Dealing with the Legacy of Mine Pit Lakes

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Equity Mine Pit Lake, Nevada.

Hardrock mine pit lakes are, by definition, located in the planet's most pronounced metal-rich areas. The value of the metals – gold, silver, and copper – fund the excavation, but unwanted trace constituents like arsenic, antimony, selenium, and mercury are often elevated too. Most of the pits extend through sulfidic rock, which degrades initial water quality as sulfate, acid, and trace-metals liberated by pit-wall oxidation leach into the lake. But even ambient groundwater in mineralized areas can contain elevated trace-metals, producing a long-term degradation in pit water quality as these solutes are evaporatively concentrated in the lake. Potential environmental impacts include the loss of water to evaporation, health risk to wildlife or humans, and degradation of groundwater quality.

Pit lakes aren't necessarily large liabilities – a moderate-size, 40,000 acre-foot pit lake with slight acidity could probably be neutralized for under $1 million. But more sophisticated remediations such as biotreatments that remove antimony, arsenic, or selenium, could cost $15 million or more. (For comparison, backfilling such a pit would cost closer to $60 million). The problem with such cost speculation is that current pit-lake models almost certainly do not constrain the uncertainty of future water quality. Pit lakes are science experiments with largely unknown outcomes, launched into the future for perpetual management by the trustees of the lakes. For better or worse, this management burden exists. The challenge now, as many large U.S. open pit mines approach closure, is to develop

an affordable framework for long-term pit-lake management that protects the environment and advances environmental science.

Unreliable Predictions and Other Problems

The problem of relying on predictions for future impacts and financial liabilities of a pit lake is more fundamental, reflecting the tendency of humans to underestimate uncertainty. This tendency is almost certainly more pronounced in environmental models of natural systems, where the greater complexity increases the need for subjective decisions about uncertainty. Our own estimates of acid release from pit wall rock illustrate this effect in pit-lake models.

For years, mine pit water quality forecasts used essentially uncalibrated models to estimate acid production in pit walls. When a method for measuring oxidation rates in the field was developed in 1996, wall rock was found to be producing between two and 50 kg sulfate per square meter per year – several times greater than previously predicted. Given a realistic assessment of uncertainty in parameters – from global climate change to changes in regulatory levels of arsenic – developing confidently-bound estimates of future pit-lake liability may not be possible.

A Path Forward: Adaptive Managment

Adaptive management, a concept developed by the International Institute of Applied Systems Analysis for managing ecosystems amidst evolving science and policy (Hollings, C.S., 1978), provides a solid framework for perpetual management of pit lakes. Most broadly, this approach treats environmental disturbances as science experiments. Rather than expecting behavior to match predictions, adaptive management is designed to test hypotheses about the ecosystem, anticipate "learning over decade-long time scales," and respond as necessary with policy changes (Lee 1993). Importantly, adaptive management has been applied to much more complex problems such as rehabilitation of salmon runs on the Columbia River ecosystem, and lessons from this have been meticulously documented (Lee 1993). With judicious structuring of an adaptive management program, there is enormous potential to provide environmental protection and advance the science of mine management.

The flexibility of adaptive management programs provides an ideal cover for criticism for operators and trustees. If predictions fail, adaptive management "still permits learning, so that future decisions can proceed from a better base

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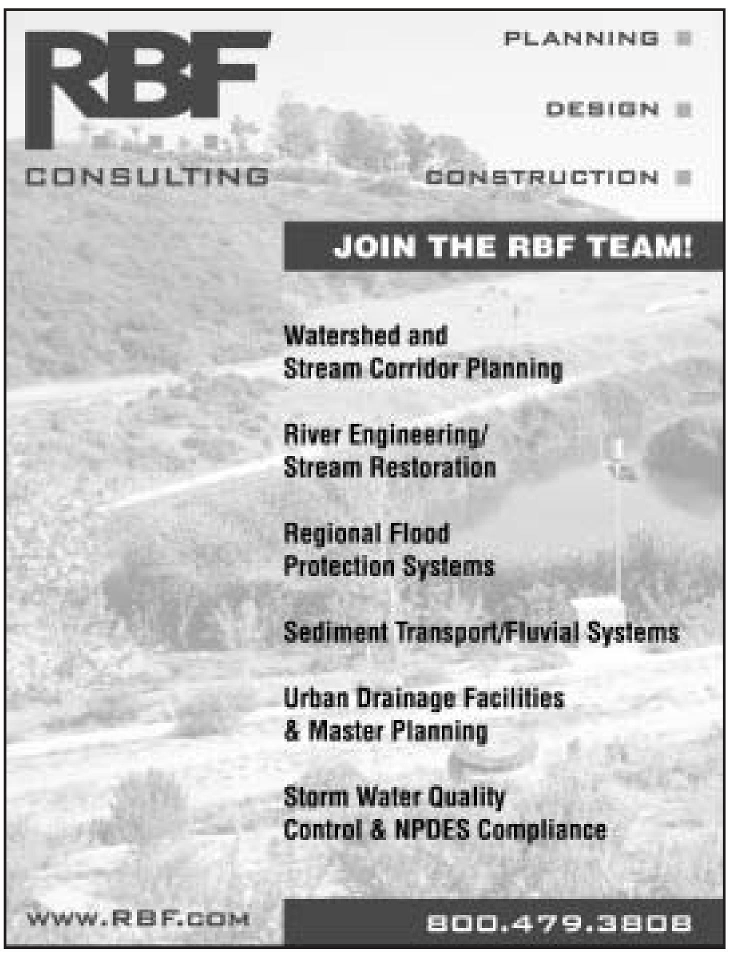
of understanding" (Lee 1993). A U.S. Geological Survey study of bank-sediments management in the Colorado River recently demonstrated that the tributary sand is exported too rapidly to be of much use in restoring banks during man-made floods, directly contradicting the environmental impact statement hypothesis (Rubin et al., 2002). This could have been a modeling fiasco, but not under the Glen Canyon Adaptive Management Program, which was "established precisely to help incorporate such scientific advances into management decision making." While the potential exists to abuse such flexibility, the admission of this uncertainty is a more honest assessment; and if data are collected properly, uncertainty will be reduced in the future.

The following is a suggested list of components for a pit-lake adaptive management plan.

Establish trust funds for management of each lake: This would initially manage data collection and improve predictive models as parameter accuracy improves, and eventually fund remedial activities. By utilizing capital generated from the mine, this meets criteria of Sustainable Development.

Consider sharing liability across trust funds: Assuming that uncertainty in model predictions is random, then on some scale the under- and over-predictions of management costs will balance, and pooling of trust funds in an insurance model should provide better overall environmental protection.



Identify a central repository for technical reports: A wealth of potentially-useful environmental analyses of hard-rock mining is essentially unobtainable, dispersed in consulting reports. A university library is a logical repository for holding relevant mining studies.

Develop a technical management group to assimilate prediction and remediation information: Incorporating future innovations into prediction and remediation of pit lakes will require a technically-proficient management team that includes representatives from academia, federal and state land management agencies, and mining. An immediate need exists to refine key model parameters – wall-rock oxidation rates, metal releases from oxidation, and stability of trace metals in sediment are most critical. Development of pit-lake test cases to identify reliable models would follow. An assessment of remedial alternatives could proceed in parallel, ultimately leading to an assessment of total pit-lake liability for perpetual management, monitoring, and if necessary, remediation.

Perpetual management of mine pit lakes is an unavoidable component of future U.S. land management. Undertaken in a research-focused adaptive management framework, pit lake management has the potential to improve the knowledge base of environmental science and minimize the financial liabilities.

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