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Addendum

Treatability Test Plan Addendum for 100-NR-2 Groundwater Operable Unit

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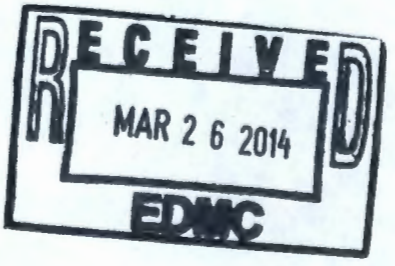
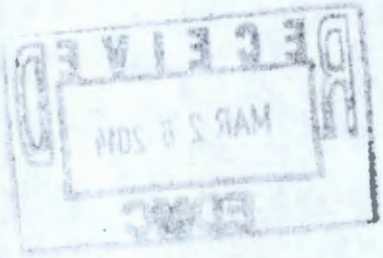


100-NR-2 Apatite Treatability Test Plan Implementation

Concurrence to proceed with the Treatability Test Plan addendum for field-scale water infiltration experiments at 100-NR-2 Groundwater Operable Unit.

K.M Thompson Date 1/05/2009
K.M Thompson
DOE/RL

D. Goswami Date 1/6/09
D. Goswami
Washington State Department of Ecology



1.0 Introduction

This addendum to the Strontium-90 Treatability Test Plan for 100-NR-2 Groundwater Operable Unit (DOE-RL-2005-96) describes the plan for conducting a preliminary field-scale water infiltration experiment in the vicinity of the apatite treatability test site. The experiment will be conducted to evaluate strategies for infiltration of Ca-citrate-PO4 solutions from near ground surface and the type of equipment needed to monitor the infiltration front.

A significant amount of Sr-90 mass (40% to 70%) in sediments along the Columbia River shoreline at 100-NR-2 is held in the variably-saturated sediments within the zone of water table fluctuation, which is driven by seasonal and diurnal variability in Columbia River stage. It is also likely that there is a higher concentration of Sr-90 in low-conductivity zones in this variably saturated zone, due to less water flushing. Development of a strategy to infiltrate the Ca-citrate-PO4 solution through this zone is currently funded by DOE/EM-22. Small-scale and 2-D infiltration experiments conducted in the laboratory (< 1.5 m) have shown that infiltration of a Ca-citrate-PO4 solution can be used to emplace apatite precipitate in specific locations in the vadose zone. Using a constant concentration and moderate to rapid infiltration rates of Ca-citrate-PO4 solution, apatite formation occurred primarily in the upper third of the infiltration zone. However, manipulation of the solution concentration and infiltration rate resulted in apatite precipitate formation over the lower half of the infiltrated zone, which is desired for field scale application. This proposed work will utilize laboratory scale results available to date and conduct preliminary field-scale water infiltration experiments.

Work elements for this project were developed based on the Statement of Work for Contract 36402, Release 35, *Apatite Infiltration Gallery Pilot Investigation at 100-NR-2.* The objectives of these preliminary field-scale water infiltration experiments are to evaluate: a) infiltration strategies and their effectiveness for distributing treatment solutions at depth (i.e., trench, drip emitters, soaker hose, etc) and b) geophysical methods and tools needed to monitor the resulting infiltration front (i.e., surface and/or crosshole electrical resistivity measurements, neutron moisture profiles, surface and/or ground penetrating radar).

Previous evaluations of the potential for infiltrating water through the roadbed fill materials overlaying the 100-NR-2 Apatite PRB site have indicated that compaction of these materials may significantly limit infiltration rates. A perc test conducted by Fluor Hanford (FH) during setup of the Apatite PRB field test site showed very low rates of percolation, although it's unclear how representative this test was of conditions that will be encountered once the upper three feet of roadbed material is removed or under a more areally distributed application scheme. Results from this project will be compared with results from the EM-22 funded bench- and intermediate-scale Ca-citrate-PO4 infiltration studies to provide a preliminary evaluation of whether the physical/hydraulic properties

of the roadbed material and underlying Hanford formation are conducive to formation of apatite minerals at depth through surface (or near surface) application of reagents. If warranted, the next phase of testing would use these results to develop a field-scale infiltration strategy for effective emplacement of apatite minerals over the depth interval of interest.

This field-scale experiment will be conducted at the downstream end of the Apatite PRB location, in the vicinity of well 199-N-137. Given the limited technical risk associated with this activity, a stand-alone treatability test plan will not be prepared. Instead, this activity will be conducted under this addendum to the Apatite PRB Treatability Test Plan, with test specifics (e.g., application approach and field setup, infiltration volumes and rates, monitoring frequency, etc.) documented in a field test instruction.

2.0 Work Elements

The following work elements will be performed during the 100-NR-2 preliminary infiltration testing.

2.1 Well Network Installation

Eight dual purpose boreholes, providing for 1) unsaturated zone monitoring through vertical Electrical Resistivity Tomography (ERT) electrode arrays, 2) access for borehole moisture logging such as neutron probe and ground penetrating radar (GPR) and 3) a short well screen for collecting aqueous samples from near the water table interface, will be installed at the proposed field test site (Figure 1). Boreholes will be installed by the cable tool method using 8-in nominal diameter drill casing. This configuration will provide sufficient room for the 4-in diameter well completions and ERT electrodes / porous cups that will be strapped to the outside of the PVC permanent well casing.

Generalized stratigraphy at the site, based on characterization data from nearby well 199-N-137, is shown if Figure 2. Expected strata include 5 to 6 ft of roadbed fill material overlying ~10 ft of coarse-grained sediments of the Hanford formation. The contact with the underlying Ringold Formation is at a depth of ~16 ft below ground surface (bgs). The water table at the site is highly variable due to changes in Columbia River stage and can range from as high as 6 or less ft bgs to 17 ft bgs or more during extreme low river stage conditions. Typical low river stage conditions will result in depths to water of around 15 ft bgs. The proposed well design provides for cross-hole ERT monitoring within the variably saturated zone while retaining the ability to collect aqueous samples at the water table under all but the most extreme low-water conditions.

2.1.1 Drilling Related Sampling

During drilling of the two boreholes located within the footprint of the infiltration gallery (Figure 1), continuous core will be collected using a split spoon sampler lined with 6-in-

long sections of lexan liner material. In addition, spectral gamma and neutron moisture logs should be conducted on these boreholes. For the remaining 6 boreholes, no sediment

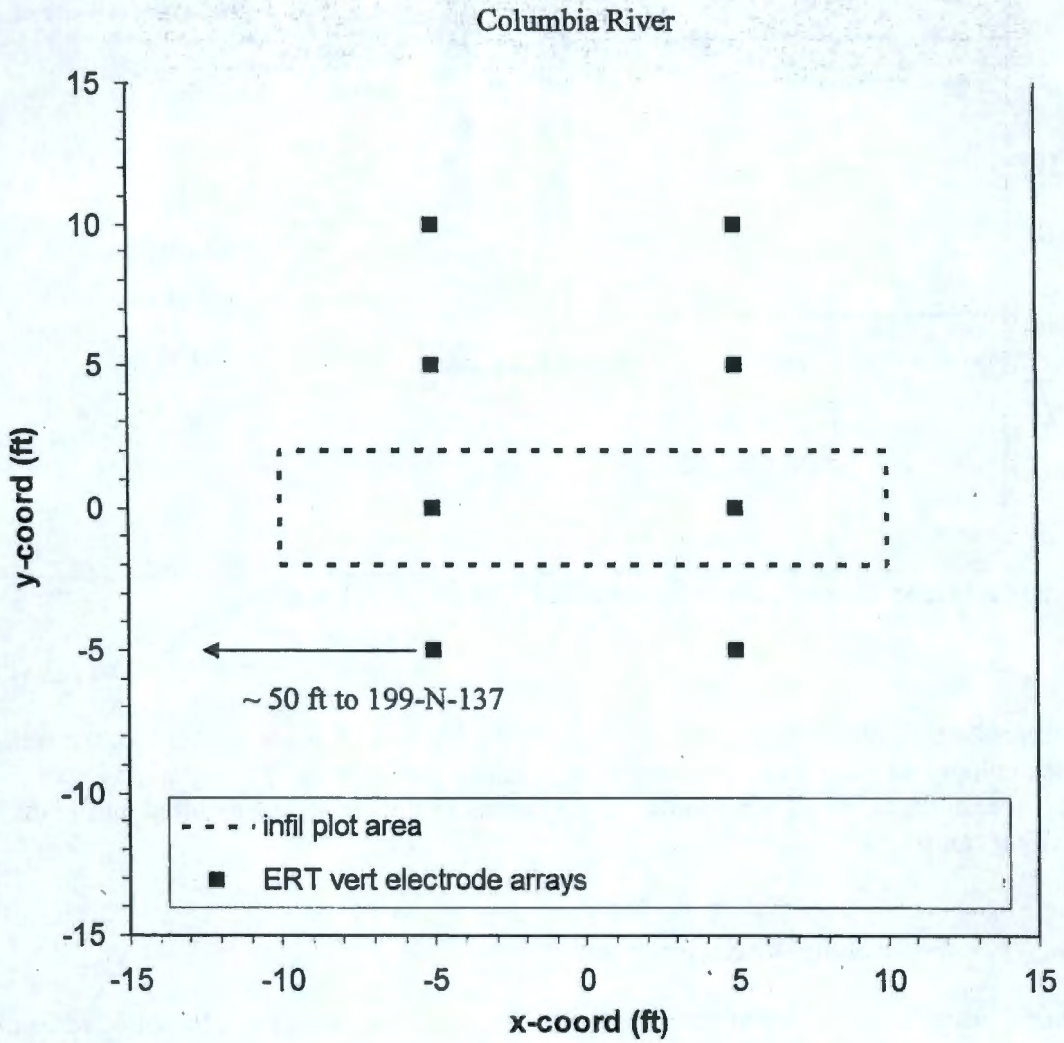


Figure 1. 100N Infiltration Experiment Well Layout Diagram

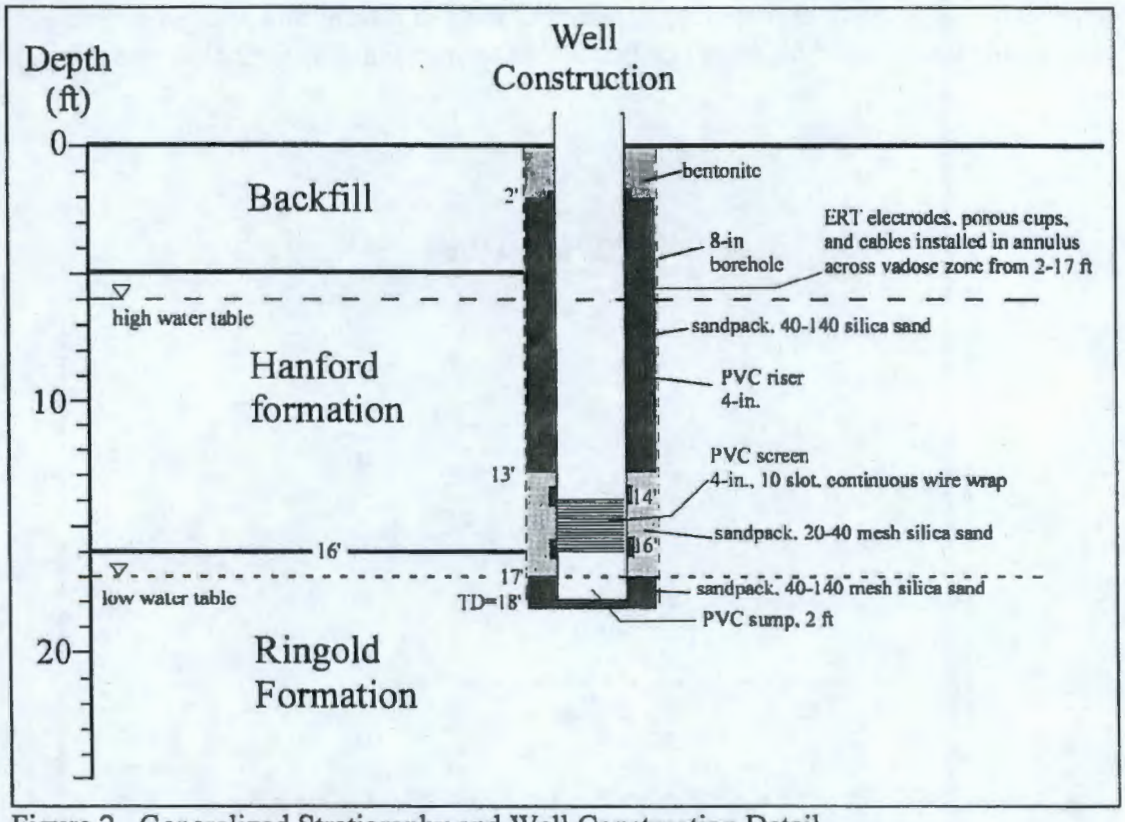


Figure 2. Generalized Stratigraphy and Well Construction Detail

sampling or geophysical logging will be required. However, it is important for the well-site geologist to produce a comprehensive, detailed geologic and photographic log of borehole cuttings for all 8 boreholes. No aqueous sampling will be required during the drilling campaign.

2.1.1.1 Sediment Sampling Requirements

During installation of two of the eight boreholes, continuous core will be collected from ground surface to total depth. Four-inch (ID) core will be collected in 2 to 5 ft long runs; the split-spoon sampler will be lined with precut 0.5 ft long lexan liner sections. Upon retrieval of the sampler, the ends of each 0.5 ft core segment will be photographed and capped and the liner labeled according to depth and well number. The core sections will also be labeled with an "up" arrow indicating core orientation. Once the core section has been appropriately labeled, end caps will be securely taped to prevent them from coming off during transport or storage. Once samples have been collected, they will be transported to a PNNL laboratory for processing and analyses (see Section 2.3).

2.1.1.2 Geophysical Logging

Once the two boreholes that are being continuously cored have been advanced to total depth, they will be logged from inside the temporary steel casing using the total and spectral gamma, and neutron moisture geophysical logging tools. The gross and spectral gamma logs will be run at a 6-inch vertical resolution, using 200 second count times, while neutron moisture log will be run at 3-inch vertical resolution.

2.1.2 Well Construction Detail

The wells shown in figures 1 and 2 will be permitted as temporary installations and will be decommissioned once testing has been completed. This approach is being proposed for several reasons including 1) ERT electrodes and neutron probes that will be used to monitor advancement of the wetting front would be negatively impacted by either a bentonite or grout annular seal so a fine sand annular fill material will extend across the vadose zone to within ~ 2 ft of ground surface, 2) adopting a temporary installation approach will save on costs associated with installing surface vaults and may offset the cost of decommissioning the piezometers, 3) given the shallow installations and limited seal material, there's a relatively good chance that the casing strings could be pulled intact, or partially intact, at completion of the test, which may allow for reclamation of the ERT electrodes for future use, and 4) this approach should simplify decommissioning of the borehole since it will likely remain open across the roadbed material once the casing material is pulled.

A total of 8, 4-in diameter, Schedule 40, PVC-cased wells will be drilled and completed to a total depth of approximately 18 ft (see Figure 2). These wells will have a dual purpose of providing: 1) access for installation of ERT electrodes and other subsurface point sensors on the exterior of the PVC casing; and 2) access for groundwater monitoring. ERT electrodes, cables, and wires will be installed within the annulus, attached to the outside of the PVC casing and screen (Figure 2). Porous cups and associated sample collection tubing will also be attached to the outside of the casing.

After the borehole is drilled to a total depth of 18 ft, a 2.5-ft long, 4-in. (ID), 10-slot, continuous wire-wrap PVC screen (actual screen open area length = 2 ft) will be installed with the screen interval extending from 14 to 16 ft bgs. Actual screen depth may be adjusted in the field based on stratigraphy encountered during advancement of the borehole. Attached to the bottom of the screen will be a section of blank casing and end-cap that together form a 2-ft-long sump. PVC casing (4-in diam.) will extend from the top of the screen to approximately 0.5 ft above ground surface. Annular fill material will consist of 20-40 filter pack sand to 1 ft above and below the screen (13 - 17 ft bgs), 40-140 sand from TD to 17 ft bgs and from 13 ft to ~2 ft bgs, and bentonite to ground surface. For the two wells installed within the footprint of the infiltration gallery, the 2 ft bentonite seal at the surface should not be installed. Instead, a 3-ft-long section of carbon steel protective casing should be left in place to protect the PVC casing during excavation

of the trench. Due to the temporary nature of these wells, no surface completion will be required.

2.2 Trench Excavation

CHPRC will contract for backhoe services to excavate a trench of finished dimensions of 20 ft long by 4 ft wide by 3 ft deep (Figure 1 and 3). Care should be taken by the contractor to provide a relatively flat final trench bottom surface and any additional compaction of the material should be minimized. Trench sides should be sloped as required to meet any applicable slope stability criteria and limit any sloughing of material back into the trench. Once completed, the trench bottom should be backfilled with 4 to 6 inches of pea gravel.

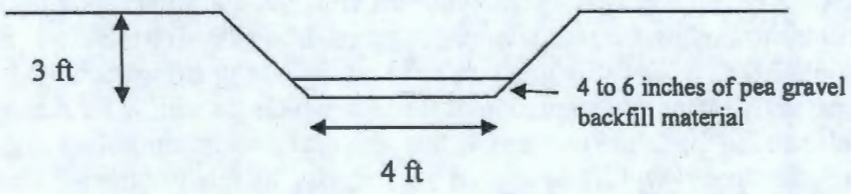


Figure 3. Generalized Trench Construction Diagram (cross section).

2.3 *Sediment Core Physical Property Analysis*

Measurements of saturated hydraulic conductivity (Ksat) will be made on 4 samples (two roadbed, two Hanford). The Ksat measurements will be made on the intact cores using either the constant head or falling head method (Reynolds and Elrick, 2002). The constant head method is usually preferable for coarse, high permeability sediments while the falling head method is typically used for sediments of relatively low to moderate permeability. Hanford formation sediments are usually very coarse and highly permeable, but the compacted road-bed materials may have very low hydraulic conductivities. Therefore we will use whatever method is most well-suited to the materials. Measurements of relative permeability-saturation-capillary pressure (k-S-P) relations will be made on the same samples that are used for Ksat measurements using the multi-step outflow method (Dane and Topp, 2002) with an automated measurement system (Figure 4) housed in EMSL's Subsurface Flow and Transport Experimental Laboratory (SFTEL). Larger diameter columns and end plates for the apparatus depicted in Figure 4 will be machined, as necessary, to accommodate very coarse samples. The bulk density, particle density, and porosity of the cores on which these Ksat and k-S-P measurements are made will also be determined. Following completion of the Ksat and k-S-P measurements, particle-size analyses will be performed on the samples using wet sieve and hydrometer methods. This same particle size analysis will be performed on the remaining core samples collected.

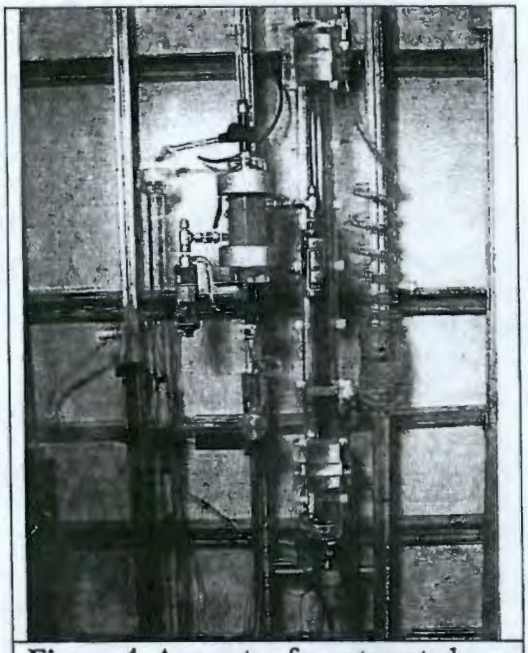


Figure 4. Apparatus for automated, laboratory measurement of sediment hydraulic properties (k-S-p relations) in EMSL (SFTEL).

2.4 *Infiltration Monitoring Systems Design and Setup*

Initial logging of moisture content in the boreholes will be performed in the temporary well casing by Stoller. Post-completion logging prior to and during infiltration experiments will be performed using a Campbell-Pacific, Inc. neutron hydroprobe and a ground penetrating radar system, both of which are owned by PNNL. Independent calibrations will be developed to calculate volumetric water contents from count data obtained using PNNL's neutron probe.

Quantitative spatial and temporal information on the infiltration process will be obtained using GPR and ERT measurements. Four surface GPR lines will be collected between the vertical electrode arrays (Figure 1) in a direction parallel to the river to obtain quasi-3D snapshots of the infiltration front. GPR data will be acquired with 100-MHz antennas to maximize signal penetration depth. Each GPR line will be acquired with 0.5-m trace

spacing and 2-m antenna separation and a sampling frequency of 2 ns. Based on similar surveys on the Hanford Site, the initial acquisition protocol will use a time window of 800 ns and 32 stacks per trace but may need to change depending on site conditions. Data will be post-processed to remove any low-frequency EM interference and unwanted noise. 2-D radar velocities along each line will be converted to dielectric constants, which in turn will be converted to volumetric water content using the Topp equation. Four such surveys are planned, one prior to the start of the infiltration test to quantify initial conditions, two during the test to obtained 2-D snapshots of the moisture distribution, and one after completion of the test to quantify redistribution.

ERT measurements are typically made by applying a DC voltage over two current electrodes and subsequently measuring the voltage across another two electrodes, the potential electrodes. By using a system that allows the automatic switching of current and potential electrodes across multiple electrodes placed in the soil (i.e., a multi-channel system) numerous measurements can be made automatically without the need to physically move electrodes or cables. The ERT data will be acquired with an automated multi-channel system using a combination of surface and borehole electrodes. Four lines will be staked out using a standard measuring tape and plastic pin flags, with electrodes spaced at 5-m intervals along each transect. Each transect will run between the boreholes (Figure 1) parallel to the river. Electrodes will be 18-in long and constructed from commercial-grade copper grounding rods. Subsequent to electrode installation, each electrode location will be surveyed on a Receptor Tyrosine Kinase (RTK) global positioning system (GPS) to obtain its spatial coordinates which is needed for data processing. The electrodes will be connected to the resistivity meter, via a multiplexer, using a multi-conductor cable. This system will be used to collect both DC resistivity and induced polarization data. Time lapse resistivity measurements will provide quantitative information on the progress of the infiltration front whereas induced polarization measurements may provide insight into geochemical changes, such as precipitation, that change the exchange capacity and surface area to pore volume ratio. Resistivity data will be processed using the commercially available RESD2INV software. Depending on scheduling, it may be necessary to rent a resistivity system to perform the measurements.

2.5 Infiltration Experiment

Information and analysis results from several sources will be used to develop an infiltration design for this field-scale water infiltration experiment, including 1) EM-22 funded bench- and intermediate-scale infiltration experiments and supporting modeling effort, 2) improved site specific hydraulic property estimates obtained from the analyses discussed in section 2.3, and 3) geophysical measurements performed during the drilling campaign. Application volumes and rates will be specified based on results from design simulations that incorporate these site specific characterization data. Test specifics for the infiltration experiment (e.g., application approach and field setup, infiltration volumes and rates, monitoring frequency, etc.) will be documented in a field test instruction prepared prior to the start of field activities.

3.0 Quality Assurance

The work elements described in the TTP addendum will comply with applicable subject areas of the PNNL SBMS. SBMS is a web-based system for communicating PNNL's management systems and procedures through subject areas. PNNL's Quality Assurance Program is based on the requirements of DOE Order 414.1C, *Quality Assurance,* and 10 CFR 830, Subpart A, *Quality Assurance Requirements*. Additional project specific QA requirements are provided in the Columbia River Protection Quality Assurance Project Plan (PNNL 2008).

Currently, there exists no ASTM or community-accepted QA/QC standards for electrical resistivity tomography. However, the Environmental Protection Agency and USGS have developed recommendations of "best practices" for both resistivity tomography field procedures and data-analysis. This document outlines the collection of reciprocal or repeat data to quantify measurement errors; selection of data-collection parameters such as number of stacks and time windows; checks for outlier data and bad electrodes or channels; and selection of inversion parameters to prevent overfitting/underfitting of data.

In relation to the procurement of instruments (including rental equipment), it is advised to use equipment or components that are listed by a nationally recognized testing laboratory (NRTL) whenever possible. On arriving on the site, all electrical equipment and instruments are inspected by a qualified electrical worker responsible for and/or with knowledge of the equipment. The equipment is powered for testing and the qualified electrical worker follows the appropriate diagnostics and testing procedure in the *Electrical Equipment and Systems, Working on or near* subject area from SBMS. The findings of this inspection are documented using the Electrical Safety Design Criteria Checklist and forwarded to Electrical Safety for approval prior to acceptance and use of the equipment in the field.

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