Moab, Utah, UMTRA Site: The last large uranium mill tailings pile to be cleaned up in the United States

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Abstract. The U.S. Department of Energy (DOE) is tasked with cleaning up surface contamination and developing and implementing a ground water compliance strategy to address contamination resulting from historical uranium-ore processing at the Moab, Utah, remedial action site. During the years of operations, the facility accumulated approximately 10.5 million tons of tailings and contaminated soils in an unlined pile about 750 feet from the Colorado River. The DOE preferred alternatives are to relocate the tailings to an alternate site away from the river and to implement long-term ground water remediation. An interim action ground water extraction/injection system is currently in operation to reduce the contaminant mass in ground water discharging to the river.

Introduction

The Moab, Utah, site is a former uranium-ore processing facility located about 3 miles northwest of the city of Moab in Grand County, Utah, (Fig. 1) and lies on the west bank of the Colorado River at the confluence with Moab Wash. Arches National Park has a common property boundary with the Moab site on the north side of U.S. Highway 191, and the park entrance is located less than 1 mile northwest of the site. Canyonlands National Park is located about 12 miles to the southwest.

During the years of operation, the facility accumulated approximately 10.5 million tons of tailings and contaminated soils. The tailings are located in a 130-acre unlined pile that occupies much of the western portion of the site. The top of the tailings pile averages 94 feet (ft) above the Colorado River floodplain (4,076 ft above mean sea level) and is about 750 ft from the Colorado River. The pile was constructed with five terraces and consists of an outer compact embankment of coarse tailings, an inner impoundment of both coarse and fine tailings, and an interim cover of soils taken from the site outside the pile area. Debris from dismantling the mill buildings and associated structures was placed in an area at the south end of the pile and covered with contaminated soils and fill.

Radiation survey results indicate that some soils outside the pile also contain radioactive contaminants at concentrations above the U.S. Environmental Protection Agency (EPA) standards in Title 40 Code of Federal Regulations (CFR) Part 192.

Besides tailings, contaminated soils, and debris, other contaminated materials requiring cleanup include ponds used during ore-processing activities, disposal trenches, other locations used for waste management during mill operation, and buried septic tanks that are assumed to be contaminated. The U.S. Department of Energy (DOE) estimates the total contaminated material at the Moab site and vicinity properties has a total mass of approximately 11.9 million tons and a volume of approximately 8.9 million cubic yards (yd^3). Evidence indicates that historical

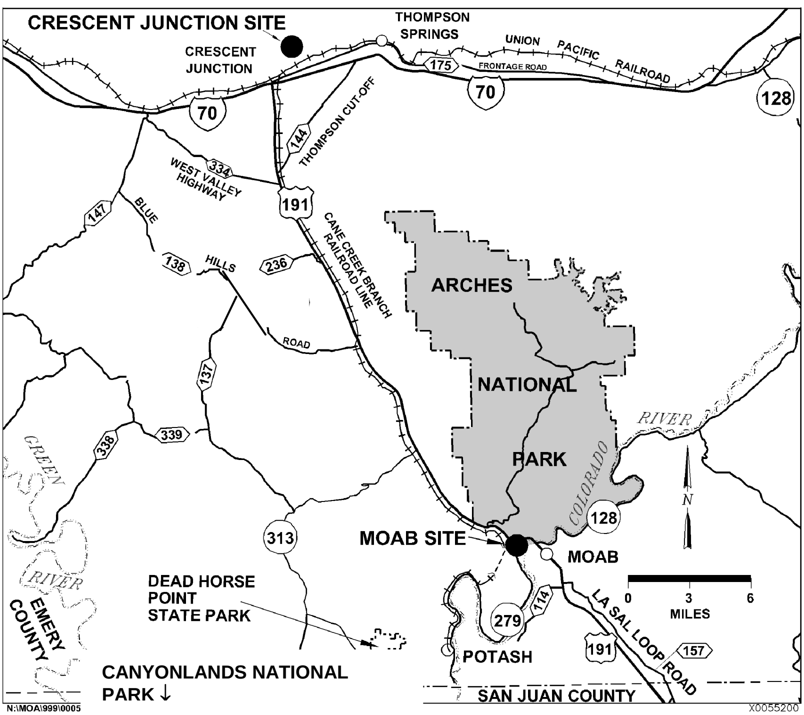

Fig. 1. Location map of the Moab site and surrounding area.

building materials may contain asbestos.

Ground water in the shallow alluvium at the site was contaminated by ore-processing operations. The Colorado River adjacent to the site has been affected by site-related contamination, mostly because of ground water discharge. The primary contaminant of concern in ground water and surface water is ammonia. DOE has identified two ammonia plumes associated with the site – a deep plume beneath the tailings pile and a shallower plume emanating from the toe of the tailings pile to the Colorado River. Ground water from the shallow plume has been demonstrated to discharge to the Colorado River and to have a localized impact on surface water quality. Degradation of surface water quality is of concern because of potential effects on aquatic species in the area, particularly endangered fish.

To minimize potential adverse effects to human health and the environment in the short term, DOE instituted environmental controls and interim actions at the site. Controls include storm water management, dust suppression, pile dewatering activities, and placement of an interim cover on the tailings. Interim actions include restricting site access and monitoring ground water and surface water. An interim action ground water extraction/injection system was implemented to reduce the contaminant mass in ground water discharging to the Colorado River.

Regulatory Framework

The title of the Moab site was transferred to DOE in 2001 along with the responsibility for site cleanup in accordance with Title I of the Uranium Mill Tailings Radiation Control Act (UMTRCA). The act further requires that remediation of the site include ground water restoration. Ground water compliance standards applicable to the Moab site are the EPA standards established in 40 CFR 192. Subparts A and B of 40 CFR 192 provide standards for cleanup and final disposal of contaminated materials for Title I Uranium Mill Tailings Remedial Action (UMTRA) Ground Water Project sites. Subpart A standards apply to protection of ground water from future contamination released from the disposal system after cleanup is complete. Subpart B standards pertain to cleanup of residual radioactive materials, including ground water, at the site. The Subpart B cleanup standards are the same as the Subpart A protection standards except that Subpart B allows for an extended time frame to attain compliance with the standards and allows the use of a natural flushing compliance strategy, providing certain other criteria are met.

Pursuant to the National Environmental Policy Act (NEPA), title 42 *United States Code* (U.S.C.) section 4321 *et seq*., DOE prepared an Environmental Impact Statement (EIS) to assess the potential environmental impacts of remediating the Moab site. DOE analyzed the potential environmental impacts of both on-site and off-site remediation and disposal alternatives involving both surface water and ground water contamination. DOE also analyzed the no action alternative as required by NEPA implementing regulations promulgated by the Council on Environmental Quality. Some government agencies and the public expressed concern about the potential effects of capping the contaminated materials at the site, one of the proposed alternatives, because of engineering uncertainty of river migration and the long-term effects of contaminated ground water entering the Colorado River. For these reasons and other factors, the DOE preferred alternative is to relocate the tailings to an alternate site away from the Colorado River and to implement long-term ground water remediation to address contamination that resulted from historical uranium-ore processing at the former millsite.

Conceptual Hydrogeologic Model

Ground water at the site occurs mostly in alluvial sediments that may be as deep as 120 meters (m) or more. Total dissolved solids (TDS) concentrations in the alluvial ground water vary naturally from slightly saline water (TDS = 1 to 3 kilograms per cubic meter [kg/m^3]; 1000 to 3000 milligrams per liter [mg/L]), to those categorized as moderately saline (TDS = 3 to 10 kg/m^3), very saline (TDS =10 to 35 kg/m^3), and briny (TDS > 35 kg/m^3). The primary source of the slightly saline water, which is found only in the shallowest parts of the saturated zone, appears to be ground water discharge from bedrock aquifers that subcrop both near the northwest border of the site and north of the tailings pile. Brine waters dominate the deepest parts of the alluvium and are attributed to chemical dissolution of the underlying Paradox Formation, a large and relatively deep evaporite unit that has been deformed to create a salt-cored anticline aligned with and underlying the Moab Valley .

A cross section of the subsurface hydrogeology through the site showing the interface between the deeper brine and the overlying brackish-to-freshwater system is illustrated on Fig. 2. The interface is assumed to exist where the TDS concentration equals 35,000 mg/L. The transition from brine to freshwater sometimes occurs over a short vertical distance; by convention, the line demarcating the boundary between brine and freshwater in such cases is typically referred to as a “sharp” interface. TDS concentrations above the interface decrease gradually before reaching an elevation where relatively freshwater is observed. This diffuse zone is brought about by mixing of more saline water with fresher water through the process of hydrodynamic dispersion. For convenience, the term saltwater interface is used to describe the depth at which a TDS concentration of 35,000 mg/L is observed.

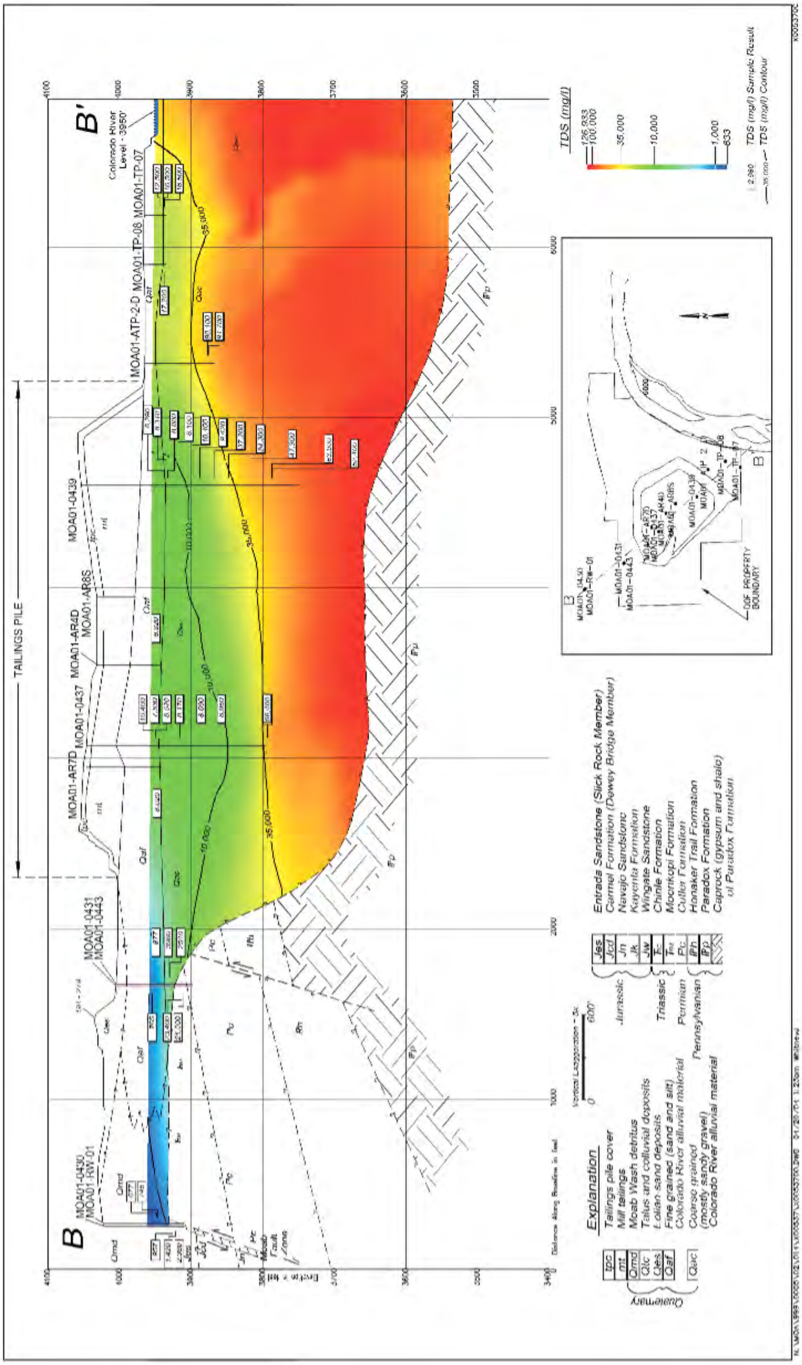

Fig. 2. Cross section through the site of the subsurface hydrogeology and the salt water interface at 35,00 mg/L TDS.

During milling operations, the tailings pond contained fluids with TDS concentrations ranging from 50,000 to 150,000 mg/L. Because these salinities exceed 35,000 mg/L, they had sufficient density to migrate vertically downward through the freshwater system and into the brine. This downward migration of the tailings pond fluids into the saltwater system is believed to have created a reservoir of ammonia that now resides below the saltwater interface. This ammonia plume below the interface probably came to rest at an elevation where it was buoyed by brine having a similar density.

Under present conditions, the ammonia plume beneath the saltwater interface represents a potential long-term source of ammonia to the freshwater system. The conceptual model presented in Fig. 3 illustrates the ammonia source at the saltwater interface (basal flux), the legacy plume, and seepage of ammonia from tailings pore fluids.

Nature and Extent of Ground Water Contamination

Site-related constituents including ammonia, nitrate, sulfate, molybdenum, uranium, gross alpha, and gross beta have contaminated the basin-fill aquifer beneath the tailings pile and beneath the former millsite. DOE identified two ammonia plumes associated with the site – a deep plume beneath the tailings pile and a shallower plume emanating from the toe of the pile to the Colorado River (Fig. 4). Although ammonia has no EPA standard in 40 CFR 192, it occurs at concentrations significantly greater than natural background, is the most prevalent contaminant in the ground water, and is the constituent of greatest ecological concern that is discharging to the Colorado River.

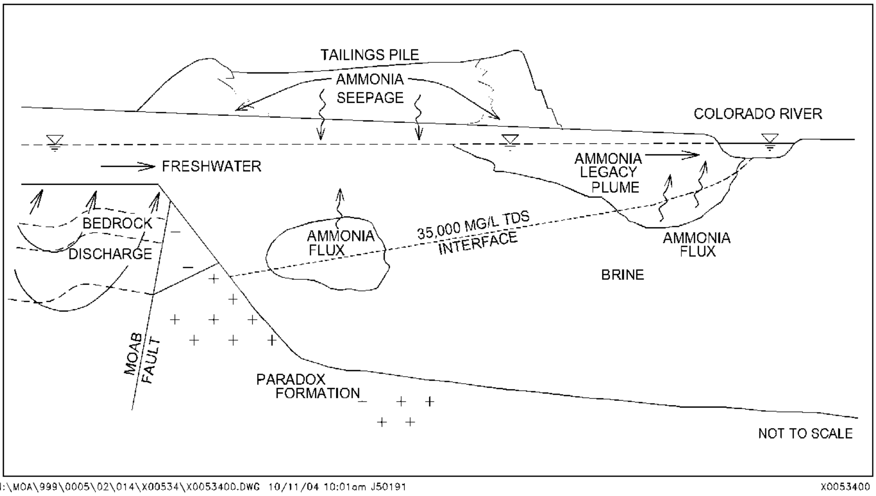

Fig. 3. Conceptual model of seepage of ammonia concentrations from the tailings pile.

The highest ammonia concentrations in surface water samples are detected in samples collected in backwater areas adjacent to the site. Ammonia levels have been of concern since ammonia was first detected river samples, largely because of the designation of this segment of the Colorado River as critical habitat for the

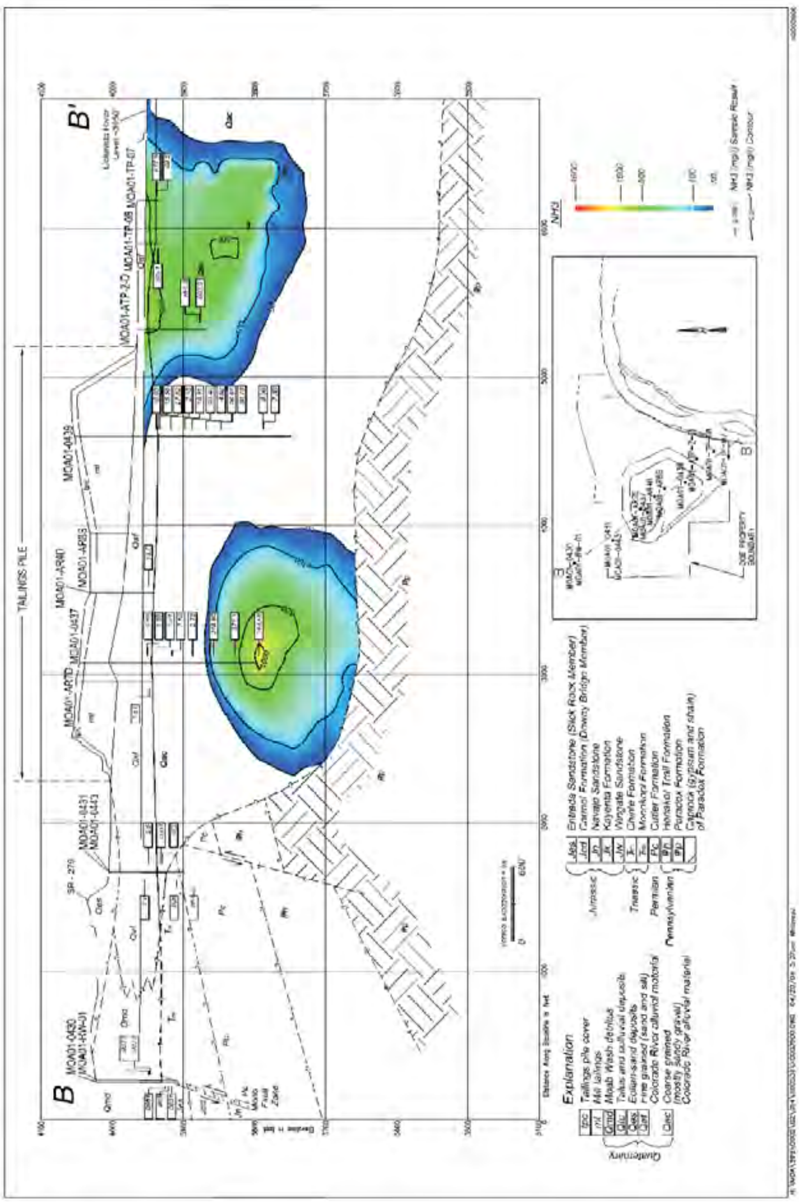

Fig. 4. Cross sectional view of ammonia concentrations in ground water beneath the tailings pile area.

Colorado pikeminnow (previously referred to as Colorado squawfish) and three other endangered fish species (razorback sucker, bonytail chub, and humpback chub). Pikeminnow favor slow-moving backwater areas of the river as nursery habitat for young-of-year fish.

Tailings Fluid Dewatering

As the mill tailings were slurried to the disposal area and formed the pile, pore fluids in the tailings naturally accumulated within the pile. To dewater the tailings pile, the former site trustee installed a system of 17,000 “wicks” (vertical band drains) in the pile prior to DOE site ownership. The vertical band drains provide a pathway for the pore fluids to more quickly travel out of the pile. Overburden material was added to the top of the pile to provide additional weight that helps “squeeze” or force some of the fluids up to the top of the pile through the vertical band drains. A lined evaporation pond was constructed on top of the tailings pile to collect the fluids being collected from the vertical band drains (Fig. 5).

DOE continues to dewater the Moab tailings pile. As of April 30, 2005, approximately 1,054,797 gallons of pore fluids (Fig. 6), 59,893 kg of ammonia, and 60 kg of uranium have been pumped from the pile and evaporated from the lined evaporation pond. Dewatering the pile allows consolidation of the pile to occur prior to relocation and will minimize the amount of wet material that has to be

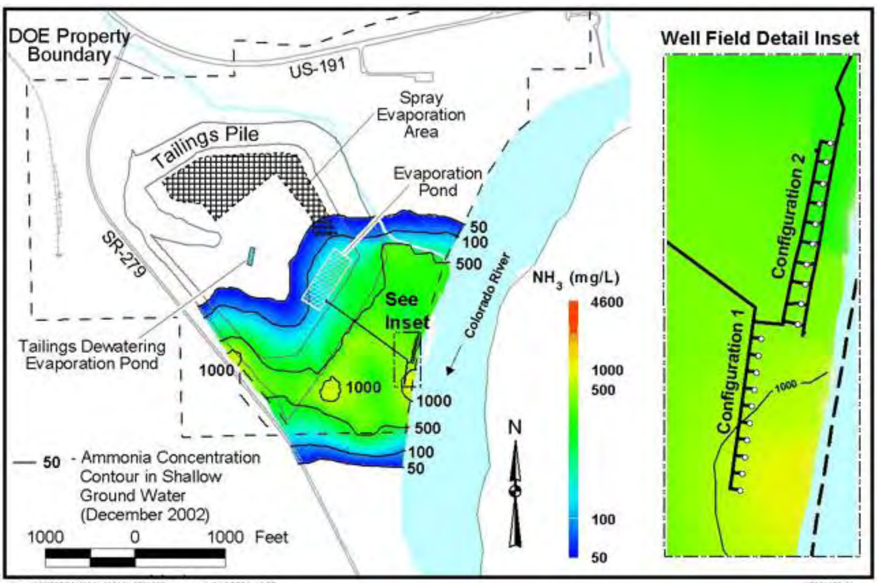

Fig. 5. Locations of the interim action systems and ammonia concentrations in the shallow ground water beneath the tailings pile.

handled. Dewatering also reduces the amount of contamination from the pile that can leach into the ground water or to the Colorado River. The effectiveness of the dewatering system is decreasing as excess pore pressure from the additional soils of the overburden material is dissipated.

Extraction and Freshwater Injection Well Fields

In 2003, DOE implemented the first phase of the ground water interim action at the site while a decision for the long-term solution to site contamination was being developed. Referred to as Configuration 1 (Fig. 5), the first phase consisted of 10 closely spaced extraction wells designed to remove contaminant mass (ammonia) from the ground water system before it discharges to critical habitat areas of the Colorado River. The expected hydraulic result of operating Configuration 1 extraction wells is to manipulate the ground water flow gradients near the river as shown conceptually on Fig. 7.

Operation of the Configuration 1 system at relatively high pumping rates results in a growth of the cone of depression that extends to the river. The pumping rates are operated to minimize upconing of the saltwater interface to the backwater areas and increasing ammonia and TDS loading in those areas and to maximize a reversal of the ground water flow gradients near the west bank of the river to in-

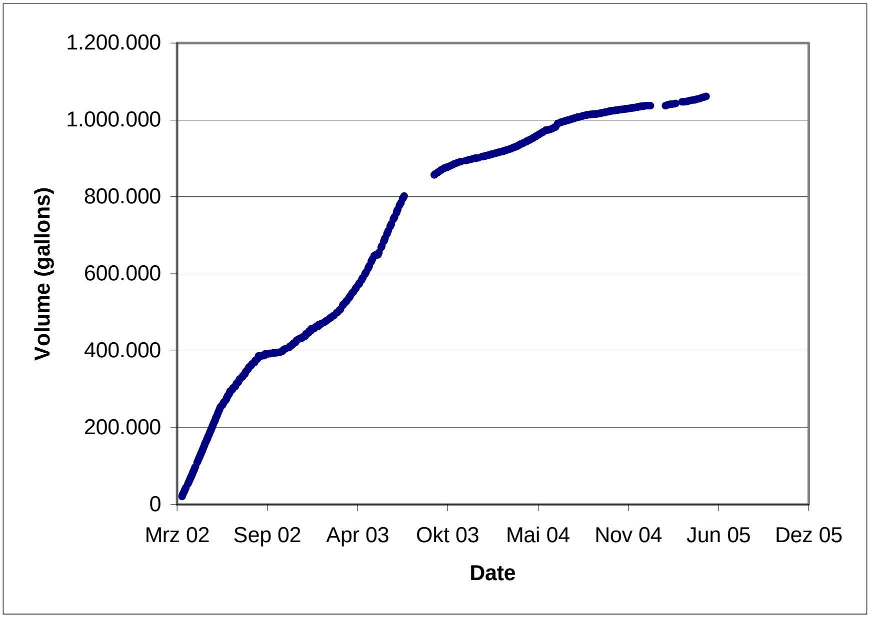

Fig. 6. Cumulative volume of tailings pore fluids extracted by the dewatering system.

troduce clean river water into the near-bank backwater areas and reduce ammonia concentrations by dilution. Dilution only occurs in the shallow ground water because underflow of the pumped zone would continue transporting ammonia toward the riverbed.

Configuration 2 of the interim action was completed in 2004 with the addition of a series of 10 dual-purpose extraction and freshwater injection wells to the north of Configuration 1 (Fig. 7). The objective of freshwater injection is to create a freshwater mound that would provide a hydraulic barrier between the ammonia plume and the river. A conceptual model of the effect of operating the Configuration 2 system with freshwater injection is shown on Fig. 8. Mounding of clean water at the injection well provides a hydraulic barrier between the ammonia plume and the river. Freshwater discharging to the near-shore backwater areas provides dilution of ammonia concentrations and thereby improves the quality of the surface water. It is possible that freshwater injection occurring near the bank of the Colorado River, advection and dispersion of the freshwater, depresses the saltwater interface and moves the ground water discharge of the ammonia plume farther east and beneath the Colorado River.

Treatment by Evaporation

Ground water extracted from the shallow aquifer from Configurations 1 and 2 is pumped via pipeline to a solar evaporation pond for treatment (Fig. 5). The evaporation pond covers approximately 4 acres and was constructed outside the 100-year floodplain on top of the tailings pile. In addition to the evaporation pond, a 17-acre land-applied spray evaporation system was installed in 2004 to enhance evaporation of ground water pumped from the interim action extraction wells by using a sprinkler system installed on top of the tailings pile next to the evaporation pond. The sprinkler system consists of micro-spray nozzles on 25-ft centers. The system was expanded to include an additional 11 acres in 2005. The combined 28 acres of sprinklers operate in conjunction with the existing evaporation pond, which has more than doubled the capacity of the existing interim action. The system is designed to evaporate the water before it infiltrates the tailings pile and to provide dust suppression.

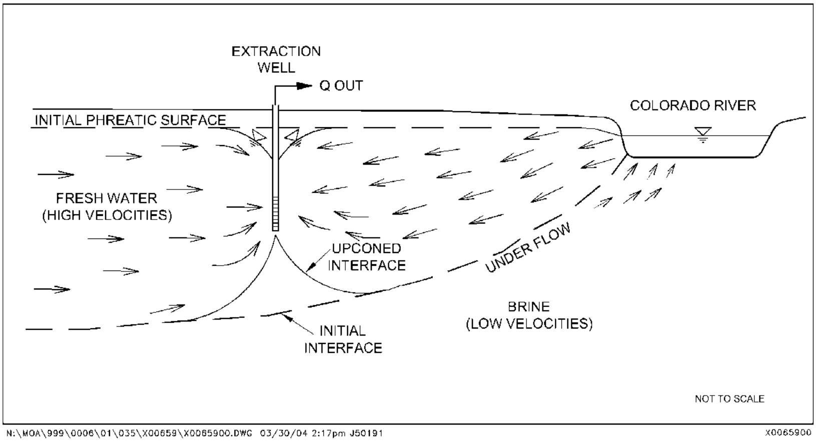

Fig. 7. Conceptual model of the Configuration 1 extraction system.

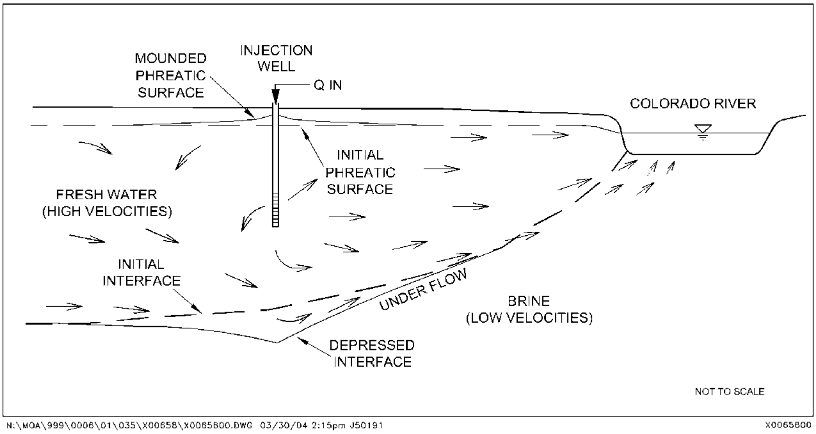

Fig. 8. Conceptual model of the hydraulic barrier by the Configuration 2 freshwater injection system.

Conclusions

In October 2001, DOE was tasked with the requirements to clean up surface contamination and develop and implement a ground water compliance strategy to address contamination that resulted from historical uranium-ore processing at the abandoned Moab millsite. The Moab site is the last large uranium mill tailings pile to be cleaned up in the United States.

DOE instituted environmental controls and interim actions at the site to minimize potential adverse effects to human health and the environment in the short term while a draft EIS was being prepared to evaluate long-term remediation alternatives. Comments received from some government agencies and the public on the draft EIS, released for public comment in November 2004, expressed concern about the potential effects of capping the contaminated materials at the site because of engineering uncertainty of river migration and the long-term effects of contaminated ground water entering the Colorado River. For these reasons and other factors, the DOE preferred alternative is to relocate the tailings to an alternate site away from the Colorado River and to implement long-term ground water remediation.

The final EIS, incorporating public comments and summaries, will be distributed to the public in summer 2005. A final Record of Decision is expected to be issued in fall 2005. The interim action system will continue to operate and may eventually become part of the final ground water remedy. Monitoring data are currently being collected to demonstrate the effectiveness of the system prior to design and construction of the long-term ground water strategy.

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