Using the Economy of Sukari Gold Mine to Prove the Potential Economy of Hamama Gold Project, Eastern Desert, Egypt

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This paper represents an attempt to examine the economic potential for Hamama Gold Project (HGP) and hence decision about go/not-to-go to invest in this area. Discount Cash Flow (DCF) model has been established to calculate NPV by taking the risk and uncertainty produced from geological and technical factors into account. This revealed the potential economics of this project. The actual production and cost data of Sukari Gold Mine (SGM) of Egypt have been taken as an indicator for evaluate processes of HGP where positive results proved the acceptable to investment.

Keywords: Economic potential, Hamama gold project, Discount cash flow, Net Present Value.

INTRODUCTION

The mining industry was always considered as risky work. Risk from the technical, environmental, social, and economic uncertainties starting from exploration and evaluation of mineral resources passing through mine development and production stage. Uncertainties also associated with operating, marketing, and safety risks. The difficulty of mineral project evaluation is how to deal those risks/uncertainties, so making a decision to invest in mining is very complicated (Lilford, 2002).

Many factors affect the value of mineral resources. These factors divided into technical factors and economic factors. Technical factors include geology, the geometry of the ore body, tonnages, grade, and grade distribution in orebody, cut-off grade, and recovery. Economic factors contain the price of the commodity, capital and operating cost, tax regime, inflation, and the discount rate have been taken into account (Allen, 2019).

DCF analysis is used to know the benefit which may be coming from the HGP. This study discloses the possibility of contributes gold mineral resources and associated mineral resources in the growth of the Egypt economic especially SGM contributes by 2% of Egyptian Export Balance.

This study aims to make a decision about go/ or not for investing in the HGP, therefore, DCF models are proposed to give an economical vision about the project value through NPV for the project with analysis risk and uncertainty. Decision making for investment or not in the study area depends on NPV calculated from the DCF model. Calculation of NPV for the proposed gold mine projects associated with risks and uncertainty. Risks and uncertainty were studied depending on the income approach as represented by DCF model to know the limits of profitability and losses.

Income approach contains the creating cash flow model and NPV calculation. DCF model results from the income approach depends on prediction of cost and production data. Also, using the actual cost and production data for SGM to know the logicality of calculating results for the HGP.

From exploration work data on Hamama gold resources in the Eastern Desert, suppose these resources have often positive NPV. According to geographical location, geological conditions and available infrastructure for the studied deposit this produce decrease of capital and operating cost this leads to decrease cost/oz produced for the proposed gold mine projects.

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Risk and uncertainties associated with the gold mine projects value produced from many factors used in creates of the DCF model. To identify the risks associated with evaluating processes the project must study the effects of change in the ounce price, capital and operating cost applied on the NPV. Uncertainties associated the gold deposits evaluation coming from mineral resource estimation due to decrease of geological confidence about ore tonnages and grades. Arrive to acceptable certainty in the calculations through appropriate interpretation geological and exploration data for the studied deposits (Smith, 2002).

Geology of HGP and SGM:

The Sukari gold deposit is located in the Central Eastern Desert of Egypt at 24° 56' 50" N 34°42'27" E, about 23 km southwest of the Red Sea coastal town of Marsa Alam. Sukari gold deposits located in the Arabian-Nubian Shield.

The Sukari felsic porphyry outcrop is located in an easterly dipping sequence of andesite flows, serpentinites and associated volcanoclastic sediments, mainly tuffs and epiclastics. It strikes for 2.3 km and is 100 to 600 m thick. It forms a jagged-toothed, strong topographic high up to 250 m above wadi level (390m ASL). Wadi drainage plains pass to the east and west of the outcrop, and the sharply incised green – brown Red Sea Hills surround that (Centamin NI Report 2009).

Hamama deposit lies in the Abo Marawat concession in the Eastern Desert of Egypt and divided into three zones Hamama West, Hamama Central and Hamama East. Mineralization at Hamama consists of primary hypogene sulfide mineralization overlain by an oxidized zone of gold-bearing gossan. Outcrop mapping and drilling have defined the deposit to date with a strike length of 800m, an average width of around 60m, outcropping at the surface and with an average drill intersected depth of 120m below surface.

Figure 1. shows the location map for Hamama gold resources and SGM. (Wayne, 2012).
From the geological studies the similarities in geological conditions between suhari gold deposits and Hamama gold deposit summarized in:

- Gold deposits located in CED and ANS.
- Gold deposits situated within the Precambrian rocks.
- There is a similarity in lithology between studied area.
- The faults are spread in three areas.
- Some mineralized parts are controlled by alteration zones.
- The occurrence of gold is connected with existence of quartz veins.
- The presence of gold is associated with the presence of sulphides.

From the geological condition and geochemistry for two deposits and similarities between gold deposits in two areas this guide to use the same mining method and the same processing technology used in the SGM. Using the value of operating cost applied to SGM is logical to apply on HGP with a slight difference producing from other factors.

METHODOLOGY

In this study created a DCF model by using an prediction method to predict cost and production information for the study projects. Steps for DCF Model building for HGP contain:

- Calculation the Life of Mine (LOM) and Production Rate (PR) by using the Taylor-Formula.
- Estimation of capital and operating costs using multi methods.
- The above-calculated values were compared with the actual value for SGM.
- DCF Model building for Hamama Gold Project using Excel sheet. Finally,  
- Sensitivity analysis achieved by a change value of the economic factors such as the price of commodity, capital and operating cost.

RESULT AND DISCUSSION

The following section discusses using DCF models to valuation of Hamama Gold Project.

Calculation the LOM at base case Cut-Off Grade (COG) = 0.5 gr/t.

Tonnage of mineral resources for study project has a variation in certainty in ore resource estimation, it’s have inferred and Indicated mineral resources:

Indicated Resource: ±10 to 15 % (at 90 percent confidence limits).

Inferred Resource: ±25 to 15 % (at 90 percent confidence limits) (M.A. Noppé, 2014).

Confidence percent taken ±10 to 15 %, according to Indicated mineral resources for Hamama gold deposits. The justification for taking this percent of certainty predicate to the Indicated ore tonnages around 4 million tons (Mt) according to proposed production rate 1Mt/y this quantity operates the mining 4 years. Through this year’s the inferred mineral resources developed by exploration works to Indicated mineral resources. Comparison with sukari gold deposits the mineral resources developed from 26.39 Mt measured and indicated mineral resources in 2002 to 257 Mt in 2016. Figure 2 show the distribution of the mineral resource’s categories in the ore body of Hamama west gold deposits.

Figure 2: Distribution of the mineral resource’s categories in the ore body of HGP (Matt, 2017).

At the Base Case COG = 0.5 gr/t.

Ore Resources Tonnage = Inferred + Indicated

≈ 12 Mt

(Matt Bampton 2017).

Average grade Au, gr/t

\[
\text{average grade Au, gr/t } = \frac{(8.21 \times 0.87) + (3.8 \times 0.72)}{(8.3 + 3.8)}
\]

\[
= 0.82 \text{ gr/t . (2)}
\]

**Ore Resources Tonnage** 12 Mt @ Au 0.82 gr/t and Ag 29.04 gr/t.

- Ag, grade is the average grade for Hamama gold deposits.

Quantity and quality of mineral resources tonnage effects on the PR and LOM. Also, the quantity and quality of mineral resources tonnages decrease and increase with the COG selected.

Calculation of LOM using The Taylor-Formula at Base Case COG = 0.5 gr/t

Life of Mine in Years = \(6.5 \times \sqrt{\text{tonnage (in million tonnes)}}\) 
(Wellmer, et al. 2007) (3)
Life of Mine in Years = $6.5 \times \sqrt{12} \approx 12 \text{ years}$.

SGM in 2010, (43-101F1 technical report) design the DCF model on ten years. Although the SGM life more than 30 years, this due to continue in the exploration work and development of mineral resources tonnages.

**Production Rate Calculation:**

The production rate (PR) or (capacity "C" by ton/year) value depends on ore resources tonnages and life of mine (LOM). Capacity or "production rate" very important factor effect on the project merit, such as payback period (PB), discounted cash flow internal rate of return (IRR) and NPV. In gold project capacity ton/year also controlled by processing plant capacity also the project-built dump leach or not.

The average and total mineable reserve or the ‘expected ore tonnage’ are related as follows:

$$ PR = \frac{\text{Ore Resources Tonnages}}{\text{Life of Mine in Years}} = \frac{12,000,000}{12} \approx 1,000,000 \text{ ton/year}. \quad (4) $$

**According to calculations the PR**

$\approx 1,000,000 \text{ ton/year} \approx 3000 \text{ ton/day}$. In the SGM production rate start by 5 Mt/y in 2009 doubled to 10 Mt/y in 2013. Gold resources in the Hamama area suitable to increase the production if we take the geological condition for Hamama gold deposits in consideration the mineral resources tonnage will increase because the mineralization zone around length ~ 3000 m, thickness up to 100 m, depth > 250 m. Hamama gold deposits divided into Three main bodies: Hamama West, Hamama Central and Hamama East, the study applied on Hamama West only.

**Capital Costs Estimated Using Historical Method:**

Calculate the capital cost (capex) for the Hamama west gold deposits using historical estimated or actual costs using linear or power factors. This approach is well described by (O’Hara, 1980). The relationship between the costs can be expressed as follows:

$$ \text{Cost of facility} = \text{constant} \times \text{(production rate)} \times \text{‘power’} \quad (5) $$

The traditional cost estimation ‘power’ is 0.6 ("sixtenths rule"). However, Straam and O’Hara use a wider range for different types of facility, equipment or operating cost. These can lie between 0.4 and 1.0.

$$ \text{Capital cost} = A \times C^{0.6} \quad (6) $$

(Richard L. Bullock, 2018), (Wellmer, F. et al. 2007), (Allen, 2019).

Where $A$ is constant = 750000 and "C" is capacity in a t/day.

$\therefore \text{Capital cost} = 750000 \times 3000^{0.6} = \text{USD} \$ 91,500,000. $

From Table 1 and according to stripping ratio:

Total material movement from SGM = 30 Mt/y. Where,

(Total material movement= $(PR \times \left(\frac{1}{PR}\right) + PR$).

Total material movement from HGP = 5 Mt/y.

Total material movement for HGP = $\frac{1}{6}$ from total material movement for SGM, so the proportional mining capital cost for HGP = $\frac{92,800,000}{6} \approx \text{US}$M$15.5$.

Where US$ 92,800,000 is the mining capital cost for SGM in 2009.

Also, cost of the process plant, cost of on-site infrastructure, and cost of off-site infrastructure can be estimated by the same method depending on the using the same processing method, from the Table 1 PR delivered to a processing plant in HGP = $\frac{1}{5}$ from PR for SGM. Thus, the cost of the proposed process plant and infrastructure = $\frac{193,013,000}{5} \approx \text{US}$M$38.6$, Where US$ 193,013,000 is the process plant and infrastructure for SGM in 2009.

From the above results which deduced from comparative between two projects:

Total capital cost for HGP = Mining Capital Cost + Cost of Process Plant and Infrastructure = 15.5 + 38.6 $\approx$ US$M54.10$ according to year of 2009.

Calculate capital cost according to year of 2018 using the following formula:


Capex for HGP (2018) = 54.10 $\times 1.08^6 = \text{US}$M$108.14$. Capex calculated from the comparative approach (US$M108.14$) more than the capex calculated in the base case about 18%. From Figure 3 NPV equal zero when capex $\geq 50\%$ more than the capex in the base case. From Figure 3 and under this condition the NPV for HGP equal around (US$M15$).

**Operating Cost Calculated Using Cut-Off Grade Equation:**

The main categories of operating costs (opc) or Cash cost of production are:

(i) mining, (ii) processing, and (iii) G&A.

$$ \text{COG} \times \text{NF} \times \varepsilon \times \text{Price} = 0.5 \times 0.98 \times 0.87 \times 40.54 = 17.28 \text{ US$/t} \quad (8) $$

Where, NF-factors is the Fluctuation of mine returns = 98% for precious metals.

$\varepsilon$ is the recovery percentage of gold from ore. (Wellmer, et. al. 2018).

Another method for calculation of opc.

$$ \text{COG} = \text{cost} - \text{price} \quad (9) $$

$$ \therefore \text{cost} = \text{cut-off} \times \text{price} $$

$$ = 0.5 \times 40.00 $$

$$ = 20.00 \text{ US$/t} \$$

**Taking Operating cost (20 US$/t)**

From the above calculation and Table 1, the operating cost for proposed HGP ranged from 17.28 US$/t to 20 US$/t this corresponds (739 - 870) US$/oz. Actual cash cost of production for SGM (675 - 725) US$/oz in 2019.
The Egyptian Government is entitled to a royalty of three per cent (3%) of the total quantity of gold and associated minerals produced after refining less 50% of all costs related to the delivery of any gold delivered in kind for the payment thereof. AAN is entitled to recovery of all Exploration Expenditures, Exploitation Expenditures, and Operating Expenditures, at a rate of 20% per year in the case of Exploration and Exploitation Expenditures, and 100% per year in the case of Operating Expenditures of the cumulative balance in each of these categories.

After royalty payment and all cost recoveries, the remaining percentage of total production of gold and associated minerals shall be divided 50% between each Party” (Matt, 2017).

Under the concession agreements, are exempted from customs duties, any taxes, levies or fees or sales taxes so in the cash flow model royalty 3% is discount from the gross profit.

### Table 2: Predicted Cash flows model before tax for HGP.

<table>
<thead>
<tr>
<th>Year</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>2027</th>
<th>2028</th>
<th>2029</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Au, t</td>
<td>1,000,000</td>
<td>1,000,000</td>
<td>1,000,000</td>
<td>1,000,000</td>
<td>1,000,000</td>
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<tr>
<td>Gold Recovery Ag, g/t</td>
<td>0.02</td>
<td>0.02</td>
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<td>0.02</td>
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<tr>
<td>Silver Recovery Ag, g/t</td>
<td>0.05</td>
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<tr>
<td>Silver Production Ag, t</td>
<td>430,152</td>
<td>430,152</td>
<td>430,152</td>
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<tr>
<td>Gold Price US$/oz</td>
<td>1,250</td>
<td>1,250</td>
<td>1,250</td>
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<tr>
<td>Silver Price US$/oz</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
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<tr>
<td>Capital Cost US$m</td>
<td>91,500,000</td>
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<tr>
<td>Operating Cost US$m</td>
<td>20,000,000</td>
<td>20,000,000</td>
<td>20,000,000</td>
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<tr>
<td>Total Operating Costs US$m</td>
<td>20,000,000</td>
<td>20,000,000</td>
<td>20,000,000</td>
<td>20,000,000</td>
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<tr>
<td>Gross Profit US$m</td>
<td>91,000,000</td>
<td>91,000,000</td>
<td>91,000,000</td>
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<td>91,000,000</td>
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<tr>
<td>Proven &amp; Probable US$m</td>
<td>91,000,000</td>
<td>91,000,000</td>
<td>91,000,000</td>
<td>91,000,000</td>
<td>91,000,000</td>
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<tr>
<td>NPV (US$)</td>
<td>30,837,756</td>
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<tr>
<td>Discount Rate</td>
<td>0.08</td>
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<tr>
<td>E (1+e)</td>
<td>1.08</td>
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</tbody>
</table>
Table 3 explains the cash flow model and NPV after royalty discounts from the revenue. The gross profit after discount royalty equal US$M 15.15 in a year and NPV equal (US$M 22.6). The NPV is positive so the project is accepted.

### Sensitivity - Risk Analysis:

The above model developed by using different scenarios by changing economic variables entered to model. The NPV of the project is most sensitive to technical factors contains geological, the ore body, tonnages, grade, and grade distribution in orebody, cut-off grade, and recovery. Also, NPV sensitive to economic factors such as the price of the commodity, capital and operating cost, tax regime, inflation, and the discount rate applied which effects on the feasibility study for the project. (Cairns and Takayoshi 2003)

These parameters also effects on other project's merits like IRR and PB. So, in this research applied risk analysis to know the relation between variation in economic variables up/ down and NPV for HGP. In Table 4 the value of economic variables used in risk analysis and its effect on the NPV is summarized.

From Table 4 the NPV affected by changes in economic parameters like price, capex and opc. Effects produced from the price of the commodity on NPV more than effects from opc and capex. The maximum value of NPV equal (US$113) at price +30% over the price (1250 / 18 US$/ oz of Au/Ag) of the base case in sensitivity analysis results, also the minimum value of NPV equal (US$ -51) at price -30% below the price of the base case so the price of commodity very effective in the DCF and NPV due to transform profitable project to a failed project.

### Table 4: Critical variables applied on the DCF model to calculate NPV before tax for HGP.

<table>
<thead>
<tr>
<th>Sensitivity Area</th>
<th>Percentage Change</th>
<th>Value</th>
<th>NPV US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold price / Silver price US$/ oz</td>
<td>-30%</td>
<td>875/12.6</td>
<td>-51</td>
</tr>
<tr>
<td></td>
<td>-20%</td>
<td>1000/14.4</td>
<td>23.7</td>
</tr>
<tr>
<td></td>
<td>-10%</td>
<td>1125/16.2</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1250/18</td>
<td>30.8</td>
</tr>
<tr>
<td></td>
<td>+10%</td>
<td>1375/19.8</td>
<td>58.1</td>
</tr>
<tr>
<td></td>
<td>+20%</td>
<td>1500/21.6</td>
<td>85.5</td>
</tr>
<tr>
<td></td>
<td>+30%</td>
<td>1625/23.4</td>
<td>113</td>
</tr>
<tr>
<td>Operating cost US$/ t</td>
<td>-30%</td>
<td>14</td>
<td>76.0</td>
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<tr>
<td></td>
<td>-20%</td>
<td>16</td>
<td>61.0</td>
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<tr>
<td></td>
<td>-10%</td>
<td>18</td>
<td>46.0</td>
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<td></td>
<td>0</td>
<td>20</td>
<td>30.8</td>
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<tr>
<td></td>
<td>+10%</td>
<td>22</td>
<td>15.7</td>
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<tr>
<td></td>
<td>+20%</td>
<td>24</td>
<td>0.70</td>
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<tr>
<td></td>
<td>+30%</td>
<td>26</td>
<td>-14.4</td>
</tr>
<tr>
<td>Capital cost US$</td>
<td>-30%</td>
<td>64</td>
<td>58.3</td>
</tr>
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<td></td>
<td>-20%</td>
<td>73.2</td>
<td>49.1</td>
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<td></td>
<td>-10%</td>
<td>82.35</td>
<td>40.00</td>
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<td></td>
<td>0</td>
<td>91.5</td>
<td>30.8</td>
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<tr>
<td></td>
<td>+10%</td>
<td>100.65</td>
<td>22.0</td>
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<tr>
<td></td>
<td>+20%</td>
<td>109.8</td>
<td>12.5</td>
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<td></td>
<td>+30%</td>
<td>119</td>
<td>3.30</td>
</tr>
</tbody>
</table>
By examining the results related to opc, capex changes the value of the NPV is positive in all results except one NPV equal (USM$ -14.4) at opc + 30% over the opc (26 US$/ t). The NPV Change to change opc, capex, and the NPV ranged between (USM$ 3.30 & 58.3) in capex change. From the sensitivity analysis change in the price of gold and silver leads to rejecting the project because the NPV is negative in two cases when a price change by -20% and -30% below the price of the base case. Figure 3 Shows the relation between the percentage change in the economic parameters and value of NPV.

Figure 3: Change in NPV with change in economic parameter.

From Figure 3 the relation between the commodity price and NPV is the positive relationship on the figure and the NPV is positive to start the change in price percentages about 12% below the price at the base case.

Also, from Figure 3, the relation between opc and NPV is an inverse relationship, the value of NPV is positive at the percentage change in the opc until the rate of change reaches +20% over the opc at the base case. The value of the NPV is positive with the all variation in the capex values.

In the above model, the NPV is calculated before tax and royalties because the concession agreement between acquiring company and the Egyptian Mineral Resources Authority (EMRA) supports the sharing system. In the search assumed the taxes are about 30% discount from the gross profit the NPV is (USM$ -11.5) at the base case. In case applied the maximum value of (gold/silver) price (USDS 1625/23.4) in the DCF model and assumed taxes 30% and 3% royalties the NPV equal (USM$ 44). The project will be profitable with applied this assumed tax when the gold and silver price change by 10% over the price at the base case where the NPV equal around (USM$ 9).

In the sharing system after royalty payment and all cost recoveries, the remaining percentage of the total production of gold and associated minerals shall be divided 50% between each party. From Table 5 payback period (PB) calculated from DCF around (6) years at the base case according to that operating company recovered his capital investment in (6) years then the following gross profit divided 50% between each party under this condition NPV calculated (USM$ 47) at the base case.

Table 5: Predicted Cash flows model according sharing system for HGP.

<table>
<thead>
<tr>
<th>Year</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>2027</th>
<th>2028</th>
<th>2029</th>
<th>2030</th>
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</thead>
<tbody>
<tr>
<td>Production (t)</td>
<td>0</td>
<td>1,000,000</td>
<td>1,000,000</td>
<td>1,000,000</td>
<td>1,000,000</td>
<td>1,000,000</td>
<td>1,000,000</td>
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<td>1,000,000</td>
<td>1,000,000</td>
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</tr>
<tr>
<td>Grade (Ag, g/t)</td>
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<td>0.87</td>
<td>0.87</td>
<td>0.87</td>
<td>0.87</td>
<td>0.87</td>
<td>0.87</td>
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<tr>
<td>Gold Recovery</td>
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<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
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</tr>
<tr>
<td>Silver Recovery</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
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<td>0.04</td>
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<tr>
<td>Silver Production (oz)</td>
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<td>420,152</td>
<td>420,152</td>
<td>420,152</td>
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</tr>
<tr>
<td>Silver Price (US$/oz)</td>
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<tr>
<td>Capital Cost</td>
<td>US$m</td>
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<td>91,500,000</td>
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</tr>
<tr>
<td>Operating Cost</td>
<td>US$m</td>
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<td>Total Operating Costs</td>
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<tr>
<td>Gross Profit</td>
<td>US$m</td>
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<td>91,500,000</td>
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<tr>
<td>NPV (US$)</td>
<td>US$</td>
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<tr>
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</table>

Using the Economy of Sukari Gold Mine to Prove the Potential Economy of Hamama Gold Project, Eastern Desert, Egypt
CONCLUSION AND RECOMMENDATION

The conclusions drawn from the present study can be summarized as follows:
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$ 91.5 the NPV is positive equal USM$ 30.8. Operating cost and commodity prices very effective on the NPV this clear in a sensitivity analysis. The project is losses when the Gold price / Silver price is 20% and 30% less than the value of prices in the base case. also, the project is losses when the operating cost increases by 30% more than the value of operating cost in the base case.

The project reaches a maximum value of NPV equal (USM$ 113) when the price reach (1625/23.4 US$/oz of Au/Ag) which increases by + 30% over the price of the base case. Also, the minimum value of NPV equal (USM$ -51) at price decrease by 30% below the price at the base case so the price of commodity very effective in the DCF and NPV due to transform profitable project to a failed project. HGP is profitable project when applied 30% taxes and 3% royalties the NPV = US$M 44 when the (gold / silver) price (USD$ 1625/23.4)/oz.

Egyptian government adopts the sharing system in gold mines projects. From the study HGP is profitable when applied the sharing system and NPV = US$M 47 at the base case.

From the comparison between the SGM and proposed HGP in terms of economic and technical criteria, the HGP is an acceptable project for investment due to of the cost and production values for HGP lies in the range of cost and production values for SGM.

From the study, we recommend continues in the exploration work in the project area to increase the confidence in the ore tonnages and grade estimated. Also, extend in exploration work to increase the ore reserves to increase the life of mine.

ACKNOWLEDGMENT

The authors would like to gratefully thank Prof. Dr. M.R. Moharram, Prof. Dr. M. A. Gouda and Prof. Dr. Mahrous Ali Mohammed, staff members in Mining and Petroleum Dept., Faculty of Eng., Al-Azher University, Egypt. due to help us and guidance to complete and achieve this research.

REFERENCES


Accepted 13 November 2019


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