Introduction to Pit Lakes in the Southwest

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Imagine a hole in the ground big enough to see from the space shuttle. Picture the mammoth-sized equipment used to mine more than 100,000 tons of overburden and ore per day, and consider the dewatering efforts required to keep the excavation dry. Now, think about what happens at the end of open-pit mining when the majority of people and big equipment go elsewhere and dewatering stops.

When groundwater, surface water, and other post-mining drainage accumulate inside inactive open pits below the groundwater table, pit lakes form. This article provides an overview of the various technical and legal issues surrounding pit lakes in the Southwestern United States, with special attention to hard-rock mining operations for copper and gold.

Surface Mining and Open Pits

Open-pit mining is common in the copper and gold mining industry where the ore bodies are large and overburden depths are limited. Open-pit depths typically extend below the groundwater table and exceed 1,000 feet beneath the ground surface. To maintain a safe working face and to promote pit wall stability, open pits usually require dewatering, and as economic development of the pit continues, dewatering systems are continually expanded to accommodate operating inflows.

At mine closure, dewatering stops and groundwater inflow to the open-pit excavation begins. Much like a recovery curve for a very large groundwater well, the local groundwater table rises and contributes to the formation of a pit lake. Surface water run-off within the open-pit area is also a contributor to the pit lake. This transient period ends when pit-lake evaporation and/or groundwater outflow is equal to the pit-lake inflows. At this point, the pit-lake elevation will stabilize and fluctuate seasonally in response to weather variations.

Normally, the creation of a new surface water body in a semi-arid environment presents a wide variety of recreational or wildlife uses. Examples of pit lakes associated with copper or gold mines that exhibit a suitable water quality for multiple uses include Copper Flat Mine near Hillsboro, New Mexico; Yerington Mine in southeastern Nevada; and Getchell Mine in central Nevada. But there are also a number of well-known pit lakes in the western United States that exhibit acidic pH conditions and elevated levels of dissolved metals, most notably, the Berkeley Pit in Butte, Montana.

Regulatory Issues and Technical Debates

State regulations pertaining to open pit mines may require demonstration of passive containment of the pit lake, whereby a permanent inward hydraulic gradient is shown to exist due to significant lake evaporation. If passive containment is not demonstrated, the state regulatory agency may require active management of the lake to prevent a violation of water quality standards at a point of compliance. When a proposed action at an open pit mine, such as expansion, land exchange, or a new facility involving public land, triggers the National Environmental Policy Act (NEPA) process, a pit-lake study is commonly performed to predict potential water quality and quantity impacts to local water resources.

Controversial pit-lake issues tend to be driven by regulatory requirements or by non-governmental organizations. Uncertainties surrounding the prediction of groundwater recovery, pit-lake formation, and geochemical interactions contribute to the complexity of the problem. The fact that many current pit-lake studies pertain to lakes that will form in the future makes it difficult for stakeholders to assess accuracy or reliability of model predictions. In general, the technical debates associated with pit lakes revolve around their hydrology, predicted water quality, and the monitoring programs designed to verify model results.

Pit Lake Hydrology

As the pit lake approaches a post-closure equilibrium, evaporation and groundwater outflow, if present, are balanced by groundwater and surface water inflow. Depending on the magnitude of net evaporation, the steady-state pit lake elevation can be sufficiently lower than the surrounding groundwater aquifer, demonstrating passive hydraulic containment of the lake. Under this condition, the pit lake remains as a terminal evaporative sump within the confines of the open pit. In Arizona, for example, state regulators allow demonstration of passive containment in groundwater as a significant part of the overall discharge control for a mining facility.

If groundwater outflow occurs, then passive containment does not exist. Outflow can be a result of insufficient evaporation from the pit lake or the influence of hydrogeologic structures such as higher permeability zones. If passive containment is not demonstrated, the mine operator will be required to examine the likely impacts to the downgradient groundwater aquifer and to identify potential remediation alternatives.

Pit Lake Water Quality

Pit lake water quality can vary dramatically as a function of groundwater inflow, direct precipitation and contact with pit wall-precipitation or run-off water. Wall rock-groundwater interaction, evaporation and limnological and geochemical processes operating within the pit lake itself also affect water quality. All of these factors require analysis on a site-specific basis.

Human health and ecological water quality criteria can be used to assess the need for active or passive management of post-closure pit lake water quality. For example, the New Mexico Environment Department assumes that a terminal or flow-through pit lake is subject to stream-based surface water quality control criteria. This regulatory provision triggered the Chino Mines Company in Grant County, New Mexico to propose continued dewatering and subsequent treatment of the Santa Rita open pit in perpetuity. In contrast, state regulators in other western states such as Nevada are adopting a risk assessment-style approach to post-closure pit water quality.

Morenci Open Pit mine, Greenlee County, Arizona: *Landsat 7 false color image taken in October 1999 from an altitude of 438 miles. This image uses Thematic Mapper bands 1 (blue light), 4 (near-infrared light), and 7 (mid-infrared light). The area shown is 28 miles east-west and 39 miles north-south; visual resolution is 15 meters. Mine roads and benches can be seen in the tan-colored open pit, and tailings are visible as light blue areas. The town of Clifton is at center right, along the valley of the San Francisco River. Surface water is recognizable as dark blue or black areas. Image processed and enhanced by Kevin Horstman, copyright 2002.*

Regardless of a state's position on pit water quality issues, a migratory bird kill at a pit lake will trigger the involvement of federal authorities. U.S. Fish and Wildlife is responsible for assessing financial penalties (up to $25,000 per bird) and criminal charges in the event of a violation of the Migratory Bird Act.

Monitoring Programs

Site characterization and computer models can help mine operators predict how individual pit lakes will form in the future. Due to the uncertainties inherent in paper studies, however, robust monitoring plans are required to assess whether pit lake systems are performing as predicted. Typically, monitoring programs record hydrologic data, including water levels, runoff records, and precipitation, as well as chemistry data such as indicator constituents, pH, and conductivity.

Where feasible, monitoring programs are intended to serve as early warning systems. If a monitoring program indicates inaccuracies in the predictions, the mining operator must be prepared to implement one or more contingency measures.

Summary

At some point in the future, active mining operations in the western United States will reach the end of economic mining and move into closure processes. Closure program negotiations will require all parties to recognize the scale of the disturbance and the inherent uncertainties associated with complex predictions. A risk assessment approach to pit lake water quality and practical monitoring programs show great promise for reducing future conflicts.

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