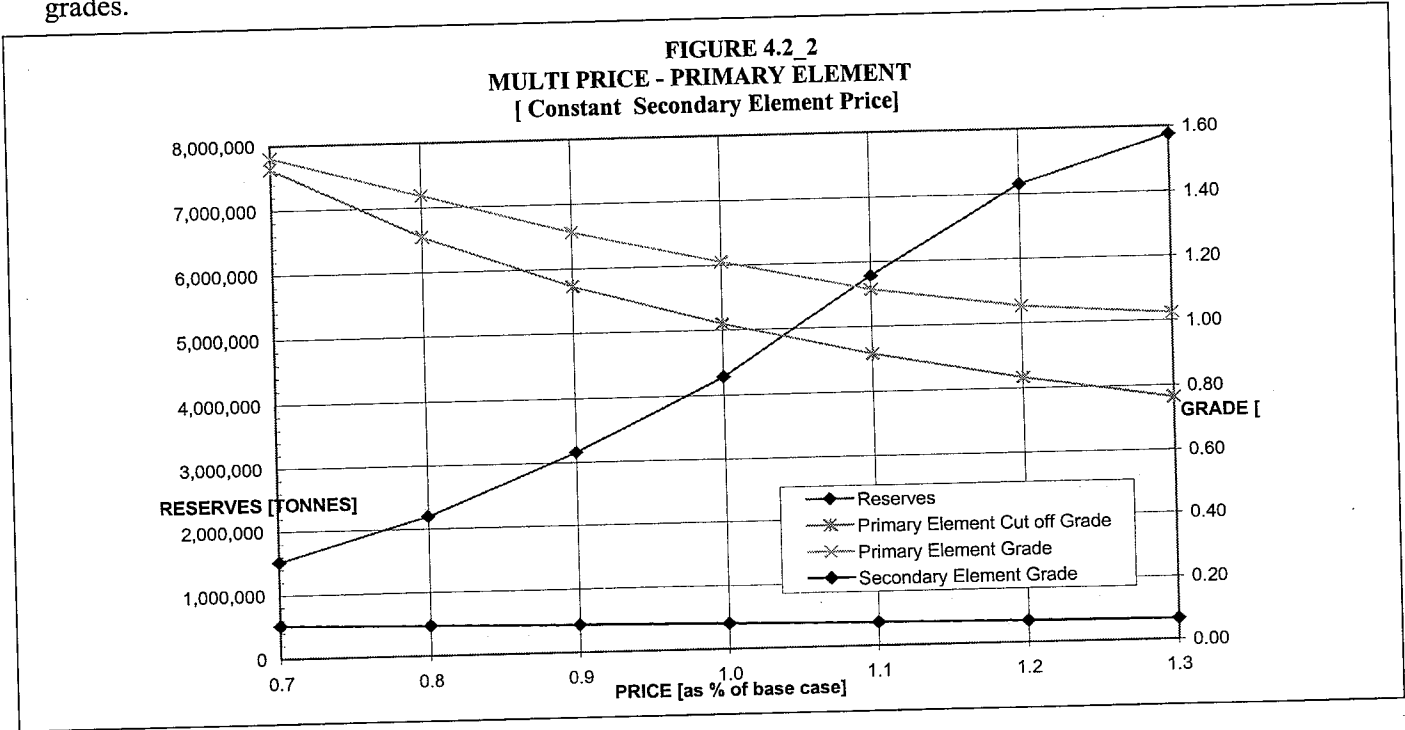


Figure 4.2_3 displays the effect of a range of prices of the secondary element on the different cashflows and the reserves.

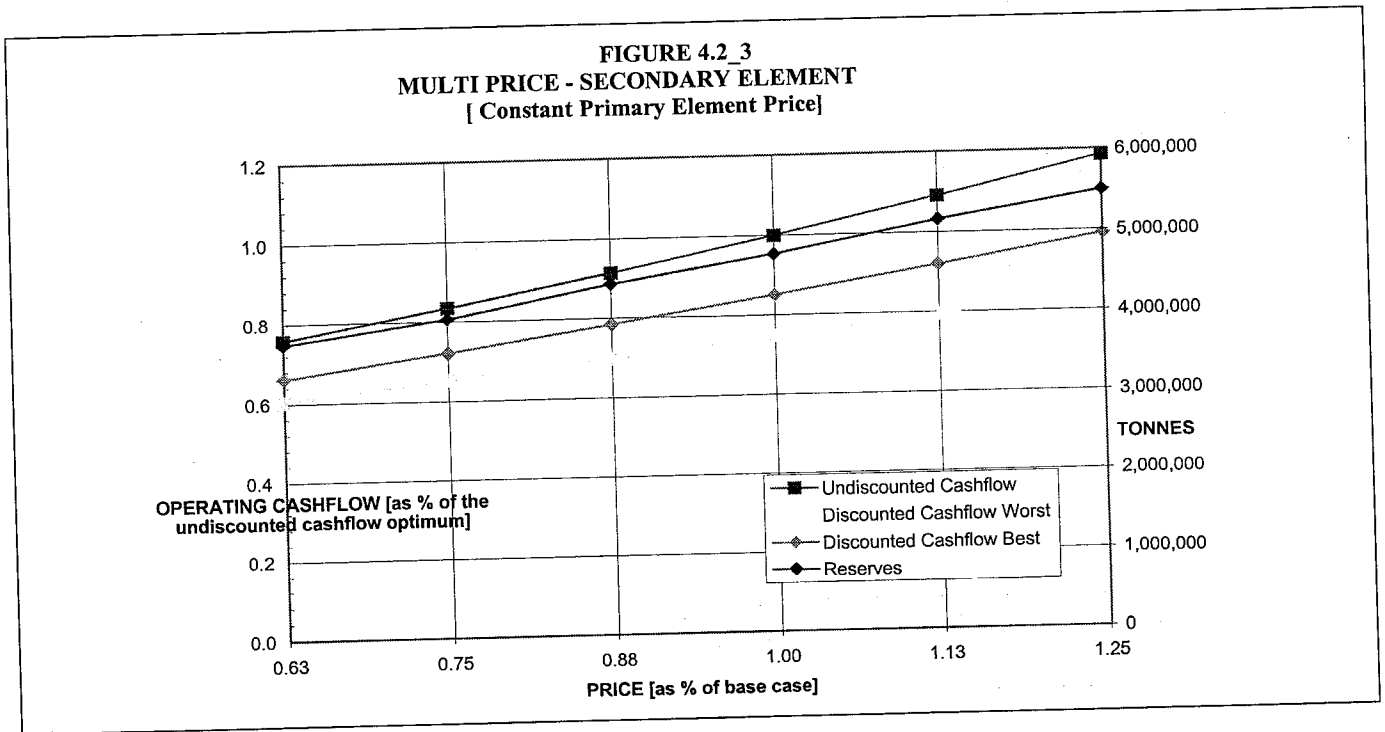


Figure 4.2_4 displays the effect of a range of prices of the secondary element on the reserves and the associated grades

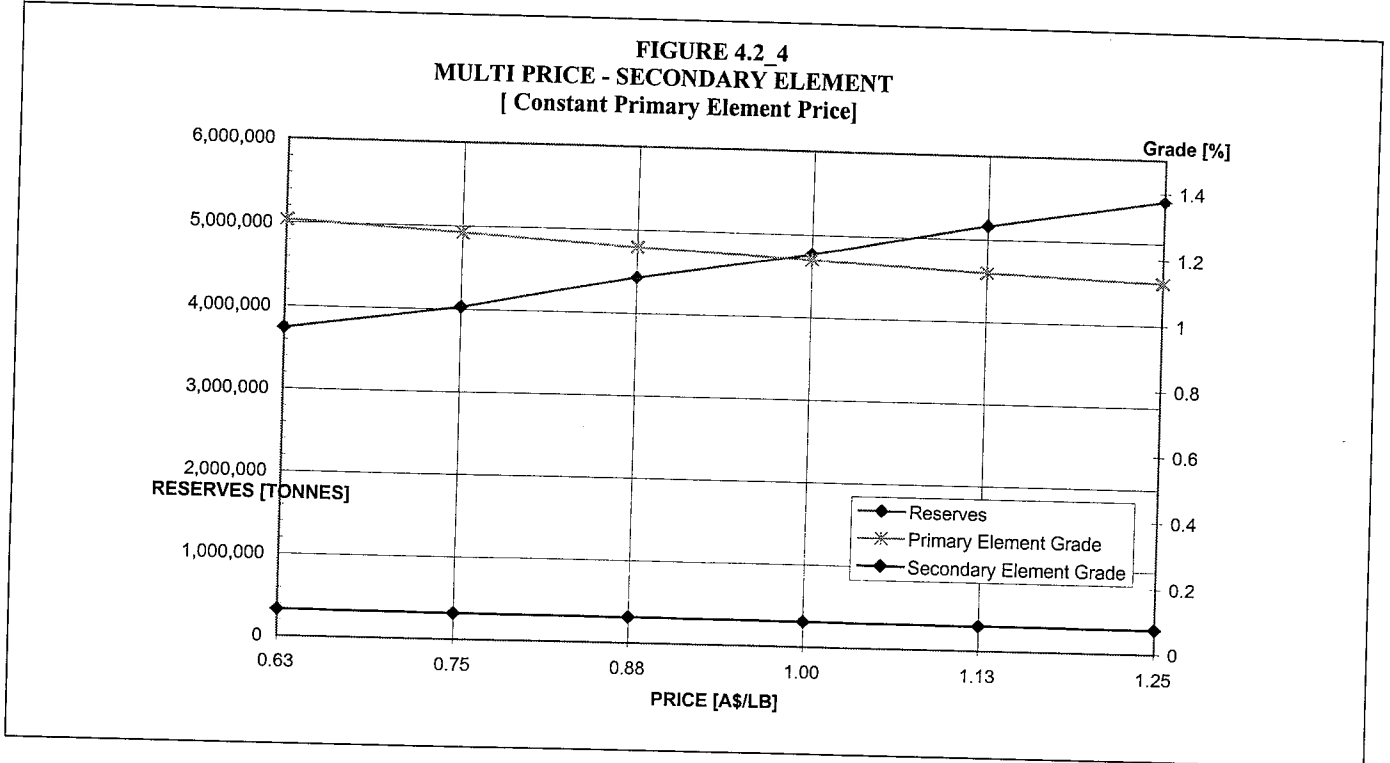
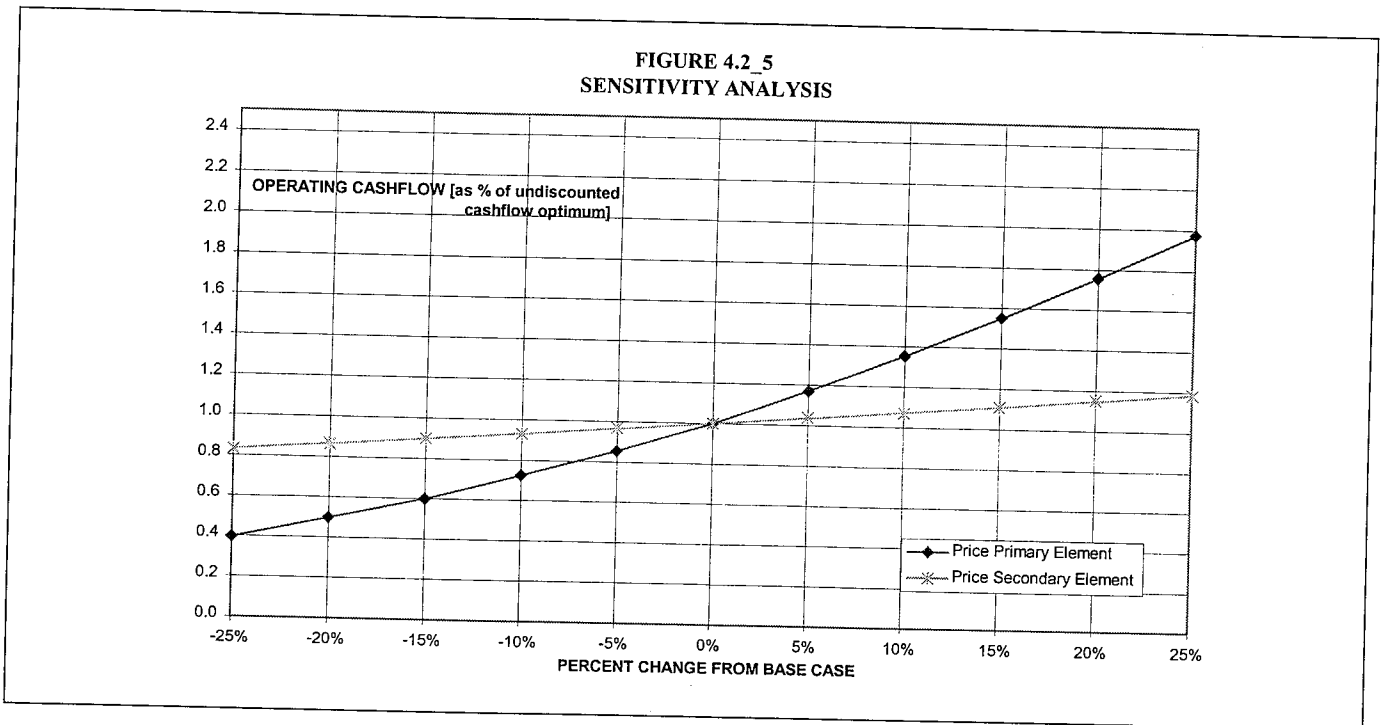


Figure 4.2_5 displays the effect of a change in price of the two elements in a different format.



4.3 Assessing the Effect of a Change in Mill Recovery of the Individual Elements Concerned

Figure 4.3_1 and Figure 4.3_2 display the effect of different mill recoveries for the individual elements. Again the flexibility and power of Whittle Four-X is clearly demonstrated in these figures. Through one FXAN run the effect of a range of mill recoveries of one of the elements can be assessed. In fact, the effect of a range of mill recovery combinations of the different elements can also be assessed in a single FXAN run.

Figure 4.3_1 displays the effect of a range of mill recoveries of the primary element on the different cashflows and the reserves.

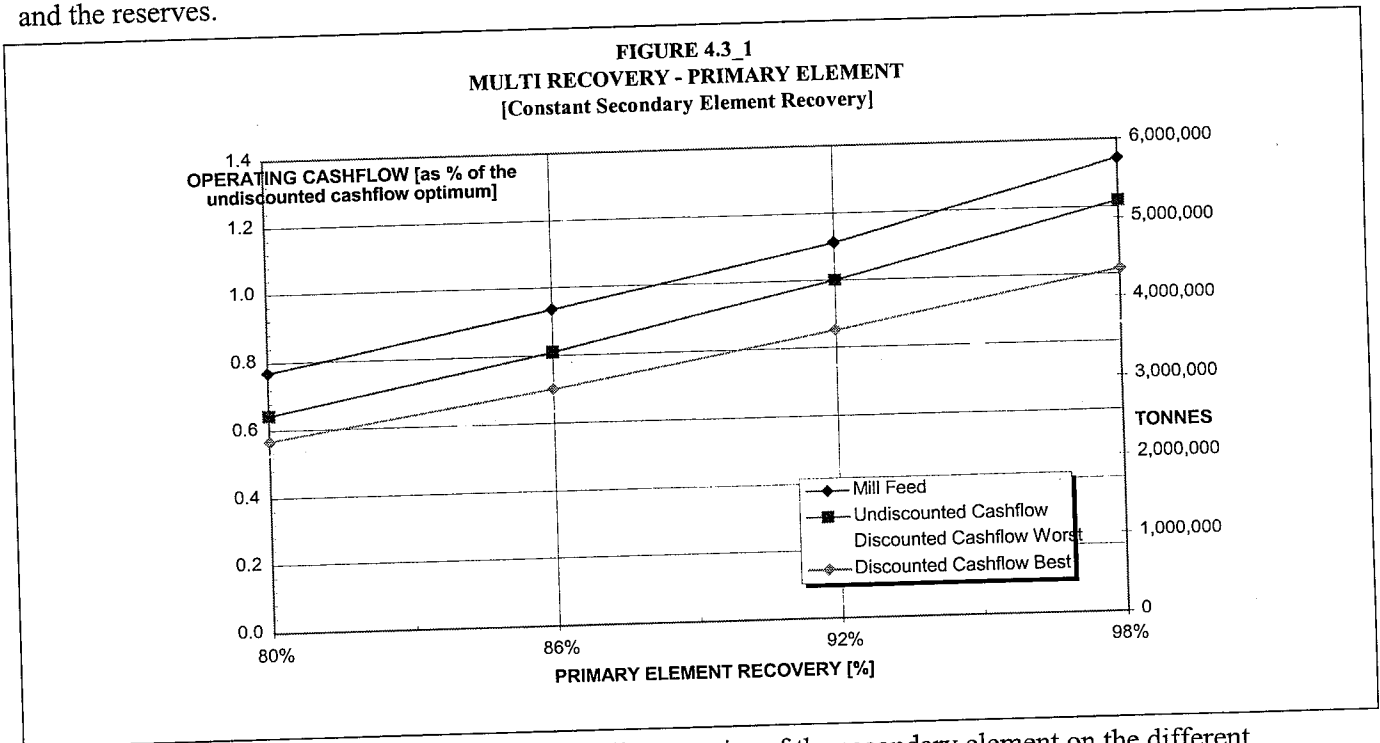
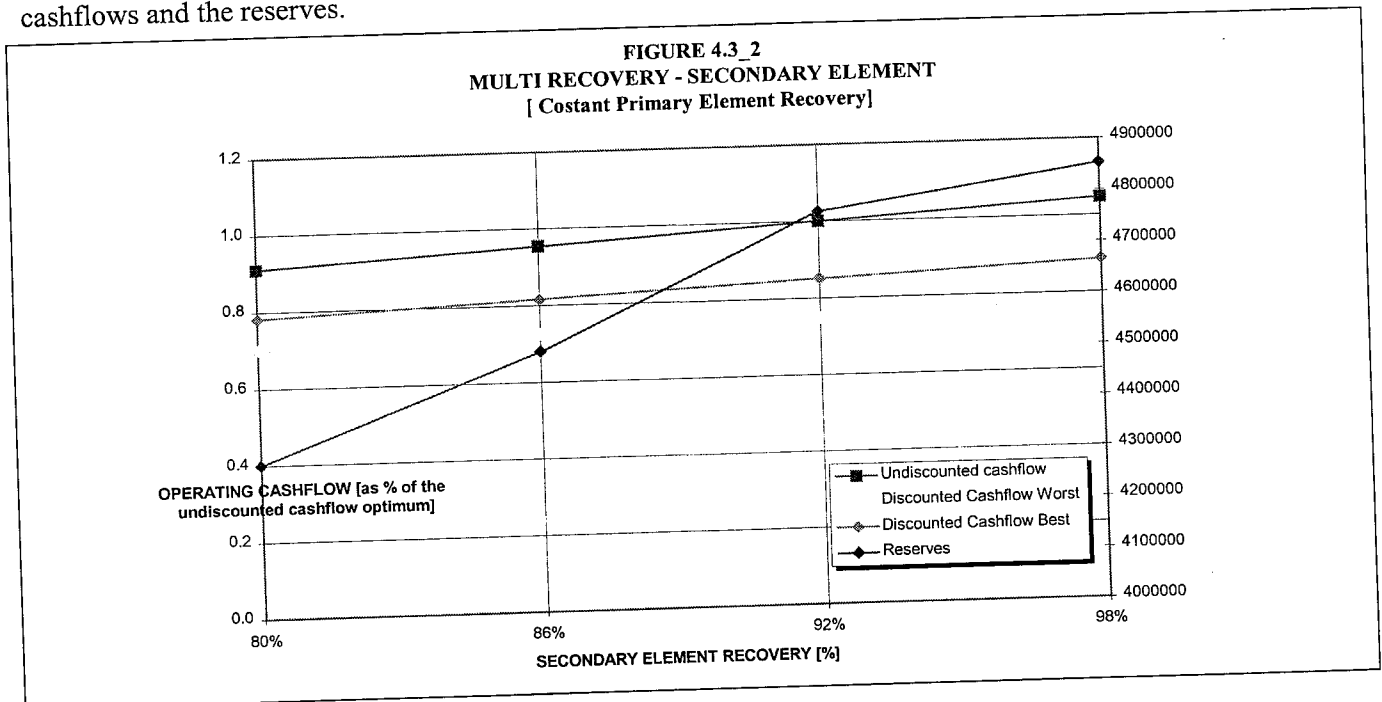


Figure 4.3_2 displays the effect of a range of mill recoveries of the secondary element on the different cashflows and the reserves.



5. Conclusions

Even though there are methods to deal with a multi element deposit in Whittle Four-D, there are problems associated with these methods. Also, one needs to be careful with the interpretation of the optimisation results derived from Whittle Four-D. With Whittle Four-X there is no need to 'trick' the software to make it think it is dealing with one commodity. It deals with explicit costs and product prices for all the elements concerned. Therefore, the results derived from Whittle Four-X can be directly used and assessed. The flexibility in dealing with a multi element deposit has been dramatically increased. The turnaround time for an open pit optimisation study of a multi element deposit can be significantly reduced.