YEAR-END TECHNICAL REPORT

September 29, 2023 to September 28, 2024

Long-Term Stewardship of Environmental Remedies: Contaminated Soils and Water and STEM Workforce Development

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FIU | Applied Research Center
FLORIDA INTERNATIONAL UNIVERSITY

Addendum:

This document represents one (1) of five (5) reports that comprise the Year End Reports for the period of September 29, 2023 to September 28, 2024 prepared by the Applied Research Center at Florida International University for the U.S. Department of Energy Office of Environmental Management (DOE-EM) under Cooperative Agreement No. DE-EM0005213.

The complete set of FIU's Year End Reports for this reporting period includes the following documents:

Project 1: Chemical Process Alternatives for Radioactive Waste*
Document number: FIU-ARC-2023-800012997-04b-009

Project 2: Environmental Remediation Science and Technology*
Document number: FIU-ARC-2023-800013918-04b-006

Project 3: Waste and D&D Engineering and Technology Development*
Document number: FIU-ARC-2023-800013919-04b-006

Project 4: DOE-FIU Science & Technology Workforce Development Initiative*
Document number: FIU-ARC-2023-800013920-04b-015

Project 5: Long-Term Stewardship of Environmental Remedies: Contaminated Soils and Water and STEM Workforce Development**
Document number: FIU-ARC-2023-800013922-04b-005

* Project Funded by DOE's Office of Environmental Management
**Project Funded by DOE's Office of Legacy Management

Each document will be submitted to OSTI separately under the respective project title and document number as shown above. In addition, the documents are available at the DOE Research website for the Cooperative Agreement between the U.S. Department of Energy Office of Environmental Management and the Applied Research Center at Florida International University: https://doeresearch.fiu.edu

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PROJECT 5 EXECUTIVE SUMMARY

The Department of Energy (DOE) established Legacy Management (LM) in December of 2003, to manage its responsibilities associated with the legacy of the Cold War. DOE has taken major steps in satisfying environmental cleanup and LM ensures post-closure responsibilities are met for the protection of human health and the environment. LM coordinates closely with other Government organizations, including those within DOE, to ensure post-closure obligations are maintained when mission-related sites are closed and transferred to LM for long-term management. LM conducts post-closure site operations at approximately 98 sites in the United States and the territory of Puerto Rico and anticipates increasing to 128 sites by 2030. LM sites are generally described by the regulatory program and the types of environmental residual contamination remaining at the sites after remediation. Recognizing that LM sites are driven by their unique requirements such as operation and maintenance of remedial action systems, routine inspection and maintenance, and records related activities, Florida International University's Applied Research Center envisions developing a unique program to address LM's goals and preparing and securing the next generation workforce that will be required to accomplish these goals.

Florida International University (FIU), the largest Hispanic serving research-extensive institution in the continental United States, is one of the nation's leading producers of scientists and engineers from underrepresented groups. In 1995, DOE created a unique partnership with FIU to support environmental cleanup technology development, testing and deployment at DOE sites. This partnership spawned a research center at FIU dedicated to environmental research and development (R&D). The center, now known as the Applied Research Center, has tackled and helped solve problems at many DOE sites.

Since 1995, the Applied Research Center (ARC) at Florida International University (FIU) has provided critical support to the Department of Energy's Office of Environmental Management (DOE-EM) mission of accelerated risk reduction and cleanup of the environmental legacy of the nation's nuclear weapons program. ARC's applied research is performed under the DOE-FIU Cooperative Agreement. ARC's applied research, technology development; test & evaluation; and STEM workforce development covers major areas of environmental cleanup operations: radioactive waste processing, facility decontamination and decommissioning, soil & groundwater remediation and modeling, and information technology (IT) development for environmental management. As discussed, and agreed among DOE EM and LM, FIU infrastructure and expertise developed under the Cooperative Agreement will be leveraged to initiate the pilot program for LM. To this end, the research & student training will be structured closely following the DOE Fellows program model.

To date, the DOE LM Fellows Program has inducted a total of six (6) FIU STEM students and engaged them in research topics investigating the use of apatite for uranium sequestration at the Old Rifle site, and the application of remote sensing technologies at LM sites.

The following lists the DOE LM Fellows that provided support in FIU Year 4 to the two research tasks executed under this project:

Task 1: Valeria Ocampo (undergraduate, B.S., Biochemistry)

Task 2: Daniel Coelho (graduate, Ph.D., Computer Engineering)

The following ARC researchers are supporting this project and mentoring the DOE-LM Fellows: Ravi Gudavalli (Ph.D., Env. Engineering, Mentor/Project Manager), Anthony Abrahao (M.S., Mechanical Engineering, Mentor), Pieter Hazenberg (Ph.D., Hydrology and Quantitative Water Management, Sr. Research Scientist), Leonel Lagos (Ph.D., PMP®, Mechanical Eng./Civil/Env. Engineering, PI, DOE Fellows Program Director), and Angelique Lawrence (M.S., Environmental Science, Technical support).

MAJOR ACCOMPLISHMENTS

Major accomplishments of this program to date include:

For Task 1:

- Extension of the isotherm experiment, formerly conducted with 1,000 ppb uranium (U) samples, with 2,000 and 5,000 ppb U samples to identify the maximum sorption capacity of hydroxyapatite. It was found that even with an increase in initial uranium concentration to 5 ppm, the sorption isotherm did not reach equilibrium, indicating the hydroxyapatite has a very high sorption capacity for uranium sequestration.
- Completion of the deliverable 2023-P5-D3, *Draft Progress Report on the Desorption of Uranium from Hydroxyapatite*. The findings highlight the sensitivity of uranium sorption and desorption behaviors under varying pH conditions. The results of this study aid in understanding the ability of hydroxyapatite to retain uranium under varying environmental conditions, specifically when pH is altered to 4, 7, and 9.
- Completion of experiments to study the effect of pH on uranium desorption from hydroxyapatite.
- Initiation of two sets of experiments to study the effects of anoxic conditions and low temperature on desorption of uranium from hydroxyapatite.

For Task 2:

- Upgrade of the mobile platform rover design using high-torque motors to improve maneuverability; upgrade of the electrical panel; utilization of a new controller; and installation of a GPS feature to enable complete autonomous scanning.
- Connection of a GPS unit to the NOGGIN® GPR to facilitate co-location of the GPR and the scanning data, and installation of a LiDAR sensor at the front of the rover to measure elevation variations that can be linked to changes in the subsurface measured by the GPR.
- Construction of an in-ground mock-up outside of the FIU Engineering and Computing facility, which enabled testing of the GPR settings and the impact of using different GPR frequencies.
- Evaluation of the GPR observations obtained at the Rifle and Mexican Hat disposal cells during the summer of 2023. Although certain features of interest were shown, the data was not completely georeferenced making it difficult to link the observed results to explicit spatial features of each cell.
- Presentation of research accomplishments by DOE Fellow, Daniel Coelho, to DOE LM collaborators on July 20, 2024.

For Task 3:

- Hosted the 17th Annual DOE Fellows Poster Session and the 17th Annual Induction Ceremony on November 7th and 8th, 2023 respectively. DOE Fellow, Shawn Cameron, was awarded 3rd place in the competition for his poster presentation. The award was presented to him during the induction ceremony.

- Induction of DOE Fellows, Daniel Coelho (PhD student) and Valeria Ocampo (undergraduate student), into the DOE Fellows Program as part of the Class of 2023.
- Attendance and participation of DOE Fellow, Valeria Ocampo, at WM2024 in various sessions including a session coordinated as part of the Long-term Stewardship (LTS) day, organized by the DOE Office of Legacy Management.
- Presentation of the ASME Award for Best Poster/Paper Presentation in WM2023 to former DOE Fellow, Olivia Bustillo, and Senior Research Scientist, Dr. Ravi Gudavalli for their poster titled *"Interaction of Hydroxyapatite and Uranium in Groundwater at the Old Rifle Site to Facilitate Site Remediation"*. The award was presented to them during the WM2024 award luncheon on Tuesday, March 12, 2024.
- Completion and submission of Deliverable 2023-P5-D2, Draft Summer Learning Experience Plan, to DOE LM.
- Completion of a summer internship by DOE Fellow, Valeria Ocampo, at Grand Junction under the mentorship of Chris Jarchow and Ray Johnson, and preparation of a draft summer internship report.
- Presentation of research accomplishments by Valeria Ocampo during FIU's annual research review of the DOE-FIU Cooperative Agreement projects.
- Completion of a draft abstract for the 2025 Waste Management Symposia by Valeria Ocampo and submission to LM contractor, Ray Johnson, to review and provide feedback. The abstract was subsequently submitted to theWM25 student poster session.

TASK 1: USE OF APATITE FOR URANIUM SEQUESTRATION AT OLD RIFLE SITE

Task 1: Introduction

The Office of Legacy Management (LM) is charged with managing the former Department of Energy (DOE) defense sites that have undergone cleanup but still have continuing post-closure management requirements. Although the goal of LM is to transition facilities/lands of these sites to beneficial use, site-specific factors often limit release for unrestricted use. These factors include groundwater that is still being treated, or which could not be effectively treated to regulatory standards, contaminants in the unsaturated zone that are inaccessible, and the presence of on-site disposal cells and landfills.

The Old Rifle Site, CO is a former operating mill which once processed uranium (U) ore from 1942 to 1958. The site was then obtained by the State of Colorado in 1988, until the ownership was transferred to the City of Rifle in 2000. During this period, surface remediation of the site began in early 1992 and was completed in October 1996. Although the facility has since been demolished and the uranium mill tailings have been moved to a disposal cell, the alluvial aquifer below is contaminated with uranium, vanadium, and selenium. This contamination occurred via seepage from the previous mill tailing piles and the raffinate pond at the site. The uranium remaining in the subsurface under the capped waste piles was predicted to be flushed by natural groundwater flow. However, today uranium has persisted at elevated concentrations in groundwater much longer than predicted. This has been determined by analyzing groundwater samples twice a year, from 1998 to 2015. Uranium, as a contaminant, poses severe potential health hazards to humans and the environment. When unmonitored in the environment, uranium has the potential to affect the quality of surface water, groundwater, and food supplies. This is a toxic chemical that can lead to acute health effects such as kidney damage and various forms of cancer.

Previous studies have shown that the injection of hydroxyapatite (HA) as a permeable reactive barrier (PRB) in groundwater leads to uranium sequestration. One investigation included a pilot study LM conducted using the PRB technology to remediate uranium at the Old Rifle Site in Colorado. While this process has proved to be effective, a better understanding of the uranium removal mechanisms behind the interaction is required. The site is currently being reused for housing an operations and maintenance facility and for conducting biogeochemical research on constituents of concern.

FIU in collaboration with DOE-LM is investigating the use of apatite injection for sequestering uranium in groundwater. Specifically, FIU is studying the mechanism of U removal from groundwater using apatite as well as the environmental factors that influence the stability of U removal. The experiment described herein was designed to imitate the real-life conditions when applying this technology as a permeable reactive barrier. It studies the interaction of hydroxyapatite and uranium when aqueous HA is first injected and is in the process of precipitating, which takes approximately 3.5 - 5.3 weeks. The purpose of this experiment is to study the incorporation and co-precipitation of uranium onto HA. The data obtained in this study will help fill the knowledge gaps on the mechanisms involved in the removal of U and the stability of U removal and assist DOE-LM in remediating uranium at other sites where uranium is present in groundwater.

Task 1: Objectives

The purpose of this study is to identify the mechanisms of uranium removal by apatite and the stability of uranium removal under various environmental conditions (such as temperature, ORP, and pH). The specific objectives of this research include the following:

- Determine the mechanism of uranium removal from groundwater by apatite.
- Study the environmental factors that influence the stability of U removal over time.

A three-phase approach has been designed to identify the mechanisms involved in uranium removal. The first phase concentrated on the synthesis, formation kinetics, and characterization of hydroxyapatite (HAp) by mixing calcium (Ca), citrate ($C_6H_8O_7$) and phosphate (PO_4^-) solution. This step was essential in understanding the formation of HAp and its structural properties. Phase two focused on the incorporation and co-precipitation of uranium (U) with hydroxyapatite, simulating real-world conditions where uranium is present in aqueous environments. Uranium, a toxic heavy metal, can bind with hydroxyapatite through the exchange of its calcium ions with uranium species, facilitating the binding of uranium to the HAp surface or its incorporation into the crystal structure. The final phase, which is the current focus, examines the sorption and desorption behavior of uranium onto hydroxyapatite. Specifically, this phase investigates how uranium behaves under different environmental conditions, including oxic and anoxic environments, as well as at varying temperatures (22°C and 7°C). Understanding these mechanisms is critical for optimizing hydroxyapatite as a potential remediation material for uranium contamination at DOE LM sites.

Task 1: Methodology

<u>*Sample Set-up*</u>

To investigate the interaction between hydroxyapatite and uranium under diverse environmental conditions, three studies were conducted: oxic, anoxic, and temperature-controlled conditions (22°C and 7°C). Under anoxic conditions, uranium is reduced from its soluble U(VI) state to the less soluble U(IV) by electron gain, decreasing its mobility and increasing its possibility of precipitation (Wang et al., 2014). Temperature affects uranium's mobility; lower temperatures are expected to slow uranium dissolution and reduce its solubility.

Each study was set up utilizing Scenario A and Scenario C hydroxyapatite, both of which are composed of varying stochiometric rations of calcium-citrate and phosphate (**Error! Reference source not found.**). Scenario B was not used due to having impurities. All samples (oxic, anoxic, and temperature-controlled) were prepared by combining 15 mL deionized water (DIW), 5 mL 1000 ppb uranium solution, and 0.02 g hydroxyapatite from either Scenario A or Scenario C. Before starting the anoxic studies, the glove box was conditioned by vacuuming the glove box and removing the air present, followed by the introduction of mixed gas composed of 95% nitrogen and 5% hydrogen. This process was repeated until oxygen levels were reduced and the hydrogen concentration stabilized at 2%. Various liquids, including sodium hydroxide (NaOH), hydrochloric acid (HCl), uranium solution, and DIW, were transferred into the glove box and equilibrated for a week. During this time, the oxidation-reduction potential (ORP) was monitored periodically.

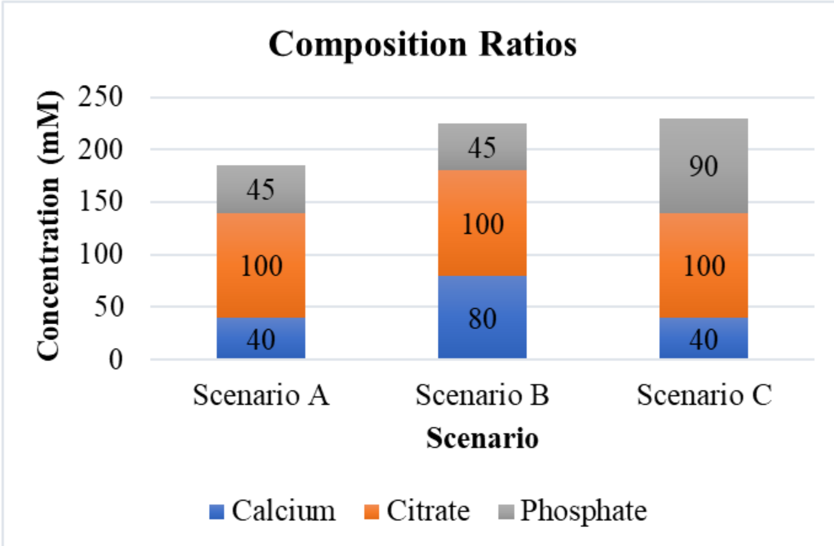

Figure 1. Composition of calcium, citrate, and phosphate ratios.

Temperature studies were then set up under oxic conditions at 7°C following the same preparation as the previous oxic samples. After preparation, the samples were transferred to a chamber maintained at 7°C.

Sorption Studies

After hydroxyapatite was brought into contact with a 250-ppb uranium solution in each sample, the pH was measured and adjusted to 7 using 0.1 M NaOH/HCl. The pH was measured and adjusted daily over the course of one week, a duration specifically chosen to allow the samples to reach equilibrium. Samples were then centrifuged at 2,700 rpm for 30 minutes and supernatant was collected and analyzed using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) to measure the uranium concentration in the samples.

Desorption Studies

After the samples had completed sorption and were analyzed via ICP-MS, they were centrifuged at 2,700 rpm for 30 minutes to separate the supernatant from the precipitate. The supernatant was then removed and replaced with 20 mL of fresh DIW. The pH of the samples was then adjusted to 4, 7, and 9 using 0.1 M NaOH/HCl to examine the role of pH under varying conditions, including oxic, anoxic, and different temperatures. The pH measurements and adjustments were performed periodically over 21 days, with 200 µl aliquots collected on designated dates. All aliquots were subsequently analyzed using ICP-MS, and the results were examined to observe fluctuation in uranium concentration throughout the experiment.

ICP-MS Analysis

Aqueous samples were analyzed using an iCAP RQ Quadrupole Inductively Coupled Plasma-Mass Spectrometer (ICP-MS, Thermo Fisher). Prior to analysis, the samples were diluted with 1% HNO_3 to ensure the uranium concentrations fell within the calibration curve range, which spans from 0.1 to 100 ppb.

Task 1: Results and Discussions

Sorption and Desorption of Uranium under Oxic Conditions

ICP-MS results were used to evaluate the uranium sorption capacity of hydroxyapatite under oxic conditions at a temperature range of 20°C to 22°C and a pH of 7. In both scenarios (A and C), uranium removal ranged from 97% to 100% (**Error! Reference source not found.**), indicating optimal conditions for uranium sorption onto hydroxyapatite (Mehta et al., 2016). Although Scenario A, Sample 3, exhibited slightly lower uranium removal compared to Scenario C, the difference remained within the margin of standard deviation.

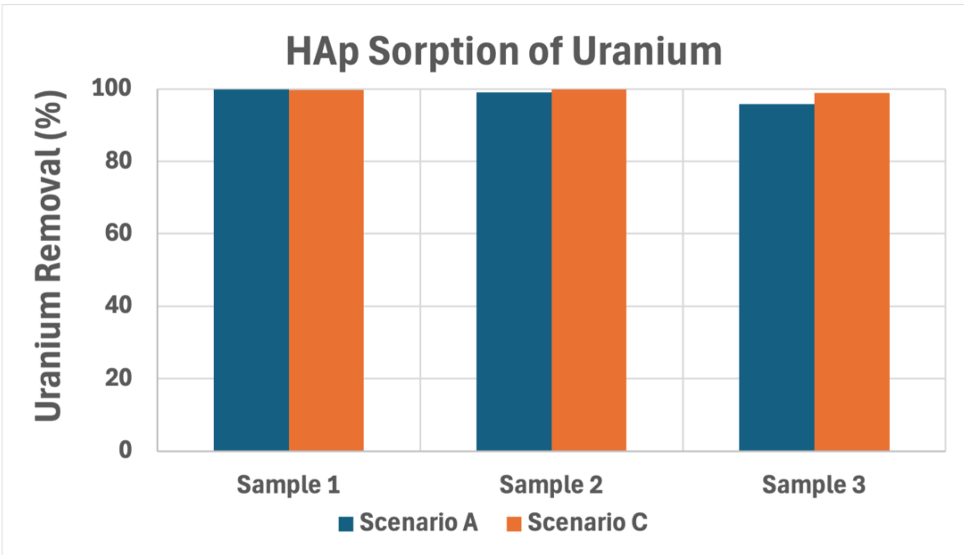

Figure 2. Uranium removal percentage of Scenario A and Scenario C at a pH of 7.

After sorption, desorption experiments were conducted at pH levels of 4, 7, and 9 over a 21-day period. In Scenario A, the highest uranium desorption was observed at pH 4, ranging from 43% to 45% (Figure 3). This result suggests several possible explanations, one being that the acidic conditions caused the HAp to dissolve, releasing uranium in the process. Another explanation may involve uranium's behavior under low pH, where it becomes more mobile, potentially leading to its detachment from HAp (Szecsody et al., 2013).

At pH 7, uranium desorption ranged between 13% and 15%, while pH 9 demonstrated the lowest desorption. The reduced desorption at pH 9 may be attributed to HAp maintaining its crystalline structure or uranium being less mobile under alkaline conditions.

In Scenario C, uranium desorption was consistently lower than in Scenario A, likely due to differences in HAp formation. Desorption at both pH 4 and pH 7 were in between 3% to 6%, while pH 9 exhibited the lowest desorption at approximately 3%. These findings suggest that uranium mobility, hydroxyapatite stability, and pH collectively influence uranium desorption mechanisms.

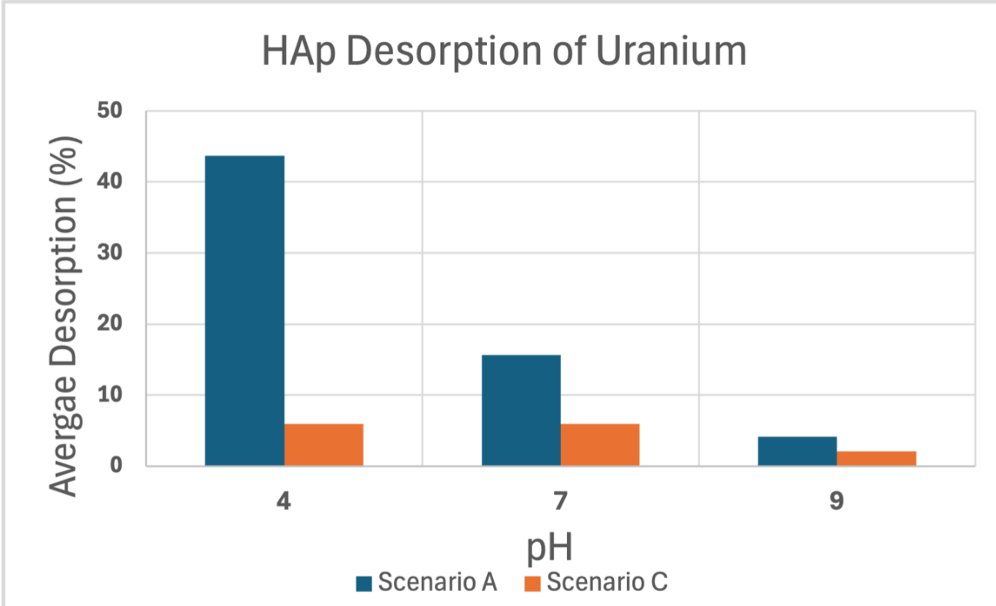

Figure 3. Scenario A and C average uranium desorption at pH 4, 7, and 9 under oxic conditions.

Sorption of Uranium Under Anoxic Conditions

Sorption for samples under anoxic conditions showed similar results to those under oxic conditions. However, sorption in anoxic samples was slightly lower, ranging between 95% and 97%, with no scenario achieving 100% sorption (**Error! Reference source not found.**). This difference might be attributed to uranium's behavior under varying redox conditions. In the presence of oxygen, uranium primarily exists as U(VI), which is more reactive and more likely to interact with hydroxyapatite. Under anoxic conditions, uranium gains electrons and is reduced to U(IV), a more stable and less reactive oxidation state. U(IV) typically forms insoluble compounds, such as uranium (UO_2), which are less mobile in the environment.

This increased stability reduced the likelihood of U(IV) interacting with hydroxyapatite through calcium ion exchange or through other sorption mechanisms. Subsequently, the reduced activity of U(IV) may explain the slightly lower sorption observed under anoxic conditions compared to oxic conditions.

Sorption Behavior of Samples at 7°C

At low temperatures, such as the 7°C used in this experiment, uranium sorption onto hydroxyapatite remains effective. Both scenarios demonstrated uranium sorption efficiencies ranging from 97% to 100% (**Error! Reference source not found.**). These results suggest that temperature may not have a significant impact on the sorption process under the conditions tested. However, the slightly reduced reaction rate at lower temperatures may influence the time required for the system to reach equilibrium. This outcome aligns with expectations, as uranium sorption onto hydroxyapatite is effective.

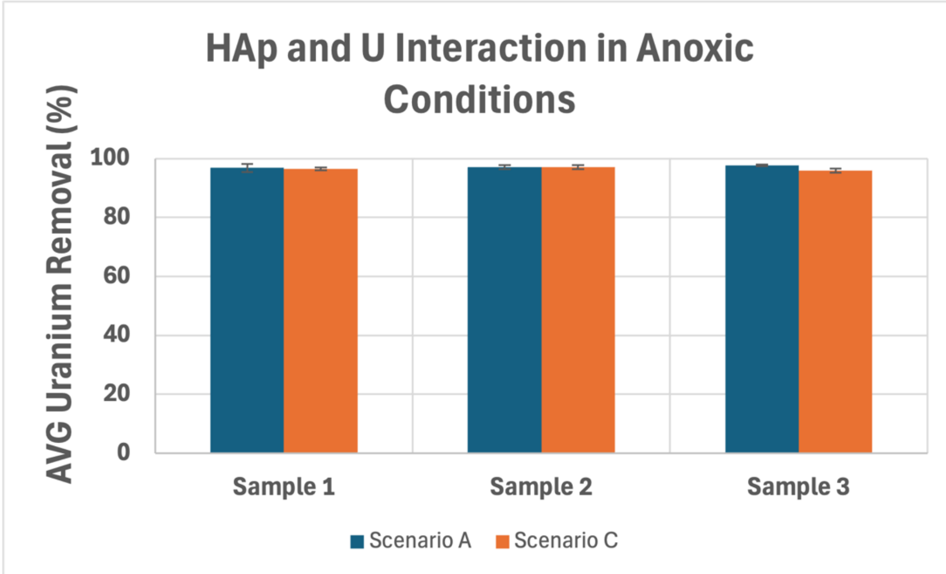

Figure 4. Scenario A and C sorption under anoxic conditions.

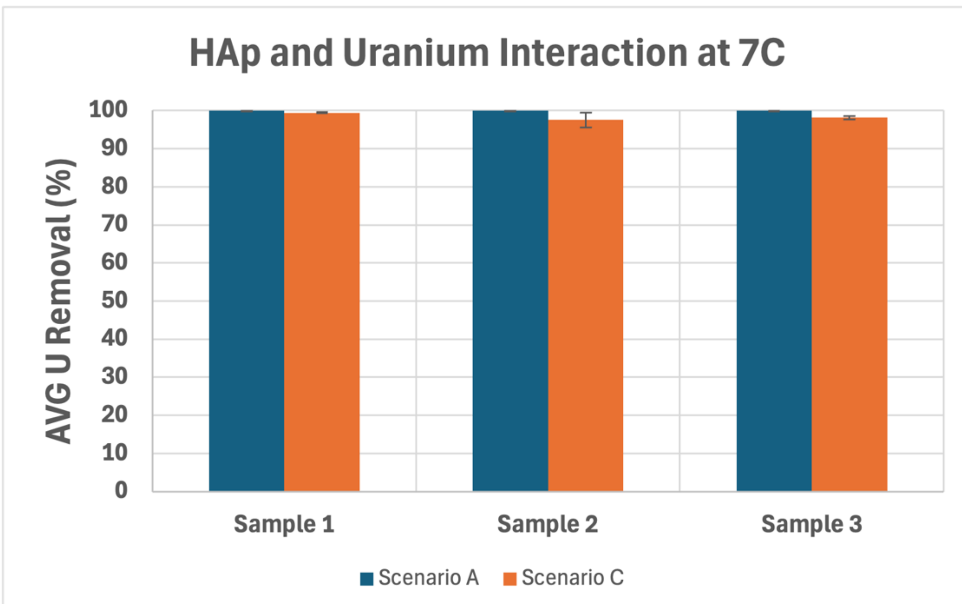

Figure 5. Scenario A and C sorption at 7°C.

Task 1: Conclusions

Across all studies, sorption consistently performed well, achieving a typical sorption capacity of 97% to 100%. Samples under oxic conditions and samples at 7°C exhibited the highest uranium sorption, while anoxic samples showed slightly lower sorption, with no sample reaching 100% under oxygen-depleted environments. Temperature appeared to have a greater effect on uranium sorption in Scenario C, whereas Scenario A maintained nearly 100% sorption across all samples.

When samples were placed under conditions that mimicked the Old Rifle site (pH 7 and temperature 22°C), hydroxyapatite successfully removed 97% to 100% of uranium. These findings indicate that hydroxyapatite is a viable technology for uranium remediation at sites with similar environmental conditions to those of Old Rifle. Further studies are recommended to fully explore the maximum sorption capacity of hydroxyapatite and its performance under varying uranium concentrations.

Desorption under oxic conditions showed higher uranium release at pH 4, likely due to hydroxyapatite dissolution or increased uranium mobility in acidic environments. In contrast, pH 7 and 9 exhibited lower desorption, as hydroxyapatite maintained its structure and uranium mobility decreased at these pH levels.

Overall, these studies aid in understanding the potential use of hydroxyapatite for uranium's remediation in groundwater. The results provide a valuable guidance on site conditions that optimize uranium removal, though further research is needed to investigate the long-term stability of uranium sorption and the risk of desorption when utilizing hydroxyapatite technology.

The data collected contributes to addressing knowledge gaps in the mechanisms of uranium removal and the stability of hydroxyapatite-based remediation. This research will aid DOE LM in developing effective strategies to remediate uranium contamination at impacted sites.

Task 1: References

Wang, Z., Tebo, B. M., & Giammar, D. E. (2014). Effects of mn(ii) on UO2 dissolution under anoxic and oxic conditions. Environmental Science & Technology, 48(10), 5546–5554. doi:10.1021/es5002067

V. S. Mehta, F. Maillot, Z. Wang, J. G. Catalano, and D. E. Giammar, (2016). Effect of reaction pathway on the extent and mechanism of uranium(vi) immobilization with calcium and phosphate. Environmental Science & Technology, 50 (6). 3128-3136.Ihttps://doi.org/10.1021/acs.est.5b06212.

Szecsody, J. E., Truex, M. J., Qafoku, N. P., Wellman, D. M., Resch, T., & Zhong, L. (2013). Influence of acidic and alkaline waste solution properties on uranium migration in subsurface sediments. Journal of Contaminant Hydrology, 151, 155–175. doi:10.1016/j.jconhyd.2013.05.009.

TASK 2: CLIMATE RESILIENCY STUDIES FOR LONG-TERM SURVEILLANCE OF DOE-LM SITES

Task 2: Introduction

Florida International University (FIU) has been investigating the effects of extreme weather and premature erosion concerns in disposal cells in collaboration with the U.S. Department of Energy's Office of Legacy Management (LM). The proposed study will contribute to Goal 4 of LM's 2020-2025 Strategic Plan: *"Sustainably manage and optimize the use of land and assets, addressing severe weather events."*

Even though the LM's disposal cells were designed to be effective for at least 200 years, concerns started when spots of subsurface erosion were discovered in 2017 at the Mexican Hat cell in Utah (Figure 6). The erosion only manifested in the surface as slight depressions where the rock cover had subsided into the voids. Construction issues, including the use of dispersive clays in the interbed layers between the radon barrier and the overlying rock cover, are potential causes. However, LM also suspects extreme weather as a contributing cause.

Despite the southwest USA being in a terrible drought, precipitation events are becoming more intense and are showing up in the meteorological record for the site. During short, severe rainfall events, the rock cover essentially plays little role in slowing runoff. Rounded cobbles, instead of angular rock, may also be a factor since water runs off them and into interstices faster than angular rock. Considering that other LM sites may have similar features, the main goal of this task is to evaluate the viability of using a Ground-Penetrating Radar (GPR) sensor for cost-effective site characterization and monitoring existing subsurface conditions of LM's disposal cells.

Figure 6. Utah Mexican Hat Disposal Cell (left) and subsurface erosion discovered in 2017 (right).

Task 2: Objectives

During Year 4, FIU has continued the development of the autonomous ground platform as well as the evaluation of existing GPR sensors. Task 2 has been divided into 3 subtasks:

- Subtask 2.1: Robot Upgrade - Focuses on the updates made to the robotic platform.
- Subtask 2.2: Data Analysis - Focuses on the data analysis of GPR data.

- Subtask 2.3: Field Deployment - Deals with evaluating the GPR sensor observations obtained in the field during the summer of 2023 and 2024 from the Rifle Disposal Cell and Mexican Hat Cell.

Autonomous GPR surveys producing detailed underground imagery can effectively inform site managers in decision-making regarding existing subsurface conditions and hydrological trends. This non-invasive method images sites without surface disturbance or potential radiological exposure if the radon barrier erodes. Furthermore, using GPR surveys to inspect disposal cells over time will benefit LM in detecting many landfill changes, such as water flow, sinkholes, underground erosion, ground creep, and sediment flow. The GPR robot in development at FIU can monitor long-term effects, correlating underground erosion with climate resilience and extreme weather events.

Task 2: Methodology

During the past year, a mobile ground platform prototype was designed and assembled at FIU to carry a Ground-Penetrating Radar (GPR) and surface lidar. The GPR sensor was selected and purchased to map LM cells and detect shallow erosion similar to spots discovered at the Mexican Hat Cell in 2017. Efforts also included building an in-house mockup to test the developed system at FIU, simulating essential coverage and subsurface characteristics common to many LM cells.

Subtask 2.1: Robot Upgrade

FIU's efforts under this subtask were focused on the integration between the available robot hardware and software. A high-precision GPS was integrated into the system's sensory network to enable autonomous driving and data acquisition. Furthermore, a GPS was connected to the GPR to allow for geolocation of the observed data. A GPS-based mapping algorithm was also implemented to scan the cells autonomously. The vision is an operator selecting an area over satellite images and the robot driving to the location and scanning the cells fully autonomously, alleviating the operator's burden of operating the system. A ground station computer or tablet will display execution details to operators supervising the mission. The system will be tested at the mockup facility developed at FIU.

Subtask 2.2: Data Analysis

This subtask involves the evaluation of the potential of GPR surveys in producing detailed underground images without surface disturbance or potential radiological exposure in case the radon barrier has eroded. The data was combined with the available GPS geolocation information to enable the development of spatial images. Furthermore, a methodology to evaluate the lidar observations and create high-resolution surface elevation information of the terrain under observation will be developed. The subsurface information acquired from the GPR will then be combined with the surface elevation information of the lidar to create combined subsurface and surface information.

GPR and lidar observations will be obtained from the mock-up facility at FIU and additional scans taken when necessary to better understand the performance and sensitivity of the GPR to detect changes in soil layers and the various artificial materials. As part of these data analyses, the team will generate Python code and write the necessary Python libraries to perform the data evaluation.

Once the Python code is written, the additional field observations to be taken in FIU **Year 5** can be quickly evaluated.

Subtask 2.3: Field Deployment

Finally, the GPR robot will be redeployed at Mexican Hat, Rifle, and potentially other LM disposal cells during the upcoming spring/summer 2025. The efforts will include packing, transporting the robot, and coordinating deployments with site managers and other LM officials.

Task 2: Results and Discussions

Subtask 2.1: Robot Upgrade

FIU conducted a detailed evaluation on how to improve the rover design for future usage. During the field campaign in the summer of 2023, considerable limitations in the design of the robotic platform were observed as well as in the ability of the GPR to obtain useful observations as there was no geospatial information associated with the images available. In Year 4 the rover was significantly upgraded to enhance its performance and operational efficiency as follows:

- New motors were installed, more specifically, high-torque alternatives were used to improve maneuverability and reliability, increasing power and durability for navigating challenging terrains. Furthermore, the electrical panel and components were updated, ensuring reliable and efficient energy distribution (Figure 7).
- A new controller was also implemented, offering an improved user interface and control capabilities. These upgrades have collectively enhanced the Rover's functionality, making it more robust and capable of advanced geophysical surveys and environmental monitoring.
- The robotic platform has also been connected to a GPS to enable complete autonomous scanning of a given domain based on a predefined analysis.
- A state-of-the-art GPS with the NOGGIN® GPR was purchased, enabling precise location tracking and accurate subsurface mapping. The GPR unit was connected to a GPS to ensure co-located information of both the GPR observations as well as its spatial location.
- Additionally, a lidar sensor was added to the rover design on the front of the platform. The lidar allows one to derive high-resolution elevation information of the surface terrain. This will potentially enable the evaluation of whether there is a link between the GPR observed features in the subsurface and surface conditions.

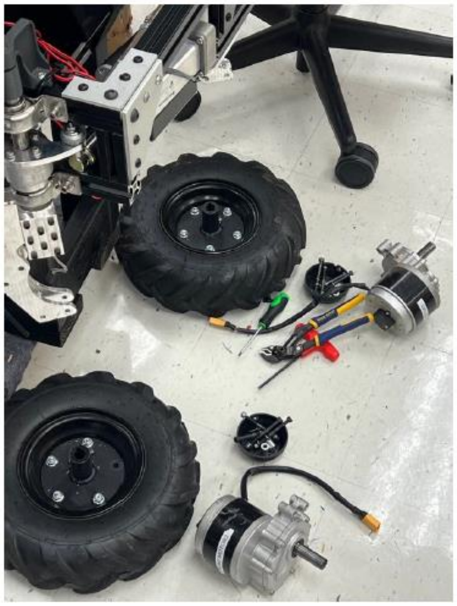
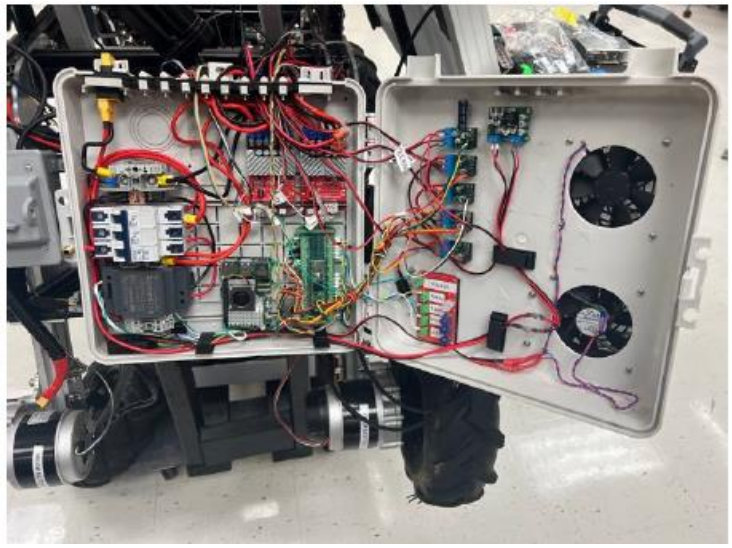

Figure 7. Motor exchange (left) and new electrical components (right) installed during Year 4.

Figure 8 shows the final version of the robotic platform developed by FIU during Year 4 of the project.

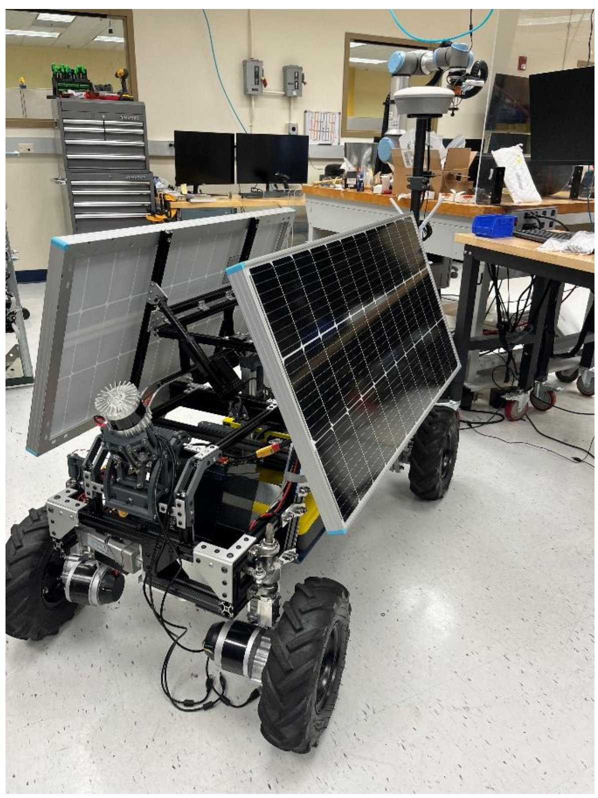

Figure 8. Final design of the Rover robotic platform with the GPR unit (yellow) at the bottom, GPR (white) at the top, and lidar situated at the front.

Subtask 2.2: Data Analysis

GPR Data Exploration, Analysis, Visualization and Interpretation

At the beginning of Year 4, a new DOE LM Fellow, Daniel Coelho, was hired to support this task and take over from the previous Fellow, Shawn Cameron, who graduated in the Spring of 2024. His first months on the project focused on gaining a thorough understanding of the ground-penetrating radar (GPR) and its capabilities. His initial focus was on visualization of previously obtained GPR data using the software package ParView developed by Noggin®. Trying to grasp and apply the mechanical aspects of data extraction during scanning and to understand its complex software components. This critical step involved getting familiar with the intricate mechanisms facilitating data extraction from each scan, laying the groundwork for further efforts. During the winter of 2024, attention shifted to refining the physical scanning process for better information flow, involving the alignment of mechanical and operational aspects to create a more integrated approach to data acquisition and processing. The challenge arose when synthesizing data from the ParView software and integrating it into the designated development environment. By applying lower and upper threshold parameters to the GPR data, it becomes possible to filter out unnecessary subsurface features. With this application, the characteristics of subsurface anomalies within the disposal cell can effectively be depicted by showing variation in contour concentrations using Point Gaussian integration.

A thorough comparative analysis was conducted between pragmatic scans and those from the authentic site obtained elsewhere. This comparison enriched the dataset, offering fine-tuned insight into the scanning process efficacy under different conditions. Moreover, the focus is on a deeper exploration of the acquired scans, involving a discerning examination to categorize the accumulated data accurately. Refinement of the analysis procedure was crucial for advancing our understanding and augmenting the system for enhanced precision in subsurface characterization.

An example of these analyses is shown in Figure 9. The GPR measurements were obtained by Shawn Cameron during the summer of 2023 in Basin 6 east of Carlsbad, NM. The GPR observations obtained in Basin 6 correspond to natural shrublands situated just a few miles west of DOE's Waste Isolation Pilot Plant (WIPP). Measured soils are natural, and the GPR signal can penetrate several meters deep.

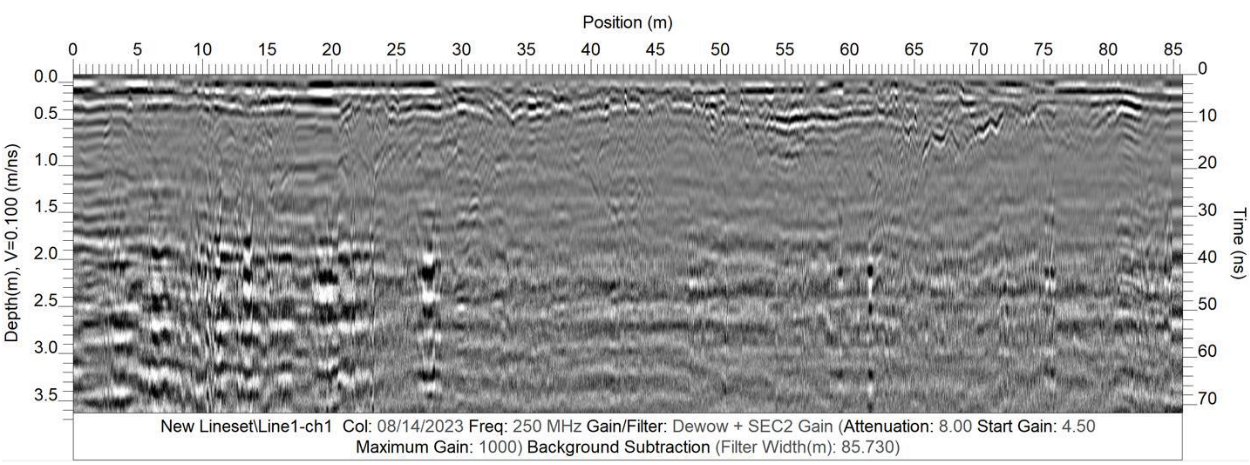

Figure 9. Former DOE Fellow Shawn Cameron's scan at gain amplification six shows the different layers the GPR detected in Basin 6 west of WIPP.

During these initial analyses it became apparent that there would be a significant learning curve in mastering the art of analyzing and synthesizing data obtained through a Ground Penetrating Radar (GPR)—an adjustment period extended beyond the data itself, encompassing a comprehensive understanding of the integrated system, from the nuances of the connected devices to the GPR operation. Therefore, a considerable amount of time was spent on developing proficiency in determining the optimal application of signal gain levels, which is crucial for enhanced data clarity. Additionally, knowledge was obtained on the impact of weather conditions affecting the scanning process. Interpreting GPR data, characterized by patterns like hyperbolas or lines, requires an understanding that these shapes are not direct representations of the objects but rather indicators of material boundaries and differences. It can be observed from Figure 9 that a strong variability in the return signal exists, with a strong return close to the surface, a continuous layer up to about 2 meters deep and a different type of layer below this. A number of steps were therefore implemented to process the data shown in Figure 9. The velocity at which radio waves traverse various mediums is not uniform but varies according to the specific material characteristics they permeate. This variability in transmission speed is primarily influenced by the distinct electrical and magnetic properties inherent to each environment. Consequently, the propagation of electromagnetic pulses will differ when passing through asphalt, concrete, soil, stone, brick, or any other substance, including air and water. This differentiation in speed is crucial for interpreting the position and depth of targets within these diverse materials using GPR.

In analyzing GPR data, several key processes are utilized to enhance the visibility of targets, which are essentially anomalies within their environments. *Background removal* is one such crucial technique. It eliminates the uniform aspects of the surrounding material, thereby making any atypical or anomalous objects more discernible. In tandem with this, the application of *gain* is vital. As signals penetrate the ground, they naturally diminish due to attenuation. Time-based gain is strategically applied to compensate for this loss, ensuring that even the faintest echoes from deeper targets are amplified and made visible. *Bandpass filters* are employed to refine the data further. These filters eliminate unwanted noise and extraneous frequencies that do not align with the operating range of the GPR. Lastly, *stacking traces* is an averaging technique that can be applied during data collection or post-processing to clarify target signals and mitigate noise. Integrating this function within the antenna or software potentially affects the radar's operating speed. In contrast, stacking is a post-processing action, thereby preserving real-time operating speeds. The suite of methodologies we employ—background removal, gain application, bandpass filtering, and stacking—forms the basis for refinement of the GPR data for precise and reliable subsurface exploration. The figures below show the processed results of the GPR data obtained in Basin 6. Figure 10 illuminates the stratified layers beneath the surface, identifies potential areas of concern, and detects anomalies hidden within the subsurface.

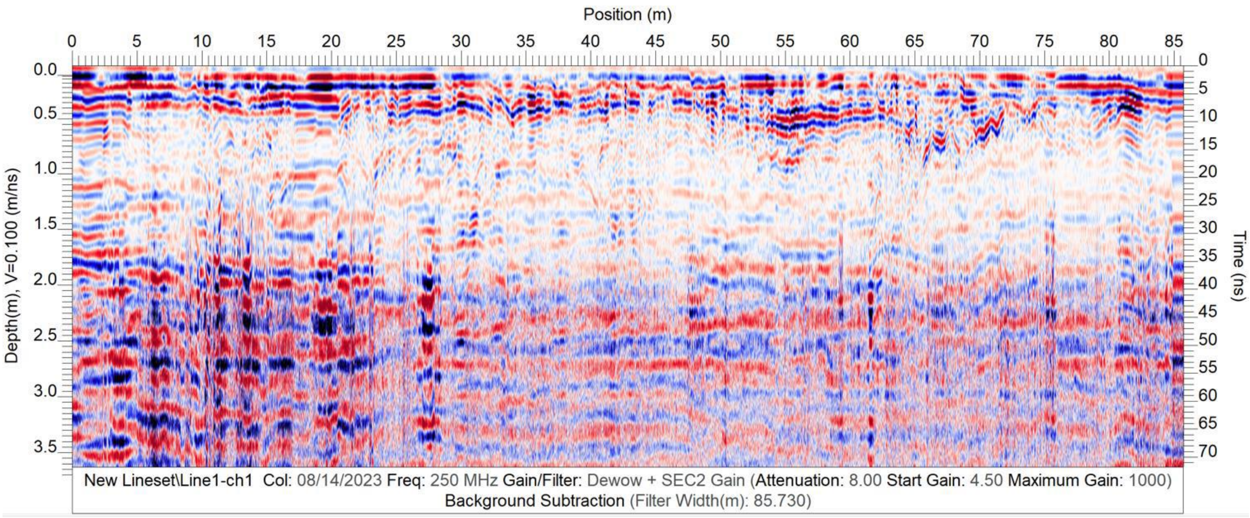

Figure 10. A seismic color palette at a gain setting of five was implemented to enhance data visualization and potentially pinpoint regions with significant signal noise for Basin 6 west of WIPP. This approach not only improves the clarity of the data representation, but also aids in the precise identification of areas with heightened signal noise.

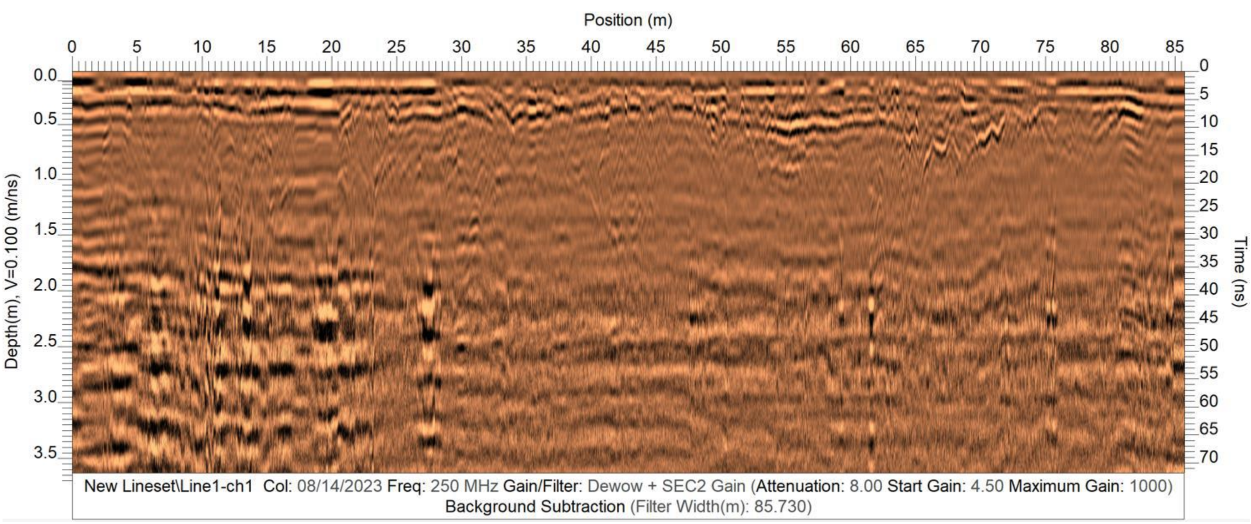

Figure 11. Copper color palette, adjusting to a gain setting of four to augment our data visualization for Basin 6 west of WIPP. This strategy is designed to improve image clarity and assist in accurately identifying areas with notable signal noise.

Analysis of GPR Data from FIU Year 3 Summer Field Deployment

During Year 4 the data obtained by former DOE Fellow Shawn Cameron, taking GPR measurements using the initial version of the robotic platform at the Rifle and Mexican Hat disposal cell during the summer of 2023, was analyzed. These results were presented by DOE Fellow Daniel Coelho during his presentation on July 30, 2024. Figure 12 and Figure 13 present some of the results for both disposal cells, indicating some potential areas of interest. Some near surface changes in the layering can be observed. Unfortunately, during the summer of 2023 the GPR observations were not aligned with GPR measurement. Therefore, no specific spatial information of the observations is available, that would potentially enable us to link these subsurface changes so surface elevation variations or it spatial location with the disposal cell. As such, it was impossible to indicate what could have been specifically observed by the GPR.

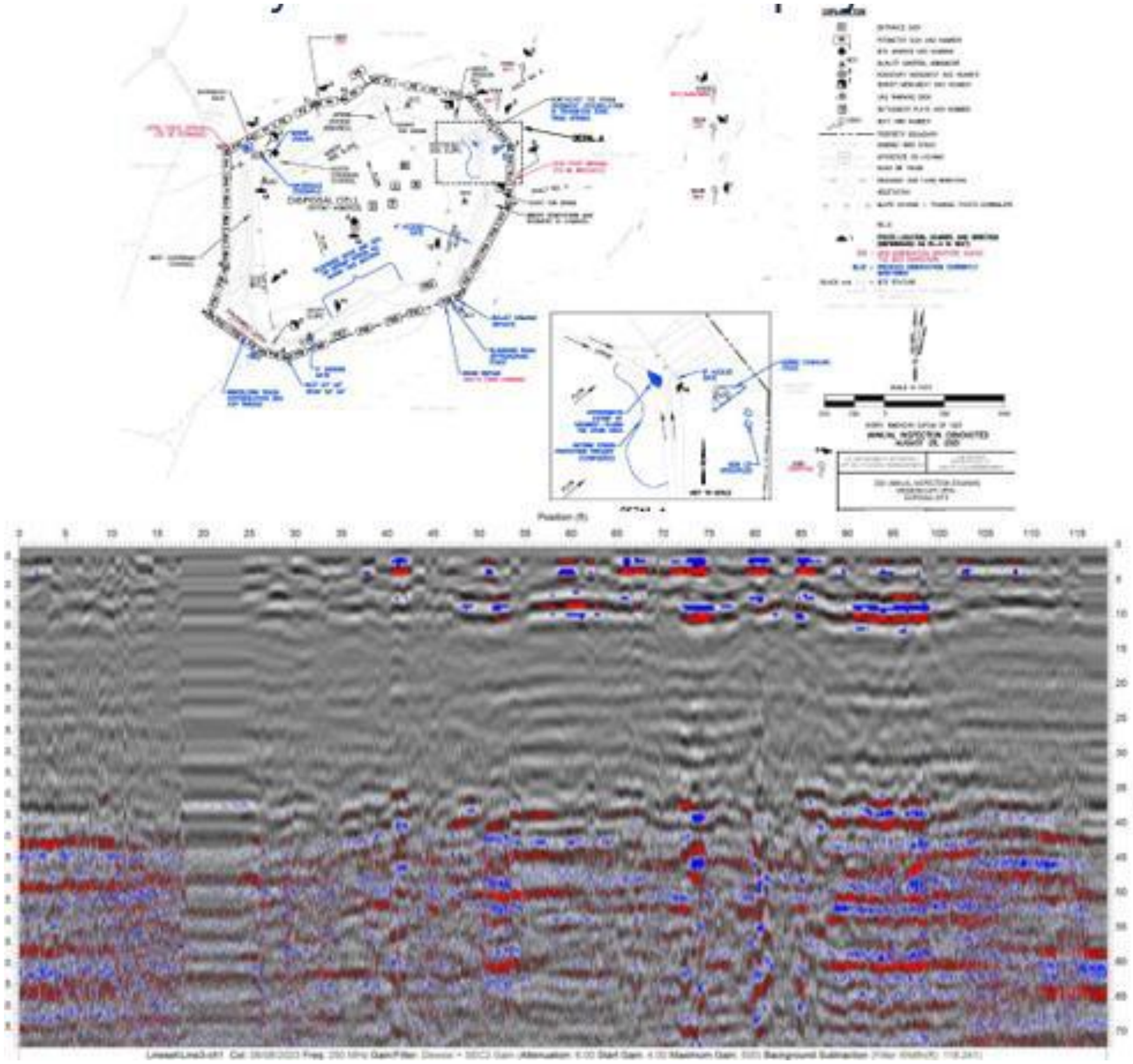

Figure 12. Example of the GPR data obtained for the Rifle cell. The campaign focused on the northeast corner of the cell. Results are shown in bottom panel, clearly indicating the various layers within the subsurface.

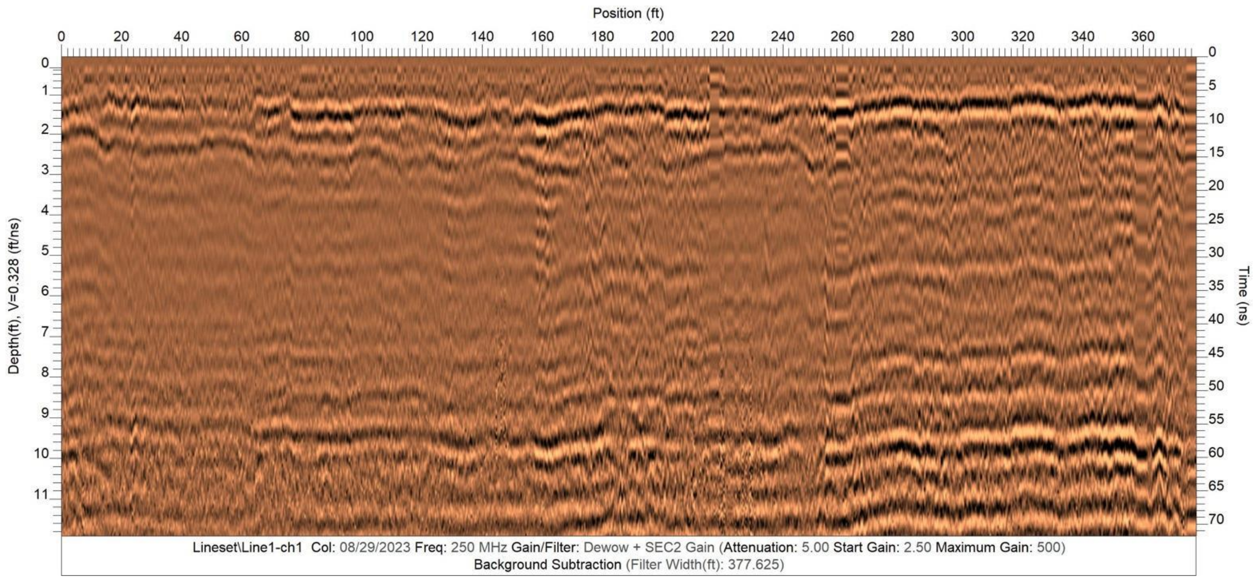

Figure 13. The palette employs a copper color scheme, finely tuned with a gain setting of four to enhance its appearance. This data, captured at Rifle, distinctly illustrates layer separation at various heights. The primary area of focus and concern is within the top four feet.

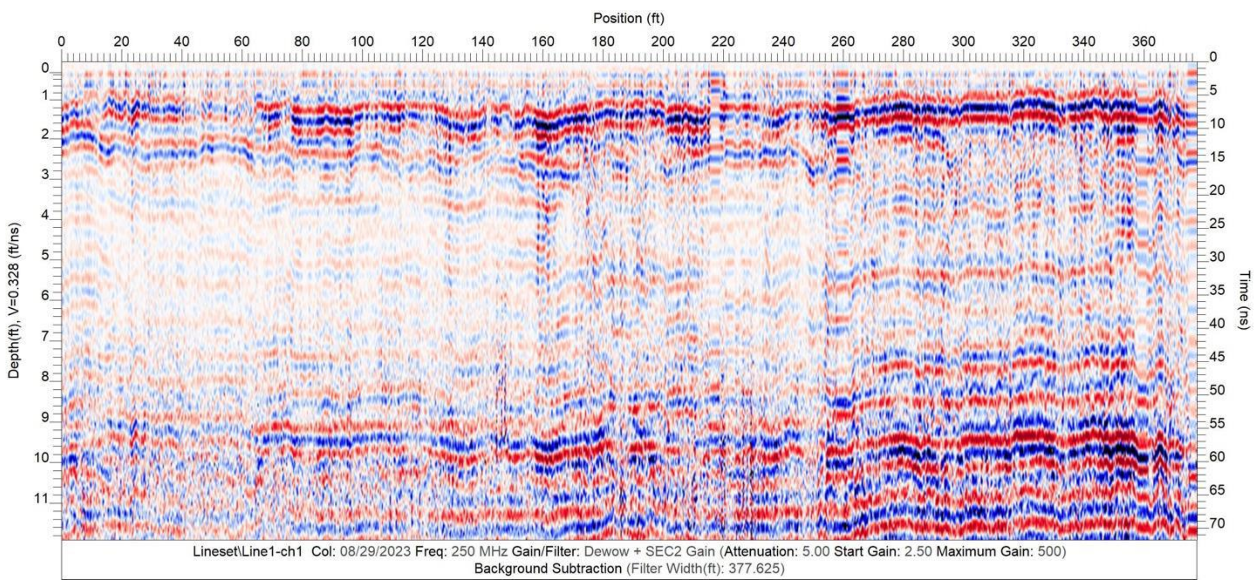

Figure 14. Seismic coloring of the Rifle observations highlight areas of concentration or regions with a high material density.

FIU anticipated redeploying the GPR robot at Mexican Hat, Rifle, and potentially other LM disposal cells during Year 4 of the project. A new GPS unit was also procured to enable the acquisition of geolocated data. Due to scheduling issues this was postponed until September 2024. In addition, our DOE Fellow, Daniel Coelho, unexpectedly left the program. It was therefore decided to postpone the field campaign to Year 5 of the project. FIU plans to hire a new Fellow during the Fall 2024 Recruitment Campaign.

Subtask 2.3: Field Deployment

A Mockup to Assess GPR Performance

To gain additional experience in processing the GPR data as well as a better understanding of the impact of adjusting the GPR settings real-time in the field, during the spring of 2024 an in-ground mock-up was constructed outside of the FIU Engineering and Computing facility. The in-ground mock-up facility permitted the evaluation of the potential of GPR (for different wavelengths) to detect known subsurface characteristics (e.g. metal pipe, rebar, plastic box) at different depths, during both dry and wet conditions. Furthermore, an in-ground mockup (as compared to the above-ground mockup created during the Spring of 2023) permits use of the rover to obtain measurements. This allowed us to mimic conditions expected to be observed at the disposal cell sites, e.g., near-surface groundwater and erosion features.

The in-ground mockup created has the dimensions of 3 feet wide, 3 feet long and about 3 feet deep. More details are presented in Figure 15 below.

Figure 15. Creation of the in-ground mockup site outside of the FIU Engineering and Computing Center.

An example of the GPR observations for the FIU in-ground mock-up is given in Figure 16. The location of the mock-up is clearly visible in this figure, through the highlighted colors on the topright corner.

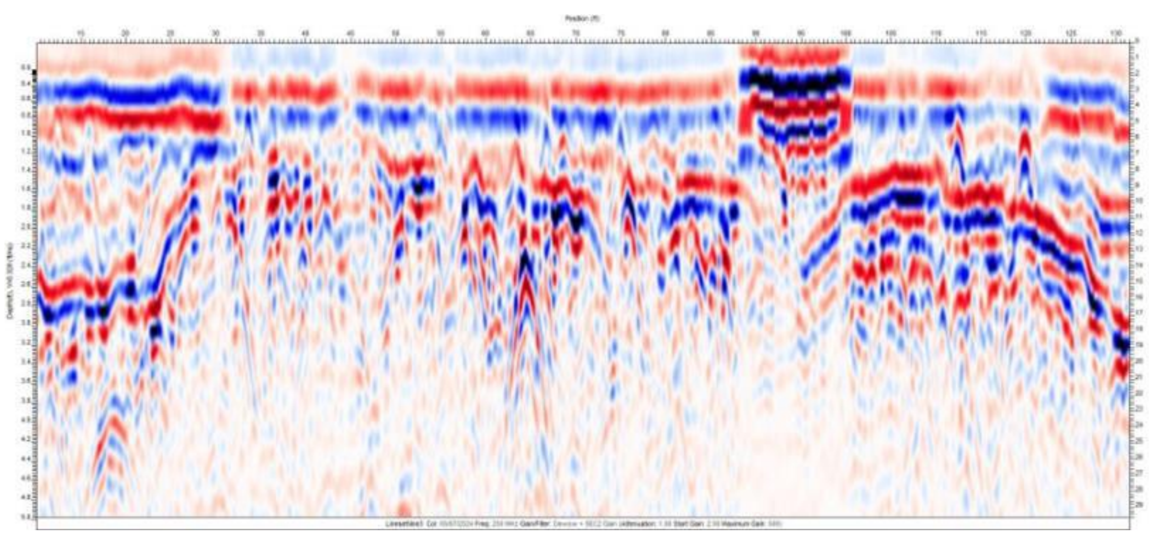

Figure 16. Example of GPR measurements obtained for the FIU mock-up cell. Mock-up is shown by the bright colors in the upper right part of the figure.

During the summer of 2024 we were also able to test the impact of using the NOGGIN® GPR system at 250 MHz and 1000 MHz frequencies (Figure 17). FIU previously purchased the 250MHz version for this project, that enables scanning a couple of meters below the surface. The vertical reach of a 1000 MHz GPR is only up to a few feet; however, the vertical resolution is much finer, potentially offering a number of benefits (e.g., being able to detect smaller erosion features. Testing both frequencies at the in-ground mock-up showed that the 1000 MHz version loses a considerable amount of energy while penetrating through the top riprap layer consisting of thick boulders. As such, this frequency was unable to provide detailed information for the subsurface below.

Figure 17. Dual scanning with 250 and 1000MHz GPRs.

On July 30, 2024, our DOE Fellow Daniel Coelho gave a detailed presentation on:

1. The mechanisms behind GPR and its pros and cons, where he presented the different types of GPR, the impact of wavelength and instrument settings on measuring depth and accuracy.
2. Results obtained at FIU for a mock-up disposal cell that was created to test the performance of the GPR as well as its ability to observe known objects (e.g. metal pipe, rebar and open areas).

The primary objective is to assess the GPR's effectiveness in monitoring subsurface conditions of LM's disposal cells, particularly regarding erosion and climate change impacts. The presentation explains the method to capture detailed subsurface images—the technology is noted for its non-destructive nature, environmental safety, and ability to provide real-time data critical for immediate decision-making. The presentation emphasizes the GPR's sensitivity to background noise and depth of penetration, noting that reducing noise enhances detection capability. The practical applications of GPR technology are demonstrated through various scanning exercises, including tests conducted at sites like Mexican Hat and Rifle, Colorado by former DOE Fellow, Shawn Cameron (see also Subtask 2.3 below). These exercises illustrate the GPR's ability to detect subsurface anomalies, such as sinkholes and erosion, despite different soil conditions and moisture levels. The data from these scans provide insight into critical areas, guiding further data collection and analysis.

Furthermore, the presentation explained the project's future directions, including integrating advanced GPS for precise 3D mapping, developing a mobile rover for challenging terrains, and automating data analysis with NIC's SDK. The goal is to enhance the efficiency and accuracy of subsurface imaging, ensuring thorough surveillance of DOE-LM sites.

Task 2: Conclusions

GPR surveys can produce detailed information of underground conditions which can help site managers in decision-making regarding existing subsurface conditions of LM disposal cell conditions. This non-invasive method images sites without surface disturbance or potential radiological exposure if the radon barrier erodes. Furthermore, using GPR surveys to inspect disposal cells over time will benefit LM in detecting landfill changes, such as water flow, sinkholes, underground erosion, ground creep, and sediment flow. The GPR robot being developed at FIU has undergone significant changes, improved robot hardware and software as well as the inclusion of additional instruments (i.e., LiDAR and GPR). This is expected to lead to improved maneuverability of the rover on top of the disposal cell, assisting its autonomous driving capability, and will enable linking surface elevation variations to subsurface conditions. Integration of a high-precision GPS into the system's sensory network will improve data acquisition geolocation.

FIU researchers and DOE Fellows will continue with the mapping of GPR observations and plans to retest the optimized GPR robot at Mexican Hat, Rifle, and Montecello LM disposal cells during the summer of 2025.

Task 2: References

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3. “Seismic Refraction What Is It? How We Use It in Our Work.” Surface Search, 25 Oct. 2016, https://surfacesearch.com/seismic-refraction-what-is-it/.
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7. “EKKO_Project™ GPR Data Analysis: Mapping: Processing Software.” Sunsoft, https://www.sensoft.ca/products/ekko-project/overview/.

TASK 3: STEM WORKFORCE DEVELOPMENT

Task 3: Introduction

Florida International University (FIU), the largest Hispanic serving research-extensive institution in the continental United States, is one of the nation's leading producers of scientists and engineers from underrepresented groups. In 1995, the U.S. Department of Energy created a unique partnership with FIU to support environmental cleanup technology development, testing and deployment at DOE sites. This partnership spawned a research center at FIU dedicated to environmental R&D. The center, now known as the Applied Research Center, has tackled and helped solve multiple problems at many DOE sites. The DOE-FIU Science and Technology Workforce Development Program is designed to build upon this relationship by creating a pipeline of STEM engineers specifically trained and mentored to enter the DOE workforce in technical areas of need. This innovative program was designed to help address DOE's future workforce needs by partnering with academic, government and DOE contractor organizations to mentor future scientists and engineers in the research, development, and deployment of new technologies addressing DOE's environmental cleanup challenges.

Task 3: Objectives

FIU ARC has expanded the DOE EM Cooperative Agreement (CA) to include this project (Project #5) within the already established DOE-FIU Cooperative Agreement to support LM's main goals and mission. Two (2) FIU STEM students are competitively selected to support the research conducted under this project. To ensure that the students will be trained in pertinent technical areas that directly support LM's goals, FIU works closely with LM management to define high target, high priority technical topics. Based on past performance, skill sets, and infrastructure at FIU, some of the technical areas of concentration include long-term monitoring; technology identification, selection, testing/evaluation; fate and transport modeling of contaminants of concern. The selected students will present their research in relevant conferences such as the Waste Management Symposia. The students will also participate in a summer traineeship program at selected LM sites. Students will use the research topics for their dissertation/thesis and publish their research results in appropriate peer-reviewed journals.

Task 3: Methodology

Subtask 3.1: Recruitment

When appropriate, FIU conducts recruitment efforts as needed during the Fall, Summer, and Spring semesters, which include the following:

1. Posters/flyers placed across the FIU campuses.
2. Attendance of members of the DOE Fellowship Committee at faculty meetings and other meetings of relevant student societies as well as classrooms to explain the program and seek applications from interested students.
3. Hosting of an ARC Open House at the beginning of the Fall semester.
4. Participation at the FIU Career Fair and engineering senior design expo during the Fall and Spring semesters.

5. Announcements on webpages designed and dedicated to the DOE-FIU Science and Technology Workforce Development Program. The webpage was developed in 2007 (https://fellows.fiu.edu) and contains information related to the program. This webpage is constantly being updated with new information and DOE Fellows research updates.

Subtask 3.2: DOE-LM Fellows Poster Exhibition/Competition and Induction Ceremony

FIU ARC will coordinate and host the DOE Fellows Poster Exhibition & Competition in November 2023. DOE-LM Fellows will prepare posters to be presented at this annual event to showcase their research accomplishments in the identified/selected areas of research. The DOE-LM Fellows will present their research conducted at ARC or during summer internship assignments. In addition, FIU ARC will coordinate and conduct the DOE Fellows Induction Ceremony in November 2023 during which DOE Fellows selected during FIU Year 4 will be inducted as DOE-LM Fellows. DOE-HQ officials, DOE site mentors, FIU faculty and administrators, FIU ARC scientists, and existing DOE Fellows will be invited to participate in this event.

Subtask 3.3: Conference Participation and Presentations

DOE-LM Fellows will attend and participate in industry conferences, including the Waste Management Symposia, American Geophysical Union (AGU) and other relevant conferences, as budget allows. The students will submit abstracts and develop student and professional posters, and oral presentations based on their research performed at FIU ARC and during their summer internships.

Subtask 3.4: Summer Internship Program (SIP)

FIU-ARC personnel will assist in the planning, coordination, and execution of the Summer Internship Program (SIP). Through this program, the Fellows will participate in a 6 to 8-week summer internship at a DOE facility. DOE Fellows will be paired with scientists/engineers at DOE facilities and/or national laboratories and DOE contractors. During the six to eight weeks, the Fellows will work on environmental research projects under the guidance of their site mentors/scientists and in accordance with the LM approved summer plan. FIU personnel will provide assistance in monitoring the progress of summer interns and their research work. FIU personnel, with the help of DOE site internship program coordinators, will identify mentors at selected DOE sites to work with the FIU summer interns. FIU will work with DOE-LM GJO in the coordination and identification of summer internship opportunities and assignments at DOE-LM GJO, DOE-LM Sites and contractors' facilities.

Upon completion of the summer internships, the DOE Fellows will prepare Summer Internship Technical Reports on the research work they performed over the summer. Each DOE Fellow will seek input and review of the report from their site mentors/scientists and final reports will be submitted to DOE-LM GJO and made available on the DOE Fellows website.

Task 3: Results and Discussion

Subtask 3.1: Recruitment

FIU completed fall 2023 recruitment and hired two FIU students Valeria Ocampo (undergraduate, Biochemistry) and Daniel Coelho (graduate, Ph.D., Computer Engineering) to support Task 1 and Task 2 respectively.

Subtask 3.2: DOE-LM Fellows Poster Exhibition/Competition and Induction Ceremony

DOE Fellow, Shawn Cameron, prepared a poster titled *"Climate Resiliency Studies for Long-Term Surveillance of DOE-LM Disposal Cell Sites",* which he presented during the DOE Fellows poster competition on 11/7/2023. Shawn was awarded third place in the competition and received the award at the induction ceremony.

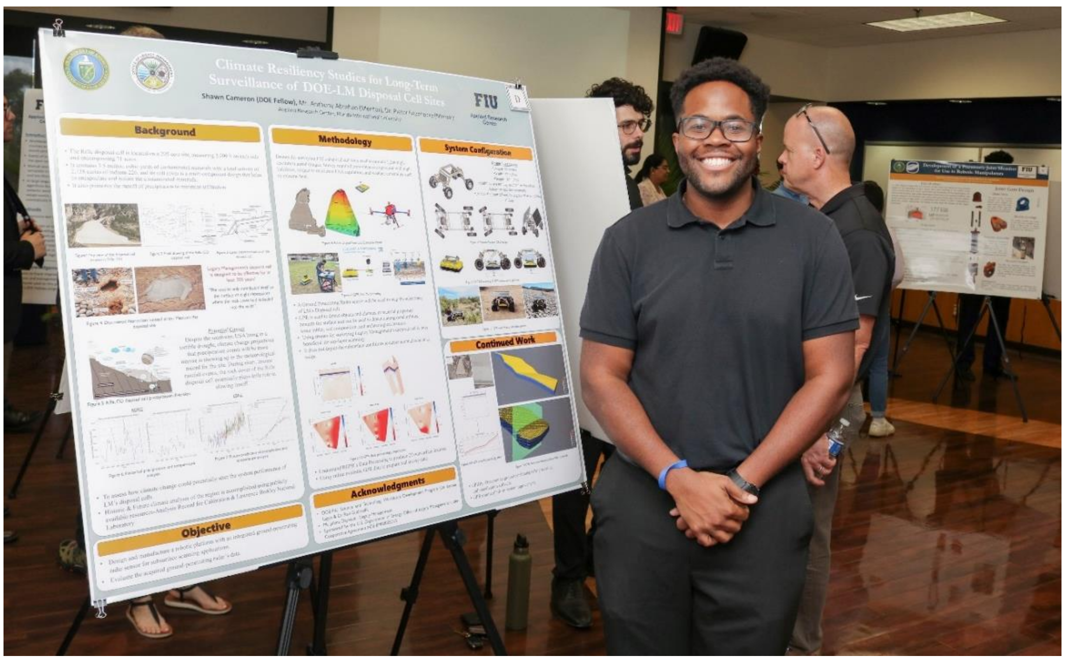

Figure 18. DOE Fellow, Shawn Cameron, presenting his poster at the 17th Annual DOE Fellows Poster exhibition.

Figure 19. DOE Fellow Shawn Cameron pictured receiving the 3rd place poster winner certificate with Drs. Ravi Gudavalli and Leonel Lagos.

FIU conducted the 17th Annual DOE Fellows Induction Ceremony on November 8, 2023 and inducted 12 science, technology, engineering, and math (STEM) students into the program. Two of the students will be supporting the DOE-LM research being conducted at FIU, while ten will be focused on DOE-EM research activities.

Table 1. DOE-LM Fellows Class of 2023 Inducted during the 17th Annual Induction Ceremony

DOE Fellow	Degree	Major
Daniel Coelho	Ph.D.	Computer Engineering
Valeria Ocampo	B.S.	Biochemistry

Figure 20. DOE Fellows Daniel Coelho and Valeria Ocampo during the induction ceremony.

Gregory Sosson, DOE-EM's Associate Principal Deputy Assistant Secretary for Field Operations, Genia McKinley, DOE-FIU Cooperative Agreement Technical Monitor and Jean Pabon (JP), Program Manager represented Department of Energy Office of Environmental Management (DOE-EM). The Office of Legacy Management was represented by Ms. Jalena Dayvault and Mr. Mark Kautsky. Mr. Kautsky delivered the remarks on behalf of DOE-LM's Director Carmelo Melendez. FIU's administration was represented by Dr. Heather Russell (Vice Provost for Faculty Leadership and Success and Professor of Literature). Dr. Leonel Lagos (DOE Fellows Program Director and Principal Investigator for the DOE-FIU Cooperative Agreement) and Dr. Ines Triay (ARC Executive Director and Interim Dean of FIU's College of Engineering & Computing) also delivered messages to the new class. DOE-EM Fellow, Brendon Cintas, delivered a message to the new Fellows highlighting his personal experience, which he found fulfilling both academically and professionally.

Subtask 3.3: Conference Participation and Presentations

DOE Fellow Valeria Ocampo attended WM2024 and participated in various sessions along with the session coordinated as The Long-term Stewardship (LTS) day, organized by the DOE Office of Legacy Management.

- LTS Day provided technical information, education, and networking opportunities for representatives from government agencies, regulatory agencies, political offices, tribal groups, and other stakeholders involved in long-term stewardship (LTS) of remediated sites and facilities.

A poster presented by Former DOE Fellow Olivia Bustillo and Dr. Ravi Gudavalli during WM2023 titled "Interaction of Hydroxyapatite and Uranium in Groundwater at the Old Rifle Site to Facilitate Site Remediation" received ASME Award - Best Poster/Paper Presentation. An award was presented to them during WM2024 award luncheon on Tuesday March 12, 2024.

Figure 21. DOE Fellows Valeria Ocampo and Daniel Coelho initiated drafting their Summer Learning Experience Plan to LM for submission in April 2024.

Subtask 3.4: Summer Internship Program (SIP)

DOE Fellow Valeria Ocampo had the opportunity to intern at the Department of Energy Office Legacy Management in Grand Junction, CO. During her internship, she worked on various tasks, including column experiments, sediment collection, water collection, and analysis. Before starting the column experiments, sediments and water samples were collected from specific locations: sediments from North Ponds and Wetlands, and water from sites well 6-2N and piezometer point at North Pond. Prior to collecting samples, all necessary materials (shovels, bags, markers) and Personal Protective Equipment (PPE) (gloves and googles) were assembled (Figure 22).

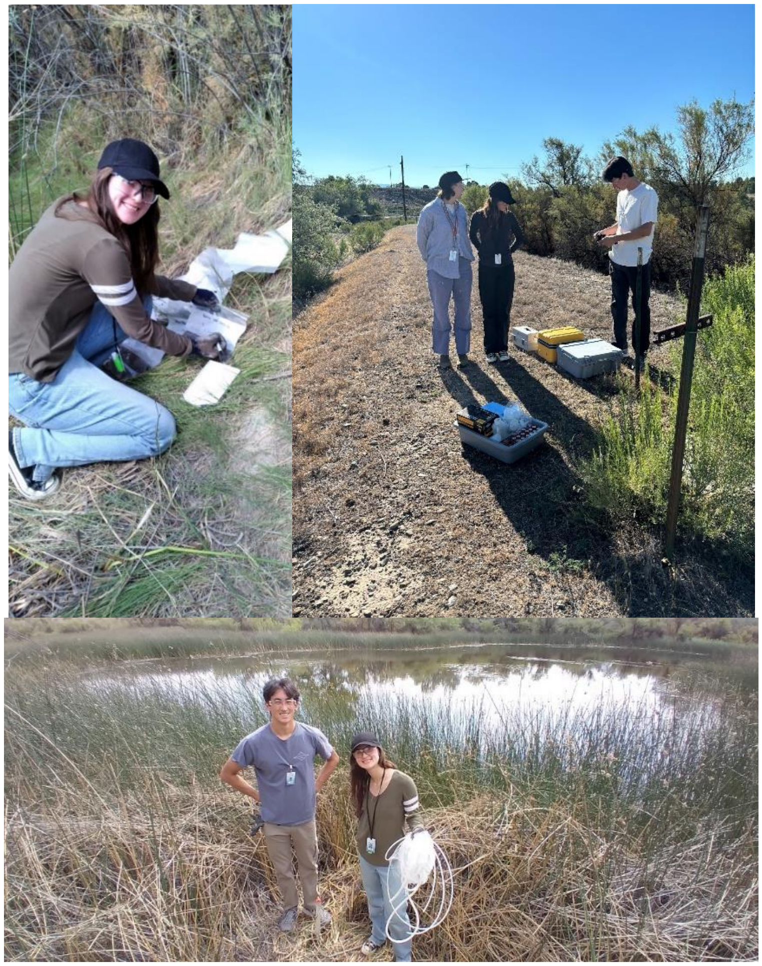

Figure 22. DOE Fellow Valeria Ocampo and fellow interns collected sediment and water samples at North Pond.

After gathering all the necessary materials, column experiments were conducted under oxic conditions at room temperature. Hydroxyapatite (HAp) was prepared using calcium-citrate and phosphate solutions, which were then injected into the columns as shown in Figure 23. This injection method was employed to ensure proper mixing of the solutions, leading to high HAp formation within the columns. The columns were left undisturbed for a period of one week to allow sufficient time for the apatite to precipitate and avoid being flushed out when influent water was introduced.

After the one-week period, influent water was used to flush the columns, and the effluent was collected and analyzed using a Kinetic Phosphorescence Analyzer (KPA). This instrument allowed Valeria to gain hands-on experience with its setup and how it operates, as well as how to use its software. The KPA analysis provided data on the uranium concentration in the effluent samples collected over a period of 10 days.

Figure 23. Valeria Ocampo (left) and Daniel Ohlson (Right) pouring in calcium citrate solutions and phosphate solutions simultaneously to ensure proper mixture of both solutions.

Ultimately, this internship at the Department of Energy Office of Legacy Management in Grand Junction, CO, offered DOE Fellow Valeria Ocampo the chance to develop additional technical skills and gain a deeper understanding on how the Office of Legacy Management handles helps with environmental remediation and long-term environmental stewardship.

DOE Fellows Other Activities

1. DOE Fellows Valeria Ocampo and Daniel Coelho completed drafting Summer Learning Experience Plans and submitted them to LM.
2. A briefing was held with DOE-LM collaborators to disseminate the updates from summer 2023 deployment at Mexican Hat and Rifle sites. Additionally, plans for summer 2024 deployments were also discussed.
3. DOE Fellow Daniel Coelho accepted a new full-time job opportunity and departed from the program. Due to this, the deployment of GPR at Mexican Hat has been delayed.
4. DOE Fellow Valeria Ocampo drafted an abstract for the 2025 Waste Management Symposia and sent to Ray Johnson for input and suggestions. The abstract will be submitted to theWM25 student poster session.
5. DOE Fellow Valeria Ocampo prepared a presentation based on the experiments conducted at FIU and at Grand Junction and presented them during FIU’s Annual Research Review.
6. DOE Fellow Olivia Bustillo joined Drummond Carpenter, PLLC as a staff engineer.

Task 3: Conclusion

This project is successfully meeting its objectives by providing research training and mentoring for students from underrepresented groups on environmental problems at DOE LM.

ACKNOWLEDGEMENTS

Funding for this research was provided by U.S. DOE Cooperative Agreement #DE-EM0005213. Office of Legacy Management provided the funding for FIU Project 5 this year. During this period of performance, two (2) new DOE LM Fellows were hired and participated in the new pilot program between DOE LM and FIU. The FIU researchers and STEM students are grateful to DOE LM for initiating this new program at FIU.

APPENDIX

The following documents are available at the DOE Research website for the Cooperative Agreement between the U.S. Department of Energy Office of Environmental Management and the Applied Research Center at Florida International University: https://doeresearch.fiu.edu/SitePages/Welcome.aspx

FIU Year 4 Annual Research Review Presentations:

1. FIU Research Review - Project 1
2. FIU Research Review - Project 2
3. FIU Research Review - Project 3 - D&D IT ML
4. FIU Research Review - Project 4
5. FIU Research Review - Project 5
6. FIU Research Review - Project 4-5 – Carlos Rios
7. FIU Research Review - Project 4-5 – Fellow Aris
8. FIU Research Review - Project 4-5 – Fellow Aubrey
9. FIU Research Review - Project 4-5 – Fellow Melissa
10. FIU Research Review - Project 4-5 – Fellow Ocampo
11. FIU Research Review - Project 4-5 – Fellow Victor
12. FIU Research Review - Project 4-5 – Fellow Theophile
13. FIU Research Review - Wrap Up - Project 1
14. FIU Research Review - Wrap Up - Project 2
15. FIU Research Review - Wrap Up - Project 3 – D&D IT ML
16. FIU Research Review - Wrap Up - Project 4
17. FIU Research Review - Wrap Up - Project 5