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Geophysical Characterization of 200 TEDF to Support Discharge Permit Renewal

September 2021

Jonathan N. Thomle
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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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FY21 Status Report

Introduction

The Treated Effluent Disposal Facility (TEDF) is a site where treated non-hazardous and non-radioactive liquid wastes are collected and disposed of in two state-permitted disposal basins near the 200 East Area at the Hanford Site. In 2016, a renewal application was submitted for TEDF that requested mass loading effluent limits instead of concentration-based effluent limits. The Washington State Department of Ecology denied this request due to a lack of groundwater monitoring wells that can be used to identify and characterize the impact of TEDF discharges on the underlying groundwater. Current TEDF monitoring wells are screened in the confined aquifer below the Ringold Lower Mud (RLM) unit and are not representative of TEDF discharges that can potentially mound above the RLM unit.

There is a need to identify an appropriate location to install a well that can be used to sample intermittent perched water from TEDF discharges above the RLM unit. The perched water samples will be used to determine if water quality is in compliance prior to reaching the water table. To help identify an optimal location for a monitoring well, geophysical methods will be used to image subsurface transport of TEDF discharges, and to identify important stratigraphic features influencing migration pathways, such as where the RLM unit pinches off to the north. Both electrical resistivity tomography (ERT) and electromagnetic methods will be evaluated for these purposes.

The overall objective of this task is to support the renewal of the TEDF discharge permit by conducting geophysical surveys to identify geologic contacts and the location of the RLM interface that creates perched water conditions. Data from this survey will also be used to aid monitoring well placement by identifying the flow path for subsurface discharge. Before geophysical surveys were performed, numerical simulation was used to estimate the anticipated performance of ERT for identifying the RLM interface and monitoring transport through the subsurface. Since the simulations demonstrated a strong potential for ERT to image TEDF releases, field surveys were approved and are scheduled for FY22. The geophysical surveys will include baseline ERT and towed Time Domain ElectroMagnetic (tTEM) surveys conducted prior to a discharge event, both of which image the bulk electrical conductivity of the subsurface After discharge, time-lapse ERT imaging will be used to survey effluent migration through the subsurface. This document summarizes the simulations and data collected to date.

FY21 Activities

The activities performed in FY21 included numerical simulations to assess the anticipated performance of ERT for monitoring discharge water migration through the vadose zone. A subsequent review of the simulated imaging results resulted in a decision to proceed with field imaging, based on a subjective determination that the images would provide useful information for optimizing the sampling well placement. Once the decision to proceed was made, a tTEM survey was conducted of the area around TEDF and within each basin before installation of the ERT system.

ERT Feasibility Assessment

An assessment was initiated to determine if ERT is a feasible method for monitoring subsurface discharges from TEDF, with the goal of identifying an optimal location for a monitoring well along the discharge flow path. A flow and transport model (provided courtesy of Matt Tonkin at S.S. Papadopulos & Associates, Inc.) was used to simulate TEDF discharges and translate porosity, concentration, and saturation information into hypothetical bulk conductivity. This is used as the "true" bulk electrical conductivity (BEC) timeseries. Next, field ERT measurements were simulated and inverted using E4D software (Johnson et al., 2010, 2017, 2020) to produce the corresponding time-lapse ERT images of BEC. A subjective comparison of the true and imaged time-lapse BEC was used to determine if the ERT images would be useful enough to merit field deployment.

The scenario selected for simulation was based on current operations, including 243 days of continuous discharge at ~11,500 cubic feet per day and 30 days of discharge at ~197,000 cubic feet per day (see Figure 1). The processing flow for the performance assessment is shown in Figure 2.

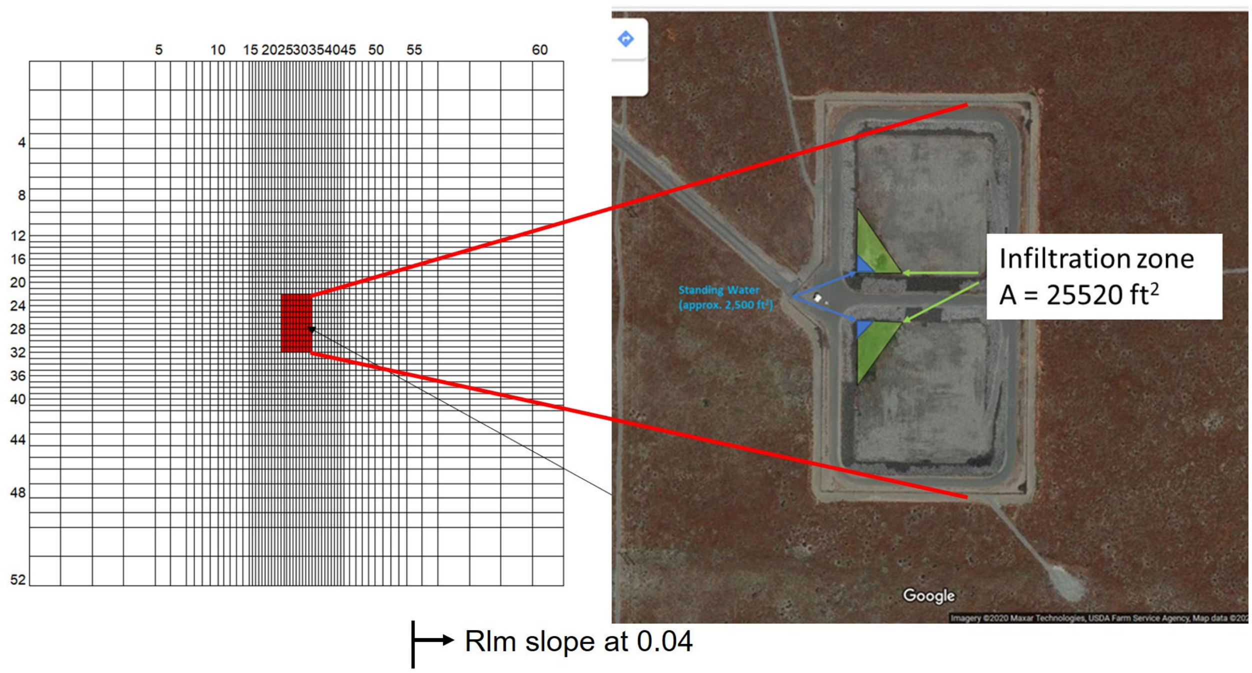

Figure 1. Infiltration simulation grid where the simulated infiltration areas at two flow rates are shown in blue and green, and the Ringold Lower Mud (RLM) is shown to slope to the east (flow and transport simulations courtesy of Matt Tonkin) [For Information Only (FIO)].

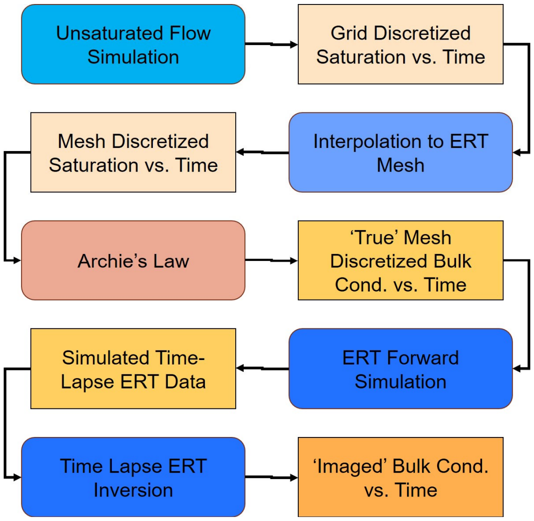

Figure 2. ERT performance assessment processing flow.

The relationship known as Archie's law (Archie1942) was used to convert porosity, saturation, and concentration data into hypothetical measures of resistivity. Since infiltration water for field testing will be river water, the infiltration and groundwater conductivity were assumed to be 0.015 and 0.040 S/m, respectively. These are nominal values reported by Johnson et al. (2015) for river water and groundwater conductivities reported in the Hanford 300 Area. The vadose zone outside of the infiltration area was assumed to have an initial saturation of 14.9%, the value used in the unsaturated flow modeling. The cementation and saturation exponents in Archie's Law vary over a relatively small interval in unconsolidated sediments. A cementation exponent of 1.3, and a saturation exponent of 2.0 were assumed, which are common values used for unconsolidated sediments.

The scenario assumed that a survey would use eight ERT electrode lines (32 electrodes per line) spaced 60 m apart, with a total of 256 electrodes spaced 15 m apart along each line. The total area that was covered by the simulated ERT is approximately 200,000 square miles (~50 acres). An image from this simulation is shown in Figure 3.

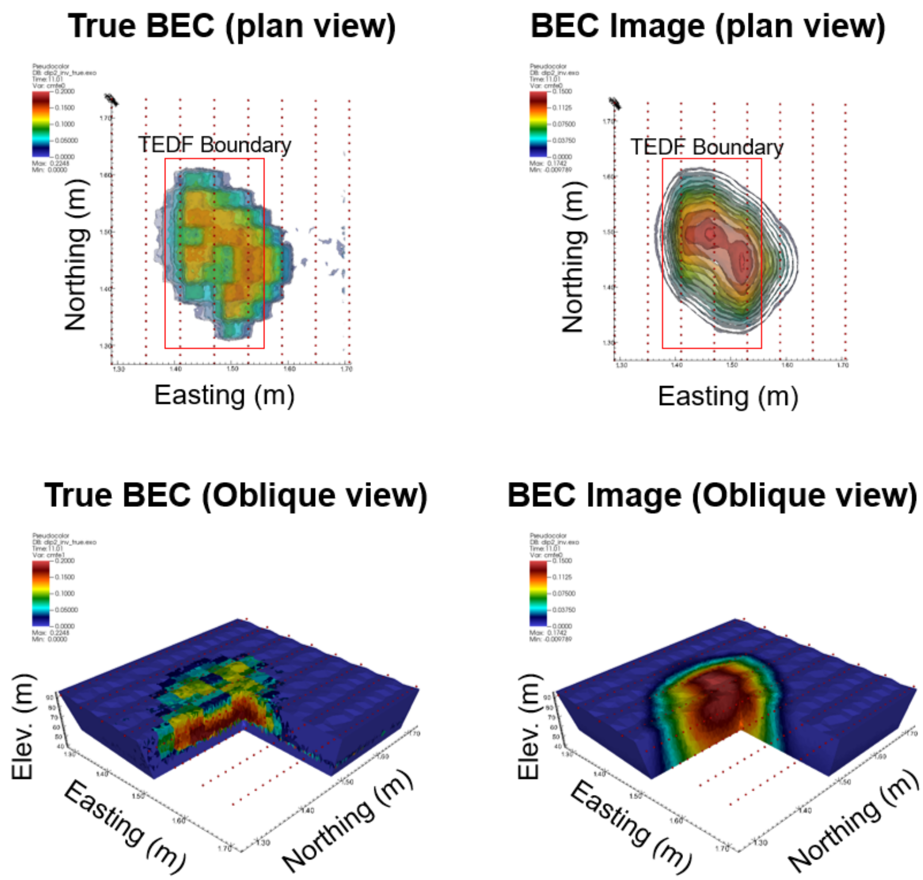

Figure 3. Numerical simulation of true and ERT imaged change in BEC resulting from a TEDF discharge. (FIO).

It was determined from this feasibility study that the proposed use of ERT would have good lateral resolution, but poor vertical resolution. This means that ERT is likely unable to resolve the height of the groundwater mound from the simulated discharge. However, ERT will be able to laterally resolve the change in footprint of the groundwater mound and locate its peak. A working group, consisting of members from the U.S. Department of Energy (DOE) Office of River Protection (ORP) and Richland Operations Offices, Washington River Protection Solutions (WRPS), and Pacific Northwest National Laboratory (PNNL), collectively decided that the simulations provided the technical support needed to perform geophysical monitoring at the TEDF site.

ERT Installation

Prior to the field work, DOE-ORP requested a briefing on the work to be performed (briefing completed 7/28/2021). An outcome of this meeting was the need to coordinate the ERT install with the weed control specialists who perform annual mowing at the bottom of the basins, which usually occurs in September once the fire danger rating decreases to a safe level.

However, since the annual maintenance does not affect the area outside the fence line, a partial install of the ERT array was initiated on 8/17/2021 (see Figure 4). Once the mowing is completed, the ERT array will be fully installed. A baseline survey is planned to be completed in FY21, assuming that mowing is permitted because the fire danger is low.

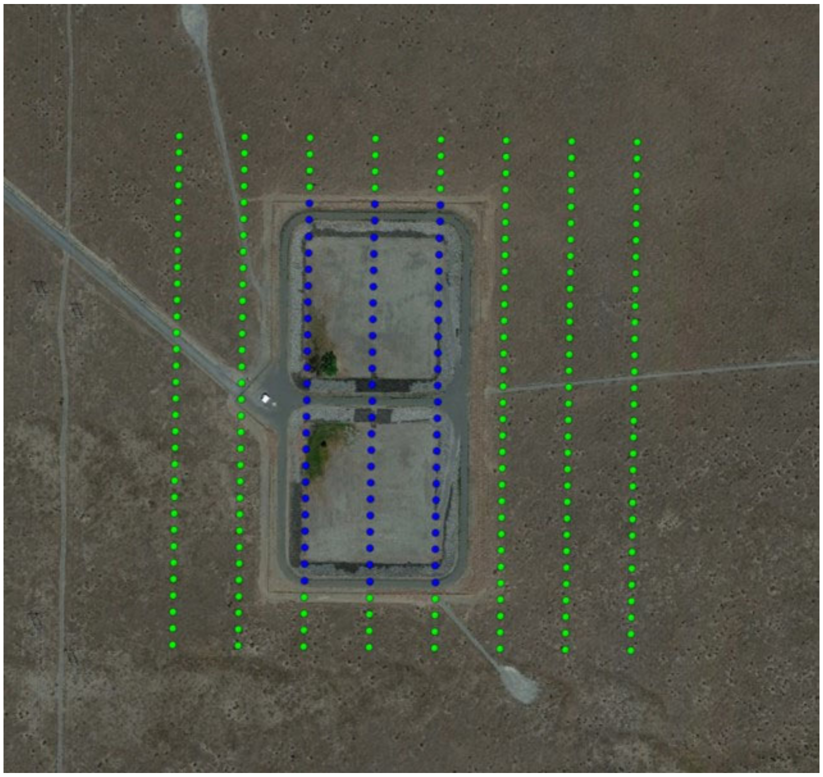

Figure 4. Layout showing which electrodes and cables (i.e. lines) are installed (green) and which are not yet installed (blue).

The ERT array includes 256 electrode locations and 8 electrode lines. Each electrode location has two 10-inch galvanized steel spikes (electrodes) pounded into the ground through holes in the bottom of a UL-listed electrical box. However, 48 electrode locations at the bottom of the basins will likely need to be installed with 3-foot-long grounding rods instead of 10-inch spikes to penetrate through the 2-foot layer of drain rock at the bottom of the basins to assure good electrical contact. These 48 electrode locations will also require ground scans and an excavation permit that WRPS will provide in support of this effort.

Once the electrodes are installed, the ERT cables will be clipped to the electrodes (two clips per takeout). These cables only have 16 takeouts so two cables are needed to cover the 32 electrode locations per line. Once installation is complete, the ERT cables will be connected to one Multiphase Technology DAS-1 unit and three corresponding multiplexers. The ERT cables, electrodes, and system are shown in Figure 5.

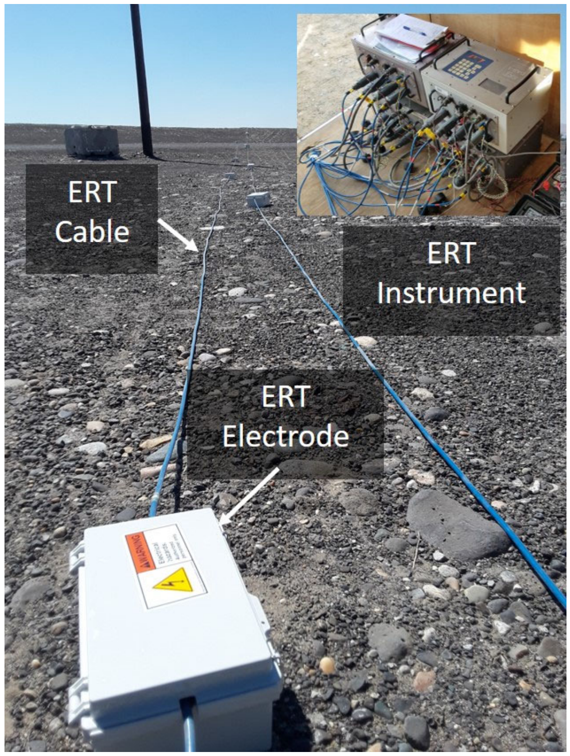

Figure 5. ERT cables, electrodes and instrumentation.

tTEM Surveys

To complement the ERT survey information, tTEM surveys will also be conducted along roads (Auken et al. 2019) only, because off-road tTEM surveys were not approved for this project. Like ERT, tTEM survey measures the BEC of the subsurface. However, they do so using electromagnetic induction sensing. Measurements are taken periodically along the tow path and each measurement is inverted to produce a 1D vertical profile of BEC. Adjacent profiles are then plotted next to each to produce a 2D cross-section. Unlike ERT surveys, tTEM survey do not require contact with the ground. However, useful tTEM data generally cannot be collected within 200 m of metallic infrastructure (pipes, tanks, fences, rail lines, power lines etc.), tTEM is not currently amenable to time-lapse or 3D imaging, and tTEM data cannot be collected or processed autonomously.

Initial test surveys were conducted at TEDF on 8/6/2021 and 8/16/2021 (see Figure 6). The tTEM was used to collect geophysical data within the basin, around the road above the basins, and on the road between TEDF and well 699-41-35 (see Figure 7).

Figure 6. Aarhus tTEM system pulled by an Argo track vehicle.

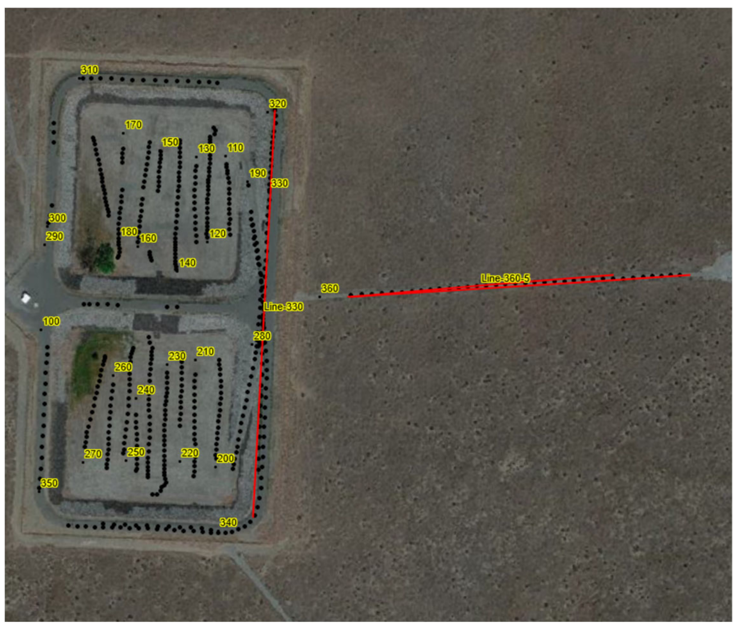

Figure 7. Map of areas where tTEM data was collected (FIO).

Large power lines near the facility and the metal fence surrounding the facility caused interference with the electromagnetic data. However, no metallic interference existed between TEDF and well 699-41-35, generating a preliminary image of the subsurface as shown in Figure 8.

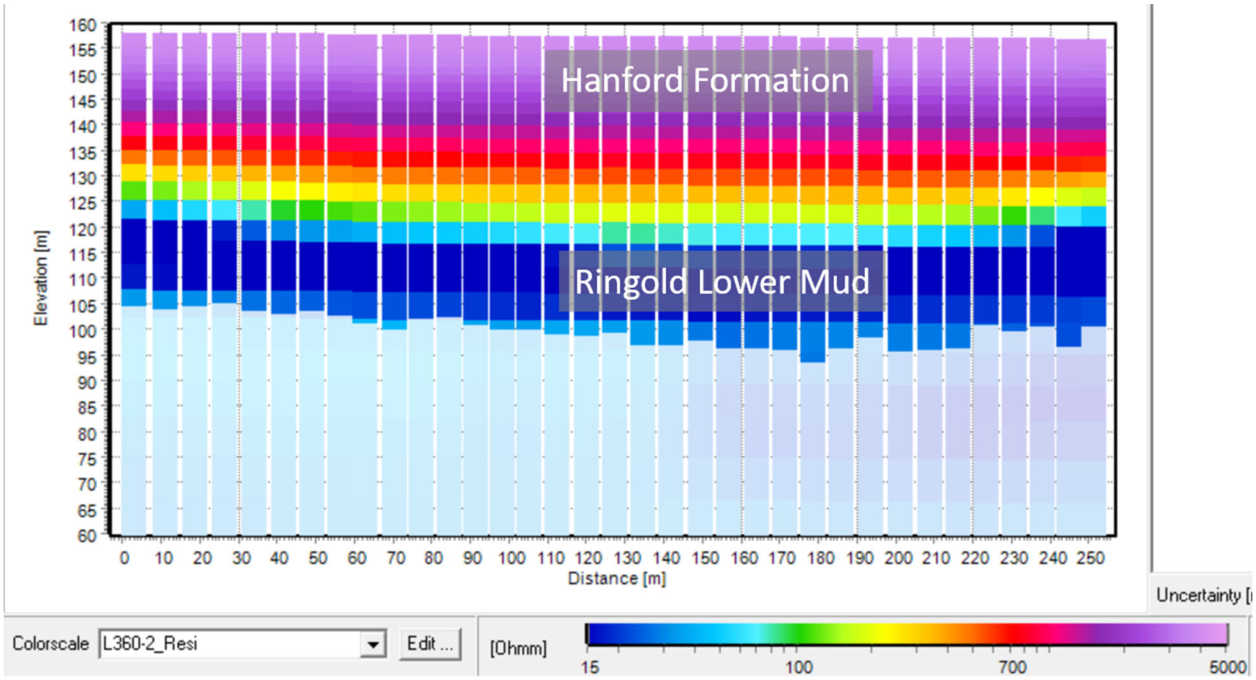

Figure 8. Preliminary tTEM data collected between TEDF and well 699-41-35 (FIO).

FY22 Activities

The baseline survey is planned for collection early in FY22 once installation of the ERT system is completed. Once the baseline survey has been completed, autonomous ERT monitoring data will be collected for several months during a large discharge event at TEDF. This large discharge event, containing Columbia River water, will be initiated by WRPS upon PNNL request.

ERT will monitor the changes in saturation within the subsurface under TEDF to determine the location of the mounded peak formed by the discharge event and the footprint of the water release as it travels through the soil profile. The highest point of the water mount will provide the optimal location for the sampling well. Images will be processed as data is collected, with two images generated per day over the monitoring time frame.

Once enough data has been collected to identify the information needed, the ERT system be demobilized and the electrode lines removed. The need for additional tTEM surveys will be evaluated once all the ERT data has been collected. Survey results will be documented in a PNNL report.

Quality Assurance

This work was performed in accordance with the Pacific Northwest National Laboratory (PNNL) Nuclear Quality Assurance Program (NQAP). The NQAP complies with the United States Department of Energy Order 414.1D, *Quality Assurance*. The NQAP uses NQA-1-2012, *Quality Assurance Requirements for Nuclear Facility Application* as its consensus standard and NQA-1-2012 Subpart 4.2.1 as the basis for its graded approach to quality.

Any data presented in this document is preliminary, for information only, and subject to revision.

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