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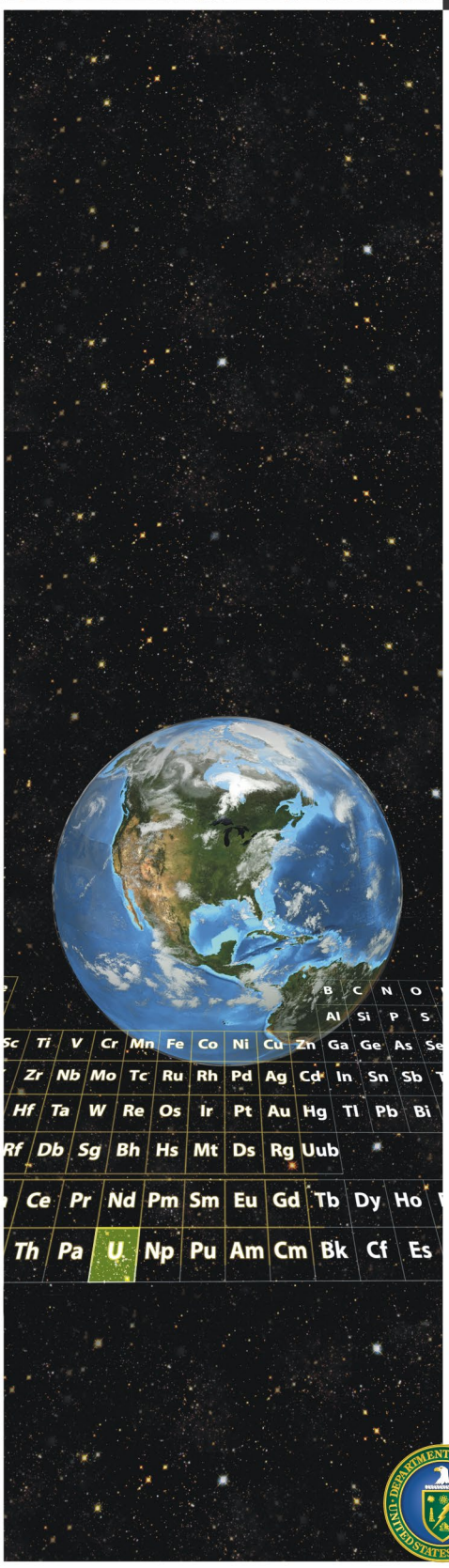
Environmental Sciences Laboratory



Applied Studies and Technology

Fiscal Year 2022 Annual Briefing

October 2022

U.S. DEPARTMENT OF ENERGY | Legacy Management

Introduction

A goal of the U.S. Department of Energy (DOE) Office of Legacy Management (LM) is to "incorporate advances in science and technology to improve our capabilities" in advancing the protection of human health and the environment.[1] Incorporating improvements in scientific understanding and technology applications into site management and remediation strategies improves cleanup effectiveness, protectiveness, and sustainability, which can result in long-term cost savings. The Applied Studies and Technology (AS&T) program is a core component of LM's efforts to fulfill this goal.

This AS&T annual briefing was developed to document the Legacy Management Support (LMS) contractor's application of AS&T project outcomes to improve long-term surveillance and maintenance (LTS&M) and reduce costs during fiscal year (FY) 2022. However, many improvements are qualitative and difficult to quantify monetarily, although the results of these improvements are often more significant than those that can be readily quantified. These results include the advancement of the LM objectives presented in the *2020–2025 Strategic Plan*.[1] All AS&T projects support LM's objectives.

LTS&M Improvements and Cost Savings from AS&T Projects

This briefing presents the incorporation of AS&T study outcomes into LTS&M, resulting in improvements to LTS&M, and cost savings in FY 2022.

Cover Performance Studies

In FY 2022, the AS&T program continued disposal cell cover performance studies that focused on enhancing LM's understanding of how natural processes affect long-term disposal cell performance. These studies addressed gaps in the scientific understanding of the ways in which disposal cell covers are changing over long time periods, associated human health and regulatory risks, and LTS&M options that improve performance and reduce costs over time. LM's vision to invest in multiyear studies of cover performance has led to the development of innovative approaches to improving the long-term sustainability of disposal cell covers. These studies are also leading to alternative disposal cell designs and improved performance evaluation methods and policies. Study achievements and applications of study findings to LM LTS&M activities in FY 2022 are described in the following sections.

Effects of soil-forming processes on cover engineering properties: This AS&T project is a collaboration with the U.S. Nuclear Regulatory Commission (NRC) and university scientists. Findings were published in an NRC contractor report, NUREG/CR-7288, *Evaluation of In-Service Radon Barriers over Uranium Mill Tailings Disposal Facilities*,[2] in FY 2022. The report presents findings from the collaborative cover performance studies, including ecological and pedogenic processes and how they affect hydraulic properties, radon flux, radon diffusion, and engineered performance of Uranium Mill Tailings Radiation Control Act (UMTRCA) cover systems. Overall, the studies show that, with few exceptions, "low-permeability radon barriers" no longer have a low permeability. Saturated hydraulic conductivity is already approaching the naturalized state, as determined using natural analogs, potentially causing increases in percolation of precipitation into tailings. The studies also show that ecological and soil-forming processes have increased radon flux at the surface of radon barriers; however, average radon fluxes for the "worst case" conditions tested remain below the NRC flux standard.

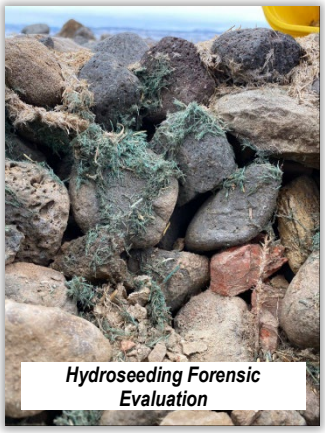
Williams, M., Fuhrmann, M., Stefani, N., Michaud, A., Likos, W., Benson, C., and Waugh, J., 2022, Evaluation of In-Service Radon Barriers over Uranium Mill Tailings Disposal Facilities: U.S. Nuclear Regulatory Commission, Rockville, MD, NUREG/CR-7288.

Caldwell, T, J. Huntington, G. Davies, S. Tabatabai, M. Fuhrmann, 2022. Basis for Technical Guidance to Evaluate Evapotranspiration Covers, U.S. Nuclear Regulatory Commission, Rockville, MD, NUREG/CR-7297.

Study results have already influenced NRC guidance and disposal cell design reviews. NRC published NUREG/CR-7297, *Basis for Technical Guidance to Evaluate Evapotranspiration Covers*,[3] in September 2022. *This report cited work performed by LM AS&T scientists 20 times.* NRC also referenced LM AS&T studies multiple times in its review of the Homestake Mining Company's (Homestake's) license amendment request for its Grants Reclamation Project.[4] Both NUREG documents will immediately impact and support the DOE Office of Environmental Management (EM) Crescent Junction, Utah, Disposal Site redesign and the LM Bluewater, New Mexico, Disposal Site spillway redesign. Results will also inform the final closure design of the Grand Junction, Colorado, Disposal Site (GJDS).

[1] DOE (U.S. Department of Energy), 2016. *2020–2025 Strategic Plan*, DOE/LM-1488, Office of Legacy Management, January.
[2] NRC (U.S. Nuclear Regulatory Commission), 2022. *Evaluation of In-Service Radon Barriers over Uranium Mill Tailings Disposal Facilities*, NUREG/CR-7288, March.
[3] NRC (U.S. Nuclear Regulatory Commission), 2022. *Basis for Technical Guidance To Evaluate Evapotranspiration Covers*, NUREG/CR-7297, September.
[4] NRC (U.S. Nuclear Regulatory Commission), 2022. *U.S. Nuclear Regulatory Commission Comments Homestake Mining Co. of California, Grants Reclamation Project Large Tailings Pile Evapotranspiration Cover License Amendment Request*, September 28.

AS&T study findings, in concert with other cover performance projects, will also support LMS contractor recommendations to LM for managing selected conventional covers as evapotranspiration (ET) covers and for efficiently monitoring ET cover performance based on health and regulatory risks. Implementation of these recommendations could result in significant LTS&M cost savings and improved long-term protectiveness.


Hydroseeding Forensic Evaluation

Enhanced cover assessment projects: AS&T scientists and university partners are investigating options for discontinuing vegetation management on selected rock-armored disposal cell covers and managing them as ET covers to reduce percolation of precipitation into the underlying tailings. Results from lysimeter studies at the GJDS show that the permeability of tested covers increased about 100-fold just 6 years after construction. In the test section where plant growth was controlled, percolation through the cover system was over 15% of precipitation, an average of 34.6 mm/yr 2016-2021. In the other test section where native plants were allowed to establish in the rock armor, percolation dropped to near zero, an average of 1.4 mm/yr 2016-2021. Study results were presented at the Battelle 2022 Remediation of Chlorinated and Recalcitrant Compounds conference. Favorable results from the lysimeter test facility led to pilot study test plots being installed in 2019 on the GJDS cover system to evaluate methods for accelerating vegetation establishment on an in-service disposal cell, subsequent changes in water balance and radon diffusion, and potential plant uptake of contaminants. Biannual monitoring was initiated in 2019 and continues. Various hydroseed mixtures were applied to the enhanced vegetation plot in 2020 and were not successful in establishing vegetation due to lack of penetration through the riprap. As a result, alternative methods are planned for 2023. AS&T scientists supported an NRC site visit at the Bluewater, NM site to discuss ECAP projects and vegetation for ET covers in February 2022.

Soil water balance model evaluation: This AS&T project, initiated in FY 2021, evaluates available soil water balance models used to estimate meteoric water percolation rates through disposal cell cover systems. It is a collaboration with Pacific Northwest National Laboratory and the University of Wisconsin. Water balance modeling is a critical component of the permitting process for disposal cells with alternative or ET covers.

The project team conducted an initial review of 19 available models by comparing their capabilities with those necessary to simulate the physical processes that influence percolation rates through disposal cell covers. Of the 19 available models reviewed, five candidate models were deemed potentially suitable for ET cover water balance modeling. These five models will be further evaluated using 20 years of LM lysimeter instrumentation data from the Monticello, Utah, Disposal Site. Vegetation and water balance measurements from the Monticello site will be used as calibration targets to evaluate the models. Agreement between the Monticello site field data and model outputs will demonstrate the model's usefulness for ET cover performance assessment and identify shortcomings whose correction will improve modeling codes. A key application of this project will be the evaluation of UMTRCA covers that become candidates for future management as ET covers.

Uranium mill tailings monitoring initiative: Initiated in FY 2022, this project builds upon previous AS&T cover performance studies to assess the consequences of water percolating through cover systems. Enhanced Cover Assessment Project lysimeter data have shown that over 15% of precipitation can percolate through radon barriers of disposal cells with traditional rock-armored covers, where vegetation is controlled. However, there is still a limited understanding of the processes within and below the uranium mill tailings themselves. These fundamental knowledge gaps make answering certain essential questions problematic. These questions include:

- Is percolation through tailings an ongoing source of contamination to groundwater or is it forming secondary persistent contaminant sources below the disposal cell?
- If percolation through tailings is an ongoing source of contamination, what is the approximate mass flux of contamination through the disposal cell(s)?
- What are the geochemical conditions within and below the mill tailings?
- What are the controlling factors for uranium dissolution and contaminant transport?

FY 2022 activities primarily comprised a scoping phase that involved forming a project team, refining the technical approach, and acquiring instrumentation. This study supports the National Laboratory Network (NLN) high-risk site working group recommendations for the Shiprock, New Mexico; Tuba City, Arizona; and Bluewater, New Mexico, Disposal Sites. Therefore, one of these will be the initial study site with fieldwork initially planned for FY 2024. The AS&T program will be collaborating with Dr. Craig Benson of the University of Wisconsin-Madison through DOE Consortium for Risk Evaluation with Stakeholder Participation funding.

Disposal cell erosion risk evaluation: This project was initiated in FY 2020 to evaluate the susceptibility of LM disposal cells to surface and internal erosion. This project informs modifications to LTS&M to highlight potentially higher-risk sites and site areas that require enhanced monitoring. This project also informs NRC and impacts disposal cell design reviews. To improve LTS&M, LMS personnel who perform site inspections continue to be trained to identify potential erosional features. Identifying and addressing erosion issues early can result in significant cost savings. Identifying high-risk sites will also allow LM to fiscally plan for potential problems in the future. Future activities will incorporate the results of the AS&T Climate Resiliency Project into the risk ranking system based on future climate scenarios.

Erosion Features at the L-Bar Site

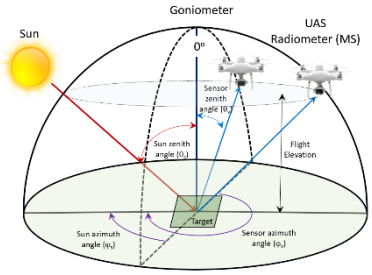
Seven UMTRCA sites were inspected in FY 2022 as part of the project. Other activities included initiating a comprehensive review of design and construction documentation for UMTRCA Title I and current and pending Title II disposal cells. Results are being summarized in a *Retrospective Assessment of UMTRCA Disposal Cell Design Criteria and Cover Performance* report. The report will summarize information on the criteria and approaches used for designing disposal cell covers and cover and site erosion protection measures, including differences in design criteria and construction approaches implemented at various UMTRCA sites. The report will also include recommendations for prioritizing response actions at UMTRCA sites where erosion issues are identified that may require corrective action. A field investigation was completed at the L-Bar, New Mexico, Disposal Site to evaluate erosional features identified on the cover and analyze cover component properties. AS&T scientists continue to provide erosion and cover design subject matter expert (SME) support for multiple sites that are presented in this briefing.

Other AS&T Studies

National Laboratory Network (NLN) collaboration: This project was initiated in FY 2020 as a collaboration with DOE's NLN to develop long-term strategies for high-risk LM sites to reach end states that minimize site-specific risks, lower LM's liability, increase stakeholder confidence, and prioritize resources. Sites are classified as high risk based on the risk ranking system LM developed in 2019. The risk ranking system quantifies site risk from high to low in the areas of human health, stakeholders, regulations, and institutional controls. The risk rankings are combined into an overall site risk index. The collaborative working groups efficiently evaluate site information and consider information gaps and factors that directly contribute to a site's high-risk index.

In FY 2022, the collaborative working groups addressed the Weldon Spring, Missouri, Site and the Rifle, Colorado, Disposal Site (ongoing). Additionally, LM initiated a collaboration with EM in September 2022 to address the Atlas Mill site in Moab, Utah. In addition to LM and NLN personnel, the working groups include EM and the EM contractor, North Wind Solutions, LLC. Finalized working group recommendations from previous collaborations have resulted in a new AS&T project in FY 2022: the Mill Tailings Monitoring Initiative, which is described above.

Unmanned aircraft system (UAS) multispectral calibration: This project was initiated in FY 2020 and is a collaboration with the University of Arizona. Calibration of multispectral instruments on UAS platforms is typically based on instructions provided by the sensor's manufacturer; this results in inconsistencies between datasets collected by different sensors. However, LM's applications of optical data require rigorous data preprocessing and radiometric calibration, similar to those applied in spaceborne satellite remote sensing, to allow for comparisons of data through time and to account for different atmospheric conditions and different sensors. The purpose of this project is to develop these calibration procedures, which are critical to monitoring disposal cell cover performance and evaluating climate change risk.



Procedures are being developed using data collected by the National Ecological Observatory Network (NEON) Airborne Observation Platform over the University of Arizona Santa Rita Experimental Range in Tucson, Arizona. The UAS data are being compared to the NEON sensor data to determine optimal data acquisition and calibration procedures. Procedures will be finalized in early 2023.

Synthetic aperture radar (SAR): LM has the world's largest drainage lysimeter at the Monticello site. It has been monitored by AS&T scientists for more than 20 years, and these unique data continue to be utilized by multiple AS&T studies to improve LM's understanding of near-surface water balance processes and its ability to simulate them. Using these data, the AS&T program and researchers at the University of Montana's Numerical Terradynamic Simulation Group (NTSG) assessed the potential of spaceborne SAR to model soil moisture across the full vertical and horizontal soil profile of the Monticello site disposal cell. Leveraging the powerful predictive capabilities of machine learning, spaceborne SAR, and available remotely sensed data, the AS&T program and the NTSG successfully trained and validated a proof-of-concept model capable of predicting soil moisture to a depth of 2 meters with high accuracy. Based on these preliminary results, a comprehensive evaluation of these data and methods will be coupled with a cutting-edge technique called GPS-interferometric reflectometry to use GPS signals reflected from soil to improve the predictive accuracy of these models.

GPS base station collecting reflected signals for soil moisture modeling

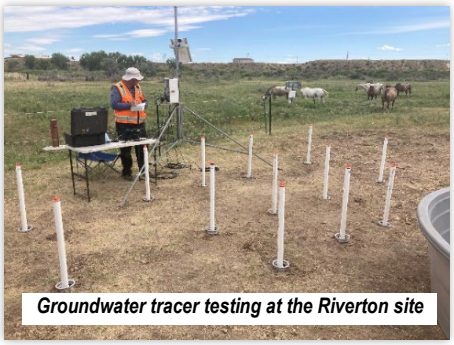
LM can use these spatially explicit, three-dimensional (3D) mapped estimates of soil moisture to identify areas within a disposal cell where water may travel through the cover system and potentially impact groundwater quality or to identify excessively dry soil where radon gas diffusion may exceed regulatory standards. Preliminary results suggest that 3D landscape-scale monitoring of soil moisture using SAR technology would outperform conventional methods (e.g., soil moisture probes) in monitoring soil moisture in disposal cell cover systems because probes provide only point estimates that may fail to capture heterogeneity across the cover system.

> "*Phase I of the SAR project provided a proof-of-concept model demonstrating the ability of free, publicly available remote sensing data and powerful machine learning algorithms – a component of artificial intelligence – to create a useful tool for monitoring disposal cell performance. Phase II of the project will explore the full utility of these cutting-edge methods to improve LTS&M in a cost-effective manner.*" —LM SAR study manager

Education Collaboration Initiative: The Educational Collaboration Initiative was created to strengthen and build LM's longstanding commitment to science, technology, engineering, and mathematics (STEM) education. Its goals are to strengthen existing environmental science partnerships with Native nation colleges and Native American graduate students and to explore opportunities for new partnerships with other stakeholder colleges and universities. FY 2022 activities were as follows:

- Eleven guest lectures or seminars were given at four institutions, including Diné College, Colorado Mesa University (CMU), Colorado School of Mines, and the University of Wisconsin-Milwaukee (UWM). Three of these were given for the Diné College 2022 Summer Internship Program sponsored by the National Science Foundation Tribal Colleges and Universities Program, which also included a field tour of the Monticello, Utah, Disposal and Processing Sites.
- A field tour of the GJDS was given to CMU students.
- Two scientists sat on a total of five graduate student committees at the University of Wisconsin-Milwaukee and the University of Arizona.
- A newsletter titled "How to Get a Job in the Geosciences" was prepared for CMU.
- An LM *Program Update* titled "Collaboration with University Students Helps with Remedial Efforts at LM Site" was published.
- A journal article titled "Estimating Productivity Measures in Guayule Using UAS Imagery and Sentinel-2 Satellite Data"[5] was published.
- Multiple meetings were held with Dr. Karletta Chief, Associate Professor and Director of the Indigenous Resilience Center at the University of Arizona. Dr. Chief agreed to facilitate identifying STEM students at the University of Arizona to assist or potentially intern on LM and LMS research projects.
- Diné College and Navajo Technical University faculty were engaged to participate in a STEM workshop at the Shiprock site.
- Worked with LM to identify research projects for two Mentorship for Environmental Scholars (MES) Program interns. An AS&T scientist mentored an MES intern on his summer research project.

Persistent secondary contaminant sources (PeSCSs): The objective of the PeSCS study is to better understand the existence of PeSCSs and their influence on groundwater quality. Although uranium mill tailings are a primary uranium source for groundwater contamination, several LM sites have elevated groundwater uranium concentrations due to secondary sources formed in the subsurface decades after the mill tailings have been removed. This process can delay natural flushing beyond a target period and may require a change in groundwater compliance strategies.



Groundwater tracer testing at the Riverton site

The project focuses on the best methods for getting the necessary data and evaluating natural flushing times and on impacts on remedial strategies. Data collection and analyses from column studies and groundwater tracer testing have been completed for the LM Field Support Center at Grand Junction, Colorado and the Riverton, Wyoming, Processing Site. These methods have been applied to the Monticello site and will be applied to the Shiprock site, the Tuba City site, and the Riverton site to support the development of revised Groundwater Compliance Action Plans (GCAPs) since the current strategies do not consider secondary source effects. The NLN collaborations (described in this briefing) recommended applying these methods. In FY 2022, three students from UWM who helped complete tracer testing at the Riverton site graduated with master's degrees using data from this project.

[5] Combs, T.P., K. Didan, D. Dierig, C.J. Jarchow, and A. Barreto-Muñoz, 2022. "Estimating Productivity Measures in Guayule Using AUS Imagery and Sentinel-2 Satellite Data," *Remote Sens* 14(12).

Two of the students were RSI EnTech, LLC, intern employees. The ongoing UWM collaboration includes paper coauthorship and support for one postdoctoral fellow and one PhD candidate.

Legacy model: This project was completed in FY 2022 and assessed the impacts on LM of maintaining legacy models (used in the LM program), established a clear goal for improving LM's processes for transitioning site models, and provided recommendations on how LM can be more effective and efficient. The final report, *Transitioning Site Model Transfer Protocol*, presents recommended procedures for effective and efficient transfer of models to LM before site transition.

LTS&M sampling optimization software evaluation: This project was completed in FY 2022. LTS&M obligations require cost-effective and sustainable LTS&M practices to be developed and implemented. LM's groundwater sampling optimization efforts at the Pinellas County, Florida, Site resulted in an annual sample reduction of approximately 45%. This project evaluated three groundwater monitoring optimization software packages with respect to LM-specific sites and needs. Their capabilities were evaluated using groundwater monitoring data from the Fernald Preserve, Ohio, Site and the Tuba City site. It was concluded that Geostatistical Temporal/Spatial (GTS) is the most suitable software for use by LM under most circumstances based on the robustness of its user-friendly interface and its stability and capabilities.

Crescent Junction site support: The AS&T program is continuing to assist EM and LM to support EM's plan to change the Crescent Junction disposal cell cover design from a rock cover to an ET cover. Recent support includes (1) peer reviews of the 90% design report, including an emphasis on incorporating AS&T cover study findings and increased interaction between the AS&T program, the EM design team, and NRC personnel to identify and resolve erosion-related concerns with the currently proposed cover conversion approach and (2) helping EM develop a GCAP for the Atlas Mill site in Moab, Utah. In addition to providing significant cost savings to EM, implementation of the cover conversion will benefit LM by setting a precedent for potentially completing effective cover conversions of LM disposal cells, including the GJDS cover and possibly other disposal site covers in the future.

Climate resiliency: In a May 2020 report, the U.S. Government Accountability Office recommended that LM assess the resiliency of its sites to climate change and report and evaluate climate change impacts on its environmental liabilities estimate. LM has partnered with Lawrence Berkeley National Laboratory (LBNL) to perform the assessment and develop the report with assistance from LM and the LMS contractor through the AS&T program. In FY 2022, the AS&T program, LM, and LMS personnel gave multiple site-specific presentations and provided technical information to the LBNL team to support their evaluation. The AS&T program also actively supported the LM and LMS vulnerability assessment and resilience plan team in a data sharing and SME capacity.

AS&T SME Support

Mexican Hat, Utah, Disposal Site erosion evaluation support: AS&T staff analyzed the erosional piping issues at the Mexican Hat site. Senior LM and LMS managers were presented with the findings and implications for other LM disposal cells, as were NRC staff. AS&T staff were instrumental in assisting the LMS site lead and a multiagency collaborative working group (CWG) in developing a suite of recommended alternative remedies for mitigating continued future internal erosion of the cover. The AS&T program also helped identify and evaluate a novel potential remedial option involving geosynthetic components. Technical support continues to be provided to the LMS site lead and the CWG for undertaking a supplemental subsurface investigation program at the Mexican Hat site. Additional future support is expected to include direct support for the field investigation, evaluation of the technical and regulatory feasibility of selected other remedial options identified by the CWG, development of a work scope for conducting large-scale laboratory hydraulic flume tests to improve understanding of internal erosion process dynamics, assistance in developing and reviewing results of future numerical modeling efforts, and continued support for the ultimate development of a long-term solution to the internal erosion issue and to the issue of the maintenance of cover system protectiveness. The CWG is composed of members of the U.S. Army Corps of Engineers (USACE), the Desert Research Institute, and the Navajo Nation Abandoned Mine Lands/Uranium Mill Tailings Remedial Action Program and a professor emeritus at the Colorado State University (a subcontracted SME who performed fundamental research on disposal cell erosion protection measures and the development of design criteria for UMTRCA disposal cells).

Bluewater USACE support: The AS&T program continues to support USACE Bluewater site spillway redesign efforts. The spillway redesign will incorporate a vegetated riprap and soil design to increase ET and improve long-term cover performance. AS&T research findings have been leveraged to inform USACE and LM design efforts and to support supplemental geotechnical sample collection planning and the assessment of borrow materials. AS&T staff identified a sample collection error in the USACE geotechnical proposal that would have resulted in nearly 70 acres of unnecessary aerial surveys and soil sampling of areas unsuitable for use in cover construction. This input saved LM considerable time and money. Additionally, AS&T staff identified potentially problematic soils, including dispersive soils, at the Bluewater site. These findings have resulted in modifications to USACE's design approach and potentially significant long-term cost savings to LM.

Church Rock, New Mexico, Disposal Site support

In FY 2021, AS&T staff performed a detailed review of a proposed redesign of the Church Rock site cover that includes relocated mining wastes. As a follow-up, the AS&T program conducted a site visit in July 2022 that resulted in the identification of an alternative conceptual approach for protecting the disposal cell from long-term erosion due to possible future avulsion of a major adjacent drainageway. If the alternative approach identified were implemented, it is expected that there would be a substantial construction cost reduction compared to the cost of construction and the performance of long-term maintenance of this drainage channel if the currently proposed erosion protection design measure involving extensive armoring of this drainageway is implemented.

Homestake, Grants, New Mexico, Disposal Site support

AS&T staff performed a detailed review of the 60% design report for an ET-type cover system proposed for installation on the top slope portion of the Large Tailings Pile (LTP) at the Grants site. Several issues were identified regarding the degree of erosion protection afforded by the proposed ET cover, the potential for biointrusion impacts, and agronomic soil properties and the establishment and long-term sustainability of vegetation on the ET cover. NRC expressed many of the same concerns in their response to the license amendment request for the proposed ET cover design, in addition to concerns about the apparently dispersive nature of soils at the proposed soil borrow source. A team of AS&T personnel, AS&T-subcontracted erosion SMEs, and LM and LMS personnel also conducted a visit to the Grants site in July 2022. The site visit identified issues related to erosion, sediment accumulation, and rock riprap cover rock placement and cover layer degradation for the existing rock riprap cover on the LTP side slope. Observations from the site visit revealed additional considerations relating to design and construction of the proposed ET-type top slope area cover system over the LTP, including its effective integration and connection with the existing side slope rock cover. Similar to the proposed Church Rock site cover, resolution of these issues is expected to result in a more robust and durable cover system and significant posttransition cost savings to LM, including reductions in required maintenance.

Shiprock site: The AS&T program provided ET estimates for the groundwater modeling effort of the floodplain. An LMS senior hydrogeologist stated, “Previous flow models and water balance evaluations for the Shiprock site have neglected to explicitly include the process of evapotranspiration…. Critical to our evaluation was accurately accounting for the processes of evapotranspiration and bare soil evaporation for the overall site water balance…. [Results] allowed for us to include accurate spatial and temporal ET rate estimates and provided a basis for delineating and calibrating bare soil evaporation in our models…. [Results] show that a very significant portion of the floodplain groundwater discharges through evapotranspiration during the growing season rather than discharging directly to the San Juan River.”