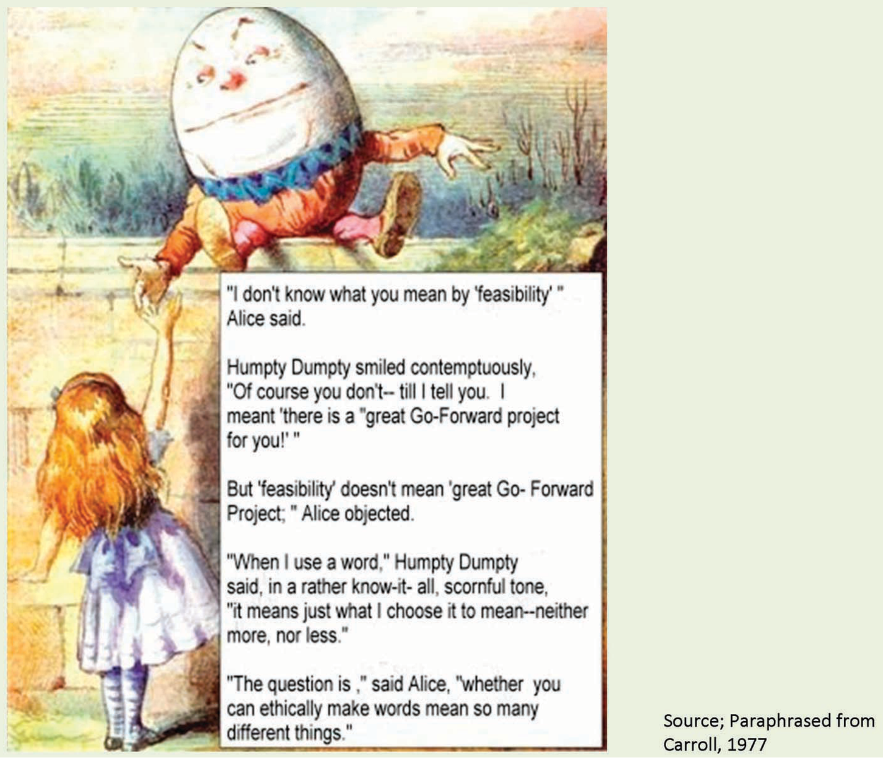
Jackling Lecture

Accuracy of feasibility study evaluations would improve accountability

by Richard L. Bullock

Figure 1

Humpty Dumpty's instruction on what words mean. (Paraphrased after Lewis Carroll, 1977)



"I don't know what you mean by 'feasibility' " Alice said.

Humpty Dumpty smiled contemptuously, "Of course you don't-- till I tell you. I meant 'there is a "great Go-Forward project for you!' "

But 'feasibility' doesn't mean 'great Go- Forward Project; " Alice objected.

"When I use a word," Humpty Dumpty said, in a rather know-it- all, scornful tone, "it means just what I choose it to mean--neither more, nor less."

"The question is ," said Alice, "whether you can ethically make words mean so many different things."

Source; Paraphrased from Carroll, 1977

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Richard L. Bullock, member SME, is professor emeritus, Missouri University of Science and Technology and senior associate, Behre Dolbear & Co. USA, e-mail bullock@mst.edu.

Believe it or not, mine evaluation and feasibility studies are as old as the industry itself. In the first recorded writing on mining by Agricola (1556), he gave several clues as what to look for in evaluating a mine, to determine if it was economically feasible. Below is the guidance from Agricola, with my interpretation of what he would include today.

Now a miner, before he begins to mine the orebodies must consider seven things, namely:

- The situation (the geography/ topography).
- The conditions (the geologic/ mineralogic and mining conditions).
- The water (availability, hydrology and ownership).
- The roads (plus the railroads, power lines, all other infrastructure).
- The climate (the weather-rainfall/ environment).
- The right of ownership (the land and legal entitlement).
- The neighbors (the social environmental concerns of the area).

It is amazing how much of his guidance has not changed in 455 years. Yet Agricola gives no guidance on determining the correct cost, or determining the correct commodity pricing. But he does give a few words of caution on the related ethics involved on buying mineral properties:

"A prudent owner, before he buys shares, ought to go to the mine and carefully examine the nature of the vein, for it is very important that he should be on his guard lest fraudulent sellers of shares should deceive him."

Three hundred years later (1866), to further amplify this point, in the most famous thing that Mark Twain never said, as an introduction to a lecturer to an audience of gold-miners at Red Dog, CA, the famed author/humorist allegedly described a mine as "a hole in the ground owned by a liar" (Farrar & Rinehart, 1935). So, one might conclude that between these two dates, the mining industry did little to improve its reputation. Unfortunately, since Mark Twain allegedly made those remarks, we have not done near enough to gain accountability for the mineral industry.

While this paper is meant for most of the mining industry, it really does not apply to those large mining houses that have, over the years, developed very good systems of rigorous procedures to perform various phases of feasibility study and evaluation of their projects. It is also true that most of these projects are

Table 1

Equivalence of feasibility terminology in the Mineral Wonderland Literature.

Author	Date	Level I	Level II	Level III	Level IV
Taylor	1976	Preliminary	Intermediate	Feasibility	
Hustrulid		Conceptual	Preliminary	Feasibility	
Barnes (reported from Australia)	1997	Resource Calculation	Preliminary	The feasibility	Basic engineering
		Preliminary	Indicative	Definitive	
		Scoping	Preliminary	Detailed	
		Order of magnitude	Prefeasibility	Bankable	Basic engineering
Mackenzie	2006	Scoping	Prefeasibility	Definitive	
Bullock	2011	Preliminary feasibility	Intermediate feasibility	Final feasibility	Basic engineering
Most common usage	2000 to 2011	Scoping	Prefeasibility	Feasibility	Basic engineering

financed within these houses, and never directly reach the financial markets.

This paper is presented to illustrate where most of the mineral industries' problems are found in presenting feasibility study information:

- The confusing equivalency of feasibility terminology.
- The range of expected accuracies projected by various authors for each level of the feasibility study.
- The range of contingency that should be used as presented by various authors for each level of feasibility study.
- The range in the amount of engineering (and other types of studies) that should be devoted to each level of the feasibility study.
- The reasons for projects not yielding the expected return of the investment predicted by the feasibility study.
- The documented mineral project capex overruns for as-built mineral properties.
- The reasons for the capex overruns compared to the feasibility projections.
- A case study example of how bias information appears in a feasibility study.
- Recommendations of how to improve the mineral industry feasibility studies.

Confusing equivalency of feasibility terminology

Since I have already quoted a couple of other well-known individuals, I thought I might best illustrate this point by paraphrasing the words of that great philosopher, Humpty Dumpty (Carroll, 1977).

Whether I am justified in using Fig. 1 to introduce this subject, I will let the readers decide. Table 1 illustrates what is presented by five different authors on the subject of terminology used in the literature to identify the various levels of feasibility studies. We can call our feasibility studies just about anything we want and they will mean whatever we want them to mean to our designated readers. Everyone accepts that there should be multi-levels of study in sequence and an iterative process of studying the same project items over and over, each time with more site information and improving the project identification and cost parameters in each study. However, we call them many different things (Table 1). Thus, you can call your initial study conceptual, preliminary, scoping, order of magnitude or a resource calculation and you can mean the same thing. On the other hand, you can call your second level study preliminary feasibility and no one will know if you are talking about the first level study or the second level study. Likewise, your third level study may be called definitive, detailed, bankable, feasibility or the final feasibility study and they are supposed to mean the same thing. This is precisely what Humpty Dumpty was talking about (Fig. 1).

Range of expected accuracies projected for each level of feasibility study

Now let us look at what 20 different authors state is the expected accuracy of the various levels of the feasibility process (Table 2). The 20 authors predict nearly everything between the ranges that are shown. Are most of these authors wrong? No, they are simply basing their estimate on what they believe must be included in the feasibility study that would yield the desired results. These include many differences, so it is no wonder their projections are different.

How is an investor or a loan officer supposed to know what accuracy to expect from a feasibility study? Is this more Humpty

Table 2

Expected accuracy of capital cost estimates.

Author	Year	Level I first study (%)	Level II second study (%)	Level III third study (%)	Basic engineering (%)
Mular	1978	± 30	± 20	10 to 15	±5
Merrow *	1981	±34 to ±40	±27 to ±34	±20 to ±27	±12 to ±20
PAH **	1981	±50	±30	±10	±5
Kuestemeyer	1987	±40 to ±50	±25 to ±30	±15 to ±20	±5 to ±10
Crowther	1988	15 to 25	5 to 15	3 to 5	
Reynolds	1990	±50	25 to 50	10 to 15	±5
Hustrulid	1995	±30	±20	±10	
White	1997	30	20 to 25	15	10
Neal	1999	-30 to +50	-5 to +30	5- to +15	
Stebbins **	2000	±4 to +25			
Johnston	2001	±30 to ±50	±20 to ±30	±10 to ±20	
Vanas*	2003	25 to 35	15 to 25	5 to 15	
Poos/PAH	2004	±35 to ±40	±25	±15	
Rupprecht	2004	30 to 50	15 to 30	10 to 15	
Sweet	2005	25 to 30		15 to 25	±10
Gamble	2007	5 to 30	5 to 17	10 to 15	
Silver	2007	5 to 30	5 to 17	10 to 15	
PAH	2009	±50	±25	±15	
Behre Dolbear	2010	±45	-15 to +25	±15	
Bullock	2011	±30	±20	±10 to ±15	
Range		**-50 to +30**	**-27 to +30**	**-20 to +27**	**-12 to +20**

Dumpty thinking?

Range of contingency that should be used for each level of feasibility study

So what about contingencies that are supposed to be added to the cost estimates to account for those unknown items not included in the cost estimate that may develop in the design or construction phase?

Many estimators use contingency to cover their inaccuracies of the estimates of items that they do know. Well, what should be used and what is actually used varies considerably between authors (Table 3). The range for Level I is 20 to 35 percent, for Level II, 10 to 20 percent and for Level III, 6 to 20 percent. Whereas what is actually attained in feasibility studies that I have reviewed is much lower, more like 15, 12 and 10 percent for the three levels.

Are you getting the Humpty Dumpty message yet?

Amount of engineering required for greenfield project cost estimating

So why are there so many differences in the expected accuracy and contingency? Well, in my opinion, it is mostly due to the amount of engineering that goes into the study. But isn't there some industry minimum standard range of engineering that goes into each level of the study? Not in the U.S., Canada, Australia or South Africa. Those countries, which have set standards for what is called a resource and what is called a reserve, have absolutely no minimum standards of engineering studies. If they did … Humpty Dumpty would have a great fall.

There are considerable advice and recommendations in the literature concerning how much effort should go into each level of feasibility study (Table 4). However, even here the range of recommendation is considerable. I suspect that these recommendations are seldom followed in the majority of feasibility studies actually being performed within the industry. As long as there are no standards, why should such recommendations be followed?

So what is the result of all this? It has been estimated that only about 10 to 20 percent of all mining projects produce the return on the investment and the net present value (NPV) that was projected by their feasibility study (McMahon, 2007). Many authors have given reasons for failure of projects to yield the expected return. These are summarized in the next section.

Why projects do not yield expected ROI predicted by feasibility study

The literature is full of reasons why mineral

Table 3

Amount of the contingency that should be added to the Wonderland feasibilty capital cost estimate.

Author	Year	Level I %	Level II %	Level III %	Level IV %
PAH*	1981	20 to 30	10 to 20	6 to 10	4 to 7
Warren	1981	25	17	13	8
Proprietary information **	1983	25	20	15 to 20	10 to 15
Bullock	2011	20 to 25	15 to 20	10 to 15	
Range		20 to 35	10 to 20	6 to 20	4 to 15
Average		24	17	13	9

* Pincock, Allen and Holt information supplied to author's former employer.

**Mining company did not wish to be identified.

projects seldom reach their projected rates of return (ROR). (Ballard, 1983; Behre Dolbear, 2010; Bennett, 1996; Danilkwwich, 2002; Dorfier, 1996; Guarnera, B J, 1997; Gypton, 2000; Hickson, 2000; Silver, 2008). These authors give many of the basic causes of each of the reasons that are briefly summarized:

- Insufficient reliable or misstated ore reserves.
- Incorrect metallurgical recovery used.
- Overestimation of mining recovery and underestimation of mining dilution.
- Using a higher commodity price(s) than the trend price.
- Lack of identification of where project's costs lie in the seriatim of other operations of the same commodity.
- Understated capital and/or operating cost.
- Major items of capital cost not even considered.
- Overoptimistic mine design or productivity.
- Overoptimistic mine development schedule and start up (learning curve) time.
- Overestimation of marketability of commodity.
- Unpredicted variation of social/business attitude of community, state and/or national government's reaction to the project.
- Unidentified environmental problems.
- Lack of experience of company and/or feasibility study contractor in developing projects, especially in a country where they have no project experience.
- The plant does not meet the design expectations.
- Differential price inflation between commodities and consumables.
- Differential exchange rates between home country and developing country.

Several of the above items will lead to capital cost overruns. The next section describes just how bad the mining industry record has been over the past 45 years.

Documented mineral project capital cost, as-built overruns and underruns

This section reports on eight different independent studies that were made on anywhere from 16 to 60 projects, ranging from 1965 to 2002 (Table 5). The lowest average overrun for a study was 22 percent, while the highest average project overrun was 35 percent. The weighted average of all projects studied was 26 percent overrun. One study showed that, for 60 projects, 58 percent of the project overran the capital cost between 15 percent and plus 100 percent. Two other studies show more than 100 percent overrun of 8 percent of the projects.

So why does the mineral industry have such a poor record on estimating the capital cost for feasibility studies? Some of the reasons are obvious. Some are not so obvious and may surprise a few of you. In the next section, I have summarized the reasons given by numerous authors with all of which I agree. (Hackney, 1965; McMahon, 2007; Silver, 2008, Bullock, 2011; Gypton, 2002; Flyvbjerg, 2002)

Reasons for the capital cost overruns of as-built projects compared to the feasibility studies

I have indicated which of these items, in my opinion, can be mitigated or certainly minimized when a proper system of feasibility studies is executed. Of course, the "Bias underestimating capital cost," which was documented by Bertisen and Davis (2007) and Bennett (1996), will never be corrected until these companies attitudes are changed by industry standards.

Items that can be mitigated or minimized:

- Construction inflation between final feasibility and construction.
- Change orders (may or may not be justified).
- Poor system or insufficient engineering

Table 4

Amount of engineering required for greenfield projects before cost cutting.

Author	Date	Desktop %	Level I %	Level II %	Level III %	Level IV %	Definition of basis
Lee	1977	N.A.	0.1 to 0.3	0.2 to 0.8	0.5 to 1.5	N.A.	Capex cost
Proprietary information	1984	N.A.	N.A.	N.A.	2 to 3	N.A.	Capex cost
Crowther	1985	N.A.	N.A.	N.A.	1 to 2	N.A.	Capex cost
Rupprecht	2004	N.A.	0.1 to 0.3	0.2 to 0.8	0.5 to 1.5	N.A.	Capex cost
Range		N.A.	0.1 to 0.3	0.2 to 0.8	0.5 to 1.5	N.A.	Capex cost
Proprietary information	1984	N.A.	3 to 6	12 to 17	20 to 26	30 to 42	Total engineering
White	1997		4 to 5	12 to 15	20 to 26	30 to 40	Total engineering
Vancas	2003	2	5	15	27	40	Total engineering
Bullock	2011	2 to 3	6 to 8	15 to 20	20 to 30	30 to 50	Total engineering
Range		2 to 3	3 to 8	12 to 20	20 to 30	30 to 50	Total engineering
Average		2.5	5.5	16	25	40	Total engineering

during feasibility studies.

- Major capital items completely missed during feasibility.
- All items not updated during each phase of feasibility.
- Poor estimating techniques.
- Time schedule overruns (about 1 percent of capital cost per month).
- Contingency allowance calculated incorrectly or chosen too low.
- "Owners' cost" left out or estimated too low.
- "Working capital" calculated incorrectly or simply chosen too low.
- Lower construction productivity than expected.
- Client company and engineering contractor bias.
    - Company needs low capex to compete for financing.
    - An engineering contractor may submit low bid and "low-ball" capex estimate to get next contract.

Reasons that cannot be mitigated or minimized:

- Unexpected inclement weather.
- Delay of equipment deliveries due to customs or manufacturers.
- Longer permitting time than estimated.
- Activities of special groups obstructing projects.
- Accidental events occurring during construction.
- Changes in environmental or other government regulations.

You would be surprised at how prevalent company and contractor bias distorts the capital cost estimate. So how would an investor or loan officer know when a company and engineering contractor are using bias data in the feasibility study? I have a classic example of a real study for which there was a due diligence performed when the company was seeking financing. I will not tell you the name of the company, the contractor, project, where it was located, nor even the multi-commodities that were involved, because I do not wish to point fingers. But I will tell you it was a very large project, involving multiple sites, in a primitive portion of an emerging country.

Case study of a company/contractor bias for an actual "Project Wonderland"

The due diligence review revealed the following problems:

Geology/reserve

- Underestimated tonnage, but overestimated grade.
- Did not cap outliers for a large portion of the deposit.

Mining items

- Density factor off by +10 percent.
- Pit slope 5° steeper than independent consulting expert's recommendation.

Metallurgical items

- Sulfide ore was okay.
- Very limited testing of oxide ore and used only favorable results.

Cost

Capital cost omitted items:

- No right of way or land acquisition cost, even though it was needed.
- No railroad concentrate cars, switch engines, cost of two railroad bridges.
- No port facilities, even though there was none available for its concentrate.
- Totally inadequate plant water system.
- No outside communication system for plant or town site.
- No plant fuel, sewage or solid waste systems, nor offices for mine superintendent staff, nor company employee change house.
- Townsite/infrastructure capital cost underestimated by 37 percent.

Operating cost:

- Mine operating cost set (not estimated) 17 percent too low.
- Concentrating operating cost estimated 13 percent too low.
- No operating allowance for townsite operation or community development.
- Startup cost underestimated by more than 200 percent.
- No cost estimate for permits, royalties and licenses, risk insurance, financing, recruiting or training cost.
- There was no allowance for any downtime or overtime in the operation.
- Working capital underestimated by at least 75 percent.
- Contingency used was 10 percent lower than what should have been used.
- There was no cost seriatim comparison completed for the project that would show that it could compete with other producers of the same commodity in periods of low commodity prices.

The financial client turned down the financing of the project, but the company found another group that did finance the next phase of the project. The project was eventually built.

Results: The actual project was five years late being built; construction cost was more than 40 percent higher than was projected (even excluding inflations) and, before the drastic commodity price rise in recent years, the property was losing money.

Financial companies reaction to the industry's poor track record

So how do the responsible financial companies react to this miserable mineral industry record? They, of course, have to discount and factor that which is presented. So if your Venezuelan project has a 36 percent internal rate of return (IRR), which might look pretty good to you, they would probably have to discount it to a real 15 percent IRR, which would not look so good in Venezuela.

How can we improve the mining industry feasibility studies to better reflect that which is actually built and produces the revenue stream that was predicted? I believe that the best way to do this is to improve the quality and standards of conducting the three phases of feasibility studies. I believe that this is the only way to reestablish credibility to the process we now use to evaluate mineral properties.

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How to upgrade the mineral industry feasibility studies

Nearly everyone agrees that the three-phased approach for greenfield mineral property development is the correct approach. Though I see more and more projects in the period of high commodity prices going from a scoping study directly to a final feasibility study or, what is worse, performing a final feasibility study from scratch. Such projects may make money in periods of high commodity prices, but will never be optimized to yield the return that may have been made from the property.

The level of accuracy must be improved for all three levels. The problem starts with the conceptual study. While useful for some purposes in its present form (identifying and pinpointing global exploration effort as an example), it has been agreed that it is not good enough to make

Table 5

Documented mineral project capital cost overruns and underruns.

Author	Years	Number of projects studied	Avg. project overrun (%)	Cost underrun > -15% < 0%	Project costs >0% <+15%	Cost overrun >15% < 100%	Cost overrun +100 %
Castle	1965 - 1980	17	+35	29	12	59	
Merrow *	? - 1980	44	+27	N.A.	N.A.	N.A.	N.A.
Bertisen	1980-2001	63	+25	N.A.	50	N.A.	N.A.
Bennet	1996	16	+27				
Gypton/ Ward	1987-1997	37	+31	16	11	65	8
Gypton	1980-2002	60	+22	42		58	
McMahon	?	N.A.	N.A.	10	90		
Thomas	?	21	+25	N.A.	2	N.A.	N.A.
Number of projects			22 to 35	10 to 29	2 to 50	58 to 73	
Weighted average			+26				

major financial decisions. As it is now performed, any marginal project can be made to look like it clears the hurdle rate of the company. Yet, the conceptual study is indeed used universally for making decisions on whether to spend more money on additional exploration and continue with the second phase of the preliminary feasibility study. I know of two projects where the amount of money spent after the initial study through the preliminary study was more than $200 million in 2010 dollars. In truth, the conceptual feasibility studies now typically have an accuracy of -35 to -45 percent and need a contingency of +35 to +50 percent. In fact, many of the feasibility study contractors use 12 to 15 percent.

For Level I, my recommendation is to perform sufficient study and engineering to bring the accuracy to ±30 percent. It is my opinion that, for a real ±30 percent accuracy on the capital cost estimate and to cover all of the items that need definition at that level, you must spend approximately 6 to 8 percent of the total engineering and other study hours. For a small project, this may amount to 8,400 to 11,200 hours of engineering and other work. But, for a large, multi billion, multi site project in an emerging nation, this percentage may amount to 54,000 to 72,000 hours. Half of that might easily be cost estimating, scheduling and project management, when done properly.

For Level II, my recommendation is to perform sufficient study and engineering to bring the accuracy to ±20 percent. For a real ±20 percent accuracy on the capital cost estimate and to cover all of the items that need definition at that level, it is my opinion you must spend approximately 15 to 20 percent of the total engineering and other study hours. This could amount to 21,000 to 28,000 hours for a small project; for a large, multi billion, multisite project in an emerging nation, this percentage may amount to 135,000 to 180,000 hours.

For a Level III, my recommendation is to perform sufficient study and engineering to bring the accuracy to ±10 percent for facilities and ±15 percent of capital cost. For a real accuracy of ±10 percent for facilities and ±15 percent for mines on the capital cost estimate and to cover all of the items that need definition at that level, it is my opinion that you must spend approximately 20 to 30 percent of the total engineering and other study hours. This could amount to 28,000 to 42,000 hours for a small project; for a large, multi billion, multi site project in an emerging nation, this percentage may amount to 135,000 to 270,000 hours.

The first thought is that this will greatly increase the time of the feasibility study. However, when combined with the correct approach to environmental baseline studies and permitting time, it should not increase the total time appreciably. Debra Struhsacker (2010), a consultant based in Reno, NV, has looked at this problem and these ideas were taken from one of her presentations.

- In the design process, exceed environmental protection and design requirements and this will eliminate uncertainties about environmental protection.
- Avoid self-inflicted delays and controversy.
- Do not start permitting until you know everything you want to do and know everything you need to know. Premature permitting will not save time – it will just create doubt, controversy and delay.

A couple examples of the trend of regulatory agencies:

- Nevada BLM policies for data requirements for "Plans of Operation."
- BLM will no longer start the NEPA process before the operator provides complete baseline, engineering and waste characterization data.

We must also do a better job of verifying the results of the feasibility study with due diligence before any outside investment is made to advance the project. We also need some standard practice that, if a due diligence is performed on a feasibility study, it becomes an attachment that will follow that feasibility as it is shopped around to various financial institutions or public offerings.

Why has the industry not set standards for what must be done in a feasibility study?

Why has such a tremendous effort been put forth to greatly improve the quality and standards of the resource and reserve classifications, but with little or no effort to improve the detailed definition of that which determines whether or not a resource will move from a resource to a reserve classification? Does the industry really believe that unethical practices of project feasibility studies only can come through misrepresentation of reserves?

The great work of the AusMin ValMin Code/JORC, the South African SAMVAL/SAMREC, the Canadian 43-101 requirements and the U.S. SEC's Industry Guide 7, plus the work of the SME Resource and Reserve Committee (Formerly Committee 79), have all contributed to the much improved standards of defining the resources and the reserves and to minimize fraud in this area. But why do they offer only a few sentences of guidance when it comes to the rest of what goes in the feasibility study? Why are there no specific guidelines or standards?

In my attempt to correct this situation, in Chapter 4.7 of SME's new *Mining Engineering Handbook* I have outlined those things that need to be studied and when they need to be studied. It is not in as much detail as I would have liked to have to presented, but space was limited. It is by no means the final answer. I would hope that it will challenge those of the large mining houses and those of the engineering contractors whom have their more complete list and rigorous standards to come forth and expand what I have presented.

What will it take to set the quality standards of conducting the three-phase feasibility study?

In my opinion, it will take the collective action of various industry participants. I believe that this could, and should, be organized similar to how the SME Resource and Reserve Committee was put together, except to combine the effort with such organizational participants as the Mining and Metallurgical Society of America (MMSA) and the Northwest Mining Association (NWMA).

I believe that this committee should be made up of qualified professionals from exploration companies, small and large mining companies, engineering consulting and contracting companies and financial institutions normally active in support of mineral developments.

Summary

We can improve the mining industry feasibility studies. We must do a better job, which reflects the project actually built and produces the revenue stream that was predicted. I believe that the best way to do this is to upgrade the quality and standards of conducting each of the three phases of feasibility study. This upgrade can only be done by spending more hours of engineering, geological, geotechnical, social and environmental study in all three phases of the feasibility process, which meet some industry standards. I believe that this setting of standards can be done by the collective efforts of SME, the MMSA and the NWMA. We must also do a better job of verifying the results of the feasibility study with due diligence before any outside investment is made to advance the project.

I would hope that by taking this approach, over the next few years we could greatly improve the accuracy of our feasibility evaluation studies and, thus, improve our industry accountability. (References available from the author.) ■