MEMORANDUM

TO: Resolution Copper Project Record
Attn: Chris Garrett, SWCA Project Manager

FROM: Charles A. Kliche, P.E., PhD

DATE: February 13, 2019 (Final Rev: March 24, 2019)

RE: **Memorandum regarding spreadsheet analysis of mining economics: "Dave Chambers, CSP2, 2/14/05 - updated with 2018 copper prices"**

I have been looking through the "Chambers mining economics - updated 2018" spreadsheet for a while now. It's not exactly obvious by looking at the spreadsheet what Mr. Chambers' assumptions were. He, it seems, has provided no narrative.

The spreadsheet seems to contain 5 Net Present Value (NPV) of cash flows (CF) over time (n = 35) for 5 different options (1 CF for each option), namely (in **bold** are the differences between the baseline case [Caving Case - Lowest Cost] and the others):

1. Caving Case - Lowest Cost (n = 35; i = 7.5%; avg Cu grade = 1.5%; Cu price = $3.00 per lb; mining cost = $5/ton; total tons mined = 1,141,200,000 over the 35 years)
2. Caving Case - Highest Cost (n = 35; i = 7.5%; avg Cu grade = 1.5%; Cu price = $3.00 per lb; **mining cost = $20/ton**; total tons mined = 1,141,200,000 over the 35 years)
3. Backfill Case - Lowest Cost (n = 35; i = 7.5%; avg Cu grade = 1.5%; Cu price = $3.00 per lb; **mining cost = $12/ton**; total tons mined = 1,141,200,000 over the 35 years)
4. Backfill Case - Highest Cost (n = 35; i = 7.5%; avg Cu grade = 1.5%; Cu price = $3.00 per lb; **mining cost = $35/ton**; total tons mined = 1,141,200,000 over the 35 years)
5. Backfill Case with assumptions of: high cost, higher grade, and only 75% of tonnage mined (n = 35; i = 7.5%; **avg Cu grade = 3.0%**; Cu price = $3.00 per lb; **mining cost = $35/ton**; **total tons mined = 867,787,500** [75% of tonnage] over the 35 years)

Chambers computed his CF per year as such:

Total mining revenue = (tons mined /day · 360 days/year · 2000 lb/ton · $3.00/lb · % Cu grade/100) - (tons mined/day · 360 days/year · mining cost $/ton)

He then discounted the yearly CF to the present by i = 7.5% per year for n = 35 years. If that CF, discounted to the present (t = 0) is greater than zero (which it was), then the project is viable, according to engineering economic theory[3, 4].

Of note:

- Chambers started the mining revenue flow at year 6;
- His pre-mining capital cost investment (normally referenced as C_o) occurred in years 1 - 5. For Options 1 & 2, the total pre-mining capital investment is $1.25Bn; for Options 3 - 5, the

total pre-mining capital investments is $1.30Bn. **<u>According to Resolution Copper, the pre-mining capital investment is closer to $11.4Bn[1]</u>**;

- Chambers used a 360 day year;
- Chambers neglected the mill recovery of around 90%[2] in calculating total revenue;
- Chambers neglected any mining dilution;
- Neglected in the CF calculation were <u>royalties</u>, <u>Federal income taxes</u>, <u>state income taxes</u>, <u>other state, local and Federal taxes</u>, and any <u>yearly capital expenditures, including development</u>.

A typical yearly CF calculation for a mining venture takes the form[3] [4]:

Calculation	**Component**
	Revenue
Less:	Royalties (usually taken NSR)
Equal:	Gross Income From Mining
Less:	Operating Costs
Equal:	Net Operating Income
Less:	Depreciation and Amortization Allowance
Equal:	Net Income After Depreciation and Amortization
Less:	Depletion Allowance (15% of Gross Income From Mining)
Equal:	Net Taxable Income
Less:	State Income Tax (AZ = 4.9%)
Equal:	Net Federal Taxable Income
Less:	Federal Income Tax (eg: 28%)
Equal:	Net Profit After Taxes
Add:	Depreciation and Amortization Allowances
Add:	Depletion Allowance
Equal:	Operation Cash Flow
Less:	Capital Expenditures
Less:	Working Capital
Equal	**Net Annual Cash Flow**

[1] Pollock, Elliot D. & Company, "Resolution Copper Company Economic and Fiscal Impact Report Superior, Arizona", September 2011, page 1.
[2] Resolution Copper Mining, "General Plan of Operations Resolution Copper Mining, vol 1", Rev 2: January 12, 2016, page 112.
[3] Gentry, D.W. & T. J. O'Neil (1984), Mine Investment Analysis, SME of AIME, New York.
[4] Stermole, F.J. & J.M. Stermole (2012), Economic Evaluation and Investment Decision Methods, Investment Evaluations Corp., Lakewood, CO.

NOTE: CF elements shaded in grey are missing from Chambers' analyses.

Some questions arise on some of the numbers (assumptions) Mr. Chambers used, specifically:

- Where did the 7.5% rate come from at which the project CF was evaluated?

  Is this rate a calculated WACC[5] (Weighted Average Cost of Capital) for the venture, or a wild guess?

- The $3.00 per pound copper might be optimistic. It's been around $2.75 recently[6] with price around $1.00 per pound from 1974 to 2004. There are a lot of drivers in copper prices, one of which is the Chinese economy. Is it going to stay hot? It's cold right now.

Copper Prices - 45 Year Historical Chart

Interactive chart of historical daily COMEX copper prices back to 1971. The price shown is in U.S. Dollars per pound.
The current price of copper as of February 01, 2019 is **$2.77** per pound.

5 Quirin, G.D. (1967), The Capital Expenditure Decision, Ch5 "Costs of Capital from Specific Sources," and Ch6 "Costs of Capital to the Firm." Richard D. Irwin, Inc.

6 https://www.macrotrends.net/1476/copper-prices-historical-chart-data

- The mining cost for each of Chambers' cases is unrealistically low. That is, is processing cost included in this cost? Are other costs associated with the proposed backfilling also included?

  Is their "Mining Cost" total cost? Ie: Mining + transportation + processing + G&A + taxes + ….? For example, while the range of block caving costs used by Chambers ($5-$20/ton) matches reasonably well with other sources ($9/ton, see Kliche[7] 2017 Table 2), the range of cut-and-fill costs ($12-$35/ton) is remarkably low compared with other sources ($68/ton, see Kliche[7] 2017 Table 2)."

- How could the Backfill Case "Low Cost Per Ton" value be lower than the normal block caving "High Cost Per Ton" value?

- Interesting: Running the numbers again using an initial investment of $11.4Bn and a selling price of copper of $2.50 per pound, the implied ROR of the "Caving - Lowest Cost" is 20% (23.7% for $3 Cu). All the other options, then, have a Negative NPV at 20%.... **Except:** the "Backfill Case with *Assume High Cost, Higher Grade, and only 75% of tonnage mined"*, which still has a $2.195Bn NPV. **WOW!!**

  Why is the "Backfill Case with *Assume High Cost, Higher Grade, and only 75% of tonnage mined"* still highly profitable? Because: The copper grade of only 3%, average, is unrealistic; the tons available at the higher grade is unrealistically high; the mining cost is unrealistically low; and the capital costs are impossible to estimate without a detailed mine plan being developed.

  For example, the Chambers spreadsheet assumes a tonnage of 868 million tons at 3% copper grade, representing 75% of the ore body planned to be mined in the GPO. A more realistic idea of tonnage can be gathered from analysis conducted on the actual grade distributions obtained from Resolution (see Kliche[7] 2017). An estimate of tonnage within the 2% shell is 386 million tons (representing 34% of the ore body planned to be mined in the GPO) and an estimate of tonnage within the 3% shell is 7.5 million tons (representing less than 1% of the ore body planned to be mined in the GPO).

- NOTE: Ores mined from the Magma Mine deposit averaged 5.69% Cu from 1915 to the end of 1964[8]. Ore tons mined per year during the period from 1950 - 1964 ranged from 276,000 to 464,000[5]; and copper production ranged from 26,000,000 lb to 49,600,000 lb[5].

  The tonnage mined at Magma during 1950 - 1964 equated to approximately 1000 tpd. According to Table 2 of Kliche[7], 2017, the operating cost for a cut-and-fill mining operation producing at 1000 tpd is approximately $68 per tonne, or about $62 per st (short ton).

  According to *Volume 1 – Administrative Information Aquifer Protection Permit Application Resolution Copper Mining Limited West Plant Site, Superior Mine Superior, Arizona*[9]:

  > "Mining of the Magma Vein, a quartz-sulfide ore body, occurred from the late 1800s through the 1940s at the West Plant Site and was followed by the discovery and

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[7] Kliche, C.A., "Draft Technical Memorandum for Alternative Mining Methods, Resolution Copper Mining, LLC, Superior, AZ", Table 2, July 7, 2017

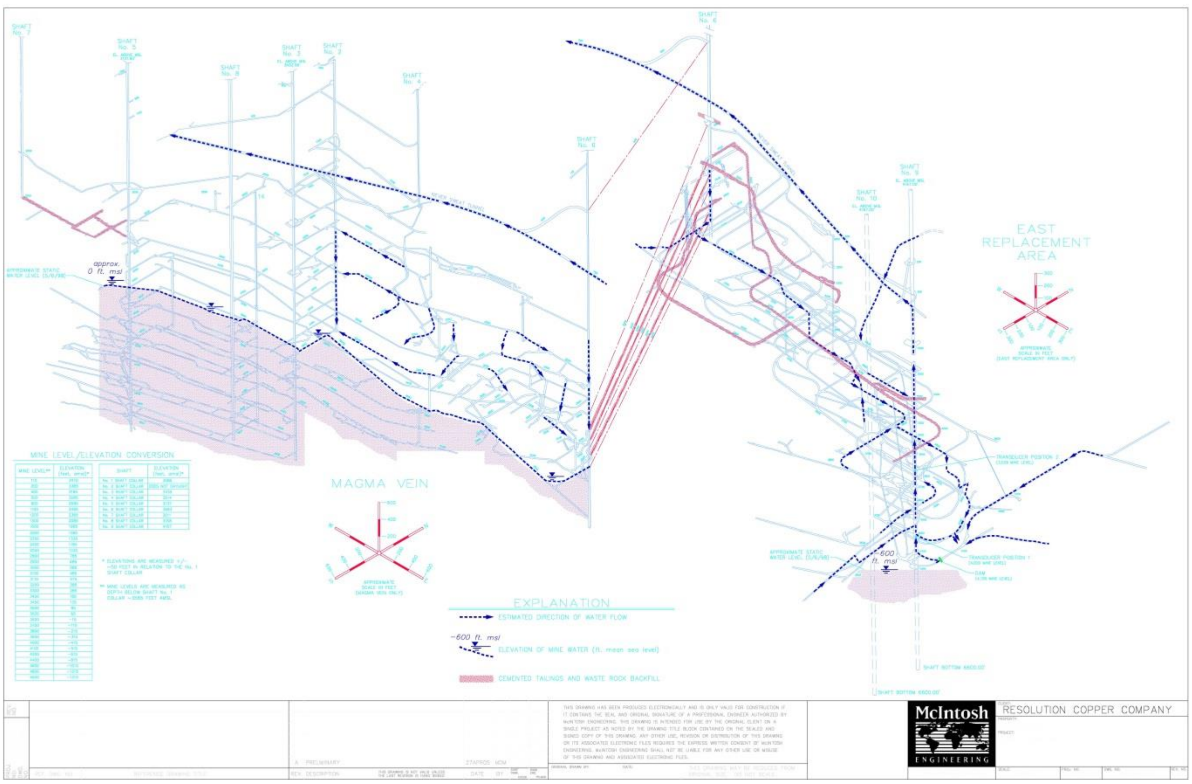
[8] Ridge John D., ed. Ore Deposits in the United States 1933/1967, vol II, "Geology of the Magma Mine Area, Arizona," AIME, 1968.

[9] Courtesy of Ms. Victoria Peacey, 3/30/17.

mining of a carbonate replacement ore body to the east. Underground mining activities conducted from the late 1800s through mid-1996 produced approximately 26 million tons of ore at the mine, out of which approximately 20 million tons were tailings. About 6 to 7 million tons of the tailings reported to the underground workings as structural support and the remainder reported to the tailings facilities at the West Plant Site.

Less than 50% of the Magma Mine was backfilled with tailings in the cut-and-fill mining process (shaded portion on figure below shows the backfilling)[10].

The final figure[9] shows the surface distribution of the tailings from The Magma Mine adjacent to the city of Superior.



- The most interesting aspect of Chambers' "analysis" is the three backfilling cases (#3. Backfill Case - Lowest Cost; #4. Backfill Case - Highest Cost; and #5. Backfill Case with assumptions of: high cost, higher grade, and only 75% of tonnage mined).

  Specifically, it appears that, in all three backfill cases in the Chambers analysis, the backfilling is to be concurrent with the mining. Yet, in 2 of the backfill cases, (#3 and #4) 100% of the tonnage which is proposed to be mined by caving is also assumed to be mined by the method employing the backfilling. The indication, therefore, is that caving will also be used as the mining method

[10] Courtesy of Ms. Victoria Peacey, 3/25/17.

for #s 3 & 4, and the filling will be concurrent with the mining (there is no capital or operating cost at the end of mining to indicate backfilling occurs after mining).

Something that most definitely was overlooked in the Chambers analysis is that broken rock swells (bulks) from its in situ volume as much as 20 - 60%, with a good average being 30 - 35%.

So, say one caves and extracts a given in situ volume of rock (say 1,000,000 yd^3) with some in situ material overlying that extracted material which is allowed to cave and bulk into the extracted volume (a very elementary theory of block caving), then the actual subsidence crater formed by the caved material overlying the extracted material will have a volume less than the volume extracted by some swell factor (ie < the 1,000,000 yd^3 by up to 30 or 35%).

Additionally, the ore rock going to and through the mill is reduced in size by various methods (called "comminution") in order to get it to sand and sub-sand (clay-like) particle size so more surface area is exposed and allow the chemical used to bond to and remove the copper and molybdenum efficiently by the extraction method being employed (flotation).

These small sand-sized or clay-sized particles, barren of the Cu and Mo after extraction, also bulk as the rock is being reduced in size. This swelling, or bulking, may be around 8 - 15%, with a good average being about 12%. This material, called "tailings" goes out the back door of the mill and is normally either placed in a containment area (tailings basin) or, in the case of certain underground stoping methods, placed back into the mined out cavity (cut-and-fill underground mining), or both, since there is usually excess material beyond what is required for backfilling underground.

Because no narrative is provided with the Chambers spreadsheet, certain assumptions have to be made in this critique, including about how the backfilling would be achieved. So, if the thought of Chambers is that the tailings be placed back into the subsidence crater, then numerous problems will entail:

1) There will be excess material beyond the volume of the crater requiring a storage facility (tailings basin) for the remainder.

2) Will the tailings be stacked, dried and conveyed or trucked back to the subsidence crater? If so, this will entail some sort of loading apparatus (reclaimer) plus conveyor system and radial stacker; or loader(s) plus trucks plus dozers plus other heavy equipment.

   Or, will the tailings be pumped back in slurry form? Then some sort of pumping plant, thickeners, etc will be needed at the tailings containment site, plus a network of pipes.

   In either case, if this operation is concurrent with the mining, then they would be dumping wet or dry tailings on top of the people and equipment working below. The water, in the wet pumping case, will percolate to the working levels and have to be pumped out. Additionally, the water may be contaminated due to exposure to sulfide materials and will need to be treated before release into the environment.

   Also, if the tailings are dumped back as the mine is being operated, mixing of the tailings and the ore being withdrawn may occur, resulting in some or significant dilution.

3) If the proposal is to pick up the tailings at the end of the mining and place them into the subsidence crater, then this would pose an additional exorbitant cost of rehandle on the company.

Now, for the case of option #5, the Backfill Case with assumptions of: high cost, higher grade, and only 75% of tonnage mined:

1) Is this some kind of proposal to only mine the higher grade material via block caving (resulting in the guesstimated 75% of tonnage)?

Did Chambers look at the grade distributions to see if this is even possible?

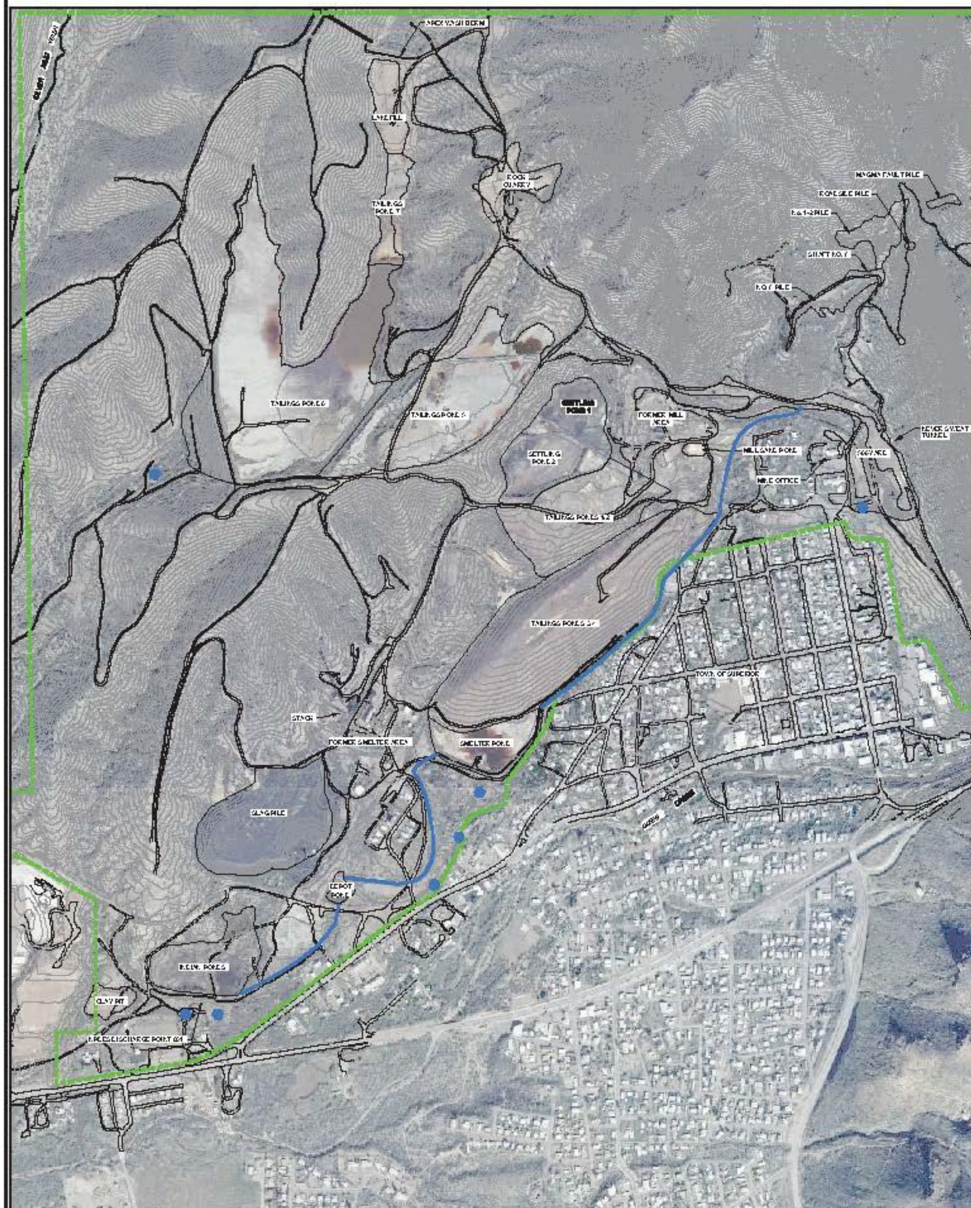
2) Where did the 3% average grade come from?

3) Where did the 75% of tonnage come from? Is Chambers privy to some sort of tonnage v (average or cut-off) grade relationship for the Resolution ore body?

4) Is the proposal here to mine the high grade areas within the Resolution deposit by some sort of cut-and-fill stoping method and backfill tailings into the voids created?

   If so, then 75% of the ore deposit being available for this method is way, way high.

   And 3% average grade is low.



EXPLANATION

APPROXIMATE PROPERTY BOUNDARY

Figure 1-2

SITE MAP
WEST PLANT SITE
RESOLUTION COPPER MINING LIMITED
SUPERIOR, ARIZONA

Concluding Remarks

1) The three backfilling options (#3. Backfill Case - Lowest Cost; #4. Backfill Case - Highest Cost; and #5. Backfill Case with assumptions of: high cost, higher grade, and only 75% of tonnage mined), as presented by Mr. Chambers, are unrealistic for any number of reasons.

2) The PV calculations, as presented by Mr. Chambers, are unrealistic due to bad assumptions and missing elements of each yearly CF calculation.

3) Even if backfilling of the subsidence crater with tailings is deemed a viable part of the mining/reclamation sequence, a tailings basin is going to be necessary. The size of said tailings basin may be as large, or smaller, than the one proposed by the proponents, depending on how and when the tailings would be returned to the crater.

4) [11]On August 3, 1977, the 95th Congress passed Public Law 95-87—The Surface Mining Control and Reclamation Act of 1977. The focus of the law was coal; but Section 709 called for a study of surface mining for minerals other than coal to determine whether existing and developing technology for mining minerals other than coal can be used to achieve the requirements of the Act, and to discuss alternative regulatory mechanisms to control mining. The Act directed the Council on Environmental Quality (CEQ) to contract with the National Academy of Sciences, other agencies, or private groups, as appropriate, to conduct the study. In response to a request from the Council, the Board on Mineral and Energy Resources of the Academy's Commission on Natural Resources formed the Committee on Surface Mining and Reclamation (COSMAR).

   Specifics of SEC 709 of the Act:

   "STUDY OF RECLAMATION STANDARDS FOR SURFACE MINING OF OTHER MINERALS

   SEC. 709. (a) The Chairman of the Council on Environmental Quality is directed to contract to such extent or in such amounts as are provided in appropriation Acts with the National Academy of Sciences-National Academy of Engineering, other Government agencies or private groups as appropriate, for an in-depth study of current and developing technology for surface and open pit mining and reclamation for minerals other than coal designed to assist in the establishment of effective and reasonable regulation of surface and open pit mining and reclamation for minerals other than coal. The study shall—

   (1) assess the degree to which the requirements of this Act can be met by such technology and the costs involved;

   (2) identify areas where the requirements of this Act cannot be met by current and developing technology;

[11] "Surface Mining of Non-Coal Minerals, A Study of Mineral Mining from the Perspective of the Surface Mining Control and Reclamation Act of 1977;" A report prepared by the Committee on Surface Mining and Reclamation - Board on Mineral and Energy Resources, Commission on Natural Resources, National Research Council; National Academy of Sciences, Washington, DC, 1979.

(3) in those instances, describe requirements most comparable to those of this Act which could be met, the costs involved, and the differences in reclamation results between these requirements and those of this Act; and

(4) discuss alternative regulatory mechanisms designed to insure the achievement of the most beneficial postmining land use for areas affected by surface and open pit mining.

(b) The study together with specific legislative recommendations shall be submitted to the President and the Congress no later than…."

Findings of the COSMAR group include:

(1) that the degree to which the requirements of the Act can be met by existing or developing technology ranges from readily achievable to impractical depending on specific requirements and on the location and nature of the mineral deposit and method of mining and processing; when existing or projected data made it possible, compliance costs were ascertained or estimated;

(2) that there are areas where the requirements of the Act cannot be met because of technological or economic limitations;

And:

Return to Original Contour

"The Act requires that the land be restored to approximately its original contour. This provision is generally not technically feasible for non-coal minerals, or has limited value because it is impractical, inappropriate, or economically unsound (Section 5.2.2)….

…. Further, to restore the original contour where massive ore bodies have been mined by the open-pit method would incur costs roughly equal to the original costs of mining. Although technically possible, such backfilling of a large open pit would be of uncertain environmental and social benefit, and it would be economically impractical to mine some deposits under the current cost structure."

…..

"Backfilling, provided that depletion of the mineral deposit makes it at all possible, is a costly requirement of 204 the Act if applied to some open pit operations (Sec. 515(b)(3)), as discussed below. Even if an adjacent pit is available for dumping, or if the nature of the mineral deposit is such that the pit can be advantageously dug in an elongate form, thus allowing for backfilling on one face while the pit advances on the opposite face (Banks and Franciscotti 1976), backfilling nonetheless requires rehandling of the material initially excavated. For this material, the cost of handling is at least doubled. In the case of mineral deposits that are reached only at depths of several hundred feet, this cost would be very large.

…..

Rather than backfill large open pits, placement of the rock waste and tailings conceivably can be managed in ways that would build a new landscape suitable for anticipated postmining uses. Such a concept has been presented for handling rock waste and tailings in the Sahuarita copper district (Matter and others 1974) and is consistent with certain provisions in the Act that provide flexibility in planning for postmining land use, for example, the requirements for mountain-top mining (Sec. 515(c)). Surface disposal of some solid waste is usually necessary in any case because the mined material expands during mining and processing, thus filling a volume greater than the original pit."

…..

"Changing economics often dictate that portions of ore bodies left behind in the past because they were uneconomic become economically available at some future time. One reason for this may be increased demand due to economic growth as supplies are diminished through depletion of the highest quality, most easily available deposits. Another reason is the development of new mining or metallurgical technology that improves the efficiency of recovery or diminishes production costs. Reopening of old mines may also be the result of the demand for by-products or changes in the price of by-products that can make the abandoned deposit economic once again.

If the lower grade materials left behind are buried due to the backfilling requirements in PL 95-87, the cost of recovering them in the future may be so high that they become entirely lost as a domestic resource."

…..

"…backfilling to original contour would require doubling the cost of loading and hauling, the largest components of mining costs."

<u>Bottom Line</u>: the backfilling requirements of SMCRA should not be applied to the large open pit mines and similar types of excavations, such as block caving subsidence craters, associated with hardrock mining.

5) You can't just say: "We'll mine 75% of the ore at a bit higher grade and put the tailings back into the excavation at a somewhat higher, arbitrary cost."

It just does not work that way. In order to determine if something like cut-and-fill stoping is a viable alternative to block caving, a detailed mine plan and economic feasibility analysis is required so one could do an economic and financial comparison of Alternative C&F vs Alternative BC.

Cut-and-fill (and other stoping methods) has a much higher mining cost than does block caving. On the other hand, block caving has a much higher capital cost. However, it's **<u>Operating Cost</u>** upon which the cut-off-grade is based and <u>not</u> capital cost (see Kliche[7] 2017). The increase in cut-off-grade due to an increase in operating cost makes significantly <u>less</u> ore available at some average grade above the cut-off-grade. This tonnage and grade relationship has been shown to be an <u>exponential</u> relationship (that is, as the cut-off-grade goes up, the tons of ore available goes down by some power function [see Kliche[7] 2017]).

Also, just because an alternative has a positive NPV or favorable ROI does not make it the BEST alternative for the investor(s).