MINERAL ECONOMICS

Discount rates and risk assessment in mineral project evaluations

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ABSTRACT

The concept of risk is well established in the mining industry. It is acknowledged when estimates of reserves are expressed as proven or probable, when mining and metallurgical recoveries are applied to the ore, and when contingencies are added to costs. However, it is difficult to provide a quantitative assessment of risk. The significant sources of risk in a mineral project and how these are addressed in project evaluations are discussed.

The discount rate is examined as a fundamental means of reflecting risk in discounted cash flow evaluations. Current industry practice is discussed, and a methodology for the analysis of risk levels is proposed that assesses the constituent components of the discount rate: real interest, mineral project risks, and country risk.

Introduction

This paper examines the components of the discounted cash flow discount rate and proposes a method of estimating project-specific discount rates. The motivation for this work comes from experience of project evaluations in which owners and purchasers had agreed on virtually every aspect of the evaluation except how much the project was worth. Agreement was reached on reserves, grade, recovery, capital costs, operating costs, taxes, and, by combining these components, even on the final cash flow values. The only difference in opinion concerned the *discount rate* to be used in the calculation of the net present value. Depending on the life of the project, such differences of opinion can cause a variation of more than 50% in the value placed on a project! This is illustrated in Figure 1.

Discount Rates

Need for a Discount Rate

Virtually all modern texts on project evaluation conclude that the preferred methods of evaluation are those that incorporate annual cash flow projections and that recognize the time value of money, such as the net present value (NPV) and the discounted cash flow rate of return (DCFROR) approaches, as opposed to those employing simple cost and revenue ratios or payback periods. The mathematics that is required to generate the NPV and DCFROR values is straightforward, but both methods require the definition of an appropriate discount rate to establish investment criteria. This rate is used as the discount rate in the NPV method, and the minimum rate for the DCFROR.

The most common risk assessment techniques use discounted cash flow evaluation methods. For example, the Monte Carlo simulation would be used to give a probability distribution of the NPV or DCFROR for a project. Although a discussion of the merits of risk assessment techniques is beyond the scope of this paper, the most significant are:

- Most likely case (base case)
- Best case/worst case
- Sensitivity analysis
- Decision tree
- Monte Carlo simulation
- Root sum of squares (RSS) procedure

A brief description of each is given in Appendix A.

An Appropriate Discount Rate

Unfortunately, the literature on discounted cash flow evaluations does not deal specifically with the selection of discount rates for mineral project evaluations. Most texts focus on the calculation of the corporate cost of capital. However, it should be possible to determine a discount rate that is appropriate for an individual project, on the basis of industry expectations for project returns (DCFROR), the risk factors associated with mineral projects in general, and the risks related to the specific project.

Corporate Cost of Capital

Economic and finance theory proposes the use of the corporate cost of capital as a discount rate. This value is the weighted average cost of the funds available to a company, including common stock, debt (after tax rate), and preferred shares. Referred to as the *Weighted Average Cost of Capital (WACC)*, it is expressed as an interest rate and is calculated as follows[1]:

$$r_{WACC} = r_e p_e + r_d p_d + r_p p_p \qquad (1)$$

where:

r_{WACC} = weighted average cost of capital (expressed as %)
$r_{e,d,p}$ = costs of equity capital, debt (after tax), and preferred stock, (all expressed as %)
$p_{e,d,p}$ = proportions of equity capital, debt, and preferred stock that make up the corporate capital ($p_e + p_d + p_p = 1.00$).

For evaluations on an *all equity* basis, only the cost of equity capital needs to be considered. (The $r_d p_d$ and $r_p p_p$ terms drop out because p_d and p_p are zero on an all equity basis.) There are a number of methods of assessing the cost of equity capital and expressing it as an interest rate, but the *Capital Asset Pricing Model (CAPM)* is perhaps the most widely used. The basis of this method is that the return on an individual corporate stock can be related to the stock market as a whole by the relationship[1]:

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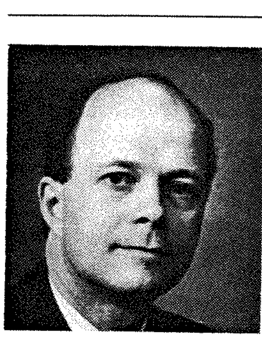

L.D. Smith holds a B.A.Sc. in civil engineering from the University of Toronto and an M.Eng. in mining from McGill University. He is the senior minerals economist for Kilborn Inc. and has been with the company since 1974. During that time he has been involved in the evaluation of numerous mining projects in Canada and internationally. He has had the opportunity to see many of the factors that influence the assessment and viability of a resource project in a variety of corporate and political environments.

TABLE 1. Corporate cost of capital by the capital asset pricing model

Stock group	Beta	Nominal (with inflation)	Real (no inflation)
Gold mining	.27	6.6% + (5.0%) (.27) = 7.94%	3.88%
Base metals mining	1.13	6.6% + (5.0%) (1.13) = 12.23%	8.02%
Market	1.00	6.6% + (5.0%) (1.00) = 11.60%	7.41%

Beta factors are taken from US Value Line Investment Survey(2), February 4, 1994.
The long-term risk-free return of 6.6% (nominal) is a 13-year average for 3-month US government bonds(2).
The risk premium of 5.0% is the long-term market yield of 11.6% (nominal)(2) less the long-term risk-free rate.
Nominal rates have been converted to real rates using a 13-year average inflation rate of 3.9%(2).

$$r_e = f + R\beta \quad (2)$$

where:

r_e = expected return on the common stock
f = risk-free return (usually based on government bond rates)
R = risk premium of market returns above long-term risk free rates
β = Beta factor for the common stock. The beta factor expresses the variability of the common stock with respect to the variability of the market as a whole. By definition, the beta of the market is 1.00. Beta values are published regularly in journals such as *US Value Line Investment Survey*(2).

From Equation 2, it is possible to develop values for mining companies. This is done for two broad categories, gold mining companies and base metals mining companies, in Table 1. (See Appendix B for the individual company values.)

The results given in this table suggest that, in evaluating an investment on a 100% equity basis, a gold mining company and a base metals mining company would use real discount rates of approximately 4% and 8%, respectively. (It should be noted that if the debt portion of these companies had been included, the cost of capital values would have been lower, since corporate borrowing rates are lower than the expected market return value and would reduce the weighted average accordingly.)

These results do not seem appropriate for a discounted cash flow evaluation. The results for the gold stocks seem especially low, presumably reflecting the special nature of gold. The beta factors measure the performance of company stocks relative to the stock market, but do not address the risks and characteristics of individual projects. Also, it does not seem reasonable that a large mining company would apply only one discount rate to all possible investment decisions.

Although the weighted average cost of capital method may provide an internal corporate *hurdle* rate for investment decisions, it appears to be necessary to look elsewhere for a means of assessing risk for the evaluation of individual mineral projects.

Industry Practice

It is the author's experience that, for cash flow evaluations at the feasibility study level of projects in low risk countries, mining companies use a discount rate in the region of 10% for evaluations in constant (real) dollars, at 100% equity, after tax. This is based on:

- discussions with numerous mining companies;
- direct experience in studies undertaken for mining companies;
- a figure of around 10% (corrected for inflation) indicated by Gentry and O'Neil(3) for new North American mineral properties (Appendix C);
- use of a minimum of 8% by the Centre for Resource Studies in Kingston, Ontario, to determine economic projects(4); and
- a 10% rate recommended by the Treasury Board of Canada for benefit-cost analyses(5).

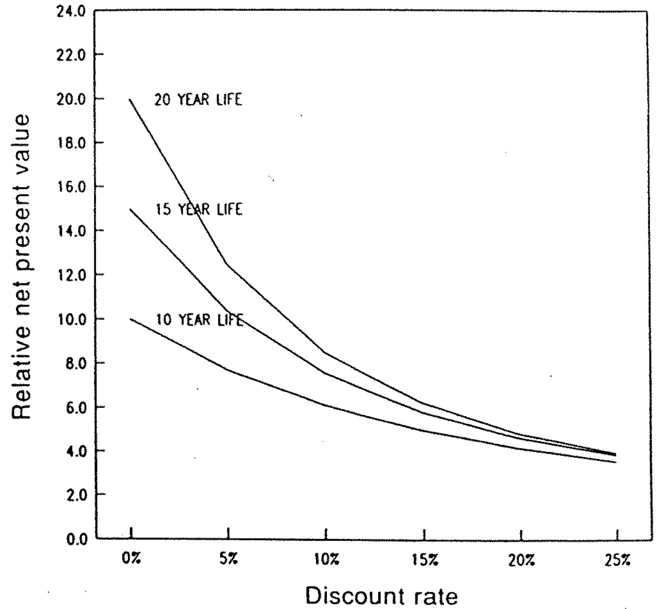

FIGURE 1. Graph illustrating the effect of the choice of discount rate on the relative NPV, particularly for longer life projects.

There does not appear to be a theoretical basis for a discount rate in the 10% range, other than the fact that a 10% rate of return (no inflation) after taxes is a reasonable rate of return compared with the return on government bonds (3% to 5%, no inflation, before taxes). Because this rate is used by major mining investors to make decisions that involve millions of dollars, it must be felt to have validity. However, the conditions under which companies apply this rate are specific, as outlined in the following paragraphs:

Constant Dollars — It is increasingly common to develop a cash flow on a constant dollar basis, that is, without inflation. It is difficult to obtain agreement on inflation forecasts, and most evaluations avoid the problem by leaving inflation out (although, by using constant dollars, inflation is effectively projected at 0%, which is as much an assumption as projecting it at any other rate). If inflation is included in an evaluation, the relationship between the constant dollar (real) discount rate (d), the inflation rate (i), and the inflated (nominal) discount rate (r), is described by the equation:

$$(1+r) = (1+d)(1+i) \quad (3)$$

100% Equity — The reasoning behind 100% equity cash flows is that an evaluation should measure the inherent value of a mineral project, not the ability of an owner to finance a project on favourable terms. Financing is as much a function of the owner's credit rating and the money market as the project itself. If financing is involved it would be necessary to modify the discount rate accordingly, by means of a lower discount rate to reflect the lower risk in the debt portion.

After Tax — Because tax is a cost of operating, it should be included in the calculation of a cash flow. Some feel that taxes should be considered as a risk in mineral projects, a view that the author does not share. With the exception of a radical change in taxation policy (which is really a function of *country risk*) it is possible to make an accurate estimate of both the amount and timing of the tax liabilities incurred by a project since the method of tax calculation is set out in detail in tax legislation.

Canada and the United States — Until recently Canada and the United States have been considered essentially risk free and there was no requirement to reflect "country risk" in the discount rate for projects in these jurisdictions. This belief is so deeply rooted

TABLE 2. Conditions that define a study at the feasibility level

Ore reserves	Include only proven and probable ore reserves (not resources); bulk sample almost certainly taken.
Ore grades	Based on sufficient and appropriate drilling and sampling.
Mining	Method is optimized; mine layout is established; mining engineer has visited the site.
Metallurgy	Recoveries and reagents are based on bench scale testing; pilot plant testing is likely; rates of production and plant capacity is optimized; flowsheets are optimized; material balances are optimized.
Site facilities and infrastructure	Soil testing is available; general layout is optimized; site visited by project team.
Capital costs	Estimated in the ± 10% range; contingency 10% to 15%.
Operating costs	Based on manning tables, mine plans, and metallurgical testwork; labour contracts are available; supply costs are based on letter quotes or contracts.
Revenue	Based on existing or signed sales contracts.
Royalties and fees	Based on signed agreements and contracts.
Taxes	Based on detailed data.
Environmental	Based on detailed data.
Closure plan	Based on detailed data.

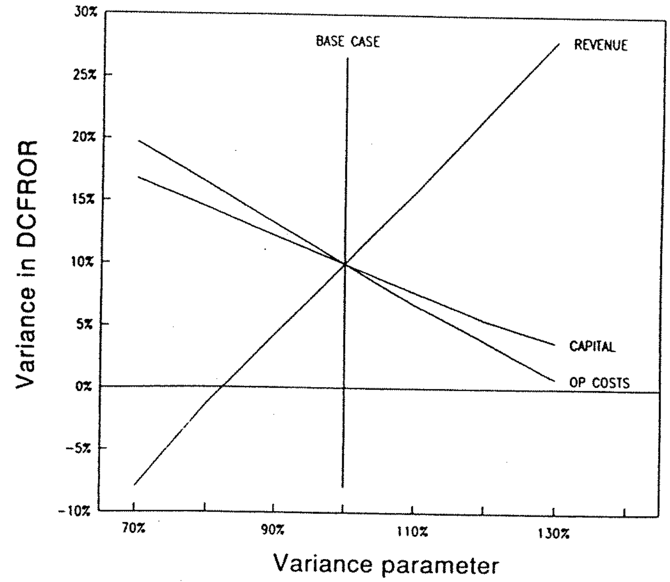

FIGURE 2. Spider graph showing typical sensitivities for DCFROR.

that even today, when projects can be delayed for years by environmental studies and hearings; when the Canadian government cancels mining rights through reclassification as wilderness areas (e.g. Windy Craggy in British Columbia); and when the United States government is considering a confiscatory tax on mineral production from federal land, North American mining companies are only gradually coming to view their homelands as other than risk free (see Country Risk).

Feasibility Studies — This condition implies a high level of data development and a high level of certainty. The term *feasibility study* has a specific meaning for mineral projects, particularly to authorities at the major stock exchanges. The characteristics that define a study at the feasibility study level are set out in Table 2 and in Appendix D.

Risk

Risk components in a Mineral Project

A discount rate for a mineral project comprises three principal components; the risk-free interest rate, mineral project risk, and country risk. Brief descriptions of each are given below.

Risk-free Interest Rate — The value of the long-term, risk-free, real (no inflation) interest rate is approximately 2.5%. This value is supported by numerous references in the literature and is set out in Ontario law (Ontario Rule 53.09). A similar value of 2.6% is obtained from the long-term figures in Table 1 (from equation 3; 1.026 = 1.066/1.039).

Mineral Project Risk — Mineral project risks include risks associated with reserves (tonnage, mine life, grade), mining (mining method, mining recovery, dilution, mine layout), process (labour factors, plant availability, metallurgy, recoveries, material balances, reagent consumption), construction (costs, schedules, delays), environmental compliance, new technology, cost estimation (capital and operating), and price and market.

Country Risk — Country risk refers to risks that are related to country-specific social, economic, and political factors.

Project Specific Discount Rate

The discount rate can be related to these three components by the equation:

$$d = I + R_p + R_c \quad (4)$$

where:
- d = Project specific, constant dollar, 100% equity, discount rate
- I = Real, risk-free, long-term interest rate (2.5%)
- R_p = Risk portion of the project discount rate
- R_c = Risk increment for country risk.

If a 10% feasibility study discount rate is used as a base, and country risk is ignored, Equation 4 indicates that the risk portion at the feasibility study level is approximately 7.5% (10% minus 2.5%). Several questions arise from this concept:

- What is the composition of risk within the 7.5% risk portion?
- How does the composition of the risk portion differ from the feasibility study to less certain studies?
- How does the composition of the risk portion differ from the feasibility study to the operational mine?

What is Risk?

The concept of risk has two basic aspects, uncertainty and consequence. The relationship between them can be expressed in the form of an equation:

$$\text{Risk} = \text{Uncertainty} \times \text{Consequence} \quad (5)$$

Uncertainty is the state of not knowing and can be reduced by obtaining more information. A high degree of uncertainty (uncertainty factor = 1.00) implies a high degree of unknowing, or a lack of information. A low degree of uncertainty (uncertainty factor = .10) reflects a high degree of knowing, or an abundance of information. It is not suggested that uncertainty can be defined as a precise term, although it can be compared to the spread (variance) of a probability distribution; the wider the spread the greater the uncertainty. *Consequence* is a measure of the effect of a vari-

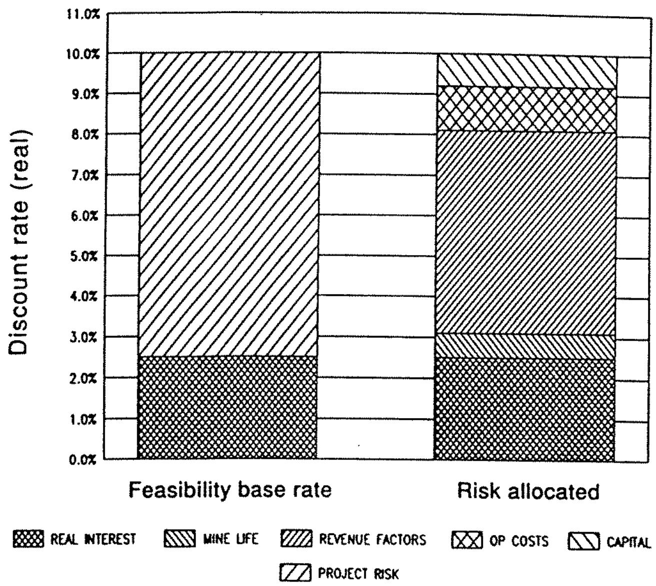

FIGURE 3. Risk components of a 10% feasibility study real discount rate. Revenue factors include metal price, grade, recovery, and throughput. 100% equity.

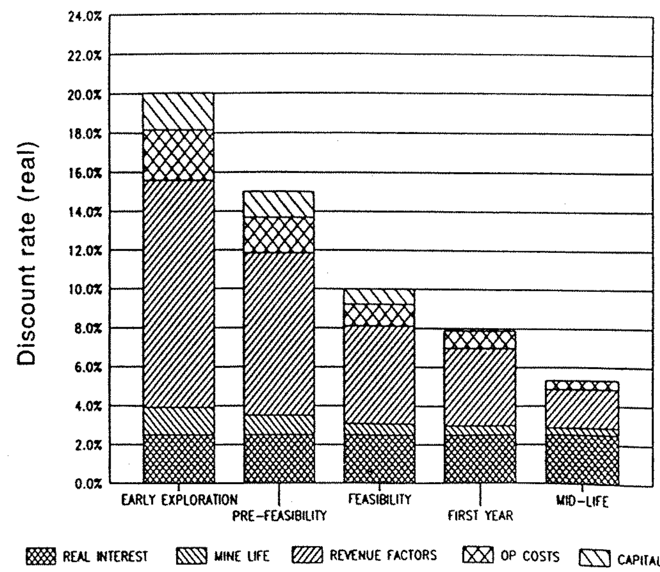

FIGURE 4. Components of real discount rates at different stages of project development. Revenue factors include metal price, grade, recovery, and throughput. 100% equity.

able on a project. Combining uncertainty and consequence gives a measure of *risk*.

For example, if a variable with a high degree of uncertainty has a substantial effect on the project, the risk from that variable is high. If a variable with a high degree of uncertainty has very little effect on the project, the risk from that variable is low. Similarly, a variable with a very low degree of uncertainty would have a low risk.

It is for this reason that the author considers that known taxes do not alter the risk factor of a project. Although taxes have a high degree of consequence, often accounting for 50% or more of the profits, they have a very low level of uncertainty (effectively zero) and, hence, contribute little or no risk. (The exception to this is politically motivated risk associated with taxes, which is discussed in the section Country Risk below.)

Quantifying Risks

For the purposes of this discussion, the factors that influence a mineral project have been grouped into those affecting capital costs, operating costs, mine life, and revenue (price, grade, recovery, and availability).

Uncertainty can be taken as the level of accuracy of each variable. For example, at the feasibility study level, capital and operating costs are assumed to be known within ±10% and recovery, which is probably known with greater accuracy, could be within ±5% of the expected figure.

Consequence can be assessed by the relative sensitivity of each factor and can be measured by determining the slope of the curve on a traditional sensitivity "spider" graph (Fig. 2). The slope is expressed as a positive value because risk is considered to be cumulative. (For example, a high risk in capital costs, which has a negative slope, does not offset high risk in metal price, which has a positive slope. The two risks sum to a combined risk.) Sensitivity is measured as the change in DCFROR (as opposed to NPV) since this result represents an interest rate and is directly comparable to the discount rate.

Uncertainty (accuracy) is multiplied by consequence (sensitivity) to give a risk product that is used to prorate the results over the 7.5% risk portion. This process is shown in Table 3 and illustrated in Figure 3.

Project Specific Discount Rates

Feasibility Study Stage

The logic that has been established for the analysis of the risk components of a discount rate at the feasibility study level can be applied to the evaluation of projects at different stages of development. The analysis shown in Table 3 can be extended to encompass projects at the pre-feasibility and early exploration stages, when lack of information creates greater risk. It can also be used to establish discount rates for a mine at the end of the construction period or in full operation, when greater knowledge has reduced the risk level. The composition of the discount rate for a hypothetical project at different stages of development is shown in Figure 4.

Early Exploration and Pre-feasibility Stage

Studies are often made at much earlier stages of project development than the feasibility study. For example, the *early exploration* study is a broad order-of-magnitude study that is usually undertaken to rank and, possibly, reject potential projects in the early stages. A *pre-feasibility* study is undertaken when more data are available, and is generally used to justify continuing expenditures toward a final feasibility study. Because these studies are made at much earlier stages of development, there is less data and the degree of uncertainty is higher. This can be accommodated in the discount rate, using the risk factor model. This is illustrated in Figure 4.

For the pre-feasibility study the uncertainty factors are higher than those for the feasibility study, reflecting a higher degree of uncertainty. For the early exploration study the uncertainty factors are higher still, reflecting an even greater degree of uncertainty (still less information). Applying uncertainty multipliers of 1.67 for the pre-feasibility study and 2.34 for the early exploration study to the risk components and then adding the 2.5% risk-free long-term interest rate gives total discount rates of 15% and 20% respectively:

Pre-feasibility Stage	$15\% = 2.5\% + 7.5\% \times 1.67$
Early Exploration Stage	$20\% = 2.5\% + 7.5\% \times 2.34$

The value of 1.67 for the pre-feasibility study was selected to give a 15% discount rate, this being a rate that is frequently used

TABLE 3. Analysis of risk factors in a 10% discount rate

Risk components	Uncertainty (accuracy)	Sensitivity (slope)	Risk product	Relative risk	Risk factor
Capital costs	10.0%	.225	2.250	.104	.8%
Operating costs	10.0%	.323	3.233	.150	1.1%
Reserves — Mine life	10.0%	.160	1.602	.074	.6%
Revenue — Price	10.0%	.568	5.683	.263	2.0%
— Grade	8.0%	.568	4.547	.211	1.5%
— Recovery	5.0%	.568	2.842	.132	1.0%
— Plant availability	2.5%	.568	1.421	.066	.5%
Risk portion			21.578	1.000	7.5%
Real long-term risk-free interest rate					2.5%
Total discount rate (no inflation)					10.0%

The "Uncertainty" and "Sensitivity" values used in this table (although based on actual projects) are intended for illustrative purposes only, and should be developed specifically for each project. The "Risk Product" value is assumed to have no meaning except to calculate the "Relative Risk" factor to prorate the 7.5% Risk Portion over the risk components. Revenue factors (price, grade, recovery and availability) all share the same sensitivity factor since they all have the effect of reducing gross revenue; these factors are grouped together in Figure 3. Mine life is assumed to be 10 years. The production rate is assumed to be constant.

TABLE 4. Components of country risk

Political risk	Government stability Political parties Constitutional risk Quality of government Foreign ownership policy (risk of nationalization) Foreign policy Government crises Taxation instability Environmental policy, environmental protectionism Land claims and protected areas
Geographic risk	Transportation Climate
Economic risk	Currency stability Foreign exchange restrictions
Social risk	Distribution of wealth Ethnic or religious differences within the indigenous population Literacy rate Corruption Labour relations

for pre-feasibility work, and that the United States Bureau of Mines often uses as a criteria for this level of study(6). The value of 2.34 for early exploration studies is double the increment for the pre-feasibility case. (See Appendix D for a tabulation of criteria to distinguish different levels of accuracy for evaluation studies.)

In these examples it is assumed that all of the risk components (capital, operating, mine life, metal price, grade, recovery, availability) are multiplied by the same uncertainty multiplier, thereby preserving the same relative proportion of each component of project risk as in the feasibility study. However, these risk components could be individually factored at different rates, depending on the level of uncertainty for each. For example, if capital in a pre-feasibility study was estimated at ±20% then the uncertainty would be approximately twice that at the feasibility level and a multiplier of 2.00 could be used for the capital risk component.

Operating Stages — First Year, Mid-life

As a project moves past the feasibility stage and into detailed design, construction, start-up, and full operation, the uncertainty associated with the risk components is reduced. For example, once construction is complete, the capital cost risk is reduced to zero, because all of the capital has been spent and the costs are known. Uncertainty regarding operating costs diminishes rapidly after the first year of operation. There is, however, little reduction in uncertainty with regard to the mine life, grade, and recovery until well into the operating life, and because of the inherent unknowns in geology, some uncertainty persists until the end of the life of a mine. On the last day of the last year, when the mine and mill close, there are no further **operational** risks and only the interest rate remains. This reduction in risk components throughout the project life is illustrated in Figure 4. (Environmental liabilities may remain at the end of the mine life, but this topic is not addressed in this paper.)

It is important to confirm this logic in actual practice. Three corroborative examples are given below.

In 1986, Ontario High Court Justice R.E. Holland gave his decision on the dispute between International Corona Resources and Lac Minerals regarding the ownership of the Page-Williams mine near Hemlo, Ontario(7). Although the final judgement transferred the ownership of the mine from Lac to Corona (Corona being required to compensate Lac for capital invested), Justice Holland devoted a considerable portion of his written decision to determining an appropriate value for the mine. His conclusion, after listening to a range of witnesses from both sides, was that the value could best be established by the discounted cash flow method (after tax) with a discount rate of 4.5% (no inflation). This rate comprised a long-term interest rate of 2.5% (Ontario Rule 53.09) and a risk factor of 2.0% that represented Justice Holland's conclusions regarding the risk portion for an already operating gold mine in Ontario.

The 4.5% rate determined in Justice Holland's ruling was used in 1991 by Capital Group Securities Limited as a basis for the evaluation of a number of operations for Falconbridge Gold Corporation(8).

The following year, First Marathon Securities Limited used a 5% discount rate in preparing fair market value estimates of International Corona Corporation and Homestake Mining Company to enable comparison of the companies' relative fair market values and stock market performances in preparation for Homestake's offer to purchase all of Corona's stock(9).

These values compare well with the discount rate shown in Figure 4 for the mid-life operation (steady state) discount rate.

Country Risk

All references to this point have been to projects in Canada and the United States to simplify the discussion of the components of discount rates. Traditionally, because these two mining nations have been considered to have zero risk with regard to political and economic stability, the country risk portion of the discount rate has been zero and has had no effect on the discount rate. However, not all projects are developed in countries that can be considered to have zero country risk, so it is necessary to assess the effect that

TABLE 5. Country risk ratings — banks and rating services

Country (partial list)	Forfaiting rates (1) Period years	Actual rate	Accum. rate	Risk increment	Citibank (2)	Institutional Investment (3)	Euromoney (4)	EIU (5)
U.S.A.	7	4.88%	4.88%	0.00%	AAA	95	100	—
Canada	7	4.88%	4.88%	0.00%	AA+	87	98	—
Australia	5	4.88%	5.94%	1.06%	AA	80	92	—
Malaysia	5	4.94%	6.00%	1.12%	A	60	65	23
Chile	5	5.06%	6.12%	1.25%	BBB	25	21	23
Mexico	5	5.06%	6.12%	1.25%	BB+	31	31	55
China	5	6.00%	7.06%	2.19%	BBB	68	78	30
Brazil	3	5.06%	8.06%	3.19%	—	35	35	70
South Africa	3	5.06%	8.06%	3.19%	—	41	41	50
Indonesia	3	6.00%	9.00%	4.13%	BBB−	48	59	40
Argentina	3	6.50%	9.50%	4.63%	BB−	25	29	55
Zimbabwe	1	6.88%	14.88%	10.00%	—	23	34	NA

"—" = Not Rated; "NA" = Not Available

Notes:
1. Forfaiting Rates are from the Banques des Echanges Internationaux[10], June 1993. "Period" refers to the forfaiting term in years. "Actual Rate" is the US$ discount forfaiting rate taken directly from the bank tables (an average of 5.06% is used where values are not given). "Accumulated Rate" is the accumulating value of all increments in rate plus 1.00% for each change in the forfaiting term; it is an estimate of the rate if all countries were rated on the basis of a 7-year term and is illustrated in Figure 6. "Risk Increment" is the increment of the accumulated rate above the Canada/U.S.A. rate.
2. "Citibank" refers to data from the Citibank Project Finance country rating service, October 1993.
3. "Institutional Investor" credit rating, 1986, from Krayenbuehl[11].
4. "Euromoney" credit rating, 1986, from Krayenbuehl[11].
5. "EIU" (Economist Intelligence Unit), The Economist[12], November 20, 1993.

the geo-political location of a mineral project can have on the discount rate and valuation. This is illustrated generically in Figure 5 and the components of country risk are listed in Table 4.

The level of risk varies from country to country and from year to year. It is essential to have both a current assessment and an historical record of a country's risk level when considering mineral investment. Measures of country risk can be obtained from a number of sources that can be divided into three groups: risk rating services, bank credit ratings, and bank forfaiting rates. These are discussed below and are shown in Table 5.

Country Rating Services

Several agencies provide country risk ratings that usually take the form of a score that is assigned to a country on the basis of several significant variables, such as: debt levels, debt repayment record, current account position, economic policy, and political stability. The scores generally range from 100 to 0, the least risky countries having the highest scores and the most risky having the lowest. Three examples of such rating scales are shown in Table 5. Unfortunately, the scores cannot be readily converted to discount rate components.

Bank Ratings

Banks express their opinions of a country's risk level in two ways: by the terms of the loans they will make to a country (life and interest rate), and by a country credit rating. The former are often confidential and not generally available. The latter are published regularly and are expressed by a letter scale, with AAA being the highest (least risk). As risk increases the rating moves downward: AAA, AA, A, BBB, BB, B. Below the B level no rating is assigned and a country is referred to as "unrated". Because this scale excludes many countries where mining is carried out, it does not provide a good basis for determining a discount rate.

Forfaiting Rates

The most useful guide to estimating an appropriate discount rate is provided by forfaiting discount rates. Forfaiting is the practice of purchasing government notes (bonds and other instruments) that have been issued and will come due in the future. Forfaiting rates are the discount rates that forfaiters apply to these future notes

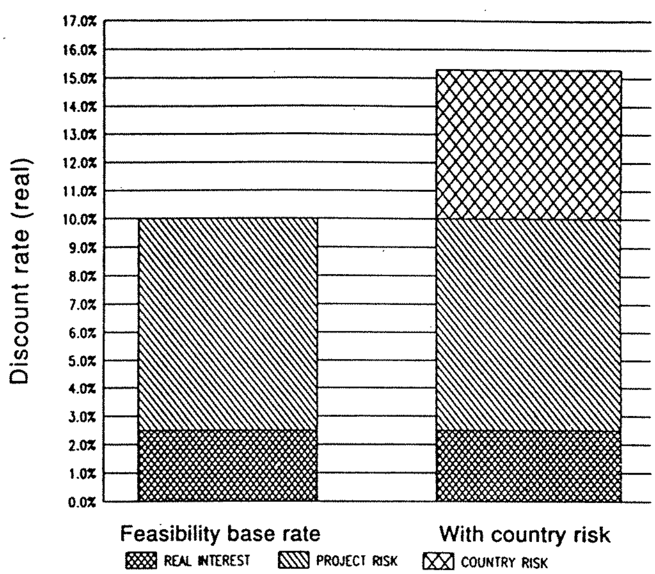

FIGURE 5. 10% feasibility study real discount rate plus country risk. 100% equity.

when they purchase them; they include a basic interest rate and a risk component. The latter can be determined by subtracting the discount rate for the least risky countries (Canada or the U.S.A.) from rates for other countries. Forfaiters further protect themselves from risk by purchasing notes from riskier countries for shorter periods. These periods include 7, 5, 3, 2, 1, and 0.5 years. Forfaiters will currently buy notes as many as 7 years ahead for Canada, 5 years for Australia, 3 years for South Africa, but only 6 months for Romania. The discount rate varies for countries with the same risk period, reflecting a variation in risk levels (Table 5).

To develop a continuously rising scale that increases from the least risky countries to the most risky countries, the author has arranged the rates in ascending order and accumulated the risk increments from country to country. An arbitrary increment of 1% is added each time the risk period is shortened by one level. This is shown in Figure 6, where the actual rates appear as a saw-toothed

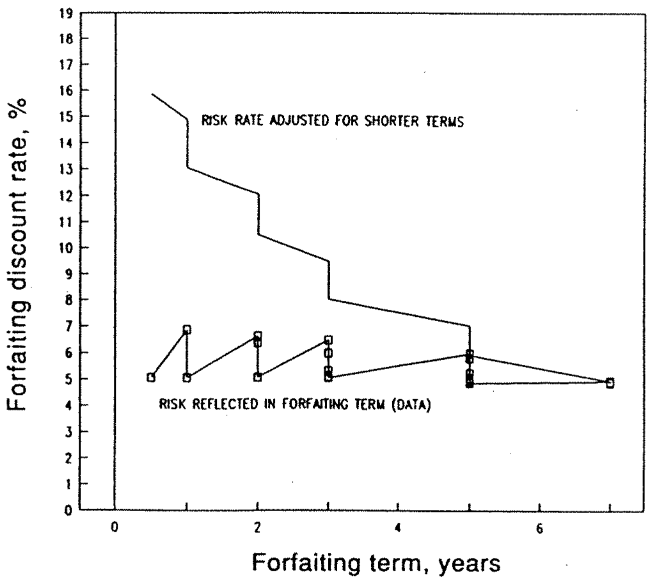

FIGURE 6. Estimate of country risk based on forfaiting rates. The curve "Risk Rate Adjusted for Shorter Terms" assumes that all countries have a 7-year term and that risk is reflected entirely in the discount rate.

pattern and the continuous scale appears as a rising, stepped curve (values are presented in Table 5).

Because forfaiting rates are an expression of risk discounting rates, they are directly applicable to the assessment of country risk in an NPV discount rate. It is worth noting that Capital Group Securities Limited added a 10% risk factor to an operating property in Zimbabwe when evaluating a number of operations for Falconbridge Gold Corporation[8]. The results in Table 5 suggest a similar figure.

Conclusions

It is not the author's intention to suggest that a risk-factored discount rate alone can be used to assess the risk associated with a project. However, analytical risk assessment techniques (see Appendix A) that employ discounted cash flow methods require the application of an appropriate discount rate, and it is the selection of that rate that has been addressed in the present paper.

The risk associated with a project varies with the stage of development of the project. This variation in risk can be reflected in the discount rate that is used to evaluate the project. Table 6 lists typical real (no inflation) discount rates that are applied in current minerals industry practice.

The rates quoted do not mean that, for example, a 10% discount rate should be used for every mineral evaluation at a feasibility study level. Each project will have a specific set of risk characteristics. Although the use of a consistent set of criteria for feasibility studies helps to provide a common basis for comparison, no two projects or studies will be the same. However, in the absence of any other information such a rate gives a reasonable starting point and is a reflection of what the mineral industry is using to value properties.

Increments of country risk can range from 0 in low risk countries to values as high as 10%, and can increase a discount rate substantially.

It is important to distinguish between the DCFROR "hurdle rate" for decision making purposes and the discount rate used to value the NPV of a property. For example, an exploration prospect that indicates a DCFROR of 15% (real) may be worth spending more money on, but one would use a 20% discount rate to determine what to pay for it. The 15% reflects the project's potential, but the 20% reflects its risk at the exploration stage.

TABLE 6. Typical discount rates (excluding country risk) in current use in the evaluation of mineral projects at different stages of development

Project stage	Typical discount rate (real)
Early exploration	20%
Pre-feasibility	15%
Feasibility	10%
Steady-state operations	5%-8%

The use of a project-specific discount rate may reflect a project's unique risks but it does not necessarily determine the purchase price of the property. Rather, it is a guide (especially if it is being used to rank investment alternatives). The buyer will try to pay as little as possible and the seller will try to obtain as much as possible. There is always considerable negotiation when mineral properties change hands. The actual price is whatever a willing buyer and a willing seller agree upon.

Suggestions for Future Research

Addressing the problem of the appropriate discount rate to apply in risk assessment has raised a number of further questions. Some suggestions for future research that have been prompted by this paper are set out below.

1. The "risk product" value in Table 3 has been used only to prorate the risk factors within the pre-set 7.5% value. Could enough information be gathered to develop a database that could be used to estimate the risk level of a project? A standard suite of factors would have to be established, because the addition of more factors would necessarily increase the total risk product.
2. How do mining companies assess country risk and how does an operating presence in a country influence the perception of this risk?
3. How do mining companies address the uncertainties of compliance with environmental regulations and how do they assign a value to the cost of such compliance in the future?
4. What discount rates do individual mining companies employ for discounted cash flow evaluations at different stages of project development and under what economic assumptions?

Information is limited on most of these topics because it is usually considered highly confidential. No doubt there is some fear that knowledge of these criteria could be used by others to anticipate corporate investment strategies. Nevertheless, their study should be pursued.

Appendix A — Risk Assessment Techniques

The purpose of risk assessment is to determine the range and distribution of likely outcomes of a project on the basis of the effects and interaction of the numerous variables that combine to define the project. Several techniques are used to assess and quantify risk in project evaluation. Brief descriptions of the most significant techniques are given below.

Most Likely Case (Base Case)

The best estimate of each variable is incorporated into a single case. This method gives only one result and affords no measure of the range or distribution of possible outcomes of a project. This is usually referred to as the "base case" and is the reference point for further analysis.

Best Case/Worst case

The most optimistic and most pessimistic values are used to produce two cases. This method gives the extreme limits of the pos-

TABLE B-1. Corporate cost of capital by the capital asset pricing model

Stock group	Beta	Nominal (with inflation)	Real (no inflation)
Gold mining	.27	6.6% + (5.0%) (.27) = 7.94%	3.88%
Base metals mining	1.13	6.6% + (5.0%) (1.13) = 12.23%	8.02%
Market	1.00	6.6% + (5.0%) (1.00) = 11.60%	7.41%

Beta factors are taken from US Value Line[2], February 4, 1994.
The long-term risk-free return of 6.6% is the 13-year average for 3-month US government bonds[2].
The risk premium of 5.0% is the long term market yield of 11.6% (nominal)[2] less the long-term risk-free rate.
Nominal rates have been converted to real rates using a 13-year average inflation rate of 3.9%[2].
Nominal interest rates include inflation. Real interest rates exclude inflation. The conversion to real values can be illustrated by the calculation of the real Market CAPM rate of 7.41%:1.0741 = 1.116/1.039.

Gold:	American Barrick	.40	Base metals:	Alcan	1.15
	Battle Mountain	.10		Alcoa	1.20
	Echo Bay	.30		Asarco	1.15
	Hecla	.35		Brascan	0.80
	Hemlo	.15		Cyprus Amax	1.20
	Homestake	.15		INCO	1.15
	Lac	.25		Noranda	0.90
	Newmont	.35		Nord	1.35
	Placer Dome	.30		Phelps Dodge	1.15
	Pegasus	.10		Reynolds	1.20
	Teck	.55		**Average Beta**	**1.13**
	Average Beta	**.27**			

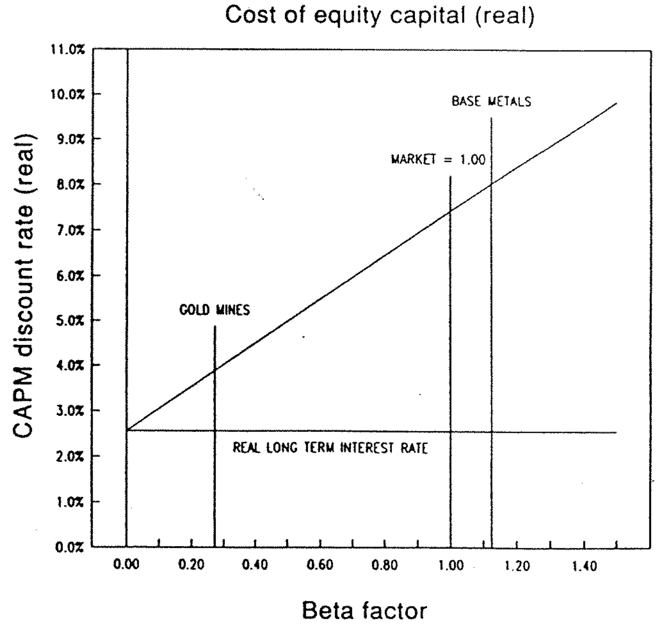

FIGURE B-1. Graph showing Capital Asset Pricing Model discount rates as a function of Beta factors.

sible outcomes of the project but does not provide a measure of the probability distribution of all possible outcomes.

Sensitivity Analysis

Cases are run for a range of likely values for each significant project variable. The effect of changes in each variable can thus be determined and the relative sensitivity of the project to changes in each variable can be assessed. This method gives no measure of the range or distribution of possible outcomes of a project but does provide the components to do so, as well as identifying those variables that affect the project outcome most significantly.

Decision Tree

A decision tree is developed with a number of nodes, which represent points of decision or variance; and branches, which represent the range of possible alternatives at each node. The sum of probabilities at each node is 1. The project is valued at the ultimate tip of each branch using the variables that have defined the branching to that point. By multiplying that value by the compounding probabilities at the nodes along the branch, the combined probability value of each combination of variables can be determined. This method gives some measure of the range and distribution of possible outcomes of a project and indicates the relative merit of each combination of variables. It requires probabilities to be determined at each node.

Monte Carlo Simulation

A probability distribution of likely values is defined for each significant project variable. Using a computer model of the project, values for each variable are selected using random numbers that choose values in proportion to their probability of occurring. The selected values are combined to determine the value of the project for that particular combination of variables. This process is repeated a large number of times (suggestions from 100 to 500 times are not uncommon) so that all likely project outcomes are represented in proportion to the combined likelihoods of the input variables. This method gives a measure of the range and distribution of possible outcomes of a project but does not indicate the relative merit of individual combinations of variables. It requires a probability distribution to be determined for each variable.

Root Sum of Squares (RSS) Procedure

The RSS method proposed by O'Hara[13] employs a skewed probability curve and requires only two points for each variable, at the 10th and 90th deciles (90% of the time the values are higher/lower). The effect of each variable on the value of the project is determined at these two points and the results are used to determine the combined effect of some or all of the variables. This method gives a measure of the range and distribution of possible outcomes of a project and can indicate the relative merit of each combination of variables. It requires two points on a probability distribution to be determined for each variable.

Appendix B — Corporate Cost of Capital

The corporate cost of capital is the weighted average cost of funds available to a company including debt (after tax rate), common stock, and preferred shares. Referred to as the weighted average cost of capital (WACC), it is expressed as an interest rate and is calculated as follows[1]:

$$r_{WACC} = r_e p_e + r_d p_d + r_p p_p \qquad \text{(B-1)}$$

where:

r_{WACC} = weighted average cost of capital (%)
r_e = cost of equity capital (%)
r_d = cost of debt capital (after tax) (%)
r_p = cost of preferred stock (%)
$p_{e,p,d}$ = proportions of equity, debt and preferred stock that make up the corporate capital ($p_e + p_p + p_d = 1.00$)

The values for the cost of debt and preferred stock are normally expressed as interest rates and so are fairly easily obtained. It is more difficult to assess the cost of equity capital and to express it as an interest rate. Several methods are available but the capital asset pricing model (CAPM) is perhaps the most widely used. The basis of this method is that the return for an individual stock can be related to the market as a whole by the relationship[1]:

TABLE C1. Risk adjusted discount rates

Investment opportunity	Risk class (Gentry & O'Neil)	Discount rate (Gentry & O'Neil)	Inflation removed (Smith)
Replacement of equipment at operating properties	I	12%	4.5%
Expansion program at operating property	II	14%	6.3%
Develop a new property, same commodity (domestic)	III	18%	10.0%
Develop a new property, new commodity (foreign)	IV	25%	16.6%

TABLE D1. Comparison of types of economic feasibility studies[14]

Item	Type 1 Early exploration	Type 2 Pre-feasibility	Type 3 Feasibility	Type 4 Final design
Orebody				
No. of drill holes[1]	X	3X	5X	10X
Reserve category	Potential/assumed	Indicated	Proven/Probable	Proven (mineable)
Bulk sampling	None	Possibly	Probably	Essential
Mine				
Mining method	Assumed	General	Optimized	Finalized
Mine equipment	None	Preliminary	General	Detailed
Equipment selection	Hypothetical	Preliminary	Optimized	Finalized
Rock mechanics	None	None	Preliminary	Essential
Visit by mining engineer	Possibly	Recommended	Essential	Essential
Plant and infrastructure sites				
Plant capacity	Assumed	Preliminary	Optimized	Finalized
Plant and other sites	Assumed	General	Approximate	Specific
Maps and surveys	None	If available	Available	Detailed
Soil and foundation tests	None	None	Preliminary	Final
Site visits by project team	Possibly	Recommended	Essential	Essential
Process				
Process flowsheets	Assumed	Preliminary	Normally optimized	Finalized
Bench scale tests	If available	Recommended	Essential	Essential
Pilot plant tests	Not needed	Possible	Probably	Norm. essential
Energy and material balances	Not essential	Preliminary	Optimized	Finalized
Facilities design				
Nature of facilities	Conceptual	Possible	Probable	Actual
Equipment selection	Hypothetical	Preliminary	Optimized	Finalized
General arrangements, mechanical	None	Minimum	Preliminary	Complete
General arrangements, structural	None	Outline	Outline	Preliminary
General arrangements, other	None	Minimum	Outline	Preliminary
Piping drawings	None	None	One-line	Some detail
Electrical drawings	None	None	One-line	Some detail
Specifications	None	Performance	General	DO Sled
Basis for capital cost estimating				
Estimates prepared by	Project engineer	Sr. estimators	Sr. estimators	Estimating Dept.
Vendor quotations	Previous	Single source	Multiple	Competitive
Civil work	Rough sketch	Drawing estimate	Drawing estimate	Take-offs
Mechanical work	% of machinery	% of machinery	Man-hours/ton	Man-hours/ton
Structural work	Rough sketch	Prelim. drawings	Take-off/ton	Take-off/ton[2]
Piping and instrumentation	% of machinery	% of machinery	Take-off	Take-off[2]
Electrical work	$ per hp	$ per hp	Take-off	Take-off[2]
Indirect costs	% of total	% of total	Calculated	Calculated
Contingency[3]	20% - 25%	15% - 20%	15%	10%
Operating cost determination				
Labour rates	Assumed	Investigate	Get contracts	Get contracts
Labour burden	Assumed	Calculate	Calculated	Calculated[4]
Power costs	Assumed	Actual	Actual	Contract[4]
Fuel costs	Assumed	Verbal quote	Letter quote	Contract[4]
Expendable supplies	Assumed	Verbal quote	Letter quote	Contract[4]
Reagents	Assumed	Verbal quote	Letter quote	Contract[4]
Parts	Assumed	Verbal quote	Letter quote	Letter quote
Economic analysis				
D.C.F	Manual	Detailed	Detailed	Detailed
Taxation data	Generalized	Detailed	Detailed	Detailed
Revenue base	Historical	Current	Letters of indication	Written proposals
Use of estimates	Compare/reject[5]	General feasibility	Budget	Funding
Relative cost	X	3X	5X	10X

Notes: [1] Per T. Hocking, senior mining engineer, Kilborn Inc.
[2] Often subject to subcontract bids
[3] In this definition the percentage assigned to contingencies is a judgement factor and is not to be interpreted as meaning that estimates are necessarily accurate within this percentage range, nor is there an implied reference to any order of accuracy.
[4] Contracts can be solicited if project is near term.
[5] Also used to establish tonnage and grade targets for exploration programs.

$$r_e = f + (r_m - f)\,\beta_i \quad \text{(B-2a)}$$

or

$$r_e = f + R\,\beta_i \quad \text{(B-2b)}$$

where:

r_e = expected return for stock i
f = risk-free return (usually long-term government bond rates)
r_m = expected return of the whole market
β_i = Beta factor for stock i. The beta factor expresses the variability of stock i with respect to the variability of the market as a whole. By definition, the beta of the market is 1.00. Beta values are published regularly in journals such as US Value Line Investment Survey[2].
R = risk premium ($R = r_m - f$)

For a 100% equity evaluation, equation B-2 can be used to calculated the corporate cost of capital, since, in an all-equity case, the last two terms in Equation B-1 are equal to zero and the value of p_e therefore becomes 1.00.

Using published beta factors, it is possible to estimate the CAPM discount rates for gold and base metals mining companies. These are calculated in Table B-1 and shown in Figure B-1.

Appendix C — Risk Adjusted Discount Rates

Table C1 is based on work by Gentry and O'Neil[3], who provide values to illustrate the concept of a "Risk Adjusted Discount Rate". They indicate that this method of risk assessment is subjective and that one of the more analytical methods should be used. (These are mentioned in Appendix A.) Nevertheless, the values that they present are instructive.

By equating the 12% discount rate for "Replacement of equipment at operating properties" to the 4.5% discount rate suggested by Justice Holland[7] in the Corona-Lac case for a steady-state operation, it is possible to estimate the inflation rate as 7.2% (1.072 = 1.12/1.045). The "Inflation Removed" value is developed by dividing the "discount rate" by this inflation factor to give an inflation-free discount rate (for example, 1.063 = 1.14/1.072).

The value for Risk Class III, which appears to correspond to a feasibility level study, matches the value suggested in Figure 4 and Table 6.

Appendix D — Comparison of Economic Feasibility Studies

The types of feasibility study performed at different stages of a mineral project are described by McOuat[14] and are compared in Table D1.

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