NYE COUNTY NUCLEAR WASTE REPOSITORY PROJECT OFFICE

TEST PLAN

TITLE: **Constant Head Saturated Hydraulic Conductivity Measurements on Repacked Core Samples**	REVISION: **0** DATE: **4-1-04** PAGE: **1 of 8**

TEST PLAN NUMBER: **TPN-8.1**	SUPERSEDES: **None**
APPROVAL 4-13-04 Project Manager — Date	CONCURRENCE 4/13/04 On-Site Geotechnical Representative — Date 4/13/04 Principal Investigator — Date 4-13-04 Quality Assurance Officer — Date

1.0 INTRODUCTION

This Nye County Nuclear Waste Repository Project Office (NWRPO) test plan (TPN) provides detailed instructions for repacking unconsolidated sonic core samples to target dry bulk densities and measuring the saturated hydraulic conductivity of the repacked samples by a constant head method. The sonic core samples were collected from NWRPO Early Warning Drilling Program (EWDP) sonic corehole NC-EWDP-19PB.

General procedures for sample collection, management, and laboratory testing are presented in TPN-5.1, *Construction of Sonic Corehole NC-EWDP-19PB.* Laboratory testing procedures include references to a number of industry-standard methods published by the American Society for Testing and Materials (ASTM) and the American Society of Agronomy (ASA). Procedures for repacking and testing sonic core samples not presently found in these standard methods are detailed in this TPN.

2.0 PURPOSE AND JUSTIFICATION

The U.S. Department of Energy (DOE) has identified the saturated alluvium in Fortymile Wash as a potential groundwater flow pathway from the proposed high-level radioactive nuclear waste repository at Yucca Mountain to groundwater users in Amargosa Valley. Nye County believes that collecting continuous core from the upper portion of the alluvial aquifer in NC-EWDP-19PB and conducting hydraulic tests on the core are necessary and important steps towards identifying potential preferential flow pathways and providing small-scale estimates of flow and transport properties. Data from such tests will support and complement the flow and transport data obtained on a much larger scale from single- and cross-hole tracer tests and high-rate, high-volume aquifer pump tests.

Although sonic core samples provide a continuous record of textural layering in alluvial sediments, core density and porosity are significantly disturbed from in situ conditions. Therefore, porosity-dependent parameters, such as saturated hydraulic conductivity, are also disturbed. This TPN describes procedures for repacking disturbed core to bulk densities and porosities similar to those found in situ, and provides details for testing the repacked core to determine saturated hydraulic conductivity and related parameters.

3.0 SCOPE OF WORK

3.1 Responsibilities

The On-Site Geotechnical Representative is the designated Principle Investigator (PI) and is responsible for supervising all data collection described in this TPN. NWRPO personnel, including contract geologists and technicians, are responsible for conducting the activities described in this TPN.

3.2 Laboratory Location

All work shall be conducted at the NWRPO testing laboratory in Pahrump, Nevada.

3.3 Overview

The procedures presented in this TPN are based on industry-standard methods to the extent possible. Specifically, saturated hydraulic conductivity testing methods are based on standards published by ASA (Klute and Dirksen, 1986) and water content measurements are based on ASTM method D-2216-98 (ASTM, 2003). Repacking methods for sonic core have been developed by the NWRPO for this TPN.

The ASA method and ASTM D 2216-98 are included in the NWRPO laboratory procedures manual (NWRPO, 2004), which describes procedures for handwritten and electronic data entry and recording other pertinent information in the laboratory scientific notebook, as specified in NWRPO quality administrative procedure QAP-3.2, *Documentation of Technical Investigations.*

The manual also includes a health and safety plan for the testing laboratory, which shall be followed by all laboratory personnel.

The following summarizes the repacking and measurement steps detailed in sections 3.10 through 3.16.

- The PI selects a representative depth interval(s) of unconsolidated sonic core for testing.
- Geologic sediments from each depth interval are repacked in tubing or piping of lengths and diameters specified by the PI to target dry bulk densities.
- The repacked sample is incorporated into a flow cell, which is vacuum-saturated with a test solution.
- A constant head supply reservoir is connected to the bottom of the flow cell and an outflow reservoir is connected to the top.
- A constant hydraulic head difference (i.e., the difference between the free water surfaces in the supply and outflow reservoir systems) is applied across the sample in the flow cell.
- Outflow volumes of test solution are calculated over measured time intervals by weighing the mass of the outflow.
- Saturated hydraulic conductivity is calculated from the hydraulic gradient, volumetric flow rate, and cross-sectional area of the sample, using Darcy's Law for one-dimensional vertical flow.
- The saturated volumetric water content of the repacked sample is calculated from mass measurements and volume calculations made during sample preparation and flow-cell setup procedures.

3.4 Equipment and Chemical Requirements

The equipment required to measure saturated hydraulic conductivity shall be used according to manufacturers' specifications or methods detailed in this TPN, and includes the following:

- Drying oven, to determine gravimetric water content of air-dried geologic samples.
- Factory-calibrated digital thermometer.
- Weighing balance, for geologic sample preparation, test solution preparation, and outflow measurements. The weighing balance requires calibration.
- Sample splitter, for dividing samples into equal and representative portions.
- Sample tamper of approximately 5-kilogram (kg) mass, for sample compaction.
- Rigid-wall flow cells with watertight top and bottom diffuser caps.
- Constant head solution supply reservoir (i.e., container).
- Solution outflow reservoir (i.e., container).

In addition, the following chemicals are required:

- Calcium sulfate.
- Thymol, or other biologic activity inhibitor.
- Distilled water.

3.5 Equipment Calibration

Weighing balances shall be calibrated according to manufacturers' requirements and the data recorded in the laboratory scientific notebook. Drying-oven temperatures shall be checked with a factory-calibrated digital thermometer before samples are dried.

3.6 Laboratory Safety

The laboratory health and safety plan shall be followed by all laboratory personnel. Chemicals shall be handled safely; material safety data sheets (MSDSs) shall be used to determine whether special protective clothing and/or eye protection are required. Hazardous chemical wastes shall be disposed of properly.

3.7 Environmental Conditions

Saturated hydraulic conductivity measurements are temperature-dependent and shall be conducted in a temperature-controlled environment.

All samples shall be stored to minimize water evaporation and biological activity. Sample container material shall be chosen to avoid contamination and the potential sorption of constituents to the container walls.

If the PI specifies additional testing outside the scope of this TPN, flow cells shall be sealed at the inflow and outflow ends and stored in a cool environment to reduce biological activity until the additional testing can be conducted.

3.8 Chain of Custody

The transfer of samples from the DOE Sample Management Facility to the NWRPO laboratory shall be controlled and documented with the NWRPO Transfer-of-Custody Form. Samples shall be maintained under custody at all times, either in view of the current holder or secured in locked storage. Sample identification and control shall ensure that a sample and its derivatives can be traced from its original field location to the point of analysis and that the integrity of the sample has been safeguarded during the analytical process.

3.9 Sample Interval and Target Bulk Density Selection

Prior to repacking and analysis, the PI shall select representative depth interval(s) of unconsolidated sonic core samples for testing and specify target dry-bulk densities for repacking the samples. Approximately 15 samples, covering the range of particle-size distribution found in well NC-EWDP-19PB, shall be selected for testing. Target dry bulk densities shall be based on in situ density measurements described in TP-8.0, *Field Collection, Logging, and Processing of Borehole Samples*.

3.10 Sample Repacking

The process described in this section yields reasonably reproducible repacking results for coarse-textured unconsolidated sediments such as those found in or near Fortymile Wash. The following steps assume that 1) sample materials shall be repacked in 12-inch-long by 6-inch Schedule 40 PVC tube segments, with four 3-inch-thick lifts in each, and 2) if the dimensions of the PVC tube or lift thickness are altered, quantities listed in the following steps shall be modified and the modifications documented in the laboratory scientific notebook.

1. Determine the subinterval of core necessary to yield an approximately 18-kg sample, using the sample interval selected by the PI.
2. Remove the subinterval from the core box and air dry. To achieve target dry bulk densities corresponding to highly compacted sediments, it may be necessary to air dry to a gravimetric water content of approximately 5 percent, rather than the typical 1 or 2 percent. This added water content facilitates compaction of coarse-grained sediments. Alternatively, core material can be rewetted to approximately 5 percent water content from a completely air-dried state.
3. Use a sample splitter to divide the air-dried sample into six representative 3-kg subsamples.
4. Determine the gravimetric water content of one of the subsamples, using ASTM D-2216-98. Four of the subsamples will be used for repacking, and the remaining one will serve as a backup.
5. Calculate the sample mass necessary to achieve the target dry bulk density for each 3-inch-thick lift.
6. Split each subsample into the smaller sub-subsamples required to achieve the calculated sample mass described in step 5.
7. Add enough of the sub-subsample to the PVC tube to achieve an approximately 1.5-inch-thick lift. Care should be taken to emplace each sub-subsample in such a way that particle-size fractions are homogenized to the extent possible.
8. Use the sample tamper to achieve preliminary compaction of this approximately 1.5-inch sublift by dropping the tamper 10 times from a height of approximately 6 inches above the sample.
9. Add remaining sub-subsamples required to complete the 3-inch lift and compact as described in step 8.
10. If compaction is not sufficient to achieve the target dry bulk density (i.e., the sample lift thickness is greater than 3 inches), continue dropping the tamper either until target density is reached or 20 times more.
11. In cases where it is not possible to achieve a 3-inch-thick lift with the calculated amount of sample material, remove or add material as necessary. The particle-size distribution of the added or removed material should be as representative as possible of the whole sample. Record the mass of added or removed material and use the result to recalculate the dry bulk density when repacking is complete.

12. Repeat steps 6 through 11 for the three remaining lifts.

3.11 Test Solution Preparation

1. Prepare the test solution with distilled water, calcium sulfate, and thymol, according to the ASA method (Klute and Dirksen, 1986).
2. De-aerate the test solution with a vacuum generated by an aspirator or vacuum pump.

3.12 Setup and Sample Saturation

1. Determine the mass of water that can be contained in the end cap diffusers; this mass will be used to calculate saturated volumetric water content.
2. Place a rigid plastic screen and watertight diffuser on each end of the PVC tube containing the repacked sample.
3. Determine the mass of the entire flow cell described in step 2; this mass will be used to calculate saturated volumetric water content.
4. Place the flow cell in a vacuum chamber, apply a vacuum, and slowly raise the test fluid level in the chamber to saturate the sample from the bottom upward.
5. Remove the saturated flow cell from the vacuum chamber and attach the constant head supply reservoir system (Klute and Dirksen, 1986) to the bottom end cap, taking care not to introduce air bubbles.
6. Attach the outflow reservoir to the top of the saturated flow cell.

3.13 Test Run

1. Adjust the hydraulic head difference across the repacked sample (i.e., the difference in elevation of the free water surfaces in the supply and outflow reservoirs) to obtain an outflow of between 25 and 250 grams of test solution per hour. For highly permeable samples, attempt to keep the hydraulic head difference less than 1 foot (i.e., a hydraulic gradient of less than 1).
2. Collect the test solution outflow for a length of time that yields at least several hundred grams of test solution.
3. Record the hydraulic head difference and the temperature of the outflow at the start and end of each test run.
4. Repeat steps 1 through 3 for five to ten test runs. Test runs may be terminated when three consecutive runs show little change in saturated hydraulic conductivity values.
5. Determine the mass of the collected test solution at the end of each test run.
6. Convert this mass to volume, using the density of the test solution (i.e., the mass of the solution-filled volumetric flask) at the average temperature of the test run.

3.14 Saturated Hydraulic Conductivity Calculation

1. Calculate the saturated hydraulic conductivity for each test run from the average hydraulic gradient (i.e., the average of the hydraulic head difference divided by the sample length), the volumetric flow rate, and the cross-sectional area of the sample using Darcy's Law for one-dimensional vertical flow, as specified in Klute and Dirksen (1986).
2. Average the last three consecutive saturated hydraulic conductivity values that show little variation and record the average to two significant figures as the saturated hydraulic conductivity of the repacked core.

3.15 Saturated Volumetric Water Content Calculations

1. Disconnect the flow cell from the supply and outflow reservoirs. Determine the mass of the saturated core plus the flow cell.
2. Calculate the mass of the solution in the saturated sample by subtracting the mass of the flow cell containing the oven-dried sample plus the mass of solution in the end cap diffusers from the mass of the solution-filled flow cell and core.
3. Using the density of the test solution at the temperature of the solution in the flow cell, convert the mass of solution in the sample to volume.
4. Calculate the volumetric water content by dividing the volume of water in the sample by the volume of sample in the PVC tube.

3.16 Data Acquisition and Reduction

Sample repacking and saturated hydraulic conductivity test run data shall be manually recorded on scientific forms and entered into the laboratory database.

4.0 ERROR AND UNCERTAINTY

Potential sources of error and uncertainty in the saturated hydraulic conductivity measurements described in this TPN include the following:

- If repacking separates particle-size fractions (e.g., coarse gravel is consistently packed against the wall of the PVC tube or fines are deposited at the base of a lift), preferential flow paths or barriers may develop. This situation can usually be avoided by repacking with relatively small subsamples, each with representative particle-size distributions, and taking care to homogenize these materials in the PVC tubes before compaction.
- Trapped air may block flow paths; such air may be minimized by slow vacuum saturation of the sample, using de-aerated water for the test solution, and minimizing the effect of the bubble tube in the constant head reservoir system (Klute and Dirksen, 1986).
- Biologic activity can increase resistance to flow. Keeping the test solution saturated with thymol or other biologic activity inhibitor and de-aerated will help minimize this resistance. In addition, storing and conducting tests on core in a temperature-controlled environment will minimize the impact of elevated temperatures on biological activity.

- Wide temperature fluctuations can result in significant error in hydraulic conductivity values. This problem can be minimized by conducting tests in a temperature-controlled environment.
- High flow rates in coarse-grained samples may result in situations where Darcy's Law does not apply, which can in most cases be avoided by keeping the hydraulic gradient less than 1 in highly permeable samples.
- Redistribution of extremely fine-grained material in the columns under flowing conditions can cause the hydraulic conductivity of some sediments to decrease with time. If this decrease occurs, it may be difficult to achieve three consecutive measurements that show little variation. Systematic decreases in apparent hydraulic conductivity should be noted and the plastic screen at the column exit examined for entrapment of fines after tests exhibiting this behavior.

5.0 RECORDS

Documents generated by this TPN are QA records and shall be submitted to the QARC by the responsible individual in accordance with QAP-17.1, *Records Management*.

The QA records generated by this TPN include the following:

- Data-entry forms.
- Laboratory scientific notebook.
- Laboratory database.

6.0 REFERENCES

ASTM. 2003. ASTM D-2216-98, "Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass." In: *Annual Book of ASTM Standards,* Vol. 04.08, American Society for Testing and Materials, 2003.

Klute, A. and C. Dirksen. 1986. "Hydraulic Conductivity and Diffusivity: Laboratory Methods." In: Klute, A. (ed), *Methods of Soil Analysis,* Part 1, Physical and Mineralogical Methods (2nd ed.), American Society of Agronomy, Chapter 28, pp. 687-700.

NWRPO. 2004. *Procedures for the NWRPO Rock Hydrologic Testing Laboratory*, Nuclear Waste Repository Project Office, Pahrump, Nevada. March 2004.

NWRPO. 2004. *Health and Safety Plan for NWRPO Hydrologic Rock Testing Laboratory*, Nuclear Waste Repository Project Office, Pahrump, Nevada. March 2004.

QAP-3.2, *Documentation of Technical Investigations*.

TPN-5.1, *Construction of Sonic Corehole NC-EWDP-19PB*.

TP-8.0, *Field Collection, Logging, and Processing of Borehole Samples*.

7.0 ATTACHMENTS

Not applicable.