FINDING BENCHMARKS AT URANIUM MINE SITES

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Uranium mine closure in Ambrosia Lake Valley, just east of Gallup, New Mexico, presents challenging technical and regulatory issues. Because mining began before current regulatory requirements were established, data to define historic conditions are sparse; the original concentrations of groundwater contaminants in the mineralized zone are unknown. Establishing benchmark numerical values for background/baseline constituents of concern in groundwater is now critical to mine-site closure or permitting. Further, the influences on groundwater quality in the area's underground mines are varied and complex and benchmarks that could demonstrate successful remediation are poorly defined.

For more than 30 years beginning in the mid-1950s, at least 14 uranium mines were developed in the valley, at depths up to 2,500 feet below the surface. Uranium was mined by conventional room and pillar methods, resulting in an extensive network of mine workings at each mine. However, uranium deposits ordinarily do not stop at section boundaries, so most of the workings are interconnected from one end of the valley to the other over an area approximately 10 miles long and three miles wide.

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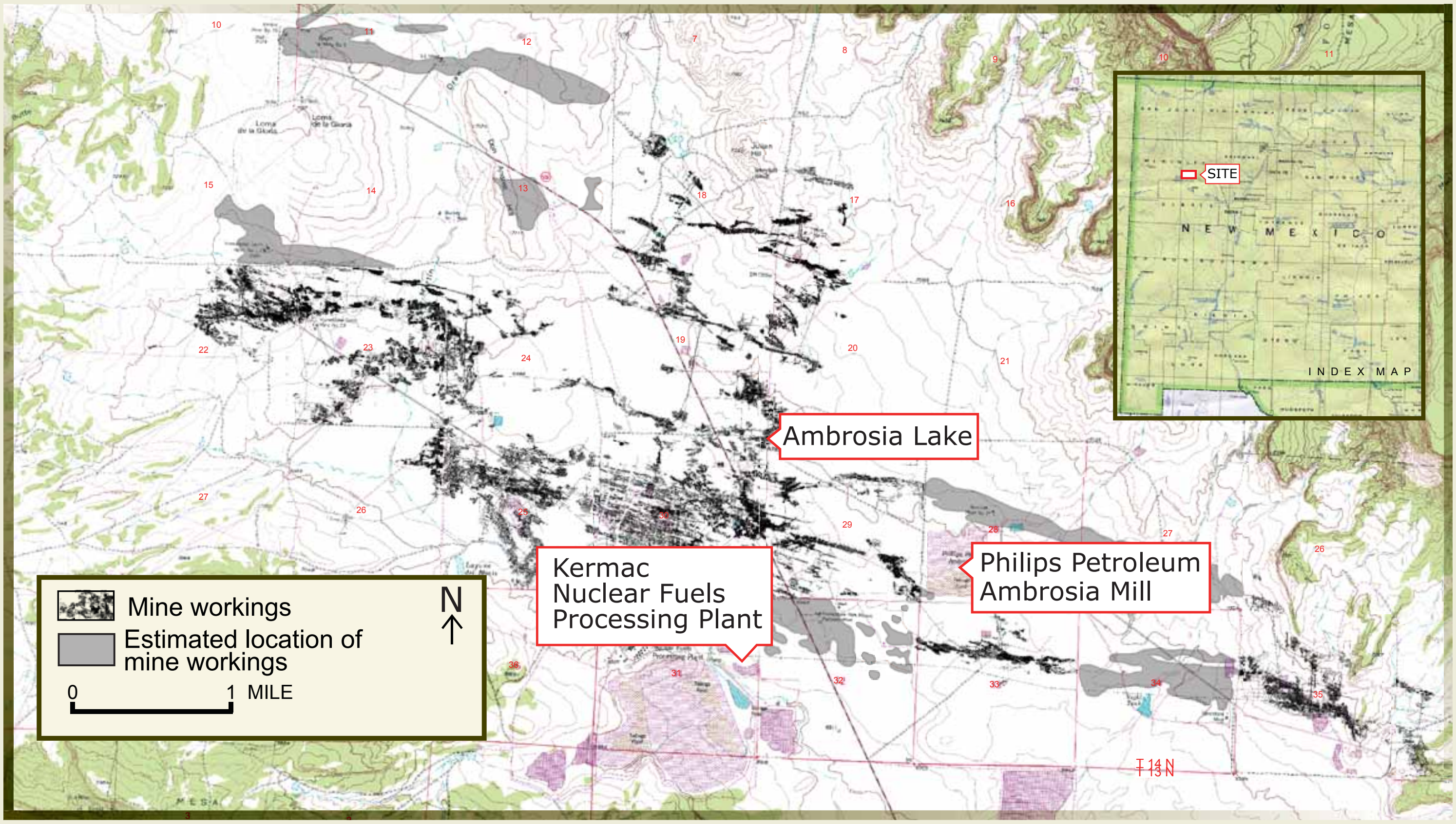
Uranium ore was extracted from the Westwater Canyon Member (WCM) of the Morrison Formation. The WCM is composed of alternating, lens-like sandstone and mudstone interbeds, with ore deposits ranging from a few feet in length and thickness to mile-long masses over 30 feet thick. The scale of interbedding ranges from inches to a few tens of feet. Pyrite, a highly reactive sulfide mineral, is present in amounts ranging from none to two percent of the ore zone and is variable on the scale of feet or even inches.

Large-Scale Dewatering

Past mining activities necessitated large-scale dewatering: more than 250,000 acre-feet of water was pumped from Ambrosia Lake Valley. The U.S. Geological Survey has estimated that the potentiometric surface of groundwater in an 80-square-mile area in the valley has been drawn down



The mine workings in Ambrosia Lake Valley cover some 30 square miles in northwest New Mexico.

more than 500 feet from dewatering. The area affected by drawdown of 100 feet or more is estimated to be on the order of 1,000 square miles.

Most mine dewatering stopped by 1986 and water levels are now recovering. Estimates of the time required to fill the regional cone of depression range from several hundred to several thousand years. The water does not simply rise up uniformly, but is complicated by dipping strata and geologic structures, and diverted by the vast network of mine workings with gradients in all directions. Some deeper mine workings on the southeast end of the ore trend already are flooded but it will be hundreds of years before shallower workings on the northeast end are filled, causing the center of the cone of depression to migrate from the southeast to northwest over time. Thus flow paths will continue to change as groundwater flows back into the area, blurring the traditional hydrogeologic concept of upgradient/downgradient.

Water Quality Impacts of Dewatering

Before mining began, uranium ore zones were anaerobic; pyrite, uranium, and other metals were relatively stable. But as dewatering progressed, the ore zones were exposed to oxygen and pyrite oxidized, producing sulfate ions and acid. The production of sulfate increased the total dissolved solids concentrations in groundwater within and discharged from the mine workings, and the increased acidity dissolved the metals, including uranium, selenium, and molybdenum, causing their concentrations in groundwater to increase as well.

As the mine workings become flooded again, oxygen will be consumed and the subsurface conditions will return to a more reduced state. This change will favor the precipitation of metals, removing them from groundwater. However, because of the complexity of the underground workings and changing flow paths, predicting the timing, degree, and location of water quality changes is difficult.

Finding a Benchmark

The presence of ore deposits at Ambrosia Lake Valley suggests that the regional groundwater quality was highly variable even before mining began. The fact that no pre-mine water quality data were collected compounds the challenge of establishing benchmark values—water quality standards to be achieved at specific locations—for remediation efforts. Yet determining the best estimates of these values is critical: a small change in a benchmark can translate to an enormous change in the cost of remediation for an operator.

Lack of pre-mine background data is a challenge to determining what the benchmark values should be. Changes in flow direction, variability in aquifer matrix materials and their states of oxidation, and uncertainties inherent in trying to predict flow in a complex void space also make defining where benchmarks should be applied difficult. Any benchmarks that might be set as closure goals will likely not be as simple as traditional upgradient and downgradient monitoring of water quality parameters.

Regulatory Status

Resolution of these issues will require the participation of both regulators and mine operators to formulate a reasonable and effective strategy to protect human health and the environment. Both groups generally agree that pump-and-treat options for remediation are not feasible because this would continue to allow oxygen into the workings, causing continued leaching of constituents from the aquifer matrix and no improvement in groundwater quality. They also agree that the existing cone of depression is causing the degraded groundwater to flow toward the center of the drawdown, thereby restricting any impacts to the area surrounding the mines. However, a path to regulatory compliance is uncertain.

From a regulatory perspective, long-term monitoring of groundwater is an absolute minimum requirement, but the question of what and where to monitor is currently unclear. Constituents such as sulfate, uranium, and selenium clearly exceed state standards, but their concentrations prior to mining are highly uncertain.

At present we are left with more questions than answers. Even if pre-mining water quality conditions were known, where should a compliance location be established to measure concentrations? In general, flow will be contained within the mined area for a long time. However, flow directions will change in complex ways over time, related to infilling of the complex void space represented by the mine workings. Should monitoring locations be upgradient and downgradient relative to the existing flow regime, or to the one that will be established when recovery is complete in several hundred years? If the former, what information will monitoring provide? Add to this the fact that there is renewed interest in reopening some of the mines in question and you have a regulatory conundrum on a scale equal to that of the technical complexities we have described.

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