Evaluating the Relative Risks of Pit Reclamation Alternatives at the Golden Sunlight Mine (Montana, USA); A Multiple Accounts Analysis.

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Abstract

A Multiple Accounts Analysis (MAA) was initiated to develop and evaluate potential alternatives for the pit reclamation at the Golden Sunlight Mine, Montana USA. Seven alternatives were developed and ranged from those that included pit backfill (of various scenarios) to those that retained an open pit or a pit lake (a.k.a. pit pond). One of the issues of most concern and most uncertainty was the potential impact or risk to down-gradient surface water and groundwater as a result of reclamation; and the ability to make an assessment of the relative risks of any one alternative over the others. The term 'risk' here was defined as a general term implying legal risk (e.g. exceedances of standards); as well as other, less quantitative risks such as the risk of creating a bad public perception, local, regional or international outcry, or regulated procedural changes in on-going operations or reclamation. Risks to down-gradient waters in these scenarios were variably dependent on technical issues such as different mine water collection schemes, including various methods of and locations for collection associated with the different alternatives. In order to assess these risks, in combination with other advantages and disadvantages of each alternative, a multi-stakeholder group involving members from the mining company, the public, state and federal regulators, consultants and representatives from 5 NGO's was formed and tasked with the relative evaluation of potential alternatives using the MAA.

1 Introduction

The State of Montana has a very strong history of mining; indeed many place names within the State are derived from early prospectors' names or the mineral wealth of the local area. Montana's name itself comes from the Spanish word for mountainous. Mining in the state is now the third largest industry in Montana behind agriculture and tourism, which only recently surpassed mining in standings. Perhaps as a result of a strong mining history and a strong growing tourism industry, it is also home to a number of very active environmental groups.

The Golden Sunlight Mine is an open pit and underground gold producing operation owned by Golden Sunlight Mines Inc. (GSM), a subsidiary of Placer Dome U.S. Inc. It is located near the town of Whitehall in southwestern Montana, USA. Operations at Golden Sunlight began in 1982 and are projected to continue into 2009.

Reclamation planning at the site has been an iterative process since mining began. One of the most recent iterations of reclamation planning has involved the evaluation of seven alternatives specifically for the reclamation of the open pit. At the request of the state regulatory agency, GSM agreed to conduct the evaluation in a multi-stakeholder technical working group (TWG) format using the Multiple Accounts Analysis (MAA) as a discussion platform. Participants in the TWG included representatives from GSM and their technical consultants, the Montana Department of Environmental Quality (DEQ) with their technical consultants, the Bureau of Land Management (BLM), the Environmental Protection Agency (EPA), representatives of five environmental groups, as well as a local rancher, with facilitation of the process by Robertson GeoConsultants (RGC).

2 Description of MAA Methodology

The MAA process serves a number of objectives. First, it acts as a platform for the engagement of stakeholders. Secondly, it allows for the identification of stakeholder issues. Thirdly, it allows for the evaluation of an alternative from a list of alternatives by providing for the combined assessment of the relative impacts and risks of each alternative. The MAA process allows indicators and values for intangible issues (e.g. aesthetics, risk etc.) as well as very tangible issues (e.g. costs, stability and safety etc.) to be included in an alternatives evaluation. The technique was developed to be transparent, defensible and easily communicated to stakeholders and other interested parties. The MAA makes it possible to differentiate among alternatives in ways that are not possible if data, or issues, are viewed and assessed singly and independently. This method allows for consideration of numerous and variable issues, even issues historically considered too imprecise for evaluation.

The MAA begins by identifying the issues (adverse and beneficial impacts including risks etc.) that are to be included in the evaluation. This results in an explicit listing of issues that must be considered. Typically the issues are organized into what has been termed *accounts* (broad categories), *sub-accounts* (main issues) and *indicators* (specific measures of the sub-accounts). Once the list, called a ledger, is complete, the alternatives are defined as to their relative impacts (i.e. as compared to the other alternatives) with respect to all indicators on the list. In this manner, the relative impacts for each alternative are quantified.

Some indicators such as capital costs or area of disturbance etc. can be expressed in quantitative terms and are readily measured and relatively straightforward with respect to the assignment of values. Others, such as aesthetics or future water quality, are more difficult to measure or predict and assign values to and by necessity require qualitative values or descriptions. It is important in these circumstances to have experienced participants in the MAA evaluation who can confidently suggest qualitative values and defend those values to the group and if not, then qualified expertise should be sought.

Qualitative values typically take the form of a ranked value such as "worst to best" or “highest to lowest”. While not quantitative, these descriptors provide a context for communicating impacts (positive or negative) that may be equally as important as other indicators, but not as easily measured. Since the accuracy of quantification as well as the ability to rank, scale and weigh alternatives all have some uncertainty, it is appropriate to use fairly coarse classification methods. Typically, a 5-point measure of values is appropriate, for example Low, Somewhat Low, Moderate, Somewhat High, and High.

The completed ledger can then be evaluated numerically. There are many models that use variations on the same theme to provide a value-based evaluation. The procedure used in the MAA involves ranking, scaling and weighting in a systematic manner such that the combined, or cumulative impacts for each alternative can be assessed (Gregory and Keeney 1994, Hope 1998, Robertson and Shaw 2004).

Ranking involves a straightforward listing of alternatives in order from best to worst with respect to each indicator. Scaling further distinguishes how great the difference between the alternatives is relative to one another.

The scale of preference in the MAA is a 9-point scale whereby the ‘best’ alternative is always given a ‘9’ regardless of whether it was valued ‘moderate’, ‘good’ etc. The other alternatives are then scaled by ‘mapping’ them to the ‘9’, if the "worst" alternative is considered to be half as good as the “best”, it is assigned a scalar value of 5 and the rankings for the remaining alternatives are distributed between these values. The methodology accommodates separation of the best from the worst ranking that is either very slight or very significant. In effect, this allows all the indicators to be normalized to a common scale.

Once normalized, the indicators on the list can be assessed in combination, however not all indicators are as ‘important’ or ‘weighty’ as the others. Therefore a weighting of the accounts, sub-accounts and indicators is completed which instills a level of importance to the issues being considered. Typically, the MAA employs a scale of 1 to 5 for weighting factors. If an analyst considers the relative "importance" of one indicator to be twice that of another then the relative weightings would be 2 to 1 (or 4 to 2 etc). The higher the indicator weight is, the greater the importance of that indicator relative to the other indicators in that sub-account.

We have found it best to attain consensus in applying weights to the components in the ledger, however this is not always possible. In such a case where opinions differ and consensus cannot be reached, sensitivity analyses can be completed whereby the evaluation includes a series or set of varying weights for those issues in which a consensus ‘weight’ cannot be agreed upon. In this manner, if the resulting preference order of alternatives is the same, a general consensus on the results can be attained regardless of the differences of opinion on specific issues. If the resulting preference order is different, then the root cause of the difference can be identified and further evaluated.

Calculating ‘scores’ is done on three levels to provide sub-account scores, account scores and an overall MAA score. The sub-account ‘score’ is calculated by summing the weighted scalar values for the appropriate indicators and dividing by the sum of the indicator weighting factors (see Figure 1). The alternative with the highest score is the "best" option with respect to the sub-account considered, and the alternative with the lowest "score" is the "worst". A similar process of weighting, summation and normalizing is applied to the sub-account scores to obtain "account scores" for each account considered in the analysis. Finally, the process is repeated again with the account scores to obtain final MAA scores for each of the alternatives.

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Indicator Weight W_i

Alternative A

Account	Sub-Account	Indicator	Indicator Weight	Alt A	Alt B	Alt C
Technical	Groundwater Capture	Efficiency	5	5	3	9
		Maintenance Requirements	1	9	7	7
		Operating Requirements	2	9	3	1
Sub-Account Score				6.50	3.50	6.75

Scalar Value $S_{i,A}$

Sub-Account Score = SUM (W_i x $S_{i,A}$)/SUM(W_i)

Fig. 1. Hypothetic example to illustrate score calculations.

3 Description of the Reclamation Alternatives Evaluated for the Golden Sunlight Open Pit

Seven alternatives were identified and evaluated in the MAA process for the reclamation of the Golden Sunlight open pit. These ranged from a minimal action alternative to an alternative with a very arduous process of backfilling. The alternatives could be generally classified as those that did not involve substantial backfill (Alternatives 1, 6 and 7) and those that consisted of significant backfill placement (Alternatives 2 through 5), all with slight variations in water management measures. Very generally, the alternatives can be summarized as:

1. **Alternative 1: No Pit Pond**. In this alternative, the pit would be maintained as a hydrologic sink by pumping water and the bottom 30 meters would be backfilled such that there would not be a free water surface pit pond formed in the bottom of the pit.

2. **Alternative 2: Partial Pit Backfill With In-Pit Collection**. This alternative would consist of placing backfill, sourced from an acid generating waste dump, to the elevation above the lowest pit wall covering all pit walls at a 2:1 slope. Ground water wells would be installed through the backfill (244-267 vertical meters) to maintain the pit as a hydrologic sink and maintain the water below the predicted groundwater discharge elevation.
3. **Alternative 3: Partial Pit Backfill Without Collection**. The third alternative is essentially the same as alternative 2, except that no methods of in-pit collection would be included, which implies use of a mixing zone and natural attenuation and dilution in the local aquifer. The amount of pit water effluent that would contribute to the local groundwater aquifer is predicted to be very low (~2.5 m^3/s), although of significantly degraded quality.
4. **Alternative 4: Partial Pit Backfill With Down gradient Collection.** As a variation of the alternative above, alternative 4 would include active down gradient collection of groundwater moving through and out of the covered backfill material in the pit. Pit effluent would therefore be collected in the groundwater aquifer below the pit in a series of groundwater capture bores.
5. **Alternative 5: Partial Pit Backfill With Amendment.** The fifth alternative was developed with the objective of engineering the backfill material (with lime amendment) and compacting the material during placement in an effort to neutralize the acidity and minimize flow from the pit area.
6. **Alternative 6: Underground Sump.** Alternative 6 would be similar to the first alternative consisting of an open void maintained as a hydrologic sink by removing water via a sump system located in the underground workings beneath the pit.
7. **Alternative 7: Pit Pond.** The last alternative would consist of allowing the groundwater table in the pit to rebound forming a pit pond (or pit lake). Water management control, if needed, could consist of treating the pit pond in-situ or pumping to the existing water treatment plant.

All alternatives would include a soil cover placed over backfill, or pit benches where appropriate as well as surface water diversions structures and, if required, treatment of pit effluent in the existing water treatment plant.

Technical studies were completed to predict the potential water quality and the amount of seepage expected in each of the alternatives defined above. The results of these studies were used as supporting documentation for the development of the MAA ledger and the evaluation of the alternatives.

4 Discussion of the MAA Ledger

The technical working group defined the ledger for the Golden Sunlight open pit reclamation during a series of meetings using four main accounts (i.e. technical, project economics, environmental and socio-economics). Specifically, the technical issues included in the evaluation were:

- The design and construction of the alternative as a whole,
- The stability and maintenance requirements of the pit wall,
- The stability of the backfill (where included),
- The stability of the waste rock dump from which backfill would be sourced,
- The stability of the underground workings beneath the pit as related to impacts to the backfill or water collection systems,
- The effectiveness, reliability and maintenance requirements of the groundwater/effluent management system,
- The maintenance requirements related to surface water management,
- The maintenance requirements of the soil cover,
- The potential for increased site water treatment requirements and associated sludge management,
- The flexibility for future improvements and/or new technologies.

Technical issues were evaluated qualitatively by assigning values of low to high to each of the alternatives for issues such as maintenance requirements or values of good to poor for issues such as stability. The issues where the alternatives were most strongly differentiated from one another related primarily to the operation and maintenance of the groundwater and effluent management system and the flexibility for the utilization of future improvements or technologies. Categories included in the project economics account consisted of:

- Capital costs (e.g. earth moving, cover placement, construction etc.),
- Long-term water treatment costs, operating and maintenance (O&M) costs on a net present value basis.

Capital costs ranged from ~ \$65,000 USD for alternative 7 (Pit Pond) to > \$500,000,000 USD for alternative 5 (Partial Pit Backfill with Amendment). The capital costs for the remaining alternatives ranged in between these values, although all much less than the cost for alternative 5.

The NPV estimates for water treatment, operation and maintenance costs (i.e. the long term care costs) for the alternatives were much closer to one another with the highest estimate being assigned to alternative 2 due to expectations that the in-pit collection system through large vertical distances of acid generating, unconsolidated material would be somewhat costly to operate and maintain 'in perpetuity'.

The third main account was the environmental account, which was defined to evaluate the relative impacts of each alternative on the physical, chemical and biological environment. This included:

- Impacts to receiving surface water,
- Impacts to receiving groundwater,
- Air quality, and
- Surface disturbance.

These issues were also difficult to quantify and were predominantly assessed with qualitative values of low to high for risks related to the potential for uncontrolled discharge, risk of violating surface water or groundwater standards, potential for increased fugitive dust emissions, potential hazards to wildlife and issues related to revegetation. Other than the issue of revegetation, the environmental issues were fairly discerning between the alternatives.

The final account in the MAA was that for socio-economic issues, including:

- Cultural resources,
- Noise,
- Safety,
- Employment,
- Revenue from taxes,
- Mineral reserves and resources,
- Post mining land use,
- Aesthetics, and
- Potential future burden/liability.

A mixture of quantitative and qualitative assessments comprised the socio-economic issues with those that were most discerning between the alternatives being related to employment, tax revenue and safety of workers during reclamation.

5 Ranking, Scaling and Weighting

Ranking and scaling was done systematically based on the descriptive values in the ledger. Weighting involved a separate step whereby the technical working group collectively assigned weights. The main account weights were as such:

1. Technical Account	Weight = 4
2. Project Economics Account	Weight = 3
3. Environmental Account	Weight = 5
4. Socioeconomics Account	Weight = 3

Within each of the main accounts, those issues that were considered more important and given higher weights (4's or 5's) were:

1. Technical Account:
   – Design and construction of the alternative as a whole
   – Pit wall stability
   – Maintenance requirements for the groundwater management system
2. Project Economics Account: (none)
3. Environmental Account:
   – Impacts to receiving surface water
   – Impacts to receiving groundwater
   – Surface disturbance
4. Socioeconomics Account:
   – Safety during reclamation efforts and post closure
   – Employment opportunities
   – Revenue from taxes
   – Mineral reserves and resources
   – Potential future burden and liabilities

6 Results and Discussion

The results of the MAA evaluation for the pit reclamation alternatives clustered into two groups (Table 1); the highest three alternatives (those with none to very limited backfill) all score near 7.7, the remaining four alternatives (those with backfill) all cluster between 5.8 and 6.3.

Figure 2 provides a plot of the 'MAA Scores Excluding Project Economics' versus Costs (combined capital costs and O&M, water treatment costs) as a more traditional cost-benefit type graphic.

In general, the MAA score decreases with increasing costs. What is more typical is that more 'costly' alternatives often increase the MAA score and an inverted curve to the one shown in Figure 2 is derived whereby at some point the added 'benefit' is not worth the added 'cost' (i.e. the curve flattens). This MAA shows that this does not hold true for the alternatives evaluated herein. In other words, in the case of GSM, higher cost alternatives do not necessarily provide a technical, environmental or socioeconomic benefit over the lower cost alternatives.

Table 1. Summary of MAA Scores.

Scores	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7
Technical	7.26	5.64	7.00	5.23	6.78	7.63	7.63
Project Economics	8.85	5.60	7.87	7.61	3.11	8.74	8.82
Environmental	8.00	7.87	5.00	7.32	6.58	8.00	7.83
Socio-economics	6.71	5.15	4.74	5.17	5.72	7.25	6.80
Combined MAA	7.71	6.28	6.05	6.39	5.77	7.90	7.77

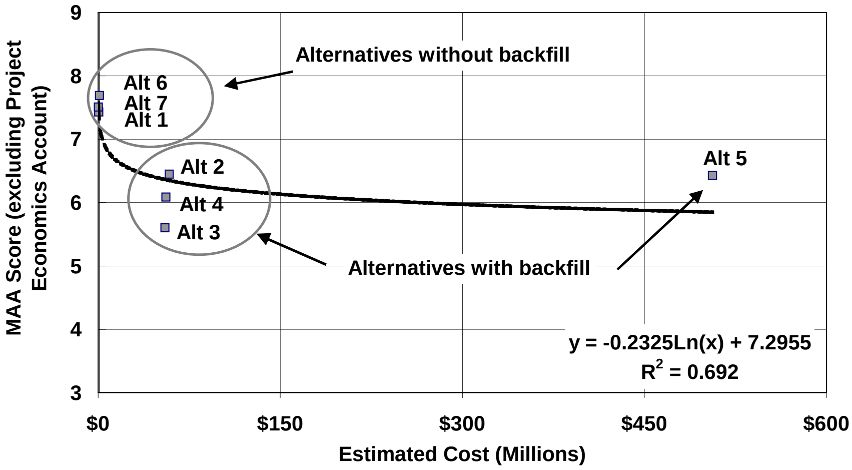

Fig. 2. MAA Score (Excluding Project Economics) versus Cost.

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