STUDENT SUMMER INTERNSHIP TECHNICAL REPORT

Long-Term Surveillance for the Department of Energy Legacy Management's Disposal Cell - Ground Penetrating Radar (GPR) Deployment

DOE-FIU SCIENCE & TECHNOLOGY WORKFORCE DEVELOPMENT PROGRAM

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EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science & Technology Workforce Development Initiative, an innovative program developed by the U.S. Department of Energy's Office of Legacy Management (DOE-LM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2023, a DOE Fellow intern, Shawn Cameron, spent 10 weeks doing a summer internship at Grand Junction, Colorado and Department of Energy-Legacy Management under the supervision and guidance of Jalena Dayvault. The intern's project was initiated on July 5, 2023, and continued through September 1, 2023 with the objective of deploying an integrated ground penetrating radar (GPR) robotic platform.

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1. INTRODUCTION

During the months of July through September of 2023, the DOE Fellow Shawn Cameron participated in several activities with the Department of Energy's Legacy Management (DOE-LM) site leaders, managers, and various personnel. The internship which lasted 10-weeks, involved participating in annual sampling activities, disposal cell inspections, and the deployment of the robotic platform developed at FIU with the integrated ground penetrating radar (GPR) for surveying LM's disposal cells. Additionally, the Fellow had the chance to test the system in a small river basin (Basin 6) in the Nash Draw region near the Waste Isolation Pilot Plant (WIPP) transuranic waste repository where there are a considerable number of sinkholes. The robotic system was tested for its ability to analyze the unique conditions and problematic subsurface issues in varying terrains.

Disposal cells, which fall under the Uranium Mill Tailings Radiation Control Act (UMTRCA) Title I, are licensed to the Department of Energy (DOE) and managed by the Office of Legacy Management (LM). The UMTRCA is a federal law that provides procedural disposal, long-term surveillance, and control of uranium mill tailings that could potentially minimize or eliminate hazardous materials to the population. Under this law, which was passed in 1978 by Congress, the DOE has decontaminated 22 inactive uranium-ore processing sites. These radioactive materials have been encapsulated and approved in the U.S. Nuclear Regulatory Commission (NRC) disposal cells. LM's disposal cells undergo routine inspection which includes the condition of the site's visible features, any changes in the condition of the cell that will go against the Long-Term Surveillance Plan (LTSP), and evaluation of the need for any maintenance, inspection, and monitoring.

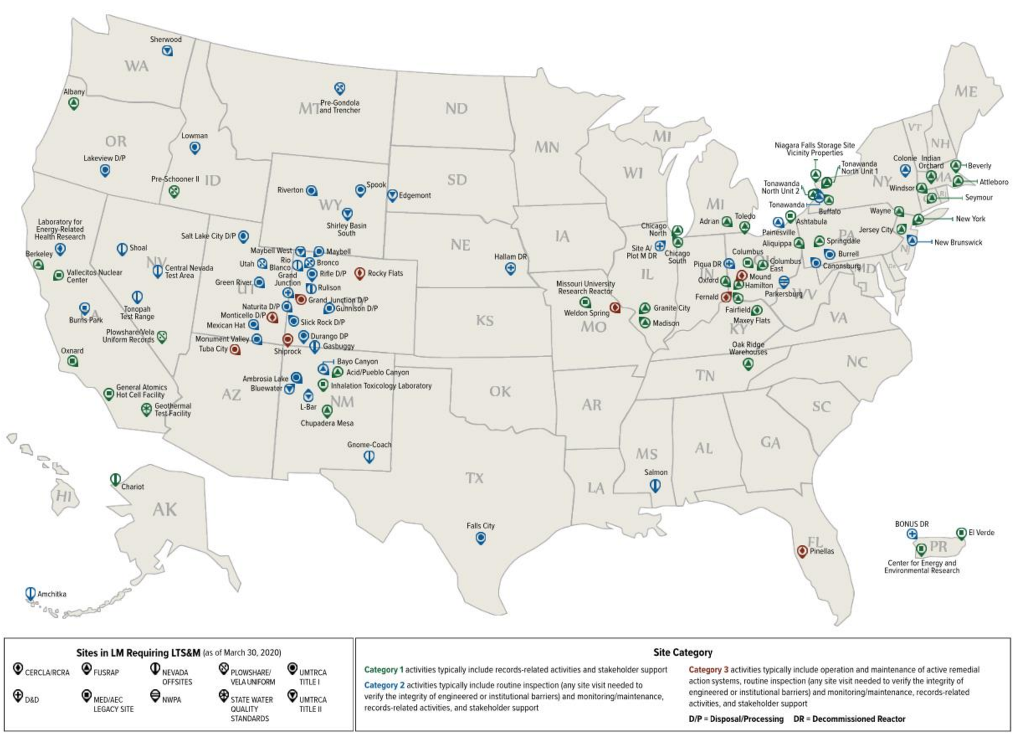

Figure 1. Legacy Managements sites across the United States.

2. RESEARCH DESCRIPTION

Legacy Management's disposal cells have the important responsibility of isolating contaminated materials for the protection of human health and the environment. Any discrepancy in the integrity of these cells could cause future problems and expose such materials. Minor occurrences of subsurface depressions and erosion have manifested itself for the Rifle, CO and Mexican Hat, UT disposal cells. Since several of these cells have similar design characteristics, these features and phenomena could prove to be problematic for other disposal cells across the United States. Due to past precipitation events, several of LM's disposal cells have suffered. Figure 2 depicts the severity of how the weather effected the Mexican Hat, UT and Shirley Basin South, WY disposal cells. The accumulation of water is one of the main causes that leads to subsurface erosion for these sites.

Figure 2. LM disposal cells degradation at Mexican Hat (Top) and Shirley Basin South (bottom).

Additionally, there are several sinkholes that exist in the Nash Draw basin which lies just west of the WIPP facility (Figure 3). The presence of these and other topographical depressions may result in increased subsurface infiltration and may have a potential impact on groundwater recharge. This can influence the rate of subsurface halite dissolution which is of interest to DOE scientists in assessing the long-term integrity and stability of the WIPP.

Figure 3. Sinkholes in Basin 6 of the Nash Draw region west of the WIPP facility.

The Rifle Colorado disposal cell is located on 205 acres of land in Estes Gulch, roughly 6 miles north of the city of Rifle, Colorado. The 205-acre site on former Bureau of Land Management (BLM) land was transferred to the DOE in August 1991 for use as the Rifle disposal cell. The disposal cell comprises 71 acres of the transferred land (seen in Figure 4). The disposal cell is a multicomponent triangular shape that measures nearly 3,000 feet on three sides. The multi-component design of the cell contains 3.7 million cubic yards of radioactive materials from the relocated tailings of the two former processing sites. Thus, the disposal cell comprises a total of 2,738 curies of radium-226. The components of the cell each have a specific task to reduce the flux escaping from the cell, protect against erosion, and provide overall protection against drying and water infiltration.

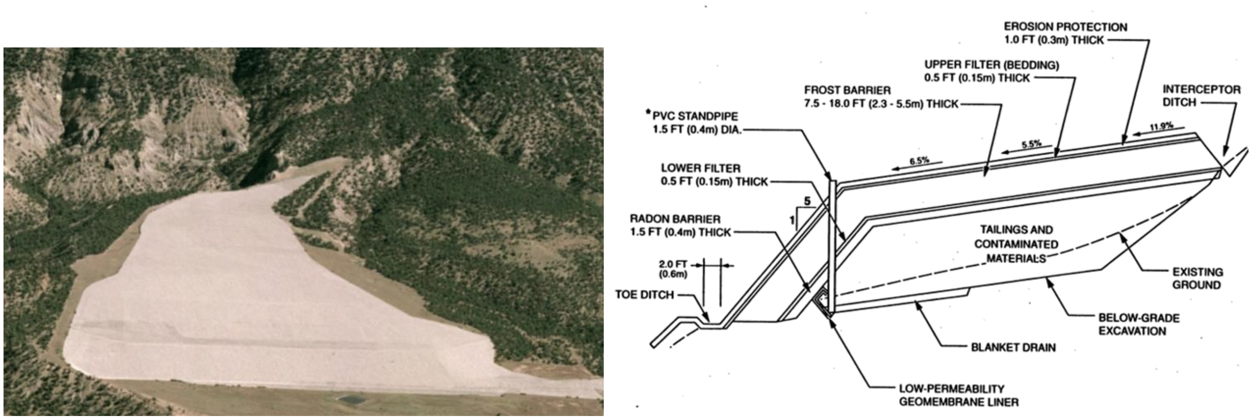

Figure 4. Rifle Colorado subsurface layer description.

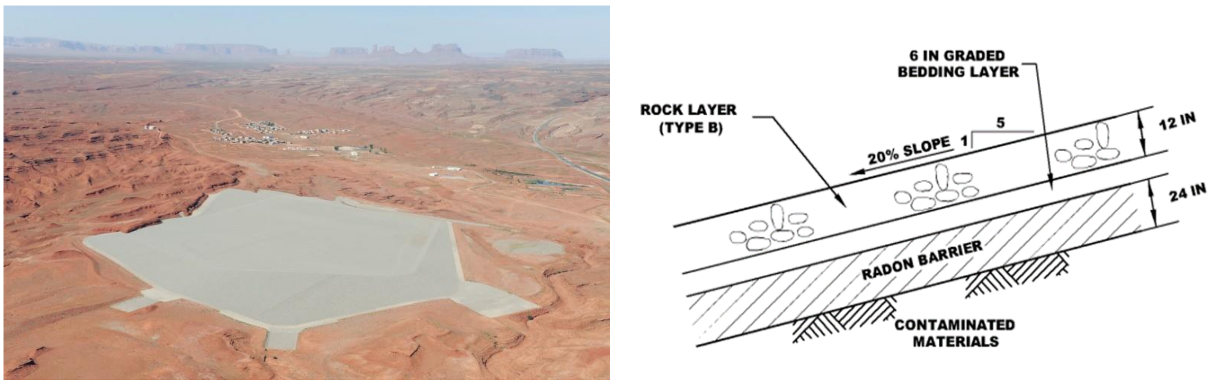

Figure 5. Mexican Hat subsurface layer description.

The objective of this research was to develop a mobile robotic platform with an integrated ground penetrating radar (GPR) that is able to traverse the terrain and survey the subsurface of LM's disposal cells as well as the Nash Draw region near the WIPP. Figure 6 displays the design concept of the GPR robotic platform that inspected the disposal cell during the internship. The design concept revolves around integrating the GPR sensors for obstacle avoidance and data collection.

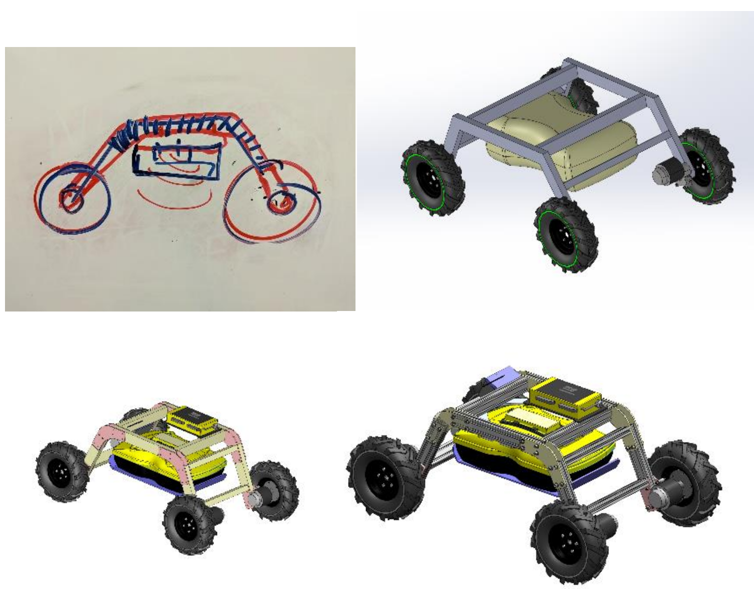

Figure 6. GPR robotic platform design concept.

The system has 4-120 rpm wheelchair motors that have enough torque to climb the inclination of the cells, 13-in lug traction wheels, a robust chassis able to handle a heavy payload, and integrated solar panels to increase the battery duration per survey inspection. The design with the integration of the solar panels is depicted in Figure 7.

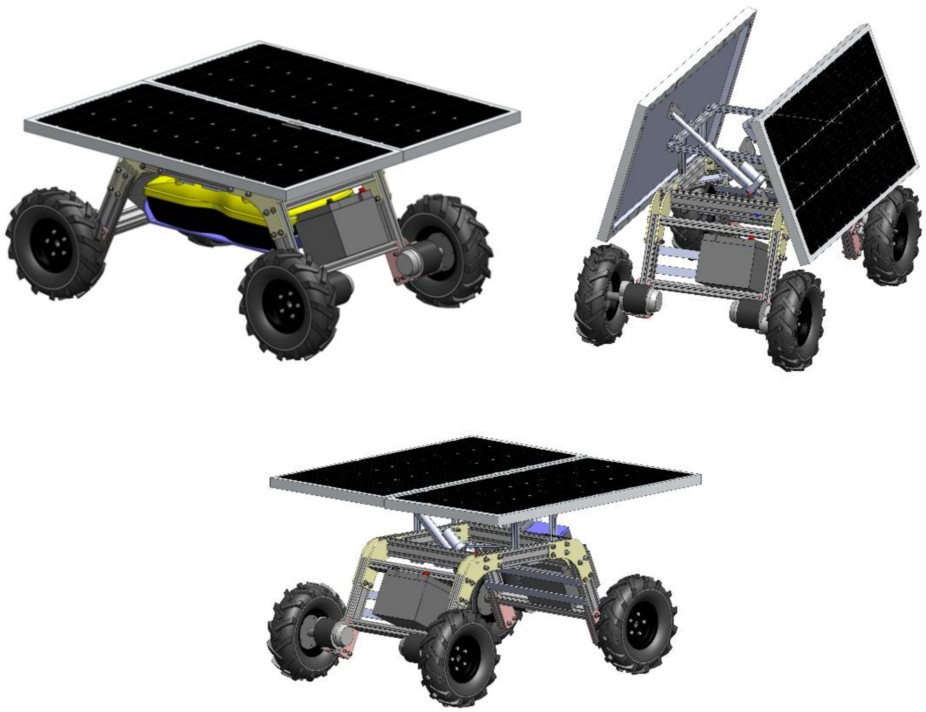

Figure 7. GPR mobile robot CAD design.

Additions made to the platform include adding actuators to the GPR sensor for data acquisition purposes. Allowing the GPR sensor to vary from its starting position to the ground increases the visualization when acquiring subsurface data while avoiding objects (Figure 8).

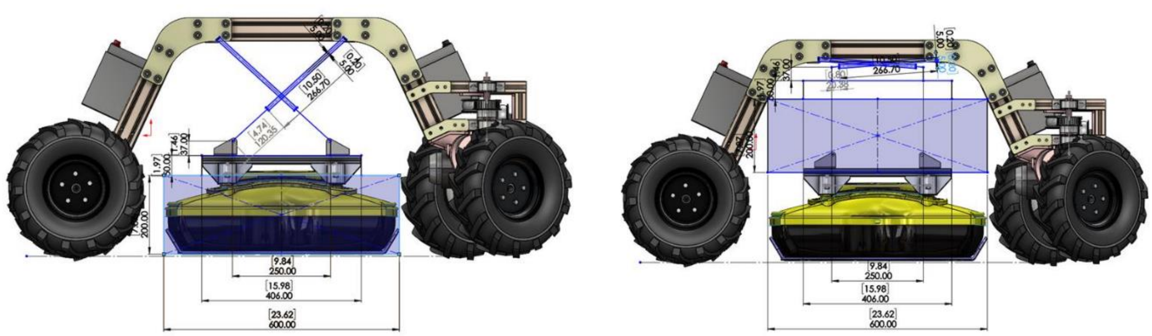

Figure 8. Actuated GPR sensor.

Further development of the robotic rover includes applying what is a called an Ackerman steering mechanism to the front of the rover (Figure 9). This addition to the system decreases the amount of skidding done on the top riprap layer of the disposal cell and optimizes the turning radius.

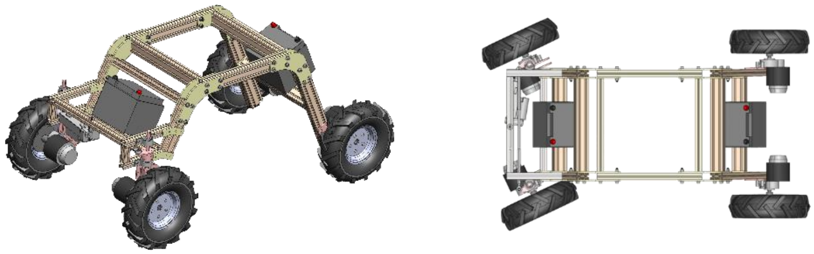

Figure 9. Ackerman steering integration.

Controlling the GPR robotic platform is accomplished with a remote control (RC) transmitter and receiver (Figure 10). The receiver and transmitter combination has a range of 10km distance of operation, which allows the operator to control the system from a distance without continually walking on the disposal cell's rip rap layer.

Figure 10. RC transmitter and receiver.

The beginning stages of the internship was to find a viable GRP open-source software that can analyze the acquired data. Several open-source software were explored to accomplish this feat, including the GPR software RGPR. RGPR is a program that is written in the statistical language R to read, analyze, export, process, and visualize GPR data.

Preparation of the data analysis before the first deployment included understanding the structure of the RGPR software. Publicly available GPR data was used for data processing which can be seen in Figure 11. This figure shows a step called "Basic GPR data processing" where the raw data is imported into the software. GPS coordinates can also be implemented into each line scan of the GPR analysis which is showed in Figure 12. This helps give a realistic visualization of how the survey scan data was acquired and pinpoints areas of interest within the data analysis. Once the line scans of the survey scan are imported into the RGPR environment. Further data visualization is then processed by first depicting the survey data in a 3D line scan in Figure 13. The depiction allows the use to view the raw data line scans in a 3D space.

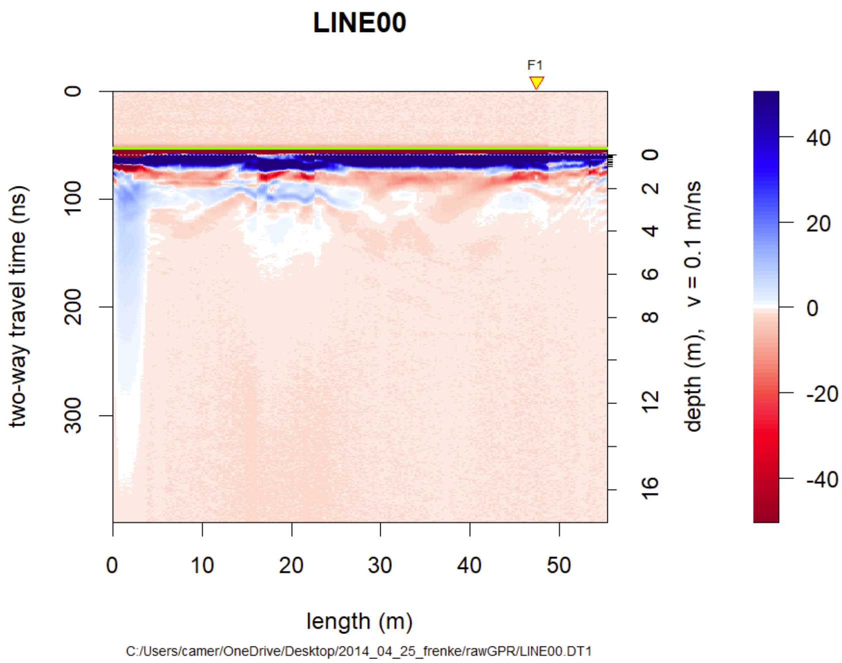

Figure 11. LINE00 Publicly available GPR data.

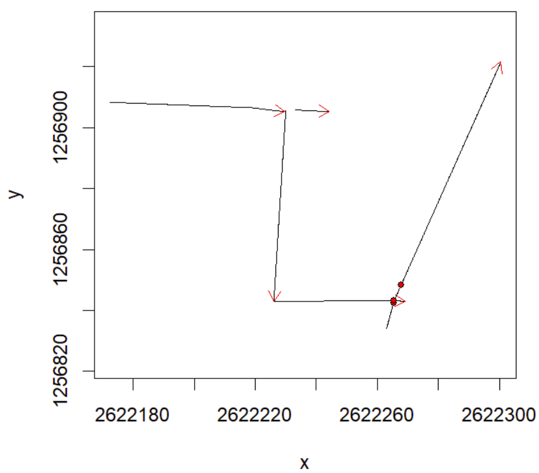

Figure 12. Inputting GPS coordinates for each GPR line-scan.

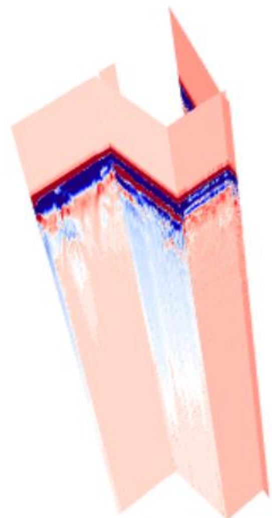

Figure 13. 3D line scan depiction.

After the data analysis of the raw data is generated with its respected GPS coordinates. A 2D splice of the image can then be inspected. Figure 14 shows how the data is visualized when it is converted in a 2D splice. This depiction of the data shows the subsurface features of the survey analysis. The RGPR program allows the user to input the desired time depth in nanosecond(ns). RGPR then generates the desired depth with the x and y axis being the coordinates.

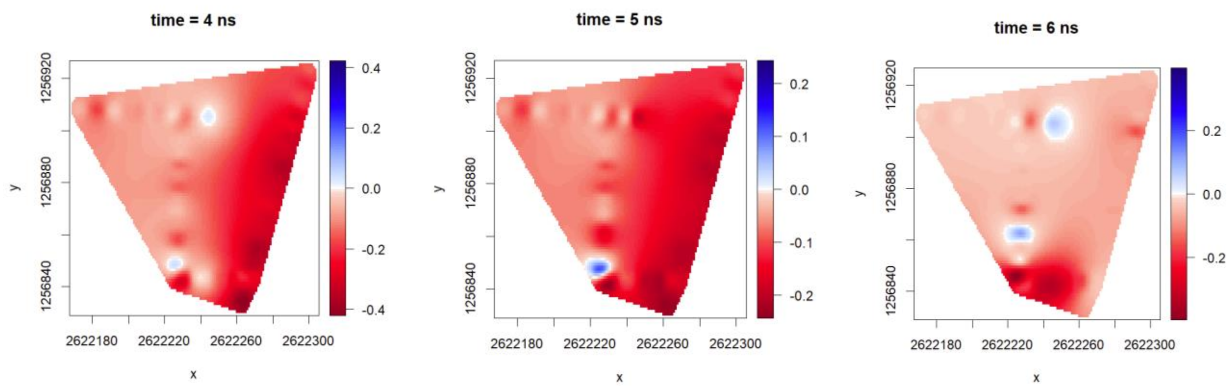

Figure 14. GPR 2D splice visualization.

3. RESULTS AND ANALYSIS

The reconstructed subsurface erosion of the Mexican Hat, UT disposal cells was one point of interest for GPR testing purposes. GPR data depicting subsurface conditions would provide LM site managers with viable information for future analysis. Figure 15 shows the disposal cell drawing and point of interest of where the GPR system performed subsurface scanning.

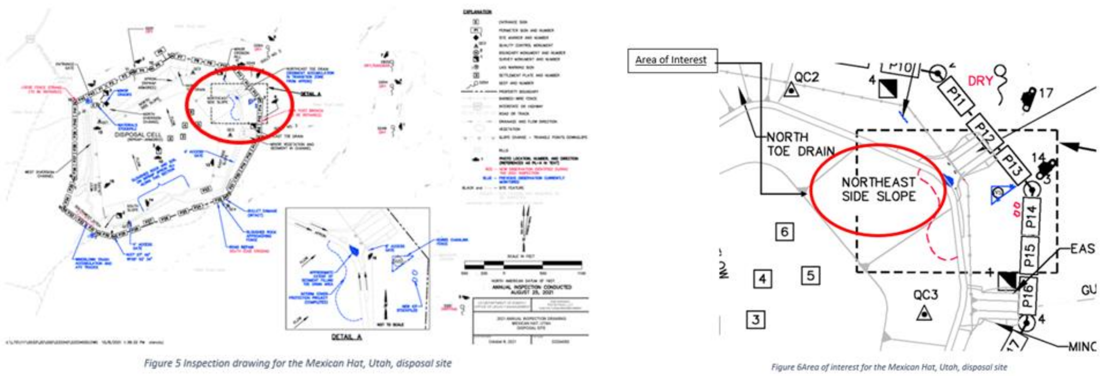

Figure 15. Mexican Hat, UT disposal cell drawing with GPR survey interest.

The GPR robotic platform successfully surveyed the desired areas which include traversing the riprap terrain and scaling Mexican Hat's inclination slope. Several line scans were taken in the concerned area that show the subsurface features. These scans are depicted in Figure 17.

Figure 16. GPR robotic platform Mexican Hat, UT deployment.

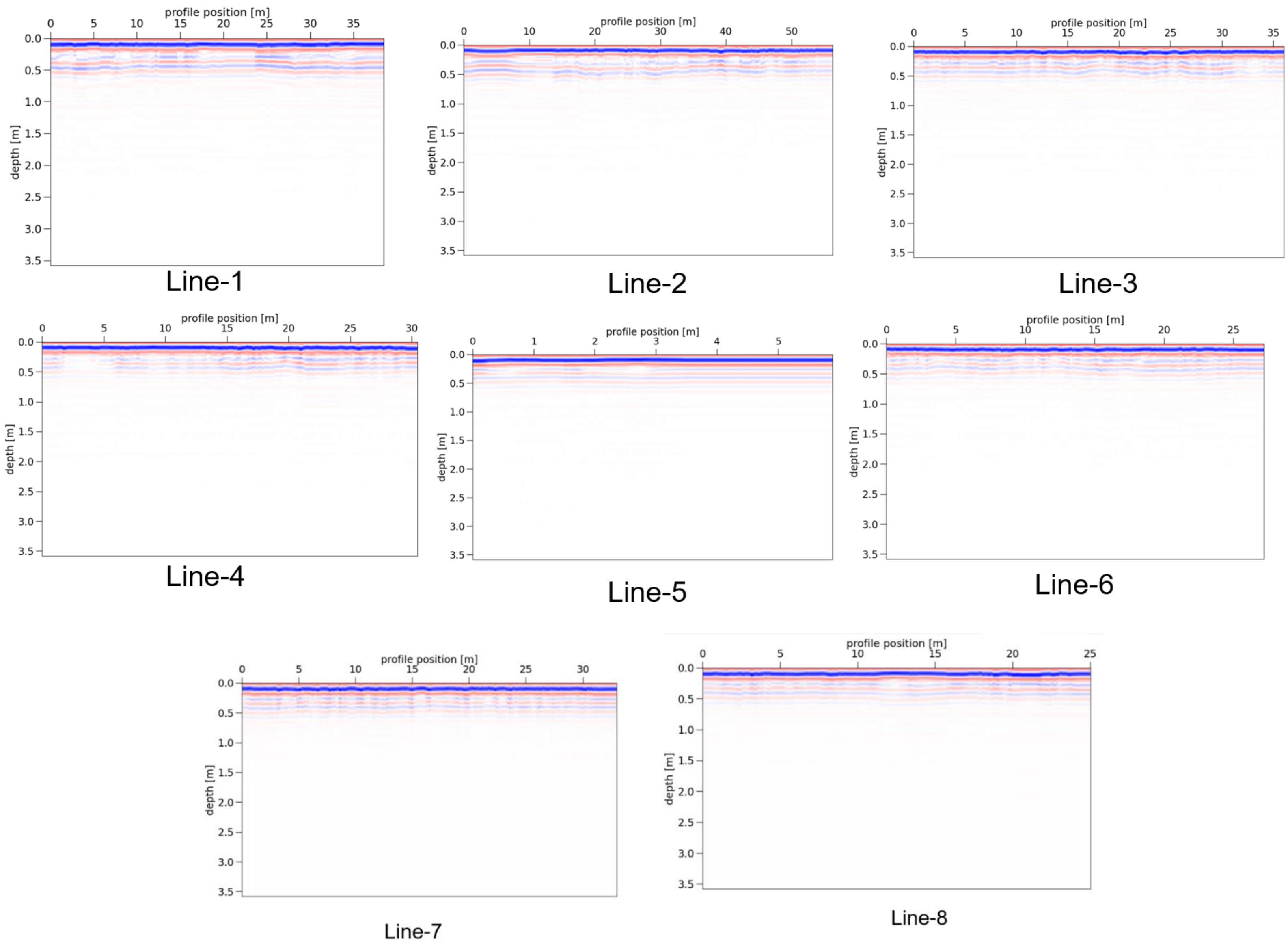

Figure 17. Mexican Hat, UT deployment data line scan 1-6.

In addition to surveying the subsurface of LM's disposal cells, other DOE site offices, such as the Carlsbad Field Office in New Mexico, has shown interest in the robotic platform with its integrated GPR sensor for surveying a small river basin (Basin 6) just west of the WIPP waste repository where there is a considerable number of sinkholes, to see if it is possible to detect subsurface accumulation of water or reoccurring erosion features (Figure 18).

Figure 18. GPR robotic platform deployment in Basin 6 west of the WIPP, New Mexico.

The Rifle Colorado disposal cell LM site managers have two points of interest where there are concerns of depressions occurring. Figure 19 shows the locations circled in red and green where the GPR robotic platform accessed the subsurface conditions for any indication of differences in their dielectric properties.

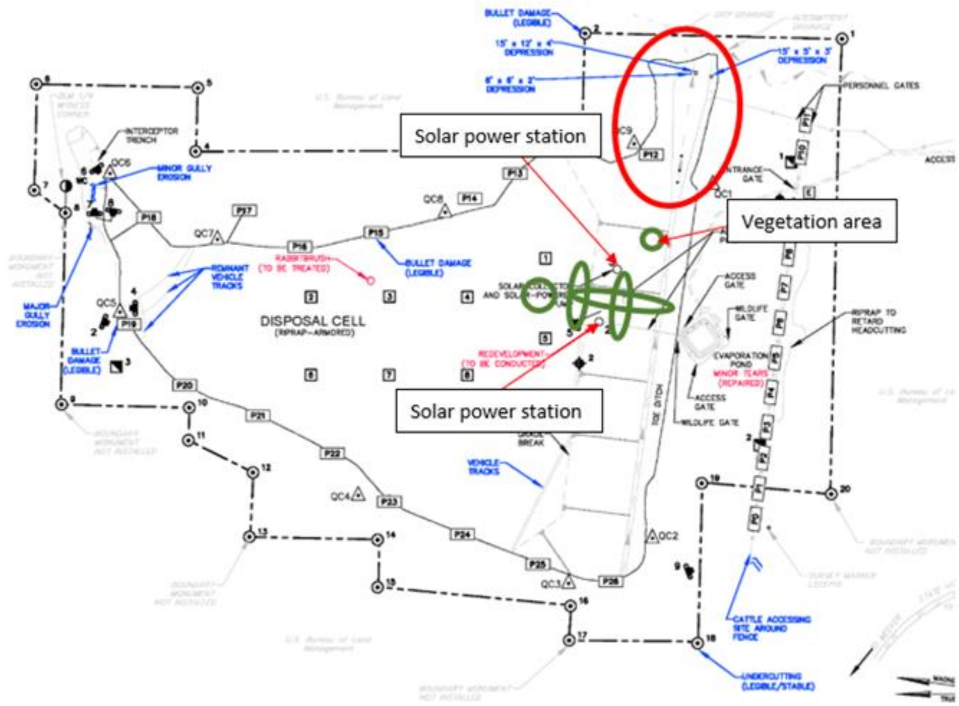

Figure 19. Rifle Colorado map drawing with GPR survey interests.

Similar to the Mexican Hat deployment, the GPR robotic platform was able to traverse the top rocky conditions the cell and scale the inclination slope where the solar panel stations are located (Figure 20). The GPR platform returning down the Rifle Colorado slope after successfully scaling up between the two solar power stations (Figure 20).

Figure 20. Rifle Colorado GPR robotic platform near the depression areas (left) and between solar panels 2 & 3 (right).

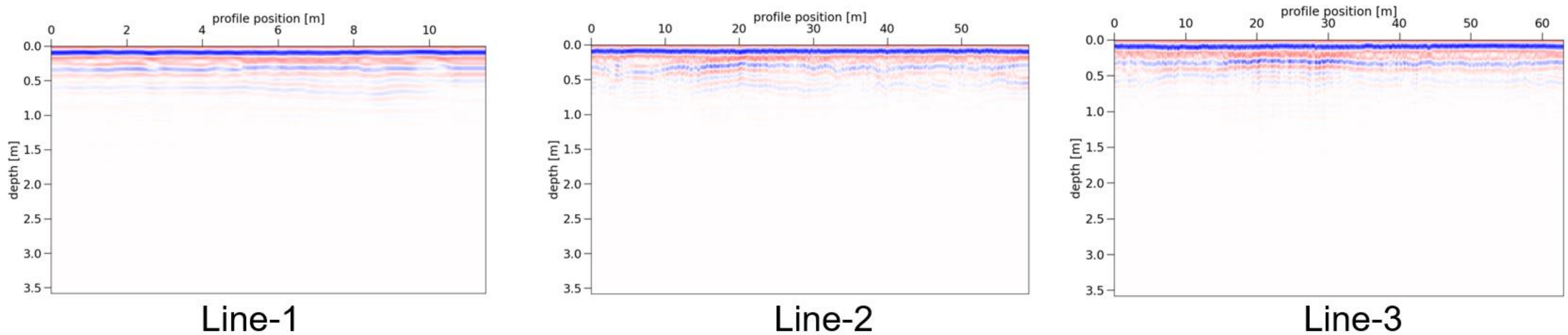

Figure 21. GPR data near the depression toe.

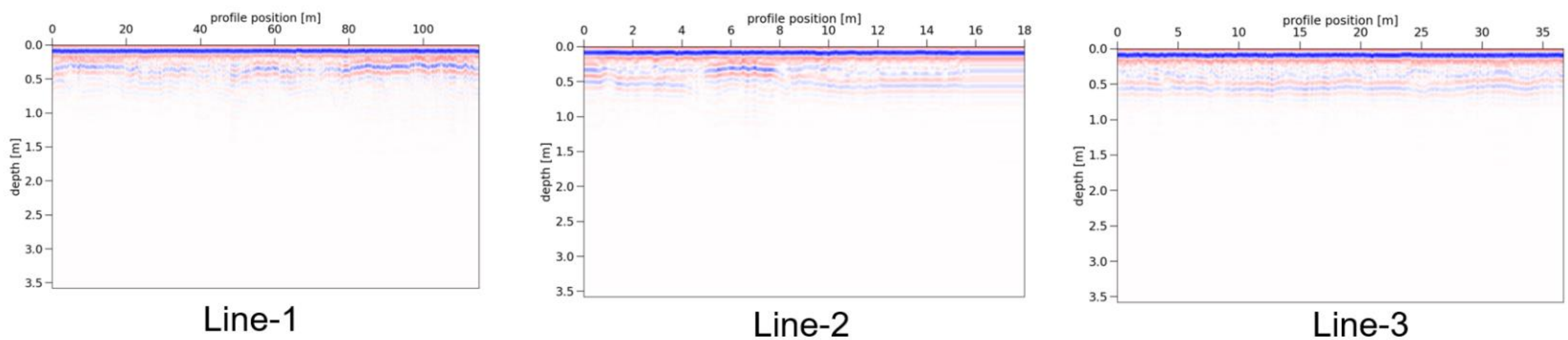

Figure 22. GPR data between solar power station 2 & 3.

4. CONCLUSION

In conclusion, this 10-week internship tested the maneuverability of a robotic platform designed by FIU over LM's disposal cells and the mounted GPR's subsurface detection capability. The GPR data acquired during this internship provides LM personnel with an essential view of their disposal cells' subsurface characteristics. Continuing the analysis of the GPR data to produce 3D depiction will give an even greater visualization of the subsurface conditions of each site location. Additionally, deploying the system at or near other facilities, such as in Basin 6 near the WIPP, validates the functionality and versatility of the GPR robotic system.

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