REMEDIAL AND RECLAMATION COST ESTIMATING FOR LARGE METAL MINE SITES[1]

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Abstract. Accurately estimating construction costs is an important part of any remedial action. Many different approaches to cost estimating remedial action construction costs exist, including using compiled unit costs from similar projects and quotes from vendors or contractors. While these costing methodologies work well at smaller sites, they often are difficult to apply at large, complex mining sites. When actual construction costs are compared to estimated costs identified in Records of Decision, significant discrepancies have been noted at several sites. One of the major areas of disagreement between actual versus estimated costs occurs when costs used by mining companies to complete reclamation or treatment are applied to sites taken over by the government, who is forced to used independent third party contractors. Another variance occurs when projects are delayed due to additional investigations and/or incremental funding is available.

This paper has three primary objectives to assist estimators in developing more accurate cost estimates for mining sites. First, it discusses several approaches to estimating remedial and reclamation costs at large metal mining sites, based on the authors' experiences at several such sites in Montana. These sites include active mines, mines owned by mining companies who have gone bankrupt, and sites being addressed under Superfund cleanup. Second, actual construction reclamation costs incurred by third-party contractors are compared to the original estimates, and the differences are analyzed. Finally, recommendations to improve large mine site reclamation cost estimating are presented.

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Introduction

Accurately estimating reclamation costs at surface mining sites is important to many interested parties. For mining companies, reclamation cost estimates may be required for estimating cash reserves needed at the end of mine life, or to satisfy regulatory and/or financial reporting requirements. For regulatory agencies, an accurate reclamation cost estimate is essential for determining reclamation bond amounts. Finally, contractors need to calculate their costs accurately in responding to requests for bids, in order to make a reasonable profit. Unfortunately, many contractors regard equipment rates as proprietary business information, and these costs are not often available to third parties for calculating reclamation costs.

The authors of this paper have been estimating mined land reclamation costs at the largest active and abandoned hard rock open pit mining and smelting sites in Montana since 1996. These sites include both active and reclaimed sites. This affords the opportunity to compare the original estimates to the actual construction costs incurred. The purpose of this paper is to examine these estimates versus actual costs under two different regulatory programs: (1) permitted mine reclamation under the Montana Metal Mine Reclamation Act (MMRA); and (2) Superfund cleanup of large mining and smelting sites under the Comprehensive Environmental Response and Liability Act (CERCLA). Comparisons in this paper are limited to earthmoving and reclamation; water treatment is beyond the scope of this analysis. Conclusions and lessons learned from this examination are presented at the end.

Reclamation Cost Estimating Methodologies

There are several ways to calculate reclamation construction costs. One of the simpler methods commonly used is to take actual costs from a similar completed project, derive unit costs, and use those derived costs to develop a site-specific estimate. For example, the Atlantic Richfield company spent $6,000,000 in design and construction costs to reclaim the approximately 500-acre Anaconda Ponds tailings impoundment in 2001 and 2002 through placement of an 18-inch soil cover underlain by a thin layer of crushed alkaline amendment. Based on this information, it would seem reasonable to assume that those costs could be extrapolated to calculate an estimate of $36,000,000 to reclaim the 3,000 acre Opportunity Ponds tailings impoundment in a similar manner. However, this unit cost method approach has several problems, including:

- The estimate is static - it does not account for inflation and new technologies and will eventually become outdated.
- Different site conditions are not factored in this type of estimate.
- Economy of scale is not considered - unit costs for small construction projects are higher than for larger projects.

Even with these problems, this type of estimating is widely used in Engineering Evaluation/Cost Analysis completed under abandoned mined land reclamation, and in feasibility studies completed under CERCLA.

The U.S. Office of Surface Mining (OSM) has published its *Handbook for Calculation of Reclamation Bond Amounts* (OSM, 2000) as a guidance document for determining bonds required for mines permitted under the Surface Mining Control and Reclamation Act (SMCRA). The procedures identified in the handbook summarize many standard engineering cost estimating procedures, including the following:

- Use of equipment performance handbooks, particularly the *Caterpillar Performance Handbook*, for determining equipment productivity rates, including adjustments for site conditions;
- Use of construction cost manuals published periodically to determine equipment hourly rates and material and installation costs;
- Incorporation of indirect costs, expressed as a percentage, to account for items such as engineering and administration costs; and
- Accounting for inflation, also expressed as a percentage, for the future years the estimate (posted bond amount) is to remain effective.

Many states and agencies have adopted the OSM approach to calculating reclamation performance bond amounts, including the State of Montana's Hard Rock Mining Program responsible for enforcing the MMRA. In calculating these bonds, the state faces two major pressures. The first is a need to for agency to obtain sufficient bonding. Because reclamation bonds may be defaulted upon and regulatory agencies may be required to implement reclamation using only those funds available, construction cost estimates completed by the agencies for permitted mines require a high standard of accuracy. If reclamation costs exceed the bonded amount, funding will be required from external sources, possible requiring legislative appropriations. The second pressure is to keep bond costs as low as possible. Mining companies are intent on keeping their regulatory obligatory and liability costs down. The regulator may also feel political pressure (real or perceived) to keep bonds low in order not to impede a particular project.

Care must be taken to balance these two pressures, because mine bankruptcies can and do occur. For instance, in 1998, Pegasus Gold Corporation declared bankruptcy. At the time, they were the operator of four major open pit/cyanide heap leach gold mines in Montana. Three of those mines have since closed and been reclaimed. The Zortman and Landusky Mines site (Zortman-Landusky), has been reclaimed almost entirely using the defaulted bond amounts. The other two mines (Basin and Beall Mountain), were closed and partially remediated prior to bankruptcy. The reclamations were subsequently completed by the bankruptcy trustees using the bond money obligated prior to the bankruptcy.

In addition to their use in developing reclamation bonds, cost estimates are also developed for abandoned mine reclamation under EE/CAs, Superfund mining sites addressed under the remedial investigation/feasibility study (RI/FS) process, and reclamation alternatives analyzed with environmental impact studies (EISs) prepared under the National Environmental Policy Act. In these instances, they are used mainly to compare costs of various reclamation/remediation alternatives. Here the decision-making process is focused on selecting the best alternative, balancing cost-effectiveness against protectiveness of human health and the environment, rather than accurately estimating the cost of construction. In recent years, however, the accuracy of the alternative estimates have been under fire as companies declare bankruptcy and Superfund dollars decline, especially when actual costs for reclamation/remedy are significantly higher than the estimates for selected remedies identified in records of decision (RODs).

Estimate Costs vs. Actual Reclamation

Two examples of recent large metal mine reclamation projects completed in Montana are evaluated in this section. The first example is the Anaconda Ponds, which is part of one of the largest Superfund sites in the U.S. - the Anaconda Smelter National Priorities List (NPL) Site. The second example is the previously mentioned Zortman-Landusky Site, which is being reclaimed under a bankruptcy settlement.

Anaconda Ponds

The Anaconda Ponds are an approximately 90 feet high, 500 acre closed tailings impoundment located at the Smelter Hill area five miles southeast of the town of Anaconda. The Atlantic Richfield Company, successor to the Anaconda Copper Mining Company, stopped operations at the Anaconda Ponds in 1980. In the ensuing years, they have drained dry except for limited ponding during spring runoff. The ponds have been designated as Remedial Design Unit 4 of the Anaconda Regional Waste, Water & Soils Operable Unit (ARWW&S OU) of the Anaconda Smelter site. The selected remedy presented in the 1998 ROD for the Anaconda Ponds, as well as other Waste Management Areas designated at the site, was *in situ* treatment or placement of a soil cover to establish long-term vegetation with the goal of limiting deep percolation of precipitation into acidic copper mine tailings and prevent wind erosion and transport of metals-contaminated dust.

Cost estimates were provided in the 1998 ROD for the Anaconda Ponds (EPA and DEQ 1998) for both soil cover and land reclamation alternatives. Atlantic Richfield, the potentially responsible party (PRP), completed remedial action construction in 2002. While unit equipment, labor, and material costs and contractor invoice amounts are business confidential information between Atlantic Richfield and its contractors, Superfund requires PRPs to provide the total cost of construction, including engineering design, in the remedial action construction completion report (RACCR). Note that remedial action construction completion is a significant benchmark in the Superfund process, indicating that work at a site has been completed and it is ready to move into the operations and maintenance phase.

The Anaconda Ponds RACCR (Atlantic Richfield, 2003) contains a schedule of construction completed at the site and a list of equipment used to complete the remedial action. It identifies a final cost for the design and construction for the remediation of this 485 acre impoundment. Table 1 compares the 1998 ROD estimate assumptions to the actual construction data listed in the RACCR.

Table 1. Comparison of estimated remedy costs and assumptions of the 1998 ARWW&S OU ROD to the actual costs and amounts presented in the 2003 RACCR for the Anaconda Ponds.

Item	**1998 ARWW&S ROD estimate**	**2003 CCR actual**
Cost	$10,241,000*	**$6,000,000**
Time	3 years	**32 months**
Haul distance (average)	2 miles	**0.5 miles**
Haul truck size	40-ton	**40-ton**
Haul Roads (lineal feet)	44,900	**76,780**
Cover Soil (cubic yards)	1.1 million	**1.5 million**
Haul Road base (cubic yards)	0	**169,000**
Lime Amendment (tons)	0	**24,800**
Organic matter (tons)	31,000	**4,900**
Waste consolidation (cubic yards)	**0**	**71,270**

** Includes $6,920,000 in direct costs and $3,321,000 in indirect costs. Indirect costs include a 20% contingency ($1,384,000).*

Although the estimated cost was within its predicted range of -30 to +50 percent, several design components differ between the cost estimate's line items and the actual work completed. The final cover utilized a unique design termed the Plant Water Retention Basin, where a network of primary and secondary haul roads were constructed to create small (average 20 acre) cells designed to collect precipitation within the cell, and preventing a central ponding area. Although both the estimate and the actual work specified an 18-inch thick soil cover, the design required placement of a thin (average half-inch thick) layer of alkaline amendment over roughly half the impoundment surface to prevent upward migration of acid from the tailings into the cover soil layer.

Neither haul road or lime layer construction was included as line items in the 1998 cost estimate. The cost estimate was based on the most current information present at the time, which was data collected during the remedial investigation. The Plant Water Retention Basin and lime layer design were developed during remedial design, after the 1998 ROD was issued, based on remedial design data. Remedial design data collection also included borrow investigations, which identified a source of suitable cover soil much closer to the Anaconda Ponds than the known borrow area used in 1998. The significant cost savings from the shorter haul distance (0.5 vs. 2 miles) was balanced by additional costs of haul road construction, plant water retention basin installation, lime layer placement, and waste consolidation (over 70,000 yards of miscellaneous wastes near the Anaconda Ponds were excavated, transported and consolidated into the tailings impoundment).

Analysis. Although the overall cost estimate presented in the ROD is reasonably close to the actual cost of construction, closer inspection of the line items described in the ROD and the RACCR show some relatively major differences. One of the reasons for such differences is the amount of data available when the feasibility study, which generated the estimates contained in the ROD, was completed. Feasibility studies use data from remedial investigations to develop remedial alternatives. Remedial investigations are typically focused on defining the nature and extent of contamination, not providing the necessary data to complete remedial design. While supplemental investigations were conducted during the feasibility study to better refine estimates, the scope of the data gap investigations were not sufficient to accurately define costs for remedial action construction. For example, a supplemental borrow investigation conducted during the feasibility study was able to identify on-site borrow, and an off-site borrow haul distance of 25 miles was reduced to two. However, the scope of this feasibility study was insufficient to determine whether the 1.5 million cubic yards needed for reclamation was available on site. Three detailed test pit and drilling investigations were necessary to define borrow reserves before the final design for the Anaconda Ponds could be completed.

In addition to borrow investigations, Atlantic Richfield completed several investigations to complete the remedial design. As noted earlier, the ROD allowed a soil cover, *in situ* treatment, or a combination of those two alternatives. During design, Atlantic Richfield sampled the tailings, and determined that tailings were so acidic (both in potential and active acidity), that the cost of alkaline amendments necessary to treat the tailings rendered the soil cover alternative to be more cost effective. The ROD, however, did not have that data, and therefore contained a minimum and maximum cost range of \$6.5 to \$14.9 million for *in situ* treatment of the tailings.

The ROD cost estimate did compare well for equipment and the amount of time to complete remediation. This was expected, as Atlantic Richfield had been using the same contactor, Jordan

Construction, for many years, and the estimate was based on that contractor’s equipment and typical rates of production. Jordan Construction was awarded the Anaconda Ponds remedial action construction; consequently, the estimate matched the actual very well with respect to schedule. At other mine sites where a new contractor is awarded work after other operators cease, predicting the time and duration of work, as well as the equipment to be used, is more challenging.

Zortman-Landusky Mines

The Zortman and Landusky Mines are two open pits, cyanide heap leach god mining operations located in north-central Montana, in the Little Rocky Mountains. Pegasus Gold Corporation owned and operated the mines from 1979 until 1998, when they declared bankruptcy. The State of Montana had determined a reclamation bond amount for the two mines in 1996, based on a recently approved mine expansion ROD and consent decree lodged between the Montana Department of Environmental Quality (DEQ), the U.S. Bureau of Land Management (BLM), a citizen’s group, EPA, the Fort Belknap tribes, and Pegasus. Unfortunately, that bond amount was calculated based on the mine expansion, which included partial backfill of old pits and developing stockpiles of non-acid generating rock to be used in reclamation. After Pegasus declared bankruptcy in January 1998, DEQ calculated a new bond based on current site conditions, which indicated an $8.5 million shortfall in bonded amounts. DEQ settled in bankruptcy court in November 1998, receiving $10 million for the Zortman mine and $19 million for the Landusky mine based on the 1996 bonded amounts.

Because the bond amounts were insufficient and the mine expansion was terminated, DEQ and BLM conducted a Supplemental EIS to evaluate new reclamation alternatives based on then current site conditions (BLM and DEQ, 2001). In 2002, DEQ and BLM issued a ROD that not only selected a preferred reclamation alternative, but also identified an acceptable reclamation alternative if sufficient funding was unavailable to complete the preferred alternative. This alternative contained many of the elements of the preferred alternative, such that completing the lesser reclamation alternative would not deter completing the larger alternative.

The 1998 bond calculation was prepared in accordance with the OSM Handbook. First, earthmoving equipment was selected to complete the estimate. Equipment selection was based on the size of equipment used at the mine, and the estimated size of the project (between $10 and $100 million). Equipment rates were then generated using Dataquest Cost Reference Guide for

Construction and Montana prevailing Davis-Bacon wages. Cycle times for reclamation line items were then compiled using site drawings in conjunction with the Caterpillar Equipment Performance Handbook. Hours to complete line items were tabulated, and costs were calculated. After the total direct costs were summarized, indirect costs were applied at the following rates:

- Mobilization at 1%,
- Engineering and Redesign at 2%,
- Reclamation Management at 2.5%,
- Contingency at 4%,
- Administration at 5%, and
- A 3% inflation adjustment for a five year period.

Table 2 presents a comparison between several of the line items estimated in the 1996 reclamation bond and the actual reclamation completed at the Zortman-Landusky mines.

Table 2. Comparison of reclamation bond estimated costs and assumptions of the 1996 Zortman-Landusky Mine Expansion to the actual work, costs and amounts completed in 2003.

Item	**1996 Reclamation Bond Estimate**	**2003 actual**
Cost	$29,600,000	**$35,300,000**
Time	Not estimated	**5 years**
Haul truck size	100-ton	**40-ton**
Dozer for regrading	**D-11**	**D-9**

Note the discrepancy between the haul truck size assumed in the reclamation bond, and that actually used during construction. The state's contractor brought in a fleet of 8 CAT D400 haul trucks to complete the majority of reclamation work. For one line item, backfilling of the Zortman Pit, a project consisting of moving an estimated 2.6 million cubic yards, the state let another contract through a competitive bidding process, and only one contractor responded to the request for bid. This contractor did use two 100-ton haul trucks (CAT 777), but the lack of bid interest indicates that the number of contractors operating such large equipment is limited

As noted earlier, this methodology is an improvement over the unit cost method, but there are some problems. First and foremost, it does not account for the fact that large projects will take multiple years to complete, and that some shut down may occur during winter months. Second, necessary work items ancillary to the work, but required under reclamation, are lumped together into an overall category called "reclamation management" that may or may not reflect actual costs. Items such as haul road management, dust control, on-site supervisors, etc. all are grouped together in this category.

Suggestions for Improved Cost Estimating

While techniques for estimating reclamation and remediation costs for large mine sites have advanced significantly in detail and accuracy over the past decade, based on the analysis presented in this paper, there is still some room for improvement. The authors suggest the following:

- There is a need in the estimate to improve the selection of equipment used by contractors to complete reclamation. Past estimates assumed contractors would use equipment similar to that used by mining companies. Actual reclamation experience indicates that 100-ton haul trucks are seldom used by regional contractors. For estimating purposes, we recommend using 40-ton haul trucks for projects between $1 million and $10 million, and 60-ton haul trucks for projects over $10 million. Similarly, large dozers (D11 or bigger) have seldom been seen at the large metal mine reclamation projects at Montana.
- Rather than summing the total hours and costs for a project and applying indirect costs, more accurate cost estimating can be obtained through a life-cycle analysis of reclamation costs. This is illustrated in Fig. 1. Cash disbursements over the life of the project should be estimated, and their net present value can be then calculated. Adjustments for inflation to maintain the accuracy of the estimate can then be applied to net present value. This is particularly important for estimating costs at permitted mines, where abandonment by an operator may result in immediate operating costs (referred to as "interim maintenance" in Montana).

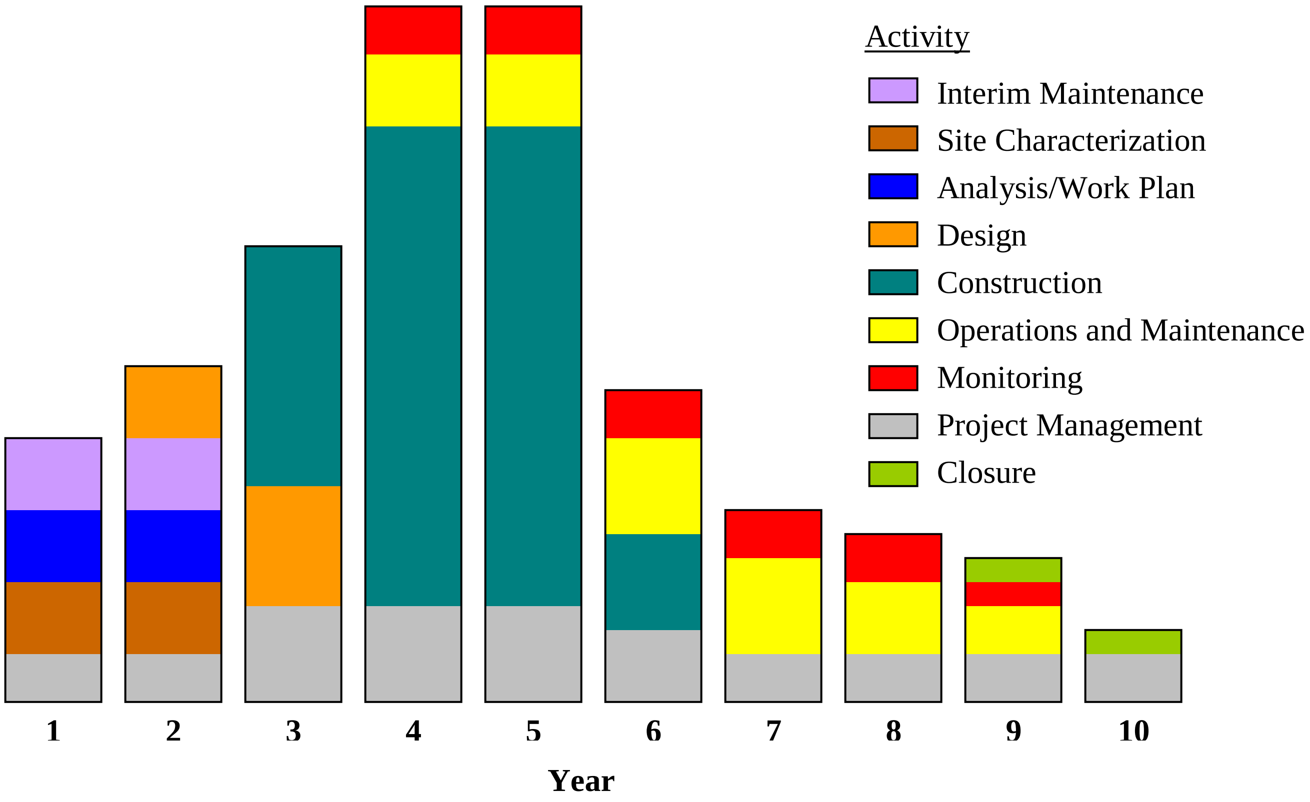

Figure 1. Example of Anticipated Cash Flow (by activity) at a Site Over a 10-Year Life-Cycle

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