MOVING A MOUNTAIN BY RAIL!
Safe Transportation and Disposal of a Uranium Mill Tailings Pile

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ABSTRACT
This paper describes identification and resolution of regulatory considerations, construction challenges, development and implementation of the transportation plan and lessons learned from the movement of a small mountain of uranium mill tailings in the United States that lies on the bank of the Colorado River in Moab, Utah.

In 1952, the discovery of significant uranium ore deposits on the Colorado Plateau and the subsequent nuclear arms race of the Cold War resulted in approximately 800 mines producing ore, largely used for building the nuclear arsenal for the United States of America. During the uranium mining heyday, the federal government and private industry built a number of ore processing sites on the Colorado Plateau in southwestern United States. The waste from uranium mills consists of sandy and clayey materials and contains the radioactive element radium and other chemicals, such as ammonia, vanadium, and arsenic. The mill tailings pose a potential hazard to public health and safety.

By the 1980's the uranium excitement was over and the mills were shut down. As a result, more than two dozen mill tailings piles remained at the abandoned processing sites. These piles range in volume from approximately 292,000 to 3.1 million cubic meters of mill tailings. The massive Moab pile is up to 28.5 meters (m) high and contained 9.2 million cubic meters of material covering 53 hectares of land located only 230 m from the Colorado River.

The U.S. Department of Energy (DOE) has safely remediated all other piles and in 2005 decided on the final cleanup remedy for the Moab site. It was decided to relocate mill tailings and associated wastes to the Crescent Junction, Utah, off-site waste disposal site, a distance of 48 kilometers (km) using primarily rail transportation. The first trainload of uranium mill tailings was shipped from the Moab site to Crescent Junction site for disposal on April 20, 2009. The Moab Project is scheduled to be completed by 2025.

INTRODUCTION
On April 20, 2009, DOE began moving the largest uranium mill tailings pile in the world to be relocated to another site. Under the Moab Uranium Mill Tailings Remedial Action Project, the tailings pile is being moved away from the Colorado River to a new engineered disposal cell.

The Moab uranium-ore processing site was constructed by the Uranium Reduction Company in 1956 and later sold to Atlas Minerals Corporation. Ore was brought to the mill site from mines throughout the surrounding area, but primarily from the Spanish Valley 48 km to the south. When processing operations ceased in 1984, an estimated 9.2 million cubic meters of mill tailings and tailings-contaminated soil was present in a pile located in the western portion of the 162-hectare property.

DOE assumed ownership of the site in 2001 and prepared a Record of Decision in 2005 that detailed the decision to move the tailings off-site. DOE evaluated shipping the tailings by slurry line, truck, or rail. Slurrying the tailings was the least attractive alternative due to the large quantity of water necessary and the need to remove the water for disposal. Trucking was slightly less expensive overall and provided more flexibility than rail; however, rail was more fuel efficient, lower risk than trucking because of its isolation from the public, and was strongly preferred by the stakeholders over adding more traffic to an already busy state highway. Because of its advantages, DOE chose to ship the tailings primarily by rail.

Prior to beginning shipments, DOE prepared a transportation plan that addressed shipping requirements and response actions and was provided to local and regional organizations for input. A transportation security plan was also prepared that describes the security requirements to stage and transport the tailings material. Training was performed for all workers whose activities involved packaging and transport of the tailings. The Moab Project also utilized the DOE Medical Emergency Radiological Response Team program to educate site supervisors and managers on DOE response capabilities. A thorough readiness review was conducted prior to initiating tailings transportation.

SITE DEVELOPMENT FOR TAILINGS HAUL

The 48 km between Moab and the Crescent Junction disposal site is serviced by Union Pacific Railroad's (UP's) Cane Creek Subdivision line, constructed in 1962 to enable transport of potash (potassium carbonate) from a mine and processing facility south of the Moab site. A siding to the rail line, named Emkay, was added at the uranium mill to facilitate receipt of ore and process chemicals. The rail line is 37 m above the tailings pile on the side of a steep slope that extends upward another 230 m to the top of a mesa.

When DOE took custody of the site, the hillside load-out located on a narrow bench at the Moab site (Emkay) was in disrepair with evidence of substantial gulley erosion. Prior to initiating design of the load-out area for the tailings relocation project, a severe storm event in July 2006 left portions of the rail covered by more than half a meter of rock and sediment that was washed down the slope from above. From the Emkay siding, the Cane Creek Subdivision line almost immediately enters a tunnel to the south. In the opposite direction towards Crescent Junction, the rail ascends at a 1-percent grade through Moab Canyon where 23-m red sandstone walls were cut for the track to maintain its grade to reach the undulating but gentle grade for the remaining 35 km to the Green River District line juncture near Crescent Junction.

To transport the tailings to Crescent Junction, the material is placed in steel containers and trucked from the pile to the rail load-out area, and loaded onto railcars. DOE had to perform significant infrastructure construction to enable getting the tailings from the pile to the train. DOE rebuilt the haul road to and from the load-out area as a one-way loop with a maximum grade of 12 percent. This feature allowed better use of the natural topography to reduce the overall amount of material needed for construction of the load-out area.

The rail company, UP, facilitated construction in two areas that were paramount to expediting the schedule. At DOE's request, UP allowed the use of the main (subdivision) line to load the train. This is not a normal UP practice, but it enabled DOE to use only a single spur (a replacement of the existing one) instead of two spurs for loading. This greatly simplified the construction of the load-out area. UP

also agreed to allow DOE contractors, approved by UP, to perform most of the rail work at the Moab site that UP had originally planned to do.

Certain obligations were included in UP's compromises, such as requiring DOE to inspect and maintain this portion of the track in accordance with UP rail safety procedures. While DOE was preparing the hillside, UP made substantial changes along the remaining tailings transport route by replacing 15,000 ties, adding ballast, cleaning drainage ditches, and laying new continuous welded rail or "ribbon" rail in lengths of 300 m or longer to upgrade some curves. Another necessary project activity was to perform upgrades, such as flashing crossing gates, drainage improvements, and asphalt approaches to crossings along the rail route.

Because the slope of the existing Cane Creek Subdivision line was too steep for loading the tailings train, 1,160 m of the existing rail beginning at the tunnel portal had to be replaced to lower the bench to the allowable grade. The rail bench elevation was lowered 4 m at its maximum to attain the necessary 0.4-percent grade. Along with this elevation reduction came other advantages and disadvantages. Lowering a portion of the rail bench lessened the overall grade the haul trucks would have to overcome to reach the load-out area. On the other hand, it made for steeper slopes above the rail that could contribute to erosion and rockslides.

DOE made a critical decision during construction of the hillside to move a portion of the rail away from the toe of a 6-m-thick rock slab above the rail line that steeply pitched towards the track. By avoiding cutting through the slab that provides structural support to the hillside, the integrity of the rock was maintained, thus dramatically reducing the risk of a slide.

With little more than a gas station and an interstate exit, Crescent Junction had an existing siding on UP's Green River District line called Brendel. UP made concessions near the Crescent Junction site by allowing DOE to replace about 1,000 m of track, to meet grade requirements where the Cane Creek Subdivision line joins the Green River District track. Additionally, UP approved the reuse of rail panels removed from a DOE site in Ohio for the new rail spurs at Crescent Junction and Moab.

TRANSPORT PROCESS

DOE began excavating tailings from the pile in February 2009. However, the tailings must be "conditioned" to reach moisture content suitable for compaction in the disposal cell. Conditioning consists of spreading the material in 0.3-m layers on top of the tailings pile and turning the material over using farm-type equipment to allow it to air dry. Conditioned tailings have a moisture content of about 17 percent, which is often less than half of the values observed during excavation.

The conditioned tailings are top-loaded into steel intermodal containers that are trucked to a lidding facility in the Support Area. The containers are then driven through a wash facility and the exterior is surveyed to ensure it is free from contamination. From the Support Area, separate trucks take the containers to the load-out area where they are placed on 27-m-long articulated railcars that hold four containers end-to-end to be shipped to the Crescent Junction rail siding.

DISPOSAL SITE

DOE decided that the best alternative for permanent disposal of the tailings materials was to construct a disposal facility near Crescent Junction. Underlain by nearly 700 m of shale, barely 25 centimeters

of precipitation annually, and ready rail and road access, the site is ideal for a long-term disposal of tailings. The area is relatively unpopulated with the nearest town being 8 km east. DOE prepared a Remedial Action Plan that presents the basis for constructing the disposal cell at Crescent Junction. The plan provides a summary-level description of the remedial action and a discussion of technical findings, along with calculation sets and supporting information to ensure the disposal cell construction and remedial action would be conducted in compliance with U.S. Nuclear Regulatory Commission (NRC) regulations and DOE Orders. NRC conditionally concurred with the plan in July 2008.

Through a temporary land withdrawal, DOE obtained 930 hectares of public lands from its sister agency the U.S. Department of Interior for the disposal cell and support infrastructure. Of those 930 hectares, 200 hectares was permanently transferred to DOE in 2008. The disposal cell is being excavated in phases, with the first phase completed in December 2008 and the second phase in process. The design height of tailings material in the cell is 50 feet total, 25 feet below grade, 25 feet above. The cell cover is being constructed continuously over the area where tailings have been placed to their design height and will add a total of about 10 feet on top of the tailings. Cover placement began in July 2010.

When the train arrives at the Crescent Junction site, each container is transferred from a railcar to an off-road haul truck, driven to the dumping area, and end-dumped across a radiological boundary. The tailings are then loaded into separate haul trucks and driven to the disposal area where they spread for compaction using a dozer. A sheep's foot roller compacts them in place in the cell. The empty container exterior is surveyed again before being placed back on a railcar for the return trip to Moab.

ACCELERATION UNDER RECOVERY ACT

Rail shipments began in April 2009 with one 22-car train per day, 4 days per week. Each day, a train was simultaneously loaded at the Moab site and unloaded at Crescent Junction, and each night, the train would move the containers between the two sites. Although the infrastructure was designed to accommodate a 34-car train, the project schedule did not show having the funds available to ship the maximum trainloads until the beginning of fiscal year 2012 (October 2011).

In May 2009, the Moab Project received additional funds through the American Recovery and Reinvestment Act (ARRA) because it was considered "shovel ready" and could efficiently put the money to use in stimulating the economy by creating jobs. The Moab ARRA Project was simply an acceleration of tailings shipments to the maximum-train schedule earlier than 2012. DOE's goal is to accomplish the ARRA work by the end of fiscal year 2011 (September 2011).

With the ARRA funding the Moab Project began shipping a second daily train 5 days per week in August 2009. This increased level of shipping entailed purchasing additional railcars, containers, other equipment, and vehicles, and hiring a second work shift. Implementing a night shift also required increasing lighting and adding other safety features. Overall, more than 200 additional employees were hired through ARRA funding. DOE began ramping up to 34-car trains in the fall of 2009. Accomplishing this while experiencing one of the coldest winters on record in southeastern Utah proved to be an enormous effort. Night work during a Utah summer is almost desirable to avoid the intense heat. On the other hand, night work in a Utah winter is almost unbearable. However, despite

the extreme cold temperatures, the Moab Project successfully shipped its first maximum train, loaded during a single shift, in mid-January 2010.

By adding a second daily train, the time allowed for loading and unloading containers and for transporting them between the sites was cut in half, from 12 hours to 6. This created a need for balanced flow between the day and night shifts and between the two sites to sustain the level of work throughout the week. Accomplishing the same tasks in half the time demanded that efficiencies be realized. UP offered the services of its corporate Lean Management resources to assist with developing a disciplined program to increase operational efficiencies. DOE and its contractors have embraced this process improvement program. UP has also implemented efficiencies on its side, such as changing the way it invoices shipments to billing by railcar instead of individual containers. DOE was able to extend the spurs at Moab and Crescent Junction in June 2010 to allow two more railcars per train. As of August 2010, the Moab Project began consistently shipping 36 railcars carrying almost 10,000 tons per train.

REGULATORY CONSIDERATIONS

The Moab Project must ship hazardous materials in accordance with U.S. Department of Transportation (DOT) regulations and DOE Orders. The activity concentration of radium-226 (Ra-226) in mill tailings varies based on the amount of other material present, such as various types of soil and debris. Historically, uranium mill tailings have been transported using cost-effective bulk transport methods through a DOT exemption issued in June 1991 (DOT-E 10594). Uranium mill tailings at the Moab Project site range from 0.185 becquerels per gram (Bq/g) to 85.1 Bq/g of Ra-226, with average concentrations at about 25.9 Bq/g Ra-226. Material shipped to date has ranged from about 3.67 Bq/g to 55.0 Bq/g Ra-226. In 2005, DOE applied for a special permit (SP) to replace the exemption, which expired in 2000. Under the SP, the mill tailings meet the hazard classification of radioactive material, low specific activity (LSA I or LSA II), and are subject to the applicable shipping and packaging requirements of 49 CFR 172 and 173. DOT approved the SP, which waived certain DOT regulations pertaining to marking, labeling, and manifesting, and allowed DOE to use alternate packaging. The SP also imposed additional controls, security, training and emergency response measures to ensure safe and secured transportation of mill tailings to the disposal site.

In addition, DOE must meet Federal Railroad Administration regulations associated with railroad crossings, and rail lines and equipment are subject to periodic inspections. UP is responsible for meeting Federal Railroad Administration standards for railcars and locomotives.

LESSONS LEARNED

Several lessons learned have resulted from interactions with UP. In addition to facilitating changes in the invoicing process, the Moab Project has worked with UP to reduce the time to complete other paperwork the railroad requires with each shipment. During the course of addressing delays by UP associated with maintenance along the Green River District line, DOE learned that UP did not dedicate a project manager to the Moab Project trains. To address this issue, UP agreed to provide (at DOE's expense) a liaison to act as a single point of contact between project and UP personnel. Inspection and maintenance of railcars and even locomotives also have resulted in some lessons learned. During inspections, project personnel were caught off guard by cars labeled as "bad order," that is, railcars that do not meet inspection as being fit for transporting containers. As a result, the Moab Project has begun

training operations personnel to inspect the cars with greater rigor in an effort to identify potential issues earlier.

Two problems arose soon after shipments began. The initial containers were 24 cubic meters and were designed to hold 36 metric tons. When conditioned, the tailings were less dense than planned, and the containers subsequently only held 29 metric tons. However, DOE also discovered that the articulated railcars could not have been loaded with four containers if they were all carrying the heavier weight. To meet the weight limit, the interior two positions on the railcars could only carry containers holding 29 metric tons of tailings. To compensate for the reduced shipping quantities from the smaller-capacity containers, DOE ordered taller containers that hold about 36 metric tons and placed them on the outer positions of the railcars.

Prior to implementing the ARRA work, the Moab Project enjoyed a strong safety culture with a relatively small, stable workforce. DOE has had to learn how to instill that safety culture in a workforce that nearly tripled in 6 months. Adjustments were also made to adapt to having a night work shift and essentially 24-hours-a-day, 7-days-a-week operations. DOE has also learned to manage sustained operations during prolonged extreme cold temperatures.

CONCLUSIONS

By striving for continuous improvement, the Moab Project has increased its consistency in meeting its shipping target and is making steady progress in moving this 9.2-million-cubic-meter "mountain." A milestone of 1.8 million metric tons of tailings shipped was achieved on August 11, 2010. With the lessons learned from over 500 shipments, efficiencies are being realized. Future concerns exist regarding project funding following the completion of ARRA work. If the number of weekly shipments is reduced due to funding constraints, a priority will be to take the lessons learned and enhancements made during the ARRA work to move more tailings per dollar spent.

REFERENCES

DOE (U.S. Department of Energy) 2009. *Moab UMTRA Project Transportation Plan* (DOE-EM/GJ1639), Grand Junction, Colorado.

DOT (U.S. Department of Transportation) Special Permit Authorization DOT-SP 14283.