

**Mock-Up Activities for the Extraction of Samples from a Saltstone Disposal Unit – 15502**

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**ABSTRACT**

Mock-up testing with respect to the core-drilling of simulant saltstone grout was conducted to support the future retrieval of field-emplaced saltstone samples from Saltstone Disposal Unit (SDU) Cell 2A. The primary objectives of extracting samples from SDU Cell 2A are to enable measurement of field-emplaced samples with respect to properties that influence long-term performance, such as saturated hydraulic conductivity, and to compare the measured properties for field-emplaced and comparable samples prepared in the laboratory.

Initial mock-up activities (Phases 1 & 2) were conducted in Fiscal Years (FY) 2013 and 2014 in order to demonstrate the viability of standard core-drilling techniques that are typically employed for sampling concrete structures. The primary requirement for the core-drilling technique was that it should minimize the potential of physical or chemical sample changes that would artificially degrade key grout properties. Mock-up activities were aimed at optimizing the techniques for core-drilling, and subsequent sample extraction, using a set-up that mimicked, to the extent practical, both the physical characteristics, and operational complexities, of core-drilling saltstone grout from the roof of the SDU.

Samples extracted from the grout monolith were subsequently characterized with respect to saturated hydraulic conductivity and compressive strength, and compared to data for cast samples prepared using the same simulant saltstone material. The comparison of these properties for the two sample types was expected to highlight potential flaws (e.g., micro-cracking) introduced by the core-drilling process. While the data for saturated hydraulic conductivity were virtually identical (approximately  $2E-09$  cm/sec), the compressive strength of the core-drilled samples (approximately 3.5 MPa (500 psi)) was on average half that measured for the cast samples. It was suspected that increased water saturation and surface scoring of the core-drilled samples might account for the disparate compressive strength data.

During Phases 1 & 2 it was determined that cores could be successfully drilled and extracted to a depth of approximately 0.9 meters (3 feet) below the grout surface. Phase 3 (FY2105) has been initiated and is primarily directed at demonstrating the ability to core-drill through approximately 1.8 meters (6 feet) of overlying grout to retrieve the desired sample from the SDU. The original drill depth of 0.6 – 0.9 meters (2-3 feet) was based on an SDU fill height of 5.6 meters (18.5 feet) and sample location of approximately 4.9 meters (16 feet); recently the allowable fill height in the SDUs has been increased to 6.5 meters (21.25 feet); hence the increased depth of overlying grout above the samples to be retrieved.

## INTRODUCTION

This paper documents Saltstone Disposal Unit (SDU) core-drilling mock-up tests conducted at the Savannah River Site (SRS) to support the future retrieval of field-emplaced saltstone (grout) samples from SDU Cell 2A. The primary objectives of extracting samples from the SDU are:

1. To enable measurement of field-emplaced saltstone samples with respect to saturated hydraulic conductivity and contaminant (most notably technetium ( $^{99}\text{Tc}$ )) leaching behavior, both of which serve as key inputs to the time-dependent contaminant transport models utilized in the Saltstone Disposal Facility (SDF) Performance Assessment (PA) [1].
2. To establish a correlation of the aforementioned properties for field-emplaced samples and laboratory-prepared simulant samples, which would validate the past and future use of data derived using saltstone simulant processed and cured in the laboratory.

To date two phases (FY2013 and FY2014) of the core-drilling mock-up have been conducted, and a third and final phase is currently in progress prior to the planned extraction of “actual” samples from SDU Cell 2A in the Spring of 2015. The first phase of mock-up testing was designed to mimic the physical complexities of core-drilling atop an SDU, to compare wet and dry core-drilling techniques, and to determine potential impacts from core-drilling on key properties of saltstone, such as saturated hydraulic conductivity. The second phase was primarily associated with further optimization of the core-drilling process, and demonstrating that the cored samples could be consistently retrieved from the core holes without imparting damage. Phase 3 will entail demonstrating the ability to core through approximately 1.5-1.8 meters (5-6 feet) of overlying sample to retrieve the sample from the desired height in SDU Cell 2A, and to establish handling, storage, and analyses protocols for the extracted samples. The grout elevation in SDU Cell 2A is 6.5 meters (21.25 feet), and no future additions will be made to this SDU. The samples to be extracted are positioned around the 4.9-meter (16-foot) elevation in the SDU; hence the need to drill through over 1.5 meters (5 feet) of overlying grout to reach the samples of interest. The subsequent text will summarize the key attributes and findings from Phases 1 and 2, and also discuss the intent of the final Phase 3.

## METHODS

### Phase 1 (FY2013)

#### *Processing Simulant Saltstone*

The simulant saltstone composition utilized for Phase 1 of the core-drilling mock-up was based on an average Tank 50 composition, the nominal dry feed mixture of 45-45-10 (wt%) ratio of fly ash (FA), blast furnace slag (BFS), and ordinary Portland cement (OPC), and a water to cementitious materials (w/c) ratio of 0.6. Saltstone components were mixed in the Scaled Continuous Processing Facility (SCPF) at Savannah River National Laboratory (SRNL) to produce approximately 2,650 liters (700 gallons) of simulant saltstone that was poured into a B-25 container (1.8 meters (L) x 1.2 meters (W) x 1.2 meters (H)) (6 feet (L) x 4 feet (W) x 4 feet (H)) (Figure 1). The SCPF was developed by SRNL to complement traditional small-scale laboratory testing of saltstone and to provide processing that more closely simulates actual SPF operations. Saltstone was added to the B-25 container in daily lifts of 20-23 centimeters (8-9 inches) to a total height of approximately 1.07 meters (42 inches). This pouring characteristic was intended to simulate actual pour lifts (and the resulting lift joints) in an SDU. The grout monolith was cured for approximately 60 days at ambient temperature. The lid on the B-25 was sealed to maintain a humid environment within the container.

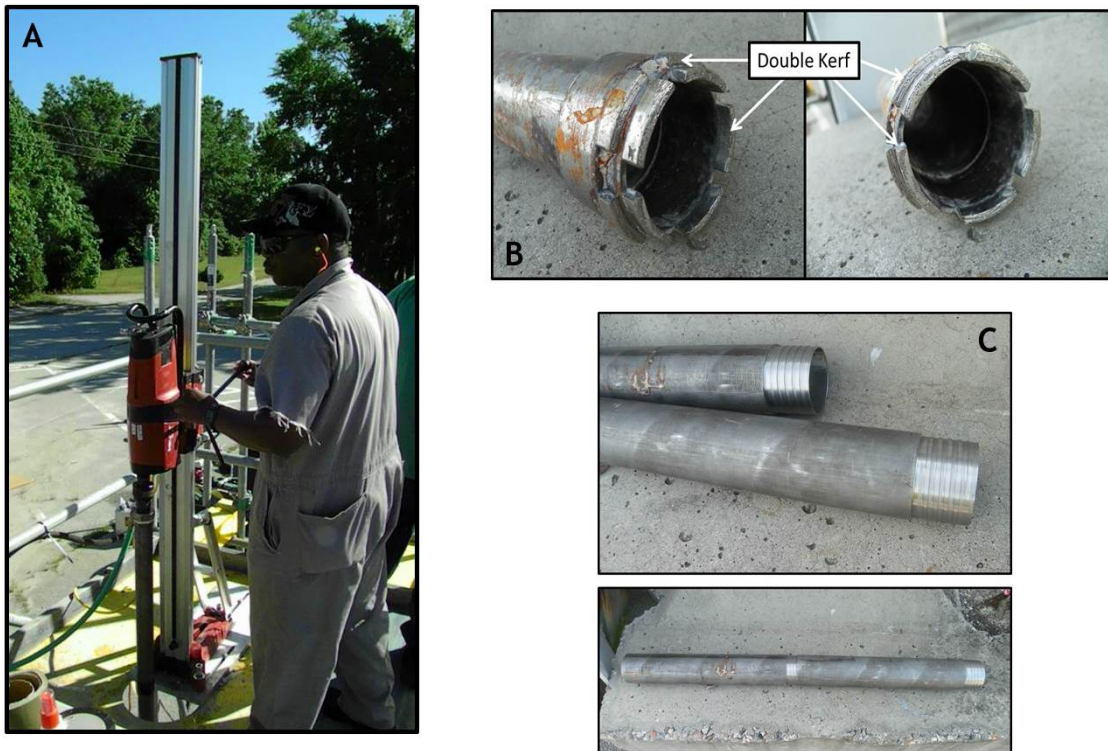


**Figure 1:** Photos illustrating the filling of a B-25 container with simulant saltstone.

### ***Core-Drilling***

The following primary equipment was utilized for core-drilling the simulant saltstone monolith:

- Hilti Model No. DD 200 Diamond Coring System (Figure 2A)
- 5.1-centimeter (2-inch) internal diameter (ID) threaded diamond core bits modified to cut a wider kerf to enable insertion of core retrieval tools (Figure 2B)
- 5.7-centimeter (2.25-inch) ID threaded extension barrels (Figure 2C).



**Figure 2:** Equipment utilized in SDU core-drilling mock-up.

**Property Testing**

Approximately half way through the filling of the B-25, simulant saltstone processed via the SCPF was also cast into 5-centimeter (2-inch) diameter by 10-centimeter (4-inch) high cylindrical molds. These samples were allowed to cure outside (adjacent to the B-25 container) in a closed container under a moist environment (Figure 3). Following coring of samples from the B-25 compressive strength and saturated hydraulic conductivity measurements were conducted on the core-drilled and cast samples in order to determine if core-drilling might be detrimental with respect to the key physical properties of saltstone.



**Figure 3:** Storage of cast samples in high humidity containment adjacent to B-25.

Compressive strength measurements were performed on eight core-drilled and eight cast samples according to ASTM C39, *Standard Test Method for the Compressive Strength of Cylindrical Concrete Measurements*. Testing was conducted approximately two weeks after the cores were removed from the B-25 container. Cast samples were demolded and tested. Core-drilled samples were cut to 10-centimeter (4-inch) lengths prior to compressive strength testing. While the compressive strength of saltstone is not a direct input into the Saltstone Disposal Facility (SDF) PA, it is a property that may highlight potential damage introduced into the grout during the coring process.

Saturated hydraulic conductivity indicates the rate at which a fluid (typically water) can move through the saturated void spaces and fractures of a monolithic material; this property was measured on three core-drilled and three cast saltstone simulant samples. The standard test method for characterizing the saturated hydraulic conductivity of a material is ASTM D5084, *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Materials Using a Flexible Wall Permeameter*. Saturated hydraulic conductivity was considered a relevant property for assessing the potential impact of the core-drilling since, like compressive strength, it is also influenced by mechanically induced damage during the coring process; in particular cracking would be expected to increase the saturated hydraulic conductivity. In addition, the saturated hydraulic conductivity is a key input to the SDF PA models since it influences the rate of water infiltration through the saltstone monolith and contaminant transport to the surrounding environment. The FY2013 SDF Special Analysis (SA) utilizes a value for initial saturated hydraulic conductivity of  $6.4E-09$  cm/sec for saltstone in an SDU [2]. While the data from this comparative testing is not intended to be a validation of currently modeled values of saturated hydraulic conductivity, it is nonetheless useful in potentially highlighting the magnitude to which core-drilling may impact saturated hydraulic conductivity measurements.

**Phase 2 (FY2014)**

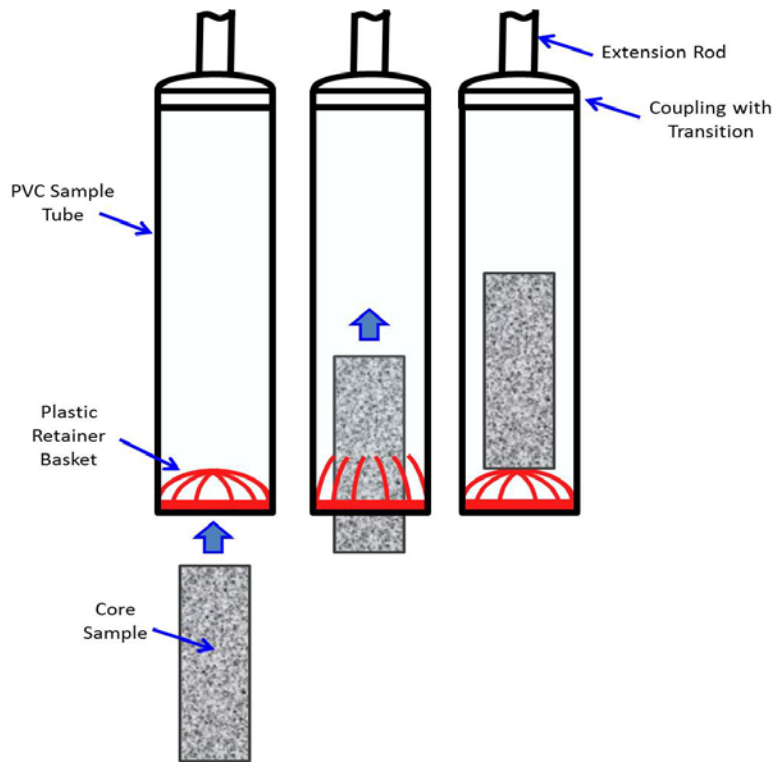
Key aspects of the Phase 2 mock-up were:

1. The B-25 monolith and the drilling equipment from Phase 1 were reused for Phase 2.
2. A dedicated platform was constructed to better mimic physical aspects atop the SDU (Figure 4).
3. Assessment of a simple, in-house core sample retrieval tool; the tool was developed based on the following key characteristics:
  - Consistent removal of core-drilled samples.
  - Use of equipment imparts no damage that would adversely affect properties of interest.
  - Simple with few moving parts.
  - Lightweight to enable handling by a single person atop the SDU roof.

The design ultimately conceived incorporated a plastic tube (that could be cut to the desired depth for retrieval) coupled with a retainer basket. The retainer basket is typical of that used in soil sampling tools. The retrieval concept is schematically illustrated in Figure 5, and photographs of the assembled device are shown in Figure 6. The purpose of the testing was to ensure the device met the required dimensional constraints of the core samples and core holes, and additionally that it was capable of securely retaining the samples upon retraction from the core hole.



**Figure 4:** Dedicated test stand for SDU core-drilling mock-up.



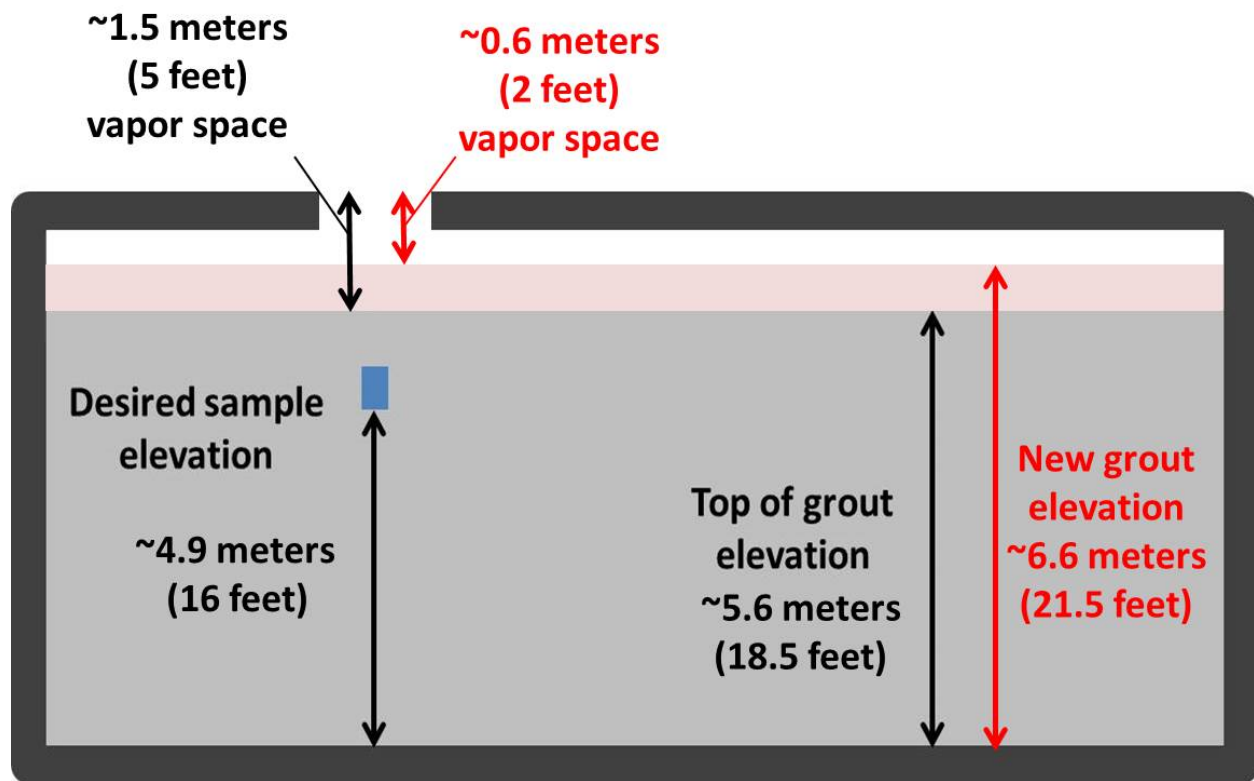
**Figure 5:** Schematic illustration of retrieval tool concept.



**Figure 6:** Photographs illustrating the core retrieval tool.

**Phase 3 (FY2015)**

During the execution of Phases 1 & 2 the assumed maximum height of grout to be emplaced in SDU Cell 2A was 5.6 meters (18.5 feet) of grout, and as such the initial mock-up activities were directed towards demonstrating core-drilling through approximately 0.6-0.9 meters (2-3 feet) of overlying grout to reach the samples around the 4.9-meter (16-foot) elevation level. However, the SDU fill heights have been increased to 6.5 meters (21.5 feet), and thus the overlying grout layer in SDU Cell 2A has increased to approximately 1.8 meters (6 feet). The simulant saltstone monolith utilized in Phases 1 & 2 mock-up activities has a maximum grout depth of 1.1 meters (3.5 feet), and thus it was determined that additional testing would be required in which the drilling and retrieval processes could be demonstrated to a depth of 1.8 meters (6 feet) or greater. Figure 7 illustrates the change in vapor space and grout overlay height for the new SDU fill height compared to the previous height.



**Figure 7:** Schematic illustrating increased grout elevation in SDU Cell 2A.

At the time of writing, the monolith to accommodate a minimum 1.8-meter (6-foot) drill depth was being processed. In place of the aforementioned salt simulant used for preparing the grout monolith used in earlier tests, Phase 3 utilized a simplified salt solution of 1.6 M sodium hydroxide (NaOH). This concentration is close to the average free hydroxide concentration recorded for Tank 50 salt solution, and will facilitate the alkali-activated reaction of the BFS. The dry feeds and w/c ratios were held at their nominal values. The 1.8-meter (6-foot) monolith was processed in 17 lifts each ranging between 7-16 centimeters (3-6 inches). These 17 lifts mimic the lift heights of saltstone poured into SDU Cell 2A from an elevation of 4.65 meters (15.25 feet) to final SDU fill height of 6.5 meters (21.25 feet).

Another significant aspect of Phase 3 is the development and demonstration of a containment system for the cores once they have been removed from the SDU. Cores will be packaged and transported to SRNL where they will be stored in an inert environment pending the following analyses:

- Density, porosity, and water content.
- Radiological composition analyses for select radionuclides including  $^{99}\text{Tc}$ ,  $^{90}\text{Sr}$ ,  $^{79}\text{Se}$ ,  $^{129}\text{I}$ , and  $^{226}\text{Ra}$ .
- Distribution coefficients ( $K_d$ ) for  $^{99}\text{Tc}$ ,  $^{90}\text{Sr}$ ,  $^{79}\text{Se}$ ,  $^{129}\text{I}$ , and  $^{226}\text{Ra}$ .
- Degree of reduced and oxidized  $^{99}\text{Tc}$ .
- Saturated hydraulic conductivity.

Where applicable the measured properties of the core-drilled samples will be compared to simulant samples processed and cured in the laboratory. This should provide an indication with respect to the validity of laboratory-derived data to demonstrate the performance of field-emplaced saltstone.

## RESULTS & DISCUSSION

Results are presented on the phases of mock-up testing completed in FY2013 and FY2104 (i.e., Phases 1 & 2). As previously stated, preparation of the 6-foot high monolith for Phase 3 has been initiated and the final mock-up testing will begin later this year.

### Phase 1 (FY2013)

Key details and observations of the core drilling mock-up are listed below:

- A total of twelve grout samples were cored from the B-25; eleven of these samples were wet cored and one sample was dry cored.
- The dry cored sample was retained in the drill bit and could not be removed on site. Due to the success with wet coring subsequent cores were retrieved utilizing the wet technique.
- The wet drilled cores contained multiple through-thickness fractures (Figure 8). Samples typically fractured at the lift height joints and sometimes additional fractures were observed between the lift height joints. Note that the core lengths were sufficient for assessment of the key cured grout properties.
- The longest intact wet cored samples retrieved were approximately 20-23 centimeters (8-9 inches).





**Figure 8:** Photo of a wet cored sample with multiple through-thickness fractures (red arrows = lift joints).

Eight samples retrieved from the Phase 1 core-drilling mock-up were subjected to compressive strength testing, and 3 samples subjected to saturated hydraulic conductivity testing. The data from these tests was compared to data derived from the aforementioned cast samples that were processed using identical grout (see Tables 1 and 2).

**Table 1:** Compressive strength data for cast and core-drilled simulant saltstone.

Cast Samples			Core-Drilled Samples		
Sample ID	Compressive Strength MPa (psi)		Sample ID	Compressive Strength MPa (psi)	
SSB-25Cast1	6.83 (991)		SSB-25Core4-F	3.11 (451)	
SSB-25Cast2	6.81 (988)		SSB-25Core5-E	4.28 (621)	
SSB-25Cast3	6.95 (1008)		SSB-25Core6-E	4.39 (636)	
SSB-25Cast4	7.16 (1039)		SSB-25Core7-D	3.60 (522)	
SSB-25Cast5	6.96 (1009)		SSB-25Core8-D	4.08 (592)	
SSB-25Cast6	7.27 (1054)		SSB-25Core10-F	3.61 (524)	
SSB-25Cast7	7.31 (1060)		SSB-25Core11-C	3.34 (484)	
SSB-25Cast8	7.33 (1063)		SSB-25Core12-D	3.81 (552)	
	Average	<b>7.08 (1027)</b>		Average	<b>3.78 (548)</b>
	%RSD	<b>3</b>		%RSD	<b>12</b>

**Table 2:** Saturated hydraulic conductivity data for cast and core-drilled simulant saltstone.

Cast Samples		Core-Drilled Samples	
Sample ID	Saturated Hydraulic Conductivity (10 <sup>-9</sup> cm/sec)	Sample ID	Saturated Hydraulic Conductivity (10 <sup>-9</sup> cm/sec)
SSB-25Cast9	2.0	SSB-25Core4-H	1.8
SSB-25Cast10	2.0	SSB-25Core11-D	1.8
SSB-25Cast11	2.2	SSB-25Core12-C	1.8
<b>Average</b>	<b>2.1</b>	<b>Average</b>	<b>1.8</b>

While the saturated hydraulic conductivity for core-drilled and cast samples was virtually identical, the compressive strength of the core-drilled samples was approximately half that measured for the cast samples. The disparate data for compressive strength was potentially the result of additional water content of the wet-cored samples, and the presence of surface scoring resulting from slight wobble of the drill bit. ASTM C42, *Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*, indicates that the strength of concrete can be degraded by both drill bit wobble, and the amount and distribution of moisture in the specimen at the time of testing.

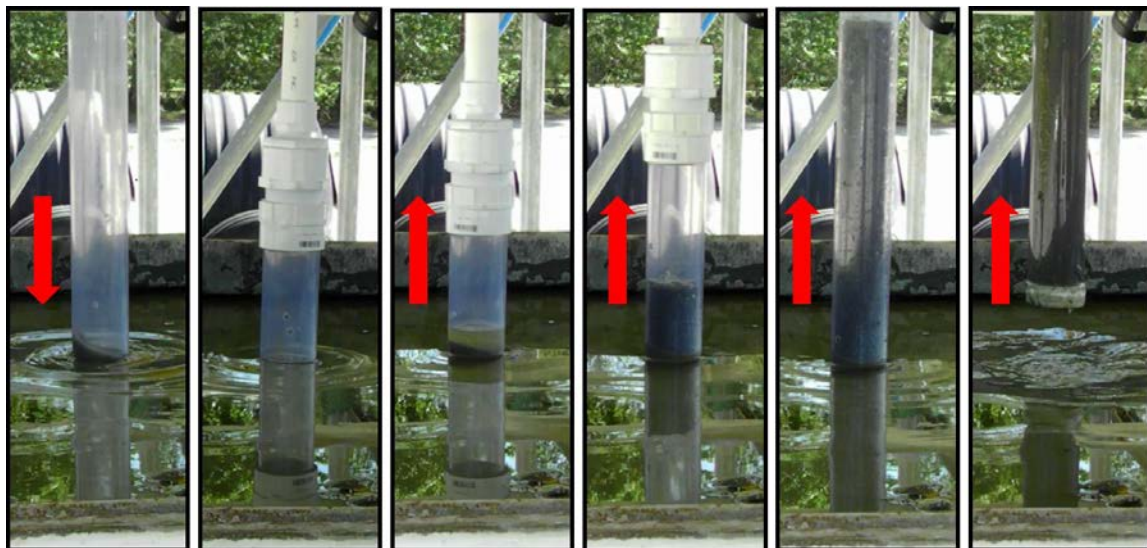
**Phase 2 (FY2014)**

The main focus of Phase 2 was the development and demonstration of an in-house designed core extraction tool. Figure 9 illustrates application of the tool in retrieving a core, and Figure 10 shows the

sequence of core retrieval including insertion of the core retrieval tool into the core hole and ultimate extraction with the core visible in the plastic tube of the retrieval tool. The tool is essentially lowered through the vapor space and pushed into the core hole. Despite the fact that the cores are in multiple pieces, the retrieval tool is able to align the samples as the tool is pushed further down into the core hole. Once the operator detects that the bottom of the core hole is reached the retrieval tool can be retracted.



**Figure 9:** Core extraction utilizing the purpose-built core retrieval tool.



**Figure 10:** Insertion and retraction of core retrieval tool.

The retrieval tool proved very easy to manipulate, and was successfully demonstrated for retrieving entire 1.07-meter (3.5-foot) cores that were divided into several samples by through-thickness fractures.

#### **CONCLUSION**

Phases 1 and 2 of SDU core-drilling mock-up tests demonstrated the feasibility of the wet core-drilling process and subsequent extraction of simulant saltstone samples from a grout monolith (approximately 1.07 meters (3.5 feet deep)) without imparting sample damage that might adversely affect the measurement of key performance properties. Testing demonstrated that coring and extraction did not affect the saturated hydraulic conductivity of core-drilled samples in comparison to samples that were cast into standard concrete molds. However, the average compressive strength of the core-drilled samples was approximately half that measured for the cast samples though higher moisture contents for the wet-cored samples and surface scoring were tentatively suggested as bases for the disparate strength data. Phase 3 of the SDU core-drilling mock-up is underway and will demonstrate the ability to core and extract samples located under 1.5-1.8 meters (5-6 feet) of overlying grout. Actual retrieval of samples from SDU Cell 2A is anticipated in Spring 2015.

#### **REFERENCES**

1. *Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site*, SRR-CWDA-2009-00017, Rev. 0, Savannah River Remediation LLC (2009).
2. *FY2013 Special Analysis for the Saltstone Disposal Facility at the Savannah River Site*, SRR-CWDA-2013-00062, Rev. 0, Savannah River Remediation LLC (2013).