Deep Learning-Based Water Seepage Monitoring in F-Area 3 Basin Cap

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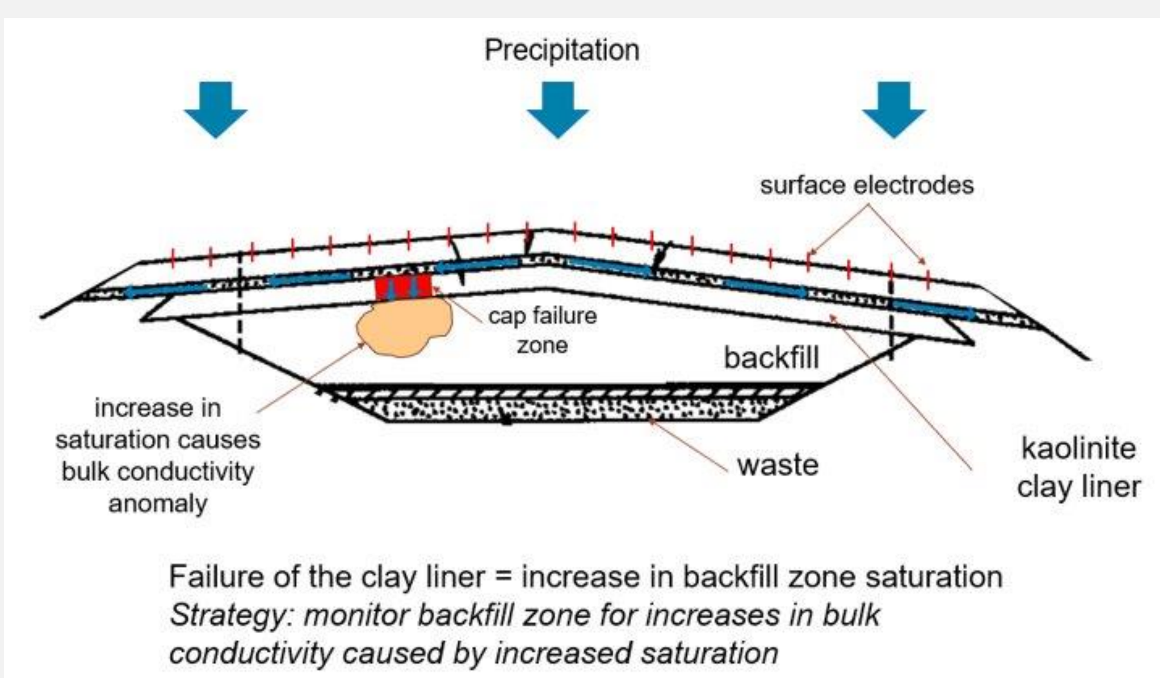
Introduction

- Between 1955 to 1988, the F-Area Basins received approximately 1.8 billion gallons of low-level acidic waste from the processing of uranium slugs and irradiated fuel in the F-Area Separations Facility. The acidic waste contained a variety of radionuclides and dissolved metals that, after entering the basin, either evaporated or seeped into the underlying soil. This seepage contaminated the groundwater with radionuclides like plutonium isotopes, cesium-137, strontium-90, uranium isotopes, iodine-129, technetium-99, and tritium.
- As part of the remediation efforts, in 1991, the basins were closed by dewatering them, stabilizing the remaining waste, and covering them with a low-permeability, multilayer cap to reduce the rainwater infiltration.
- Due to changes in terrain and weather, parts of the cap can lose effectiveness and water can seep to the ground through those "holes" in the cap.

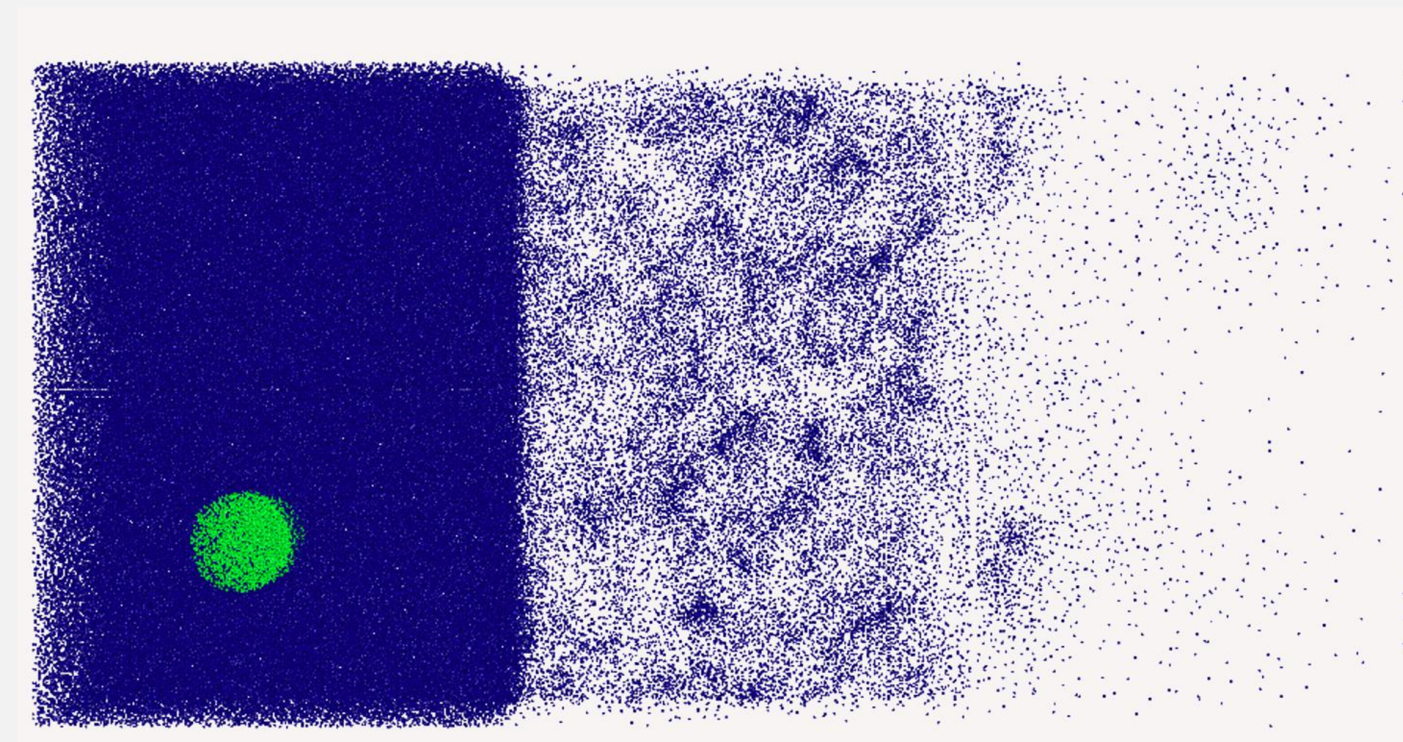


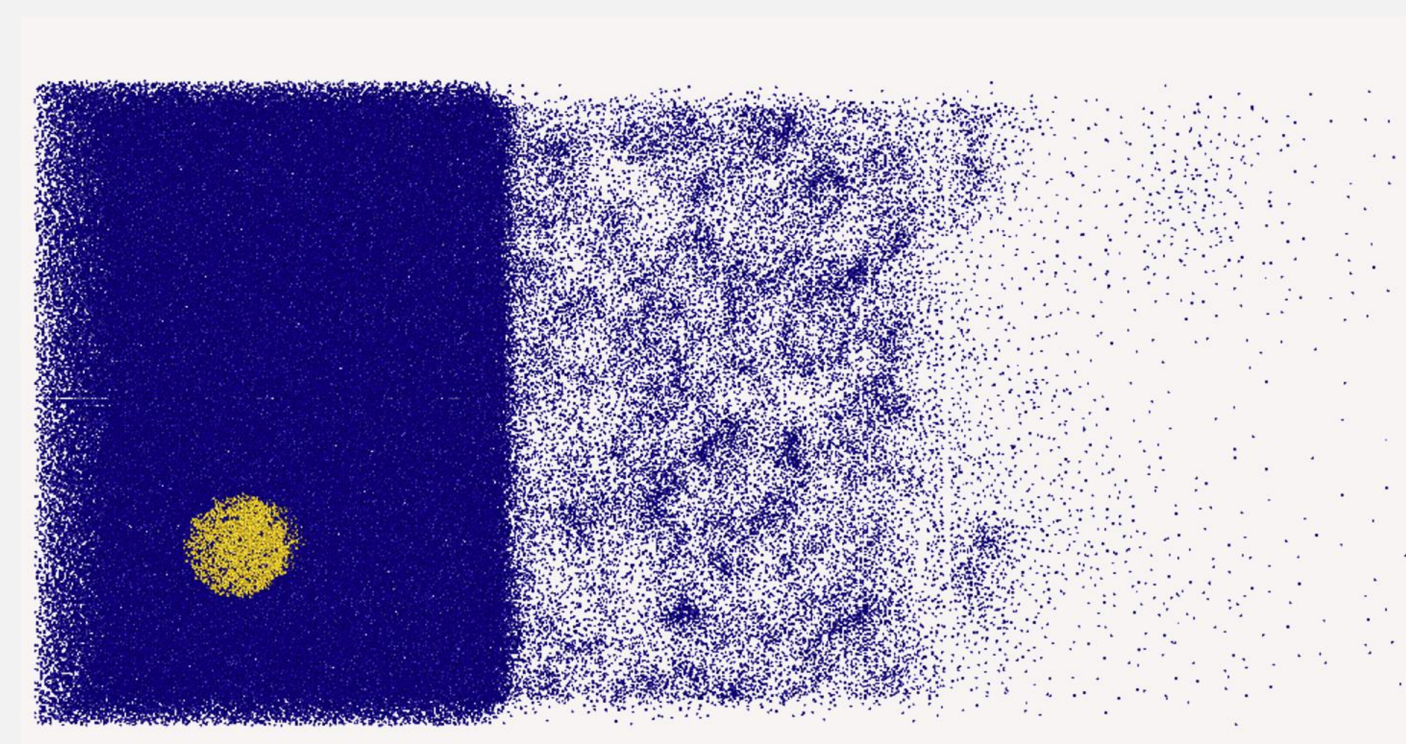
- Electrical Resistivity Tomography is used to measure the resistivity on the subsurface area. Decreases in resistivity are correlated with the presence of water.
- Usually, a person must use their judgement and heuristics to determine if there is water seepage in the cap.

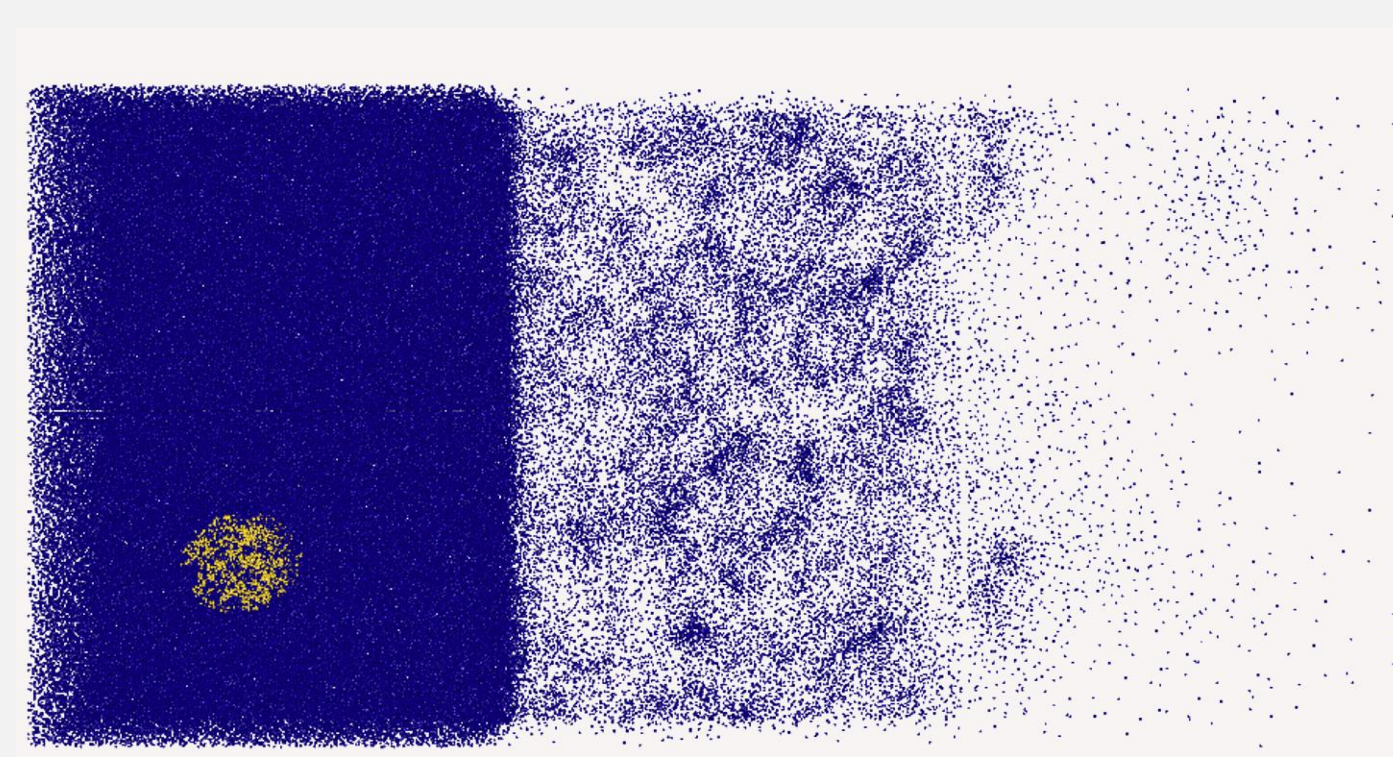
Objective

- Given ERT and weather data, determine if there is water seepage through the cap. If there is water seepage, determine where within the cap the seepage is happening and the degree of severity of the seepage.
- In anomaly detection terms, determine if there is an anomaly, where it is, and how severe it is.

Results







Methodology

- Split the data in such a way that the train, validation, and test sets have a distribution that resembles the true distribution of the population.
- Preprocessed data using scalers, but no dimensionality reduction.
- Compressed data to reduce its memory size requirements.
- Implemented an autoencoder deep learning model for 3D data.
- Implemented hyperparameter optimization to find the optimal autoencoder that can capture the data distribution.
- Implemented upper bound tolerance intervals for non-normal distributions as dynamic thresholds for anomalies since most points did not follow a normal distribution.
- Visualized results in 3D space that users can pan, zoom, and move around in.
- Implemented prediction that made use of the preprocessing, autoencoder, and postprocessing workflows.

Discussion

- For most months, there is a high fidelity between the ground truth and the model's predictions. It can accurately capture if there are anomalies, where they are, and how severe they are.
- For April 2023 and October 2022, the model struggles to get predictions as good as the other months. However, the general trend of results is still present.
- Possible causes: lack of year-round data, weak signal of weather data within the model, among other variables.

Path Forward

- Identify and resolve the reason for the discrepancy between results across months.
- Implement a user interface to allow others to extend the current system beyond the F-Area 3 Basin Cap.
- Further refine and test the system with new data and simulated anomalies.
- Identify, implement, and test other possible deep learning solutions.

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