The Piñon Ridge Project
Design and Permitting of a New Uranium Mill Tailings Facility – 10512

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ABSTRACT

Strategically located within the Uravan Mineral Belt District of western Colorado, the Piñon Ridge Project is the first new uranium mill being proposed for construction in the United States in over 25 years. In 1992, dramatic changes to the US regulatory environment for uranium ore processing occurred making regulatory compliance an increased challenge for a new facility. Such changes to the regulations include enforcement of a prescriptive liner for surface impoundments and reduction of the exposed tailings surface. Proposed as a 7.4 million ton uranium milling operation over its expected 40 year life, the mill will receive uranium ore from a number of mines in the region. The project includes design and permitting of a uranium/vanadium processing facility, three tailings cells, evaporation ponds, and ore stockpile pads. The focus of this paper is to provide a summary of the design of the tailings cells. The general status of the Mill License Application submitted to the Colorado Department of Public Health and Environment (CDPHE) during the fourth quarter of 2009 is discussed.

INTRODUCTION

Energy Fuels Resources Corporation (EFRC) is in the process of pursuing licensing of a new conventional uranium mill strategically located within the Uravan Mineral Belt District. The proposed mill, the Piñon Ridge Project, is located in Montrose County, Colorado, and is the first conventional uranium mill being proposed in the United States in over 25 years.

As part of the Piñon Ridge Project, uranium tailings are proposed to be disposed in three 30.5 acre tailings cells with a combined capacity to store approximately seven million tons (Mt) of tailings. The project has a 40-year design life at a design mill throughput of 500 tons per day (tpd) of tailings. Figure 1 is a photo of the proposed mill site, located in the Paradox Valley.

Regulatory Background and Licensing Process

Located in the Agreement State of Colorado, the Piñon Ridge Project is pursuing licensing through the Colorado Department of Public Health and Environment (CDPHE). As an Agreement State, Colorado has the responsibility for licensing the possession and use of radioactive materials under the Radiation Control Act (Title 25, Article 11) and Colorado's Rules and Regulations Pertaining to Radiation Control (6 CCR 1007-1). As of January 2006, thirty-three states have entered into agreements with the US Nuclear Regulatory Commission (NRC), under which regulatory authority has been delegated to the state over most radioactive materials used in non-federal facilities, pending that the state program is compatible with NRC requirements. (Note: New Mexico, although an "Agreement State" in most other circumstances, had relegated its licensing and regulatory authority for uranium mills and related source material facilities back to the NRC some years ago.)

Figure 1. Photo of the proposed Piñon Ridge uranium mill site, looking north across the valley.

Per agreement between the NRC and the Governor of Colorado, CDPHE is the sole regulator of radioactive materials in Colorado under the Colorado Radiation Control Act (CRS 25-11-101, et seq). The implementing regulations for the management and control of radioactive materials are detailed under the Colorado Rules and Regulations Pertaining to Radiation Control (6 CCR 1007-1). Examples of some of the specific CDPHE regulations under 6 CCR 1007-1 that are applicable to the licensing of a uranium mill in Colorado include:

- Part 1 "*General Provisions"*
- Part 3 "*Licensing of Radioactive Material"*
- Part 4 "*Standards for Protection Against Radiation"*
- Part 17 *"Transportation of Radioactive Materials"*
- Part 18 "*Licensing Requirements for Uranium and Thorium Processing"* and its Appendix A, *"Criteria Relating to the Operation of Mills and the Disposition of the Tailings or Wastes from these Operations"*

Additionally, CDPHE will incorporate NRC guidance into the license review process including use of the following (for example):

- NUREG 1620 "*Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978"*
- NRC Regulatory Guide 3.5 "*Standard Format and Content of License Applications for Uranium Mills"* (Under revision as Draft Guide 3024*)*
- NRC Regulatory Guide 3.8 "*Preparation of Environmental Reports for Uranium Mills"*
- NRC Regulatory Guid*e* 4.14 *"Radiological Effluent and Environmental Monitoring at Uranium Mills"*

At least nine months prior to anticipated construction, an applicant must submit the mill license application to CDPHE (construction is prohibited until a license is issued). At least 12 months of pre-operational characterization and monitoring data will have been collected prior to license submittal.

Initially, CDPHE must review the application package for completeness and has 30 days to determine this. The application package for the Piñon Ridge Project was determined by CDPHE to be substantially complete in mid-December 2009.

The first public meeting/hearing must be conducted by CDPHE within 45 days of the completeness determination, with a second meeting within 30 days of the first. The County Commissioner review of the Environmental Report (submitted as part of the license package) is requested within 90 days of the first public meeting. CDPHE must approve or deny the application within 270 days of response from the County Commissioners, or within 360 days of the second public meeting if there is no County Commissioner response.

Key Regulatory Requirements Relating to Uranium Mill Tailings

Under the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978, as amended, the Environmental Protection Agency (EPA) has the responsibility of establishing standards for exposure of the public to radioactive materials originating from mill tailings for active uranium extraction facilities licensed by the NRC or its Agreement State. In the specific case of the Agreement State of Colorado, CDPHE has developed and regulates exposure standards for the public under 6 CCR 1007-1, Part 18 "*Licensing Requirements for Uranium and Thorium Processing"* and its Appendix A, *"Criteria relating to the Operation of Mills and the Disposition of the Tailings or Wastes from these Operations*" which incorporates the EPA standards.

US regulations pertaining to the design and operation of uranium tailings disposal cells became increasingly more stringent in 1992, including the requirement for tailings cells to have a double liner separated by a leak detection and collection layer, with the lower composite liner system comprised of a geomembrane underlain by three feet of low permeability clay. Further, the revised regulations promote fully below-grade tailings disposal. Because the uranium industry is now awakening from a long recession, these regulations are now coming to the forefront, needing to be implemented for the first time since their inception over 17 years ago for new uranium tailings disposal projects.

The Colorado state regulations indicate that flexibility is provided in the criteria which allows for optimal tailings disposal on a site-specific basis. Several of the guidelines for uranium tailings disposal include providing consideration for disposal of tailings below grade, stated as the 'prime option', providing good wind protection to the tailings via topographic features, and employing the groundwater protection standards set forth in the Code of Federal Regulations (CFR). The US guidelines for uranium tailings disposal are not completely indifferent to those for other parts of the world. For instance, the International Atomic Energy Agency (IAEA 2002) guidelines include maximizing placement of waste material below ground level, and minimizing the need to relocate waste at closure.

GENERAL TAILINGS CELL DESIGN CONCEPTS

The Piñon Ridge Mill is designed to operate at 500 tpd with an expected life of 40 years. Each of the three proposed tailings cells (Cells A through C) have been designed to provide a minimum capacity to accommodate 2.5 million tons of tailings with 3 feet of freeboard, having liner footprint areas of 30.5 acres. The tailings cell layouts are illustrated in plan view in Figure 2.

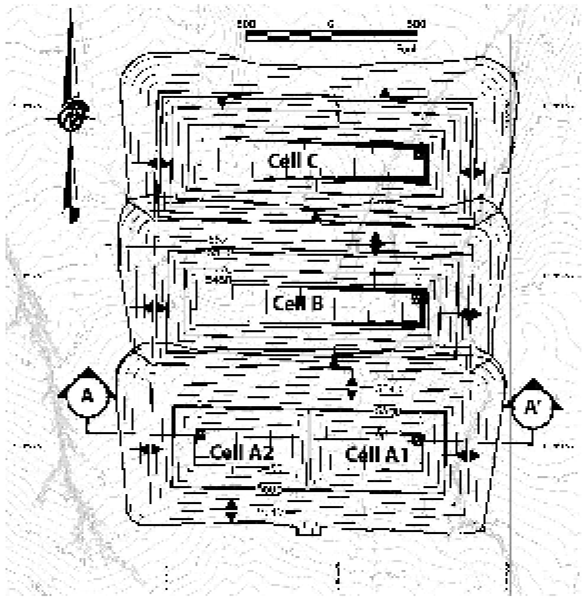

Figure 2. Tailings cell layout indicating location of Section A-A'.

The tailings cells were designed for construction predominantly in the existing subgrade, with excess cut dedicated to future closure cover construction. The tailings cells have internal side slopes of 3H:1V, and a minimum base grade of one percent. The limits of the tailings cells are lined with a double layer liner system with an intervening leak collection and recovery system to contain process solutions, enhance solution collection, and protect the groundwater regime. Intermediate benches have been incorporated in the design to provide additional anchorage of the underliner component of the secondary composite liner system, as well as buttressing of the liner to limit wind uplift.

As a precautionary measure, the first tailings cell (Cell A) slated for construction has been designed as a split cell to facilitate separate collection of process solutions for redundancy during facility start-up if unforeseen problems with the liner system develop, allowing half of the cell to be decommissioned and repaired while continuing mill operations (Figure 3). Detailed design of future tailings cells (Cells B and C) includes a split-cell option with anticipation of a single-cell design.

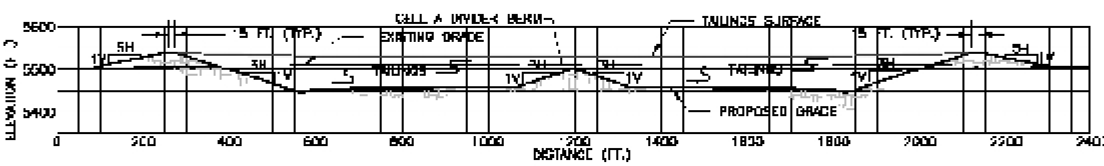

Figure 3. Cross-section A-A' through proposed tailings Cell A.

TAILINGS CELL LINER SYSTEM DESIGN

During the course of design, a number of meetings were held with CDPHE to obtain early feedback on the proposed design concepts, prior to official submittal of the designs as part of the Mill License Application, submitted during fourth quarter 2009. The liner system currently proposed for the tailings cells has evolved as a result of these meetings.

Closure of the tailings cells includes leaving the liner system in-place in perpetuity. Regulations for closure indicate that the liner should remain effective for 1000 years, to the extent reasonably achievable. Further, the geosynthetic components of the tailings cells are required to be constructed of materials which prevent wastes from migrating into the liner during the active life of the facility. At the design production rate of 500 tpd, the active life of each tailings cell is anticipated as approximately 14 years. Closure of each tailings cell will be initiated once deposition within each cell is completed, including dewatering and construction of an interim cover to limit radiological hazards.

Liner System Summary

Based on site-specific conditions, and following the guidance of 40 CFR 264.221, the tailings cells were designed with the following liner system for groundwater protection (from top to bottom) (Figure 4):

- 60 mil high density polyethylene (HDPE) upper (primary) geomembrane;
- Leak Collection and Recovery System (LCRS) consisting of HDPE geonet on the base of the tailings cells, and a drainage geocomposite on the side slopes;
- 60 mil HDPE lower (secondary) geomembrane;
- Reinforced geosynthetic clay liner (GCL) as the low permeability underliner component of the secondary composite liner system; and
- Prepared subgrade consisting of native silty sand and sandy silt soils.

For the tailings cells, the upper geomembrane layer of the liner system was designed to remain uncovered. This is a practical approach for tailings cells because the tailings solids represent little puncture threat to the liner as they are relatively fine-grained, regular equipment access over the liner is not expected, and a soil cover over the liner would be difficult to maintain in the relatively high energy environment associated with hydraulic discharge of slurried tailings. A partial cover has been designed on the gently sloping impoundment floor to prevent damage from wind uplift and to act as a drainage layer for the purposes of reducing the hydraulic gradient on the liner and enhancing tailings densification.

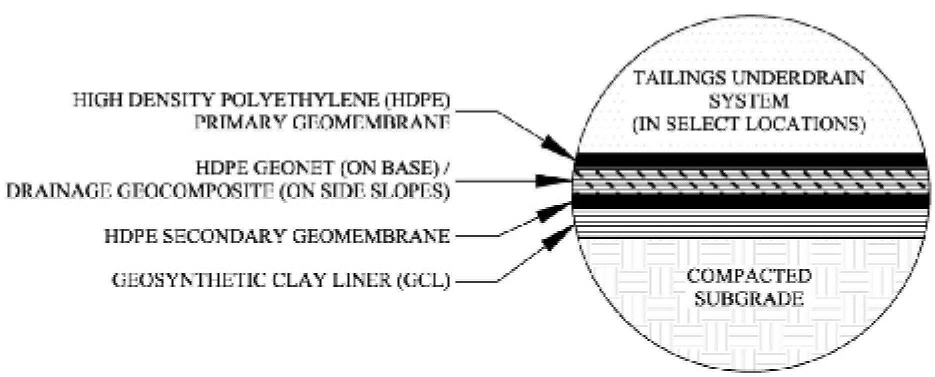

Figure 4. Tailings cell liner system detail.

Upper Primary Geomembrane Liner

Since the upper primary geomembrane will be exposed to atmospheric conditions as well as a variety of chemicals associated with uranium and vanadium processing, use of a HDPE liner is proposed. During early meetings, regulators expressed concerns regarding the degradation resistance of HDPE geomembrane, particularly when exposed to ultraviolet (UV) radiation. These concerns were effectively assuaged by reviewing the expected performance requirements for the liner system and summarizing available liner performance data from the engineering literature.

The portions of the tailings cell liner systems that will be exposed to UV radiation for the longest period of time are located near the top of the cells, which are the least critical from a hydraulic containment standpoint (i.e., the hydraulic heads will be low to nonexistent during a short operating life followed by negligible hydraulic loading in the post-closure period). The base of the tailings cells, which will be subjected to the highest hydraulic heads, will be covered with tailings at the on-set of operations and therefore exposed to UV radiation for a very short time.

UV radiation can be expected to cause some deterioration in appearance and mechanical properties with time. A review of available literature investigating the UV resistance of HDPE geomembrane from field performance (Hsuan et al. 1991; Rowe et al. 2003; Ivy 2002; Adams & Wagner 2000; Rollin 2004) and laboratory test data (Koerner et al. 2005; Martin 2005) provides evidence that exposure of a 60 mil HDPE geomembrane to UV for 20 years or more will not result in significant degradation of the geomembrane. Therefore, the amount of deterioration expected will not compromise the performance of the liner system during its anticipated operational life.

Although standard (black) HDPE has been proven to be highly resistant to UV radiation over long periods of time, an additional feature was incorporated into the liner design, which should further reduce the potential for UV damage to the exposed portion of the liner system. The upper primary geomembrane liner will include a light-reflective surface that is resistant to UV radiation and is coextruded with the primary black geomembrane liner. All of the physical properties of a standard black HDPE geomembrane remain the same, but the light-reflective design feature provides added benefits by increasing the weathering resistance by reflecting more solar radiation, while at the same time reducing the range of expansion/contraction resulting from temperature fluctuations, reducing desiccation effects to subgrade soil materials, and improving detection of installation damage. This design enhancement, while not necessary to achieve acceptable system performance, will reduce UV degradation and should also improve constructability, aid quality assurance, and improve system performance.

Single-sided texturing (textured side down) on the upper primary geomembrane is included to increase frictional resistance at the contact with the LCRS layer. Textured rubsheets will be extrusion welded where required by mill operations to facilitate tailings deposition and access during operations.

Additionally, use of conductive liner is proposed for the upper geomembrane to aid in quality assurance testing. This design enhancement was incorporated as a result of meetings with regulators during the facility design. After the liner system is installed, spark testing will be conducted on the conductive liner as a cost-effective and precise way to detect defects in the liner.

Leak Collection and Recovery System Layer

An important feature of the tailings cell liner system is the Leak Collection and Recovery System (LCRS) layer, designed per 40 CFR 264.221 (by reference from 10 CFR 40 and 6 CCR 1007-1, Part 18). The LCRS is designed to minimize hydraulic head on the lower geomembrane liner. The LCRS has been designed as an HDPE geonet in the base of the tailings cells, and a drainage geocomposite on the side slopes. Geonet was not considered suitable for use on the long side slopes of the tailings cells due to its anticipated low interface shear strength when placed in contact with geomembrane. Instead, a drainage geocomposite, comprised of a geonet laminated on both sides to a nonwoven geotextile filtration media, is proposed to increase frictional resistance with the overlying and underlying textured geomembrane liners.

Per the requirements of 40 CFR 264.221, the transmissivity of the selected LCRS drainage layers exceed the minimum transmissivity requirement and is designed with a minimum grade of one percent. The LCRS layers were designed with transmissivities sufficient to prevent liquid build-up above the secondary geomembrane, per the methods outlined in Giroud et al. (1997b). Leakage collected in the LCRS layer will be routed via gravity flow to a LCRS sump. Collected solution will be recovered via an automated submersible pump installed in one of two HDPE riser pipes, and pumped back to the tailings surface.

Lower Secondary Composite Liner System

The lower secondary composite liner system underlies the LCRS layer to maximize the amount of solution recovered in the LCRS and act as a final flow barrier, protecting the subgrade. This composite liner system consists of a 60 mil HDPE double sided textured geomembrane overlying a reinforced geosynthetic clay liner (GCL). HDPE was selected due to its natural resistance to the chemicals in the solution, and the double sided texturing is used to increase the frictional resistance with the overlying and underlying geosynthetic layers.

Due to lack of locally-available clay sources in the vicinity of the Piñon Ridge Project, alternative underliner materials which meet or exceed the prescribed underliner (i.e. three feet of 10^{-7} cm/s clayey material) were considered. Alternatives evaluated included bentonite amendment of on-site silty and sandy soils to achieve a low permeability underliner, and use of GCL as the underliner material. The use of GCL was ultimately recommended for this site as soils amended with up to three percent bentonite tested to be nearly one order of magnitude more permeable than the prescriptive clay liner requirement. Calculations according to the method proposed by Giroud et al. (1997a) demonstrate that the secondary liner system containing a GCL performs better than the secondary liner system containing the prescriptive clay liner in terms of limiting fluid flow. At the Piñon Ridge Project site, use of a GCL underliner appears to be the most cost-effective and constructible solution to meet (or exceed) the regulatory requirements.

CLOSURE CONSIDERATIONS

The tailings cells for the Piñon Ridge Project have been designed to consider closure and to integrate the design for compatibility with a number of concepts. The closure design is aimed to minimize the need for long-term active site care and maintenance during the post-closure period.

Considerations incorporated in the tailings cell design included design of perimeter berms with 10H:1V (horizontal:vertical) external side slopes to aid performance of the closure cover, dewatering of tailings as feasible prior to placement of closure cover materials, and design of a final closure cover which meets the requirements of the regulations with regard to erosion protection as well as limiting radon flux to acceptable levels. Due to input from CDPHE during the design process, an evapotranspiration (ET) cover (i.e. water balance cover) was selected to meet the regulatory requirements.

As deposition is complete within each tailings cell, an interim cover will be placed to limit exposure to radiation until the final cover is constructed. Additional capacity is provided within the final tailings cell to accommodate future closure considerations, such as disposal of the liner systems removed from the evaporation ponds and ore pads, etc., during site decommissioning and closure activities.

CONCLUSIONS

Regulations enforced beginning in 1992 which govern the design of new uranium mill facilities in the US are currently being applied for the first time at a new facility for the Piñon Ridge Project, located in western Colorado. As an Agreement State, Colorado has the authority to license the possession and use of radioactive materials in Colorado under the Radiation Control Act (Title 25, Article 11), and Colorado's Rules and Regulations Pertaining to Radiation Control (6 CCR 1007-1).

In general, the regulations provide minimum requirements, some prescriptive and some flexible, in order to allow for optimization on a site-specific basis. The tailings cell liner system design described in this paper includes adjustments to suit site-specific conditions, while meeting, and sometimes exceeding, the prescriptive and general performance requirements of the applicable regulations.

Early meetings with CDPHE, the responsible regulatory agency, provided a valuable opportunity to adjust the design in response to agency comments prior to submittal of the Mill License Application. The Mill License Application was submitted to CDPHE on November 18, 2009, and determined substantially complete on the 18th of December 2009. The application is currently undergoing the adequacy review by CDPHE.

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