



Effect of Cutoff Grade and Stripping Ratio on the Net Present Value for Hamama Gold Project, Eastern Desert, Egypt

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Authors' contributions

This work was carried out in collaboration with all authors. Authors MRM and MAY designed the study. Author MAG performed the statistical analysis and wrote the protocol. Authors AKE and HSHA wrote the first draft of the manuscript and managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript. Authors MRM, MAY and AKE are supervisors for this manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This paper represents an attempt to examine the effects of Cutoff Grade (COG) and Stripping Ratio (SR) on the Net Present Value (NPV) for the proposed gold mine in Hamama area, hence to attain best operating condition corresponding to the optimum COG and SR in the proposed gold mine. Discount Cash Flow (DCF) model has been established to calculate NPV by taking the change in the COG and SR into account. This detects the effects of COG and SR on the NPV of this project. The actual production and cost data of Sukari Gold Mine (SGM) of Egypt have been taken as an indicator in creating DCF for the proposed gold mine where maximum NPV results proved the optimum COG and SR.

Keywords: Cutoff grade; stripping ratio; discount cash flow; net present value.

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1. INTRODUCTION

One very important aspect of mining is deciding what material in a deposit is worth to mining and processing, versus what material should be considered waste. This decision is summarized by the cutoff grade policy. The cut-off grade strategy for an open pit mine influences the annual cash flows and affects the net present value of a project [1].

The cutoff grade is considered to be the main technical and economic factor of the operation of open pit mines and processing plants and it plays a major role in decision making concerning the sustainable development of mining, the volume of extraction operations and the profitability of manufacturing operations [2].

There are many theories concerning the determination of optimal cutoff grade, but most of the recent research shows that determining the optimal cutoff grade with the issue of maximizing net present value is a method which is more reliable than others [3,4,5]. In determining the optimal cutoff grade, minerals must be extracted so that they maximize the net present value of the operation [6].

The Stripping Ratio (SR) is the ratio of ore to waste. It represents the amount of waste needed to be removed to get a unit tonne of ore [7]. Overall stripping ratio is the proportion of the whole volume of overburden in the open-pit to the total reserves of the mineral. In other words, according to Equation 1, the ratio of the total volume of waste to the ore volume is defined as overall stripping ratio [8].

$$OSR = \frac{V_w}{V_o}$$

Where,

OSR: overall stripping ratio,
 V_w : Volume of waste removed to a certain depth,
 V_o : Volume of ore removed to a certain depth.

This study aims to study the effects of Cutoff Grade (COG) and Stripping Ratio (SR) on the Net Present Value (NPV) for Hamama Gold Project (HGP). To achieve these goals a DCF model is created and NPV calculated for changes of COG and SR, from which maximum NPV results would correspond to the optimum COG and SR.

2. METHODOLOGY

In this study NPV is calculated throughout variations of COG, and involved the following:

- DCF Model building for Hamama Gold Project (HGP) based on which findings of which previous studies using Excel sheet explain in Table 1.
- Deduction of the values of ore tonnage, waste rocks tonnage and the average grade from grade -tonnage curve at specified COG for HGP.
- Calculation of NPV using the values of ore and waste rocks tonnages and the average grade.

In this study NPV is also calculated throughout variations of SR, and involved the following:

- Calculation of Overall Stripping Ratio (SR) for HGP using the cross-section method.
- Calculation of the cost per ton of waste rock removal from the mine.
- Calculation of NPV throughout variations of operating cost at specified SR.

3. RESULTS AND DISCUSSION

The following section discusses effects of Cutoff Grade (COG) and Stripping Ratio (SR) on the Net Present Value (NPV) in Hamama Gold Project (HGP).

3.1 Cut-off Grade Effects on NPV for HGP

Tonnages and grades estimated in the HGP around 12 Mt @ at average grade Au, 0.95 gr/t and Ag, 29.04 gr/t this grade calculated at the base case cutoff grade equal Au, 0.5 gr/t. From the previous study established by Author's about HGP where, NPV calculated equal to US\$M 55.8, operating cost (opex) = 20 US\$/t, SR 1:4, and cost per ton removed 1.5 US\$/t [9]. This section discusses the relation between cutoff grade and NPV. This relation helps to optimize the decision making about the HGP project.

From the grade-tonnage curve in Fig. 1 we can deduce the value of ore tonnage, waste rocks tonnage and the average grade for Au, gr/t. Deducing by drawing a vertical line on the horizontal axis at the specified cutoff grade and taking the values of the intersection of this line with the grade curve and the tonnage curve on the vertical axis of each them as shown in Fig. 1.

After the determination of the previous parameters, NPV for HGP can be calculated at every cutoff grade using the DCF model in the Table 1.

The basic calculations used in the DCF model in Table 1:

- * Life of Mine in Years = $6.5 \times \sqrt[4]{12} \approx 12$ years. (Taylor-Formula). [10]
- * production rate = (Tonnes) / (Life of Mine in Years) = $12,000,000 / (12) = 1,000,000$ ton/year.
- * Capital costs estimation by O'Hara approach = $750000 \times 3000^{0.6} = \text{USD } \$ 91,500,000$. Where,
- * (750000)is constant,(3000)is the daily production and (0.6) is exponential factor [11].
- * Operating cost calculated using cut-off grade equation = cut-off \times price = $0.5 \times 40.00 = 20.00$ US\$/t. [10].
- * Recovery value coming from Laboratory experiments which achieved by acquiring company [12].

- * Gold and Silver production = Recovery \times grade \times Ore production.
- * Price is the average price in the last ten years.
- * Revenue = Price \times oz production.
- * Total operating cost = operating cost/t \times Ore production (1000,000 t/year).
- * Royalty 3% from total Revenue.
- * Gross profit = Revenue - Total operating cost - Royalty .
- * $NPV = \sum_{t=1}^n \frac{CF_t}{(1+r)^t} - I_0$.

To find more details about the DCF model for HGP review the reference [9].

In general, the tonnage and grade controlled by the cutoff grade. Tonnage and grade control the amount of gold produced thus affecting the total revenues and annual profit which using to calculate NPV. Table 2 explain the more effective parameters which used to calculate NPV. Cutoff grade, Ore tonnage and average grade for the studied gold deposit are more effective parameters because they have direct effects on the NPV. Also, Table 2 explain NPV calculated

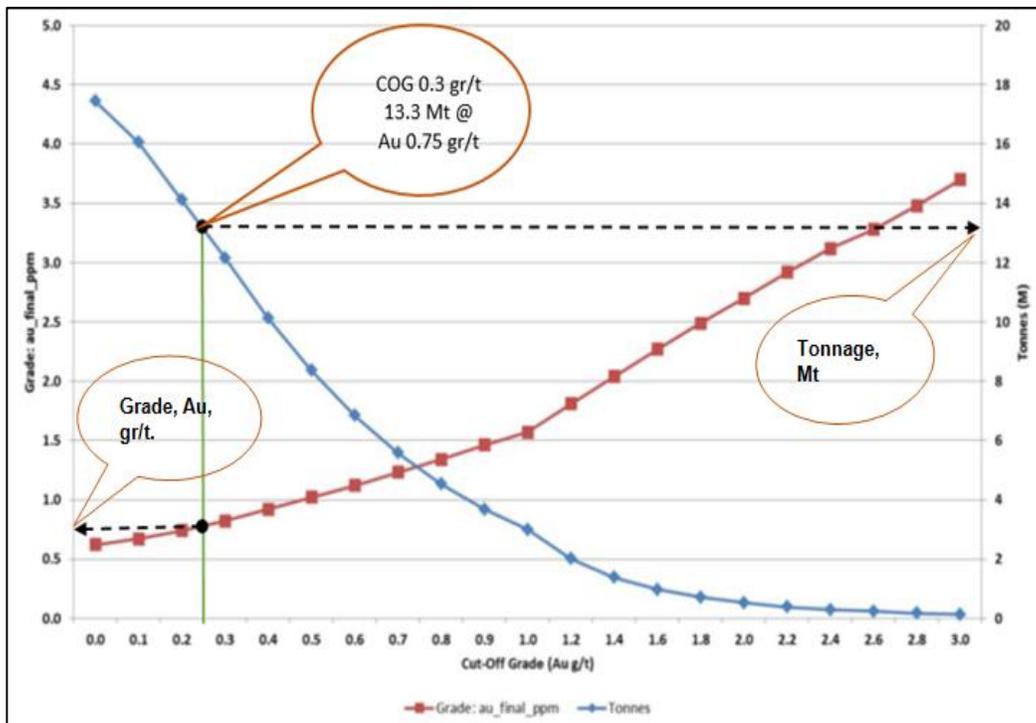


Fig. 1. Grade -Tonnage curve – gold for HGP after Wayne 2012

Table 1. Predicted cash flows model before tax for HGP [9]

Year		0	1	2	3	4	5	6	7	8	9	10	11	12
Production	t		1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Grade	Au, g/t		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Ag, g/t		29.04	29.04	29.04	29.04	29.04	29.04	29.04	29.04	29.04	29.04	29.04	29.04
Gold Recovery			0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Silver Recovery			0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Gold Production	Oz		26,573	26,573	26,573	26,573	26,573	26,573	26,573	26,573	26,573	26,573	26,573	26,573
Silver Production	Oz		420,152	420,152	420,152	420,152	420,152	420,152	420,152	420,152	420,152	420,152	420,152	420,152
Gold Price	US\$/Oz		1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250
silver Price	US\$/Oz		18	18	18	18	18	18	18	18	18	18	18	18
Revenue, US\$	Gold		33,216,24	33,216,24	33,216,24	33,216,24	33,216,24	33,216,24	33,216,24	33,216,24	33,216,24	33,216,24	33,216,24	33,216,24
	Silver		7,562,743	7,562,743	7,562,743	7,562,743	7,562,743	7,562,743	7,562,743	7,562,743	7,562,743	7,562,743	7,562,743	7,562,743
Total, Revenue			40,778,99	40,778,99	40,778,99	40,778,99	40,778,99	40,778,99	40,778,99	40,778,99	40,778,99	40,778,99	40,778,99	40,778,99
Capital Cost	US\$	91,500,000												
Operating Cost	US\$/t		20	20	20	20	20	20	20	20	20	20	20	20
Total Operating Costs	US\$		20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000
Royalty 3%			1,223,370	1,223,370	1,223,370	1,223,370	1,223,370	1,223,370	1,223,370	1,223,370	1,223,370	1,223,370	1,223,370	1,223,370
Gross Profit	US\$	-91,500,000	19,555,623	19,555,623	19,555,623	19,555,623	19,555,623	19,555,623	19,555,623	19,555,623	19,555,623	19,555,623	19,555,623	19,555,623
PV	US\$	-91,500,000	18,107,058	16,765,794	15,523,884	14,373,966	13,309,228	12,323,359	11,410,518	10,565,294	9,782,680	9,058,037	8,387,071	7,765,807
NPV (USD)	US\$	55,872,698												

according to specified COG according to DCF model in Table 1 by using tonnage and grade in the Table 2.

From the Table 2 and Fig. 2 NPV reaches to a maximum value equal US\$M 55.8 at COG 0.5 gr/t. The COG of 0.5 gr/t is common value in gold mining projects. At COG 0.1 gr/t the NPV reach to the lowest value US\$M 5.70. Also, At COG 0.9 gr/t the NPV reach to the low value is US\$M 6.90. From the grade tonnages curve the tonnages and grade deduced for the HGP around 12 Mt @ Au, 0.95 gr/t and Ag 29.04 gr/t this grade calculated at cutoff grade equal Au, 0.5 gr/t but in SGM taken cutoff grade equal Au 0.3 gr/t.

Also, the tonnages and grade at cutoff grade equal Au 0.3 gr/t like SGM, almost found 13.3 Mt @ Au 0.75 gr/t and Ag 29.04 gr/t for Hamama gold deposits with increase about 1.3 Mt more than tonnages estimated at COG equal Au, 0.5 gr/t. In case of circumstances support the

continue with the comparison between SGM and HGP in the growth plane HGP can be use dump leach method for processing ore with grade ≤ 0.3 to 0.1 gr/t.

From grade-tonnage curve in Fig. 1 the ore expected to deliver to dump leach around 4.5 Mt@ Au 0.72 gr/t these increases in the tonnage of mineral resources improvement the HGP value and support decision making and help in visualizing production plans for the mine and processing schedule over mine life.

3.2 Effect of Stripping Ratio on NPV in HGP

Overall Stripping Ratio (SR) calculated for HGP using the cross-section method equals 1:4 (Ore/Waste). The following section discusses the relationship between SR and operating cost, gross profit and NPV. From the DCF model operating cost calculated at the base case COG

Table 2. Data obtained from grade-tonnage curve and NPV calculated

COG, Au gr/t	Ore, Mt	Waste Rocks, Mt	SR, Waste/Ore	Avg. Grade, Au, gr/t	NPV, US\$M
0.1	16.5	43.5	2.64	0.65	5.70
0.2	15.2	44.8	2.95	0.70	8.60
0.3	13.3	46.7	3.51	0.75	14.40
0.4	13.2	46.8	3.55	0.85	42.50
0.5	12	48	4.00	0.95	55.80
0.6	7.7	52.3	6.79	1.10	29.20
0.7	6.2	53.8	8.68	1.15	9.70
0.8	5.2	54.8	10.54	1.30	10.30
0.9	4.5	55.5	12.33	1.40	6.90

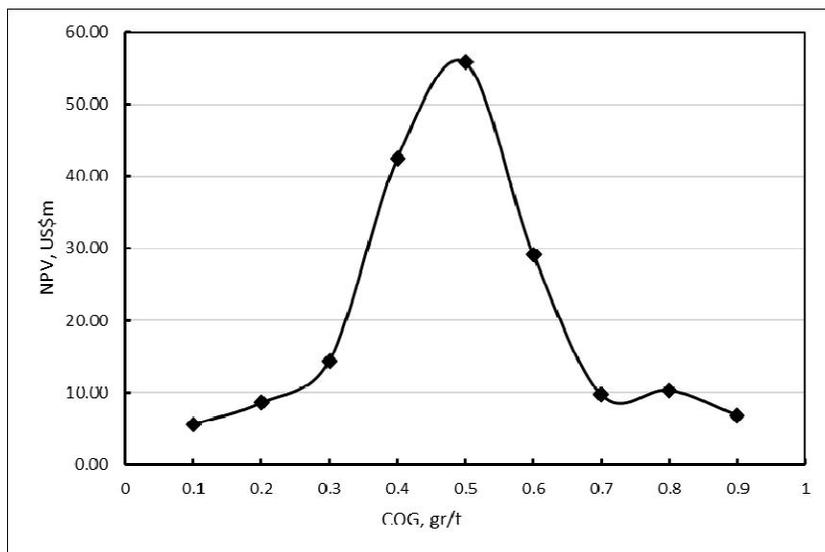


Fig. 2. Relation between COG and NPV

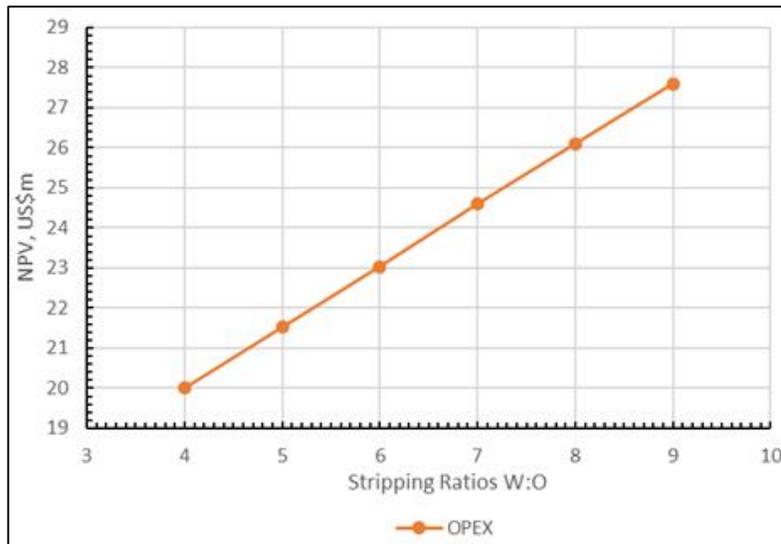


Fig. 3. Relation between SR and operating cost

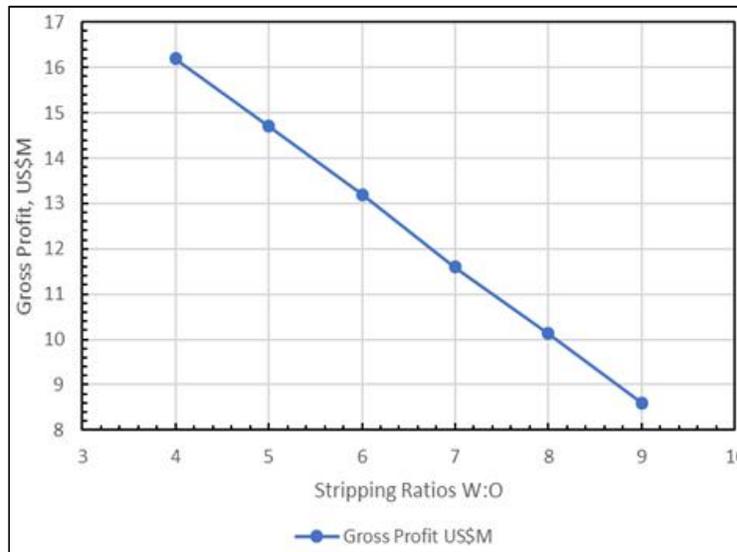


Fig. 4. Relation between SR and gross profit

0.5 gr/t and SR 1:4 was found 20 US\$/t for mining, processing and G&A costs. Change in the stripping ratio has a direct effect on the mining cost, but processing cost does not change. According that if we take the Sukari Gold Mine (SGM) in Egypt as a guide for calculating the opex for HGP the processing cost per ton equal around 12.5 US\$/t in SGM is the average value over 10 years. Hence, Mining cost in HGP = (Total opex - Processing cost).

Mining cost in HGP = (20 US\$/t – 12.5 US\$/t) = 7.5 US\$/t.

Where,

(20 US\$/t) is the total opex contains on mining, processing and G&A costs.

(12.5 US\$/t) is the processing costs.

At the base case COG 0.5 gr/t and SR 1:4 where extract one-ton ore from surface mine in HGP needs to 5 tons remove thus, cost of extract one-ton= $7.5 / 5 = 1.50$ US\$/t, so when the SR increases the opex increase also, when the SR increase the gross profit and NPV are decrease.

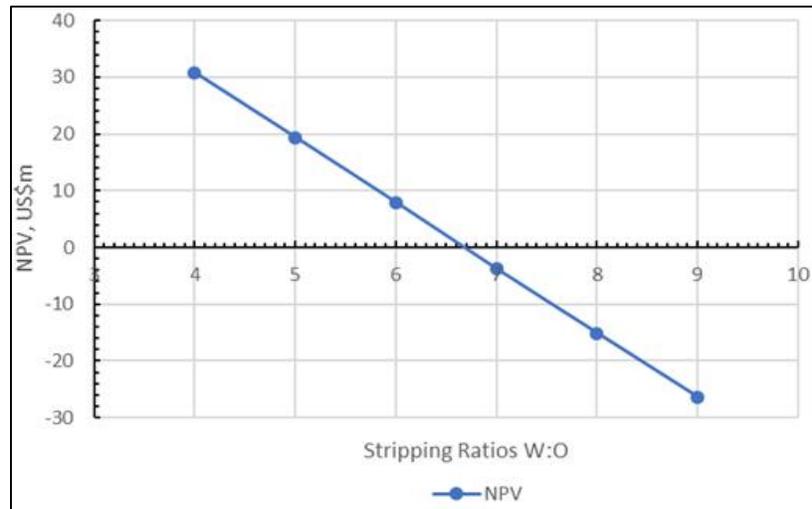


Fig. 5. Relation between SR and NPV

Table 3. Calculated values of opex, gross profit and NPV which corresponding difference SR

SR W:O	Mining US\$/t	Total opex US\$/t	Gross Profit US\$M	NPV US\$M
4	7.60	20.00	16.20	30.8
5	9.12	21.50	14.70	19.4
6	10.64	23.00	13.20	7.93
7	12.20	24.50	11.60	-3.80
8	13.70	26.00	10.13	-15.13
9	15.2	27.50	8.60	-26.4

* NPV at the base case calculates based on Avg. grade, Au 0.82 gr/t and Ag 29.04 gr/t. where based on degree of confidence and certainty for mineral resource estimation in the HGP [9]

Table 3 explain the values of apex, gross profit and NPV which corresponding difference SR in HGP at the base case opex = 20 US\$/t, SR 1:4, and cost per ton removed 1.5 US\$/t.

From the Table 3, the maximum value of NPV US\$M 30.8 at SR = 1:4 also, NPV decrease with increase SR and reach to lowest value US\$M -26.40 at SR=1: 9.

In Fig. 3 relation between SR and operating cost is the positive relationship when SR increase operating cost will be increased. In the HGP the optimum stripping ratio SR= 1: 4 (O:W).

From Fig. 4 gross profit income from HGP reach to maximum values at SR= 1: 4 also, gross profit reach to a minimum value = US\$M 8.60 when opex reach to maximum value US\$M 27.60 at SR= 1: 4

Fig. 5. explain the relation between SR and NPV from the Fig. when SR = 6.7 and operating cost =

24 US\$/t the NPV equal zero and transform from positive to negative. From the above calculation the optimum SR when equal = 1:4 because the NPV and gross profit reach to highest value.

4. CONCLUSION AND RECOMMENDATION

- HGP is profitable at the base case i.e. COG = 0.5 gr/t, Gold price / Silver price (1250 / 18) US\$ / oz, operating cost US\$ 20 / t and Capital cost US\$M 91.5 the NPV is positive equal US\$M 30.8. Operating cost and commodity prices very effective on the NPV this clear in a sensitivity analysis.
- Study the effects of the COG on the NPV in the HGP shows the optimum COG is 0.5 gr/t because NPV reaches a maximum value equal US\$M 55.8. At COG 0.1 gr/t the NPV reaches to the lowest value US\$M 5.70. Also, At COG 0.9 gr/t the NPV reach to the low value is US\$M 6.90.

- Stripping ratio effects on the operating cost because there is positive relationship between them hence SR effect on the NPV and gross profit for the HGP project.
- HGP is a profitable project at the stripping ratio (SR) up to 1: 6.7 where the NPV equals zero and transforms from positive to negative when SR exceeds 1: 6.7.
- From the study, we recommended the necessity of observation of the stripping ratio and cutoff grade through operating Hamama gold mine to know when the project transforms from profit to loss.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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