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Characteristics

Retention: Permanent

HYDRAULIC AND PHYSICAL PROPERTIES OF ARP/MCU SALTSTONE GROUT

Kenneth Dixon
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MAY 2010

Savannah River National Laboratory
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Aiken, SC 29808

**Prepared for the U.S. Department of Energy Under
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LIST OF ACRONYMS

ARP	Actinide Removal Process
BFS	Blast Furnace Slag
CSSX	Caustic side solvent extraction
FA	Fly Ash
HLW	High Level Waste
INL	Idaho National Laboratory
LLW	Low Level Waste
LWO	Liquid Waste Organization
MCT	Mactec Engineering and Consulting, Inc.
MCU	Modular Caustic Side Solvent Extraction Unit
PA	Performance Assessment
RETC	RETention Curve
SDF	Saltstone Disposal Facility
SPF	Saltstone Processing Facility
SRNL	Savannah River National Laboratory
SRNS	Savannah River Nuclear Solutions
SRS	Savannah River Site
USDA	United States Department of Agriculture
USDOE	United States Department of Energy
w/pm	water to premix ratio

1.0 EXECUTIVE SUMMARY

The primary focus of this task was to investigate the impact of (1) admixtures, (2) organics, (3) water to premix ratio (w/pm), (4) aluminate concentration, and (5) temperature of curing on the performance properties of ARP/MCU saltstone. To that end, eleven mixes of ARP/MCU saltstone grout were prepared yielding a total of 33 samples which were tested by a subcontract laboratory for saturated hydraulic conductivity, dry bulk density, porosity, and moisture retention characteristics. The particle density of each sample was calculated from the measurements of dry bulk density and porosity. Samples were tested following a minimum 90 day curing period using standard ASTM methods or equivalent.

The results of this project suggest that the addition of admixtures, organics, and a combination of admixtures and organics did not affect the performance properties of saltstone compared to the baseline ARP/MCU saltstone mix. The water to premix ratio (w/pm) of the baseline mix is 0.60. For this task, samples were tested with w/pm ratios of 0.55 and 0.65. It is generally expected that a reduction in w/pm would result in lower hydraulic conductivity and total porosity; however, this effect was not observed for those samples batched at a w/pm ratio of 0.55. Thus, a larger reduction in w/pm ratio may be necessary to observe the expected improvement in performance properties. Alternatively, the expected effect may be observed if more samples were tested at the w/pm of 0.55. The limited sample size of each batch tested weakened the overall strength of the statistical analysis making it difficult to detect significant differences For the mix batched at w/pm of 0.65, the hydraulic conductivity was found to be significantly greater than the baseline mix. Porosity of this mix was not found to be significantly different.

Three batches were formulated to investigate the effects of increase aluminate concentrations with varying w/pm ratios. At w/pm ratios of 0.50 and 0.65, the addition of aluminate resulted in significant reduction in hydraulic conductivity compared to the baseline mix. However, at a w/pm of 0.60 (same as baseline mix), the addition of aluminate did not significantly affect the hydraulic conductivity of saltstone containing admixtures and organics when compared to the baseline mix.

One batch was cured at 60^{o} C to examine the effect of temperature on saltstone performance properties. The hydraulic conductivity of all other batches tested was significantly lower than the hydraulic conductivity of the high temperature cure batch. This indicates that an increased curing temperature may have a strong negative effect on the performance properties of saltstone.

Moisture retention properties of each batch were measured using a variety of techniques. Moisture retention data were analyzed to determine transport parameters for saltstone grout using both tap water and saltstone simulant as the test fluid. The results of these analyses were used to generate characteristics curves for saltstone. These curves differ considerably in shape from those previously used to describe saltstone. This is attributed to better characterization of the dry end of the moisture retention curve than previously achieved.

2.0 INTRODUCTION

At the Saltstone Processing Facility (SPF), decontaminated salt solution is combined with a premix to produce saltstone. The premix consists of ordinary portland cement, carbon burnout blast furnace slag (BFS), and Class F fly ash (FA). The fresh, uncured mixture is transferred to the Saltstone Disposal Facility where it cures to produce a hardened waste form. The properties of the salt solution that feeds the SPF are variable and process dependent and, affect the performance properties of the cured saltstone grout.

Several previous projects have undertaken the task of establishing the hydraulic and physical properties of saltstone grouts as related to various formulations, curing conditions, and measurement techniques. The more recent of these include Harbour et al. (2005), Harbour et al. (2007), Dixon and Phifer (2007), Dixon et al. (2008), Harbour and Williams (2008), and Harbour et al. (2009). Results from these projects have provided insight into performance properties such as hydraulic conductivity, porosity, dry bulk density, and moisture retention characteristics. This previous body of work has also shown that performance properties may be dependent on variability in mix properties.

To address potential saltstone performance impacts due to variation in mix properties, additional tests have been identified for measurement of important hydraulic and physical properties (Dixon et al., 2008). This testing included measurement of saturated hydraulic conductivity, porosity, bulk density, moisture retention, and Young's modulus of simulated saltstone grouts. Bleed volume, gel time, set time, yield stress, and plastic viscosity for each mix were measured. The testing was based on a projected salt solution composition for the Actinide Removal Process/Modular Caustic Side Solvent Extraction Unit (ARP/MCU) stream that will be fed to the SPF over the next few years. The primary focus of this task will be to determine the impact of (1) admixtures, (2) organics, (3) water to premix ratio (w/pm), and (4) aluminate concentration.

In addition, testing of saltstone grout with an increased curing temperature has been conducted to gain initial insights on the potential impacts of elevated curing temperature on saltstone grout performance properties.

3.0 METHODS

A total of eleven saltstone mixes were batched as detailed in Table 1 through Table 3. All samples were tested for saturated hydraulic conductivity, moisture retention characteristics, dry bulk density, and porosity using standard ASTM methods (or equivalent) by an offsite laboratory following a 90 day curing period. The Young's modulus of each grout was measured by SRNL, which may be correlated to saturated hydraulic conductivity (Harbour et al., 2007). SRNL measured the moisture retention properties of the saltstone grouts and developed characteristic curves based on the combined dataset from SRNL and the offsite laboratory. Fresh grout properties including bleed volume, gel time, and set time were also measured by SRNL for each mix.

3.1 SALTSTONE SAMPLE PREPARATION

Samples of eleven saltstone formulations were prepared for hydraulic and physical property testing (Table 1). The cementitious materials used in the premix for each of the saltstone grout formulations were identical and were comprised of carbon burnout Class F fly ash, Grade 100 blast furnace slag, and Type II Portland cement (Table 2). The cementitious materials were received in 5 gallon containers from the vendors during truck delivery of the bulk materials to SPF. The cementitious materials are therefore part of one of the batches actually used in production of saltstone.

Two simulants were used to batch the saltstone mixes with the difference being that one simulant contained increased aluminate. The recipes for the two simulants are presented in Table 4 and Table 5. Admixtures and organics were added to the simulants for selected batches as noted in Table 1 and Table 3.

Wet properties measured for the saltstone formulations included yield stress, plastic viscosity, wet unit weight, bleed water volume, gel time, set time, and heat of hydration. The methods of Harbour et al. (2005) were followed to determine yield stress, plastic viscosity, gel time, bleed water volume, and wet unit weight.

The following subsections provide details on each formulation of saltstone grout and the logic for why each mix was tested.

3.1.1 Test 1 Control and Baseline (Batches 1 and 2)

A control mix (batch 1) was prepared based on the baseline mix modified by exclusion of the Class F fly ash (mix TR545/TR546, Table 1). Consequently, the cementitious materials premix is a mixture of 90 % blast furnace slag and 10 % portland cement. The degree of reaction is expected to be much greater than with the normal premix and therefore should result in a lower porosity and a lower permeability.

A baseline mix (batch 2) representative of the projected ARP/MCU waste stream was also prepared (mix TR547/TR548, Table 1) The baseline premix is a mixture of 45 % blast furnace slag, 45 % Class F fly ash, and 10 % portland cement.

3.1.2 Test 2 –Impact of Admixtures (Batch 3)

Recent saltstone batches have required both a set retarder (Daratard 17) and an antifoam agent (Q2) for processing of the saltstone. Therefore, the baseline mix was prepared with and without nominal levels of these two admixtures to determine whether these admixtures appreciably affect the hydraulic and physical properties of saltstone at these nominal concentrations (mix TR549/TR550, Table 1).

3.1.3 Test 3–Impact of Organics (Batch 4)

The solvent extraction process is expected to result in some carryover of organics (Dixon and Phifer, 2007). To evaluate the impact of Caustic Side Solvent Extraction (CSSX) organics, a mix was prepared with 100 microliters of solvent per 1600 gram batch (premix plus simulant).

The CSSX solvent consists of 0.75 M 1-(2,2,3,3-tetrafluoropropoxy)-3-(4-sec-butylphenoxy)-2-propanol (Cs-7SB) and 0.003 M tri-n-octylamine (TOA) in an Isopar® L diluent (mix TR557TR558, Table 1).

3.1.4 Test 4–Impact of Combination of Admixtures and Organics (Batch 5)

A mix was prepared to determine the impact of a combination of admixtures (Test 2) and organics (Test 3) together in the mix versus the baseline case without admixtures and organics (mix TR565/TR566, Table 1).

3.1.5 Test 5– Impact of w/pm Ratio (Batches 6 and 7)

It is well known that decreasing the w/pm ratio in a mix will improve permeability in normal portland cement water mixes. This test will measure the variation in permeability for the case of the ARP/MCU salt solution at two different w/pm ratios as compared to the baseline mix (TR547/TR548, w/pm 0.60). The w/pm ratios selected for the test were 0.55 and 0.65 (mixes TR575/TR576 and TR577/TR578, respectively, Table 1).

3.1.6 Test 6 – Impact of Aluminate Concentration (Batches 8, 9, 10)

The DWPF has modified its process flow sheet to include a caustic washing of high level waste (HLW) sludge to remove some of the aluminum from the HLW prior to vitrification. The resulting aluminate stream will then be blended with tank 50 material and fed to the SPF. This increased aluminate concentration in the salt solution has significant impact on heat of hydration and set times and consequently, it is likely that it will also impact permeability. Therefore, two mixes were made at w/pm ratios of 0.55 and 0.65 with a higher level of aluminate (0.28 M) and a third mix at a baseline w/pm ratio of 0.60 with the higher level of aluminate and including admixtures and organics [mixes TR582/TR583, TR588/TR589, and TR602/TR603, Table 1].

3.1.7 Test 7 – Impact of Increased Curing Temperature (Batch 11)

In an ongoing task, there is evidence that Young's modulus (a performance indicator) is reduced by increasing the curing temperature of the mix (Harbour and Williams, 2008). Since the vault temperature increases during curing as a result of the exothermic hydration reactions, one of the baseline mixes with a combination of admixtures and organics was cured at 60^{o}C rather than the normal 22^{o}C to determine the impact of curing temperature on the permeability (mix TR604/TR605, Table 1). This batch was not intended to mimic the actual curing conditions of saltstone grout poured during normal operations at SDF. This would require thermal modeling and/or actual time/temperature profiles within the vaults under various pour schedules to determine (1) an average profile of time and temperature under normal processing and (2) a conservative (worst case) profile. Rather, it was intended that batch 11 would provide some initial insight on potential impacts of curing temperature on saltstone performance properties.

3.1.8 ARP/MCU Saltstone Sample Preparation

Two large batches of ARP/MCU Saltstone were batched (~ 5 kg each) for each of the 11 mixes to provide a sufficient amount of grout for all of the testing. Six test cylinders (3 x 6 inch) of each mix were filled for hydraulic and property testing. The mold samples were capped, sealed with tape, and allowed to cure in the laboratory at ambient temperature for a minimum of 90 days prior to testing. In the case of the high temperature cure batch, the mold samples were capped, sealed with tape to prevent the loss of moisture during curing, and immediately placed in an oven at 60^{o}C. These samples were cured for a minimum of 28 days at 60^{o}C prior to hydraulic and physical property testing.

3.2 MEASUREMENT OF HYDRAULIC AND PHYSICAL PROPERTIES

Three inch diameter by 6 inch long mold samples of saltstone from each batch were submitted for testing per standard ASTM methods (or equivalent) to Mactec Engineering and Consulting, Inc. (MCT), Atlanta, GA (Figure 1a). Samples of the saltstone formulations were tested following a 90 day minimum curing period. Sample preparation and shipment to MCT was staggered so that each material was tested as closely as possible to the 90 day curing period.

3.2.1 Measurement of Saturated Hydraulic Conductivity by Mactec

The saturated hydraulic conductivity of each saltstone grout formulation was determined using method ASTM D 5084 (Method F, Constant Volume-Falling Head) using a flexible wall permeameter (mercury head). The laboratory tested cylinders approximately 3 inches in diameter by 2.5 inches long cut from the original mold samples for each saltstone formulation. Each sample was tested with the low aluminate simulant used to batch the samples (Section 3.1) including those samples batched with the high aluminate simulant. This was done to simplify testing for the laboratory and should not impact the measurements for the high aluminate samples due to the small volume of simulant introduced to the sample during the test (typically less than 5 ml).

Due to the high water to premix ratio and low degree of hydration typical of saltstone, cured saltstone grout samples are typically at or near saturation. Nonetheless, each sample was soaked in simulant prior to testing and subsequently backpressure saturated using the permeameter panel per ASTM D 5084.

Saturated hydraulic conductivity is a function of the porous medium and the properties of the test fluid. Thus, the saturated hydraulic conductivity of each saltstone sample was converted to permeability using the following equation based on the properties of the simulant used to batch the sample:

$$k = \frac{K \mu}{\rho g} \tag{1}$$

k = intrinsic permeability (darcy)
K = saturated hydraulic conductivity relative to concentrated simulant (cm/sec)

μ = dynamic viscosity of concentrated simulant (Table 6)
ρ = density of concentrated simulant (Table 6)
g = gravity (981 cm/sec^2)

The dry bulk density and porosity of each sample tested for saturated hydraulic conductivity was measured per ASTM C 642 (or equivalent). The determination of dry bulk density and porosity requires the removal of the evaporable water (at 105 ^{o}C) from each sample. As a result, each measurement was adjusted for the salt content of the pore fluid (which was precipitated during drying). Example calculations are presented in Appendix B. Thus, the raw laboratory measurements presented in (Appendix A) differ from the final results presented in the tables of this report.

3.2.2 Measurement of Moisture Retention Properties by Mactec

Mactec measured the moisture retention properties of each batch of saltstone grout by pressure extraction (ASTM D 6836 Method C or equivalent). This method provided the moisture retention properties of each grout sample to 15 bars. The laboratory tested wafers approximately 0.5 inches thick cut from the original mold samples of each saltstone grout (Figure 1b). These samples were saturated in simulant prior to testing. For moisture retention analysis, the saturated samples were weighed to determine an initial weight. These samples were then subjected to increasing pressures in a pressure membrane extractor. Between each increase in pressure, the samples were weighed. Following the final pressure increase, the samples were weighed and then oven dried. The results from these measurements were subsequently adjusted for salt precipitation as illustrated in Appendix B. Porosity (initial moisture content) and dry bulk density were estimated for each water retention sample. These results were also adjusted for salt precipitation as presented in Appendix B. Particle density for each sample was calculated based on dry bulk density and porosity [$\rho_s = \rho_b/(1-\eta)$].

3.2.3 Measurement of Moisture Retention Properties by SRNL

Cores from each batch of saltstone grout were also tested by SRNL for moisture retention properties, porosity, and dry bulk density. Particle density was inferred from the porosity and dry bulk density measurements [$\rho_s = \rho_b/(1-\eta)$]. Moisture retention properties for each batch listed in Table 1 were determined using a combination of methods including pressure extraction, measured vapor pressure (chilled mirror hygrometer), and controlled vapor pressure (vapor equilibrium).

Thin wafers (approximately 0.5 inches thick) were cut from each saltstone core for testing in the pressure extraction system and for measuring porosity and dry bulk density. The diameter and thickness of each sample were measured using a caliper. Three measurements of each dimension were made and the average was computed for use in subsequent calculations of porosity and dry bulk density. The samples were vacuum saturated in saltstone simulant prior to testing for moisture retention and physical properties (Figure 2a). Periodic weight checks were used to determine when the samples were saturated.

Following saturation, samples were tested in the pressure extraction system at pressures up to 40 bar (modified ASTM D 6836 Method C). For pressures up to 15 bar, saturated porous ceramic plates were used to provide the interface between the pressurized chambers and atmospheric conditions (Figure 2b and Figure 3a). Each porous ceramic plate was saturated with saltstone simulant prior to use. The saturated saltstone wafers were placed on the ceramic plate inside the pressure chamber which was subsequently sealed. Pressure was applied incrementally to the chamber via a manifold system and compressed gas cylinder. Multiple samples were tested simultaneously at each pressure increment. Outflow from the pressure chamber was monitored using a burette. When outflow from the chamber ceased, the samples were determined to be at equilibrium for the applied pressure. Samples were then quickly removed from the chamber, weighed and returned to the chamber for testing at the next pressure increment.

A pressure membrane extractor was used for pressures between 15 and 40 bar (Figure 3b). Membranes were saturated in saltstone simulant prior to use in the pressure membrane extractor. Testing in the pressure membrane extractor was similar to the pressure chambers using the porous ceramic plates. The samples were weighed prior to placement in the extractor which was then pressurized using a manifold system and gas cylinder. Outflow from the extractor was monitored to determine when the samples reached equilibrium for the applied pressure. Samples were then removed from the extractor, weighed and returned to the extractor for testing at the next pressure increment. Following the completion of all testing in the pressure extractors, samples were oven dried at 105^{o}C to facilitate calculation of the volumetric water content at each pressure increment. The results from these measurements were subsequently adjusted for salt precipitation as illustrated in Appendix B.

To determine porosity and dry bulk density, saturated wafers from each batch were oven dried at 105^{o}C. The oven dried mass of each sample was corrected for salt precipitation as shown in Appendix B. The porosity and dry bulk density of each wafer was determined using the aforementioned physical measurements and the corrected dry mass (Appendix B).

In addition to the pressure extraction system, a measured vapor pressure method (chilled mirror hygrometer) was used to evaluate the moisture retention characteristics of the saltstone grouts. The chilled mirror hygrometer (Decagon Devices WP4-T, Figure 4a and b) uses the chilled mirror dew point technique to measure the total moisture potential of porous materials (Nimmo and Winfield, 2002; Gee et al., 1992). Total moisture potential is the sum of osmotic and matric potential (neglecting hydrostatic pressure and gravitational effects). Generally, osmotic potential is negligible and the total potential is assumed to be equal to the matric potential. However, in the case of saltstone grout samples, there is a significant osmotic component due to the high salinity of the saltstone simulants used to batch the samples (Figure 5a and b). Therefore, the total potential readings from the WP4-T include the osmotic potential due to the salt content of the simulant and the matric potential due to capillarity and adsorptive forces binding moisture to the saltstone particles. At the drier end of the moisture retention curve for saltstone, the osmotic potential is significantly greater than the matric potential which is the opposite of what is typically assumed for most material types.

Samples from each batch of saltstone grout and a sample previously tested by Idaho National Laboratory (INL) were prepared for testing in the WP4-T by crushing the grout in a mortar and pestle. The INL sample (designated INLA and INLB in this report) was tested to provide a comparison to previously reported moisture retention properties of ARP/MCU saltstone (Dixon and Phifer, 2007). The crushed saltstone grout was then sieved to produce particles with a diameter of 1 mm or less. The sieved saltstone powder was then oven dried at 105°C. Following drying, bulk saltstone powder from each batch was stored in moisture tight containers until final preparation for testing in the WP4-T (Figure 6a and b). No attempt was made to compact the saltstone powder to a specific bulk density prior to testing as it has been shown that moisture potential is virtually independent of bulk density for drier materials (potentials < -0.1 MPa). In dry materials, most large pores are drained and structure and porosity effects are minor compared to surface area effects such as adsorption (Gee et al., 1992).

Sub-samples of saltstone powder from each batch were tested in the WP4-T for total moisture potential. Moisture potential measurements are independent of sample mass and for the first three batches tested (TR546, TR548, and TR550) the initial mass of saltstone was not controlled. For the remaining batches, two gram sub-samples of dried saltstone were used to simplify the post test calculations for volumetric moisture content.

Each batch of saltstone was tested for total potential using simulant and tap water as the test fluid. These fluids were added to the saltstone in plastic sample cups designed for use with the WP4-T. For those samples tested with saltstone simulant, the simulant was added to the saltstone powder until the sample appeared to be fully saturated (typically ~ 2.5 grams of simulant). The simulant added to the sample was consistent with the simulant used to prepare the grouts. Thus, samples batched with normal saltstone simulant were tested with normal saltstone simulant and those batched with high aluminate simulant were tested with high aluminate simulant. Samples were sealed in the plastic cups for a minimum of several hours to ensure equilibrium moisture conditions were achieved. Following the initial measurement of potential at or near saturation, the samples were either air dried or oven dried to achieve a lower moisture potential (drier condition). Samples were sequentially dried and measurements of potential were made at each increment. When testing was complete, the samples were oven dried to determine the volumetric moisture content at each test increment. Samples tested with tap water were prepared and tested in a similar fashion.

A controlled vapor pressure method (vapor equilibrium) was used to provide a comparison to the measured vapor pressure method implemented with the WP4-T (Figure 7a and b). For this method, a small amount of material is placed above a saturated salt solution inside a sealed container. The saturated salt solution produces a constant relative humidity in the headspace of the sealed container. Relative humidity is then related to total water potential by the following equation:

$$\ln\left(\frac{p}{p_o}\right) = 7.5\,x10^{-5}\left(h_m - h_o\right) \qquad (2)$$

where: p/p_o = relative humidity

h_m = matric potential

h_o = osmotic potential

At equilibrium, the material is assumed to attain the same total potential (h_m-h_o) as the vapor in the headspace of the container (Nimmo and Winfield (2002). As with the measured vapor pressure method, this method is influenced by both osmotic and matric potential.

Several different saturated salt solutions were used to provide a range of moisture potentials for comparison to the measured vapor pressure method. The salt solutions used and their properties are provided in Table 7 (Lide, 2001).

For the controlled vapor pressure method, 1 g of oven dried saltstone powder was placed above the saturated salt solution (Figure 7a and b). The samples were periodically weighed to determine when equilibrium was reached. The total potential of each sample was determined using Equation 2 and the relative humidity for each salt solution as provided in Table 7. The volumetric moisture content associated with the calculated potential was determined using the equilibrium weight of the sample and the dry weight of the saltstone material (1 g). The results from the controlled vapor pressure method were used to qualitatively confirm the results from the measured vapor pressure method (WP4-T).

3.2.4 Measurement of Dynamic Young's Modulus (E) by SRNL

The dynamic Young's Modulus (E) was measured according to ASTM C 215-02 using an E-Meter Mk II Resonant Frequency Tester by James Instruments Inc. The method involves a longitudinal impact on the end of a 3 x 6 inch cylinder of cast and cured paste, detection of the sound waves produced at the opposite end of the cylinder, and measurement of the fundamental resonance frequency of the cylinder through a fast Fourier transform of the time domain signal. Using this resonance frequency and the independently measured mass and dimensions of the cylinder, the dynamic Young's modulus was calculated as discussed in ASTM C 215-02.

Samples prepared for both hydraulic conductivity and Young's modulus measurements were cured at 22°C or at 60°C. In all cases the cylinders were filled with fresh grout, capped and securely taped. Measurement of the masses of the samples with container, lid and tape were made prior to and after curing to measure any mass loss during curing. At ambient temperature essentially no change in the mass before and after curing was noted. For the 60 °C curing conditions, a mass loss on the order of 1 gram was noted. For reference, the Young's modulus or hydraulic conductivity cylinder and sample has a starting mass of ~ 1100 grams. Therefore, a loss of 1 gram corresponds to 0.1 wt % of the total mass of the sample, a value which is insignificant in terms of property values.

3.3 DETERMINATION OF VAN GENUCHTEN TRANSPORT PARAMETERS

Direct measurement of the unsaturated hydraulic conductivity of large numbers of samples of cementitious materials is time consuming and cost prohibitive. An alternative to direct measurement is the use of theoretical methods to predict the unsaturated hydraulic conductivity based upon measured moisture retention data. These methods are generally based on pore-size distribution models, and have been shown to perform reasonably well for coarse textured soils and other porous media having relatively narrow pore-size distributions (USDA, 1998). Savage and Janssen (1997) compared measured drainage from concrete samples with predictive models produced from characteristic curves developed from van Genuchten curve fitting (i.e., RETC). They concluded that the van Genuchten method of predicting unsaturated hydraulic conductivity from moisture retention data was applicable to Portland cement concrete. This indicates that predictive models based on moisture retention data provide the most viable means of characterizing the hydraulic properties of large numbers of samples of cementitious materials. Therefore, this method was chosen to predict the unsaturated hydraulic conductivity of the saltstone grout samples based upon the measured moisture retention properties.

RETC (RETention Curve) (USDA, 1998), a U.S. Salinity Laboratory computer program designed for analyzing the hydraulic properties of unsaturated soils, was used to fit the measured moisture retention data for the saltstone grout samples. The program's curve fitting is based on van Genuchten's equation for soil moisture content as a function of pressure

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{\left[1 + (\alpha h)^n\right]^m} \qquad h \le 0 \tag{3}$$

$$\theta(h) = \theta_s \qquad h > 0 \tag{4}$$

where $\theta(h)$ is moisture content at the pressure head h, θ_r is residual moisture content, θ_s is the saturated moisture content, h is pressure head, α is a constant related to the inverse of the air-entry pressure, and n is a measure of the pore-size distribution. The constraint $m = 1 - 1/n$ was used as suggested by van Genuchten (van Genuchten, 1980; van Genuchten et al., 1991).

The generated moisture retention curves were based on moisture retention data only; no unsaturated hydraulic conductivity data were available for the samples. RETC's (USDA, 1998) van Genuchten $m = 1 - 1/n$ retention curve model was used to estimate curve fitting parameters ($\theta_r, \theta_s, \alpha, n$) for each sample.

The curve fitting parameters ($\theta_r, \theta_s, \alpha, n$) from RETC (USDA, 1998) were used to calculate the effective saturation (or reduced water content), S_e, at incremental pressure heads according to

$$S_e = \frac{S - S_r}{1 - S_r} = \frac{1}{\left[1 + (\alpha h)^n\right]^m} \tag{5}$$

where S_r denotes residual saturation. Using S_e, the relative hydraulic conductivity was calculated at incremental pressure heads using the Mualem-van Genuchten type function

$$K = S_e^L \left[1 - \left(1 - S_e^{1/m}\right)^m\right]^2 \tag{6}$$

where L is an empirical pore-connectivity parameter and assumed to be 0.5.

Saturation (S) was calculated at various pressure heads according to

$$S = S_r + \left(\frac{1 - S_r}{\left[1 + (\alpha h)^n\right]^m} \right) \tag{7}$$

where residual saturation, S_r, is equal to θ_r / θ_s (the residual moisture content divided by the saturated moisture content).

3.4 MEASUREMENT OF FRESH GROUT PROPERTIES

Rheological properties were determined using a Haake M5/RV30 rotoviscometer. The flow curves for the mixes were fitted to the Bingham Plastic rheological model to determine the yield stress (Pa), and the plastic viscosity (cP). A Vicat Consistency Tester was used to measure the final set times at a frequency (resolution) of one day.

For gel time measurements, fresh paste was poured into a series of cylinders of dimensions of 3.3 cm in diameter and 8.5 cm in height. Every 5 to 10 minutes (depending on the nature of the grout) the fresh paste was poured from one of the cylinders into a empty container. Gel time was determined by an indication of structure in the grout during pouring. For example, a sample that first exhibited structure after 40 minutes has a gel time between less than 40 minutes but greater than the time of the previous measurement. Conservatively, this is recorded as a gel time in minutes of the previous measurement.

For bleed volume, fresh paste was poured into cylinders of dimensions of 3.3 cm in diameter and 8.5 cm in height. These cylinders were capped and the volume of bleed measured after 24 hours. The tests were done in duplicate and the average of these two results was presented in units of volume % bleed liquid.

4.0 RESULTS

The results presented in this report address the potential saltstone performance impacts due to variation in mix properties. The primary focus of this task was to determine the impact of (1) admixtures, (2) organics, (3) water to premix ratio (w/pm), (4) aluminate concentration, and (5) temperature of curing on the hydraulic and physical properties of saltstone grout. Performance properties measured include saturated hydraulic conductivity, porosity, bulk density, moisture retention, and Young's modulus of simulated saltstone grouts. Bleed volumes and gel times for each mix were also measured. The testing was based on a projected salt solution composition for the ARP/MCU stream that will be fed to the SPF over the next few years.

4.1 FRESH PROPERTIES AND YOUNG'S MODULUS OF THE SALTSTONE MIXES

The fresh properties of each saltstone formulation were measured as part of this task and the results are summarized in Table 8.

Bleed water was not significant for any of the mixes. Five of the 11 mixes had bleed water at 1 day but the values were less than 1 volume % for all 5 mixes. When the mixes were checked at 28 days, there was no bleed water on any of the mixes. Gel time was less than 20 minutes for 3 of the 11 mixes whereas set time was 1 day for all of the mixes except those that contained higher levels of aluminate. In those 3 cases, the set time was between 6 to 7 days.

The rheological properties of yield stress and viscosity were typical of Saltstone mixes. Those mixes with a water to premix ratio of 0.55 had the highest values of yield stress and plastic viscosity. Interestingly, admixtures had an impact on the rheological properties. The mix with 90 wt % slag and 10 wt % cement also had higher values of yield stress and viscosity but this mix was included in this study only as a reference case without fly ash.

4.2 HYDRAULIC AND PHYSICAL PROPERTY RESULTS

MCT estimated the hydraulic and physical properties of each saltstone formulation using ASTM methods (or equivalent) following a minimum 90 day curing period. The supporting detailed test reports produced by MCT for the saltstone samples are provided in Appendix A. The results of the testing are presented in Table 9. SRNL also measured the physical properties of samples from each saltstone formulation and those results are presented in Table 10. All of the hydraulic and physical property results (MCT and SRNL) are summarized in Table 11. The summarized data includes measurements for porosity and dry bulk density as measured by both MCT and SRNL. Figure 9 and Figure 10 show a comparison of these properties as measured by MCT and SRNL. These figures show that for both porosity and dry bulk density, the MCT and SRNL measurements are comparable and support the conclusion the two data sets can be combined for further analysis.

A statistical analysis was conducted to investigate the differences between the performance properties of the various saltstone formulations (Shine, 2010). Table 12 through Table 14 provide summary statistics for saturated hydraulic conductivity, porosity, and dry bulk density.

These tables include batch means, standard deviations, and confidence intervals (α=0.05) for each batch of saltstone.

An analysis of variance (ANOVA) test for the equality of all batch means for both hydraulic conductivity and porosity was performed. To achieve equal variance among the batch means, a common logarithmic transform was performed on the hydraulic conductivity data. The results of the ANOVA showed for both properties (hydraulic conductivity and porosity), that at least one of the batch means was significantly different from the others (α=0.05). Thus, Dunnett's procedure was used to identify which batch means for these properties were significantly different as compared to a particular reference batch mean (α=0.05). The following comparisons were made for both hydraulic conductivity and porosity:

(a) All batch means were compared to the batch 2 mean (baseline mix)
(b) All batch means were compared to the batch 1 mean (control mix)
(c) All batch means were compared to the batch 11 mean (high curing temperature mix).

Table 15 through Table 17 present the results of the batch comparisons to the aforementioned reference batch means. The following sections discuss the results of the analyses. Although redundant, each section provides a brief description of each batch for completeness.

4.2.1 Test 1 Control and Baseline (Batches 1 and 2)

A control mix (batch 1) was prepared based on the baseline mix modified by exclusion of the Class F fly ash (mix TR545/TR546, Table 1). This batch was intended to provide the minimum hydraulic conductivity and porosity expected for saltstone. Thus, the property means for the control batch were compared to the means for all other batches to evaluate this assumption (Table 15). The mean saturated hydraulic conductivity of batches 8 and 9 were found to be significantly less than the mean for the control mix. These batches were intended to examine the effects of increased aluminate. Conversely, the means for 7 and 11 were significantly greater than the control mix. Batch 7 was intended to evaluate the effects of increased water to premix ratio and batch 11 was intended to evaluate the effects of high curing temperature. All of these findings are consistent with the expected outcome. It is interesting to note that the mean hydraulic conductivity of the baseline mix was not significantly different than that of the control mix. However, the mean porosity of the baseline mix was significantly greater than the mean porosity of the control mix (Table 15). It is generally assumed for cementitious materials, that a reduction in porosity is correlated to a reduction in hydraulic conductivity. Thus, batches of saltstone with lower total porosity would be assumed to exhibit lower hydraulic conductivity. Figure 9 shows that the porosity for the control batch is lower than observed for the other batches. These findings are consistent with the expected outcome for the control batch and may indicate that the porosity dataset may be more robust than the hydraulic conductivity dataset for comparing the different saltstone formulations. This may be due in part to the larger number of individual measurements of porosity for each batch (generally $n \geq 7$). A larger dataset is less influenced by outliers and more accurately defines the parameter distribution making it easier to detect significant differences among the batches. It should be noted from Table 15 that all batch means for porosity except for batch 8 were significantly greater than the mean for the control mix.

4.2.2 Test 2 –Impact of Admixtures (Batch 3)

Recent saltstone batches have required both a set retarder (Daratard 17) and an antifoam agent (Q2) for processing of the saltstone. Therefore, the baseline mix was prepared with and without nominal levels of these two admixtures to determine whether these admixtures appreciably affect the hydraulic and physical properties of saltstone at these nominal concentrations (mix TR549, Table 1). Property means for batch 3 were not found to be significantly different than the baseline mix (batch 2) which suggests the addition of admixtures did not affect the performance properties of the baseline mix (Table 16).

4.2.3 Test 3–Impact of Organics (Batch 4)

The solvent extraction process is expected to result in some carryover of organics (Dixon and Phifer, 2007). To evaluate the impact of Caustic Side Solvent Extraction (CSSX) organics, a mix was prepared with 100 microliters of solvent per 1600 gram batch (premix plus simulant). The CSSX solvent consists of 0.75 M 1-(2,2,3,3-tetrafluoropropoxy)-3-(4-sec-butylphenoxy)-2-propanol (Cs-7SB) and 0.003 M tri-n-octylamine (TOA) in an Isopar® L diluent (mix TR557, Table 1). Property means for batch 4 were not found to be significantly different than the baseline mix (batch 2) which suggests the addition of organics did not affect the performance properties of the baseline mix (Table 16).

4.2.4 Test 4–Impact of Combination of Admixtures and Organics (Batch 5)

A mix was prepared to determine the impact of a combination of admixtures (Test 2) and organics (Test 3) together in the mix versus the baseline case without admixtures and organics (mix TR565, Table 1). Property means for batch 5 were not found to be significantly different than the baseline mix (batch 2) which suggests the combination of admixtures and organics did not affect the performance properties of the baseline mix (Table 16).

4.2.5 Test 5– Impact of w/pm Ratio (Batches 6 and 7)

It is well known that decreasing the w/pm ratio in a mix will improve permeability in normal portland cement water mixes. This test will measure the variation in permeability for the case of the ARP/MCU salt solution at two different w/pm ratios as compared to the baseline mix (TR547, w/pm 0.60). The w/pm ratios selected for the test were 0.55 and 0.65 (mixes TR575 [batch 6] and TR577 [batch 7], Table 1). Property means for batch 6 were not found to be significantly different than the baseline mix (batch 2) which suggests that the slight decrease in w/pm was not enough to significantly effect the performance properties. For batch 7, the mean hydraulic conductivity was found to be significantly greater than the mean for the baseline mix (Table 16). Thus, the increase in w/pm was enough to significantly increase the permeability compared to the baseline mix. However, the mean porosity of batch 7 was not significantly different than that of the baseline mix.

4.2.6 Test 6 – Impact of Aluminate Concentration (Batches 8, 9, 10)

The DWPF has modified its process flow sheet to include a caustic washing of high level waste (HLW) sludge to remove some of the aluminum from the HLW prior to vitrification. The resulting aluminate stream will then be blended with tank 50 material and fed to the SPF. This increased aluminate concentration in the salt solution has significant impact on heat of hydration and set times and consequently, it is likely that it will also impact permeability. Therefore, two mixes were made at w/pm ratios of 0.55 and 0.65 with a higher level of aluminate (0.28 M) and a third mix at a baseline w/pm ratio of 0.60 with the higher level of aluminate and including admixtures and organics [mixes TR582 (batch 8), TR588 (batch 9), and TR602 (batch 10), Table 1].

Harbour et al. (2009) have shown a positive correlation between increased aluminate and Young's modulus which suggests that aluminate may reduce the hydraulic conductivity of saltstone. Batch 8 was mixed at a w/pm ratio of 0.55 (which is less than the baseline mix w/pm 0.60) with an aluminate concentration of 0.280 M. The property means of batch 8 were found to be significantly lower than those of the baseline mix (Table 16). This was expected since lowering the w/pm ratio and increasing the aluminate concentration should both result in reduced hydraulic conductivity. Batch 9 had the same aluminate concentration as batch 8 but had an increased w/pm ratio (0.65) compared to the baseline. The mean hydraulic conductivity of batch 9 was significantly lower than the baseline mix but the mean porosity was found not to be significantly different. Batch 10 was the same as batch 5 (which contained admixtures and organics) but with the increased aluminate concentration (0.280 M). The mean hydraulic conductivity of batch 10 was not significantly different than the baseline mix but the mean porosity was found to be significantly lower.

4.2.7 Test 7 – Impact of Increased Curing Temperature (Batch 11)

There is evidence that Young's modulus (a performance indicator) is reduced by increasing the curing temperature of the mix which would suggest a reduction in performance properties (Harbour and Williams, 2008). Since the vault temperature increases during curing as a result of the exothermic hydration reactions, one of the baseline mixes with a combination of admixtures and organics was cured at 60°C rather than the normal 22°C to determine the impact of curing temperature on the permeability (mix TR604 [batch 11], Table 1). As noted in Section 3.1.7, this batch was not intended to mimic the actual curing conditions of saltstone grout poured during normal operations at SDF. This would require thermal modeling and/or actual time/temperature profiles within the vaults under various pour schedules to determine (1) an average profile of time and temperature under normal processing and (2) a conservative (worst case) profile. Rather, it was intended that batch 11 would provide some initial insight on potential impacts of curing temperature on saltstone performance properties.

A separate comparison was conducted with batch 11 as the reference to evaluate the impacts of increased curing temperature (Table 17). The mean hydraulic conductivity of all batches were significantly less than the mean for the high curing temperature mix (batch 11). With the exception of batches 4 and 7, the mean porosity of each batch was also significantly less than that of the high cure temperature mix. These results suggest that elevated curing temperature may have a negative effect of the performance properties of saltstone. In order to fully address the impact of curing temperature on saltstone performance properties, test samples would need to be prepared under conditions that mimic the actual curing conditions at SDF.

4.3 HYDRAULIC CONDUCTIVITY AND YOUNG'S MODULUS COMPARISON

Table 18 presents a comparison of Young's modulus (E) and saturated hydraulic conductivity for the 11 mixes. There is an overall trend in this data which reveals that higher values of E are associated with lower values of hydraulic conductivity. One notable exception to this trend is the sample from Batch 1 which contained 90 Wt % slag and 10 wt % cement in the premix. Further work will be required to understand the relatively high value of hydraulic conductivity measured for this mix compared to the expected hydraulic conductivity based on the values of porosity and E. The 11 mixes batched for this task were not based on a statistical design. The approach taken for this task was to identify impacts, if any, of changes in hydraulic conductivity due to a change in one of the factors for each mix.

4.4 MOISTURE RETENTION RESULTS

Moisture retention properties of the various saltstone formulations were determined by both MCT and SRNL. The results of these analyses are presented in Table 19 through Table 26 and in Figure 13 through Figure 30. The following sub-sections describe the results the moisture retention testing and subsequent analysis.

4.4.1 Moisture Retention Properties as Determined by MCT

MCT used pressure membrane extraction to determine the moisture retention properties of the various saltstone grouts for pressures ranging from 102 cm H_2O (0.1 bar) to approximately 15,296 cm H_2O (15 bar). Moisture retention curves for each batch as determined by MCT are presented in Figure 13 through Figure 23. Figure 24 presents a comparison of the moisture retention curves for each batch and shows the average moisture retention curve for all batches. The average moisture retention curve was prepared by averaging the moisture retention data for each pressure increment across all batches of saltstone. The moisture retention curves for all batches of saltstone tested are very similar in shape. Table 20 presents the mass of simulant expelled during the pressure extraction testing for each batch of saltstone. The average mass of simulant expelled over the duration of the testing was 0.84 g. The average mass of simulant contained within a sample was 71.44 g. Thus, less than 2 percent of the total mass of simulant contained within a sample was released during the pressure extraction testing. Although the moisture retention curves for all batches were similar, it is noteworthy that batch TR604 (high temperature curing) expelled an average of 3.4 g of simulant or ~ 4.5% of the total simulant mass through 10,197 cm H_2O (10 bar). All three samples from batch TR604 cracked after the 1,020 cm H_2O (1 bar) pressure increment, therefore no moisture retention data could be obtained after this pressure increment using the pressure extraction method.

4.4.2 Moisture Retention Properties as Determined by SRNL

SRNL tested the moisture retention properties of the saltstone grouts using pressure extraction (porous ceramic plate and pressure membrane), measured vapor pressure (chilled mirror humidity sensor), and controlled vapor pressure (vapor equilibrium) methods. The results from the pressure extraction testing are presented in Table 21. The results from the pressure extraction testing were inconclusive and were not useful in determining the moisture retention properties of the saltstone grouts. The data presented in Table 21 show that several samples gained moisture with each incremental increase in pressure whereas other samples initially drained but then subsequently gained moisture. All samples were vacuum saturated in saltstone simulant (sometimes for weeks) prior to testing in the pressure extractors. Extra care was taken to insure good hydraulic contact between the samples and the porous ceramic plates (including the use of silica flour for some samples). Additionally, the samples were carefully weighed on a calibrated balance at each pressure increment. Thus, it is not clear why the samples did not drain as expected with increasing applied pressure. Multiple conversations with technical personnel at MCT did not identify any significant difference between the test procedures used by MCT and those used by SRNL. Although the methods used were nearly identical, MCT used a pressure membrane extractor instead of a porous plate pressure extractor. The pressure membrane extractor uses a thin cellulose membrane as the interface between the sample and atmospheric pressure. The porous plate extractor uses porous ceramic plates. There may be some unexplained interaction between the saltstone simulant and the porous ceramic plates that make them unsuitable for this type of testing.

Typically, samples progress sequentially through the pressure extraction system from lower pressures (using porous ceramic plates) to higher pressures (using pressure membranes). Although testing with the porous ceramic plates was generally unsuccessful, some samples were tested at higher pressure in the 50 bar pressure membrane extractor. Several samples cracked under the high pressure of the 50 bar pressure membrane extractor (Figure 8) and this testing was ultimately discontinued. Because of the initial lack of success on the first sets of samples tested in the pressure extraction system, subsequent testing was abandoned in favor of the measured and controlled vapor pressure methods. The MCT data were subsequently used to describe the water retention properties of the saltstone grouts at pressures less than 15,296 cm H_2O (15 bar).

Sub-samples of each saltstone batch were tested for total moisture potential using a measured vapor pressure method (chilled mirror humidity sensor, WP4-T). The samples were prepared and tested as discussed in Section 3.2.3. Samples were tested with tap water as the test fluid and saltstone simulant as the test fluid. Thus, there are two complete sets of data for each batch of saltstone grout. Sample IDs ending with the suffix “A” were tested with saltstone simulant and those sample IDs ending with the suffix “B” were tested with tap water. Sample IDs ending with the suffixes “C” and “D” were special cases where only a few samples were tested to explore a specific concept (such as the effect of wetting versus drying the samples).

The results of the moisture retention testing are presented in Table 22 and Table 23 and are shown in Figure 25 through Figure 29. As discussed in Section 3.2.3, the chilled mirror hygrometer sensor measures total moisture potential. Total potential is the sum of the osmotic and matric potential where osmotic potential is due to dissolved salts in solution and matric potential is due to adhesive intermolecular forces between the solution and solid particles. Ordinarily, osmotic potential is negligible and the total potential reading is considered to be equal to the matric potential. In the case of saltstone grout, there is a significant osmotic component due to the high salinity of the salt solution used to batch the samples. Osmotic and matric potential of the salt solution combine to produce negative (i.e. lower) water potentials relative to pure water. Water flow from the surrounding environment will be from areas of higher water potential to areas of lower water potential. As a result, field scale moisture flow could be from the surrounding vadose zone to the saltstone grout due to the large pressure gradient created by saltstone.

The chilled mirror hygrometer was used to measure the osmotic potential of both simulants used in the testing. The measured osmotic potential of the low aluminate simulant was found to be -24.56 MPa (-245.6 bar). The measured osmotic potential of the high aluminate simulant was found to be -30.96 MPa (-309.6 bar). Therefore, a sample saturated with simulant will have a significant osmotic potential when the matric potential is essentially zero. As the sample becomes drier, the osmotic potential of the sample will increase in a non-linear manner and will be significantly greater than the matric potential. The combination of osmotic and matric potential will tend to keep saltstone grout at or near saturation for most field conditions. For this analysis, no attempt was made to separate the osmotic potential from the total potential readings, since osmotic potential and matric potential will work together to control moisture movement within the saltstone grout. Thus, all data presented in Table 22 and Table 23 are in terms of total potential which includes osmotic and matric potential.

Moisture retention curves for each batch of saltstone using tap water as the test fluid are shown in Figure 25. Also shown is the moisture retention curve for sample INLB which was previously tested by INL (Dixon and Phifer, 2007). The general shapes of all the moisture retention curves are similar. The shapes of the moisture retention curves are consistent with that observed for other cementitious materials and consistent with the shape of the curve for the Hanford double shell slurry feed (DSSF) which has been used previously as a surrogate for saltstone (Phifer et al., 2006).

Figure 26 compares the moisture retention curves derived from the measured (chilled mirror humidity sensor) and controlled vapor pressure (vapor equilibrium) methods. All eleven batches of saltstone grout and the INL sample were tested in sealed containers exposed to various saturated salt solutions as discussed in Section 3.2.3. All samples were tested with the potassium iodide solution (KI) yielding a total of 12 data points for this potential. Due to time constraints and equipment limitations, only three batches (TR548, TR603, and TR605) were tested with the remaining three salt solutions. The results for each salt solution were averaged for presentation in Figure 26. Good agreement is noted between the measured and controlled vapor pressure datasets, which validates the measured vapor pressure results.

Figure 27 presents the combined SRNL (using tap water as the test fluid) and MCT moisture retention curves for each batch of saltstone grout and the INL sample. The MCT data, which describes the wetter end of the moisture retention curve, match well with the SRNL data, which describes the drier range of the moisture retention curve, to produce a complete moisture retention curve for saltstone.

Moisture retention curves for each batch of saltstone using simulant as the test fluid are shown in Figure 28. Also, shown is the moisture retention curve for sample INLA which was previously tested by INL (Dixon and Phifer, 2007). For these samples, the simulant used to batch the original grout samples was used as the test fluid. Thus, those samples batched with low aluminate simulant were tested with low aluminate simulant and those samples batched with the high aluminate simulant were tested with high aluminate simulant. Sample INLA was tested with the low aluminate simulant. Batch TR583 was tested with both simulants to investigate any effects from the simulant. The general shape of the moisture retention curves for all samples is similar. There appears to be no substantial differences between the curves for TR583-3A (low aluminate simulant) and TR583-3C (high aluminate simulant). Further, the moisture retention curve for INLA is consistent with the curves for the other batches of saltstone grout. Compared with the tap water based moisture retention curves, the simulant based moisture retention curves have a flatter slope over much of the moisture content range. This may be due to the added osmotic potential of the simulant relative to tap water.

Figure 29 compares the moisture retention curves derived from the measured (chilled mirror hygrometer) and controlled vapor pressure (vapor equilibrium) methods. The same vapor equilibrium data is presented in Figure 29 as is shown in Figure 26. It is noted in Figure 29 that the vapor equilibrium data does not match the measured vapor pressure data as well for the case where simulant is used as the test fluid. This is expected since the moisture gained by the vapor equilibrium samples would be expected to be more like tap water than simulant.

Figure 30 presents the combined SRNL (using simulant as the test fluid) and MCT moisture retention curves for each batch of saltstone grout and the INL sample. The MCT data, which describe the wetter end of the moisture retention curve, do not match as well with the simulant based moisture retention curves. This is due to the substantial osmotic potential of the simulant relative to tap water.

The moisture retention characteristics of a porous material is hysteretic in nature. Thus, at a given moisture potential, samples that reached that potential by wetting will have a lower moisture content than those which reached it by drying. To investigate this effect, samples from batches TR548 and TR605 were tested by wetting and drying. The results are shown in Figure 31 and Figure 32. The hysteretic effect is clearly evident although the general shape of the curves are similar.

Figure 33 and Figure 34 show the results from testing TR548 and TR605 beginning at the "as received" moisture content and subsequently drying the samples. It is noted the initial moisture content of both samples is somewhat less than expected. Although the samples were stored in sealed plastic bags to prevent moisture loss, this may indicate the samples dried some in the time between curing and testing. Nonetheless, the resulting moisture retention curves for both samples starting at the "as received" moisture content are more similar to the moisture retention curves that result from using tap water as the test fluid.

4.5 ANALYSIS OF MOISTURE RETENTION CHARACTERISTICS

The measured moisture retention data were analyzed to determine the van Genuchten transport parameters and the relative hydraulic conductivity function. As noted in Section 4.2, all eleven saltstone batches were tested using the measured vapor pressure method (chilled mirror hygrometer) using both saltstone simulant ("A" samples) and tap water as the test fluid ("B" samples). Because the moisture retention curves for the two fluids were different, these two datasets were analyzed separately. Although the statistical analysis noted some differences between batches based on hydraulic conductivity and porosity, for this analysis the moisture retention properties of the different batches were assumed to be similar. This assumption is validated by Figure 27 and Figure 30 where little difference is noted in the drainage curves for the different batches of saltstone. However, because the high temperature cure grout had a significantly higher mean saturated hydraulic conductivity than the other mixes, additional testing would be necessary to confirm the moisture retention properties of this grout.

Both sets of moisture retention data were analyzed using the RETC model (USDA, 1998). The standard Mualem relationship between n and m (i.e., m = 1 – 1/n) was used. For both sets of data, the MCT moisture retention data were included to describe the wetter end of the moisture retention curve. For both datasets, all data were included in the analysis. None of the data were averaged for the analysis. All moisture retention values were given a weight of 1 except those measurements from the measured vapor pressure method (chilled mirror hygrometer) that were near saturation. Reduced accuracy is noted for the chilled mirror hygrometer at potentials near saturation (Gee et al., 1992). Thus, values near saturation determined using the chilled mirror hygrometer were assigned a weighting factor of 0.5.

The saturated moisture content (θ_s) was fixed to the average porosity of all of the saltstone grouts (0.621). RETC was allowed to optimize the residual moisture content (θ_r) as well as the curve fitting parameters α and n. RETC outputs α and n to five decimal places. For both datasets, the calculated value for α was less than 1E-05. Therefore, a visual curve matching procedure was employed in a spreadsheet to determine the value of α based on the value of θ_r and n determined by RETC. The resulting characteristic curves are presented in Figure 35 through Figure 41 and the transport parameters are given in Table 27. Data for the characteristic curves are presented in Appendix C.

Figure 35 through Figure 37 shows the characteristic curves for saltstone as determined using tap water as the test fluid. Figure 38 through Figure 40 show the characteristic curves for saltstone as determined using saltstone simulant as the test fluid. Good agreement is noted between the observed moisture retention data and the fitted characteristic curves for both datasets. Also shown in each figure are the characteristic curves currently used in the saltstone vadose zone model which were based on an analysis conducted by INL (Flach et al., 2009). The INL moisture retention data were limited in range to less than 61,184 cm H_2O (60 bars) and the resulting characteristic curves were extrapolated beyond this range. The SRNL data covers a much wider range of moisture content and illustrates the importance of obtaining data in the dry range of the moisture retention curve. While it is expected that saltstone will stay essentially saturated over the range of expected suction values, Figures 32 through 37 clearly show that a complete moisture retention curve is necessary to produce a valid relative permeability curve (even near saturation). The INL relative permeability curve, which was based on an incomplete moisture retention dataset, suggests that small changes in moisture content near saturation result in a significant decrease in hydraulic conductivity (several orders of magnitude). The SRNL characteristic curves are more representative of cementitious materials and are similar to those derived from the Hanford DSSF grout which Phifer et al. (2006) recommended as estimates for saltstone grout (Figure 36 and Figure 37). The relative permeability curves based on the SRNL datasets are more typical of cementitious materials and results in a more gradual decrease in hydraulic conductivity with decreasing moisture content.

Figure 41 shows three sets of characteristic curves: 1) saltstone using tap water as the test fluid, 2) saltstone using simulant as the test fluid, and 3) the estimated saltstone characteristic curves recommended by Phifer et al. (2006). The curves for each are similar in shape and are consistent with what would be expected of a cementitious material. All three sets of curves differ significantly from the characteristic curves currently used in the current SDF vadose zone model, which were based on a previous INL analysis.

5.0 SUMMARY

A total of 33 samples from 11 different saltstone mixes were tested for saturated hydraulic conductivity, porosity, dry bulk density, moisture retention, and Young's modulus. The purpose of these tests was to investigate the impacts of (1) admixtures, (2) organics, (3) water to premix ratio (w/pm), (4) aluminate concentration, and (5) temperature of curing on the performance properties of ARP/MCU saltstone.

Mold samples of each saltstone formulation were prepared for hydraulic and physical property testing. These samples were 3 by 6 inch cylinders. Preparation of the samples were staggered so that each formulation could be tested as closely as possible to a minimum 90 day cure. Wet properties measured for the saltstone formulations included yield stress, plastic viscosity, gel time, bleed water volume, and set time. The results of these measurements are presented in Table 8.

The saltstone samples were submitted to Mactec Engineering and Consulting, Inc. (MCT) for testing per ASTM standards (or equivalent). The saturated hydraulic conductivity, intrinsic permeability, porosity, particle density, and dry bulk density data for each batch of saltstone as measured by MCT are presented in Table 9. SRNL also determined porosity, dry bulk density, and particle density for each formulation of saltstone. These results are presented in Table 10. Summary hydraulic and physical properties are presented in Table 11 and summary statistics are provided in Table 12 through Table 14. Statistical comparisons are provided in Table 15 through Table 17.

The results of this project suggest that the addition of admixtures, organics, and a combination of admixtures and organics did not significantly affect the performance properties of saltstone compared to the baseline ARP/MCU saltstone mix. The water to premix ratio (w/pm) of the baseline mix is 0.60. For this task, samples were tested with w/pm ratios of 0.55 and 0.65. It is generally expected that a reduction in w/pm would result in lower hydraulic conductivity and total porosity; however, this effect was not observed for those samples batched at a w/pm ratio of 0.55. For the mix batched at w/pm of 0.65, the hydraulic conductivity was found to be significantly greater than the baseline mix. Porosity of this mix was not found to be significantly different than the baseline.

Three batches were formulated to investigate the effects of increase aluminate concentrations with varying w/pm ratios. At w/pm ratios of 0.50 and 0.65, the addition of aluminate resulted in significant reduction in hydraulic conductivity compared to the baseline mix. However, at a w/pm of 0.60, the addition of aluminate did not significantly affect the hydraulic conductivity of saltstone containing admixtures and organics when compared to the baseline mix.

One batch was cured at 60^{o}C to examine the effect of temperature on saltstone performance properties. The hydraulic conductivity of all other batches tested was significantly lower than the hydraulic conductivity of the high temperature cure batch. All but two of the saltstone formulations had mean porosity values significantly lower than the high temperature cure batch. This indicates that an increased curing temperature may have a negative effect on the

performance properties of saltstone. However, the curing conditions imposed on this batch were not intended to mimic the actual curing conditions of saltstone grout poured during normal operations at SDF. This would require thermal modeling and/or actual time/temperature profiles within the vaults under various pour schedules to determine (1) an average profile of time and temperature under normal processing and (2) a conservative (worst case) profile. Therefore, further investigation using samples prepared specifically to match SDF curing conditions would be necessary to fully evaluate the effects of curing temperature on saltstone performance properties.

The moisture retention properties of each saltstone formulations were measured by MCT and are presented in Table 19. SRNL measured the moisture retention properties of each saltstone formulation using a combination of methods including pressure extraction, measured vapor pressure, and controlled vapor pressure. The results of these measurements are presented in Table 21 through Table 26.

The data for each saltstone formulation were analyzed to determine the van Genuchten transport parameters. Two data sets were analyzed, one with tap water as the test fluid and one with saltstone simulant as the test fluid. Thus, two sets of transport parameters are presented in Table 27. These parameters may be used to implicitly determine the relationship between unsaturated hydraulic conductivity and moisture content. Data for the characteristic curves are presented in Appendix C.

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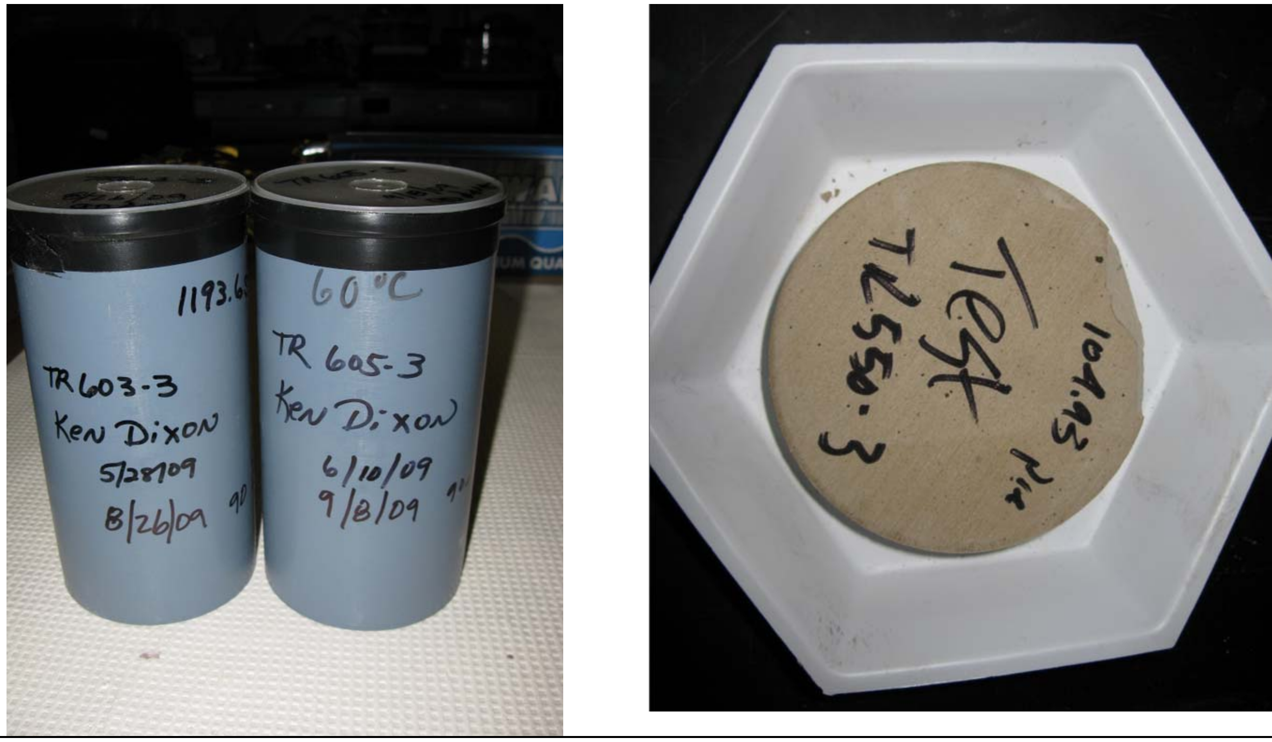


(a) (b)

Figure 1. Typical 3x6 inch saltstone mold samples (a) and typical wafer used in pressure extraction testing (b).

(a) (b)

Figure 2. Vacuum extraction system (a) and 5 bar pressure extractor (b).

(a) (b)

Figure 3. Fifteen bar (a) and 50 bar pressure extractors (b).

(a) (b)

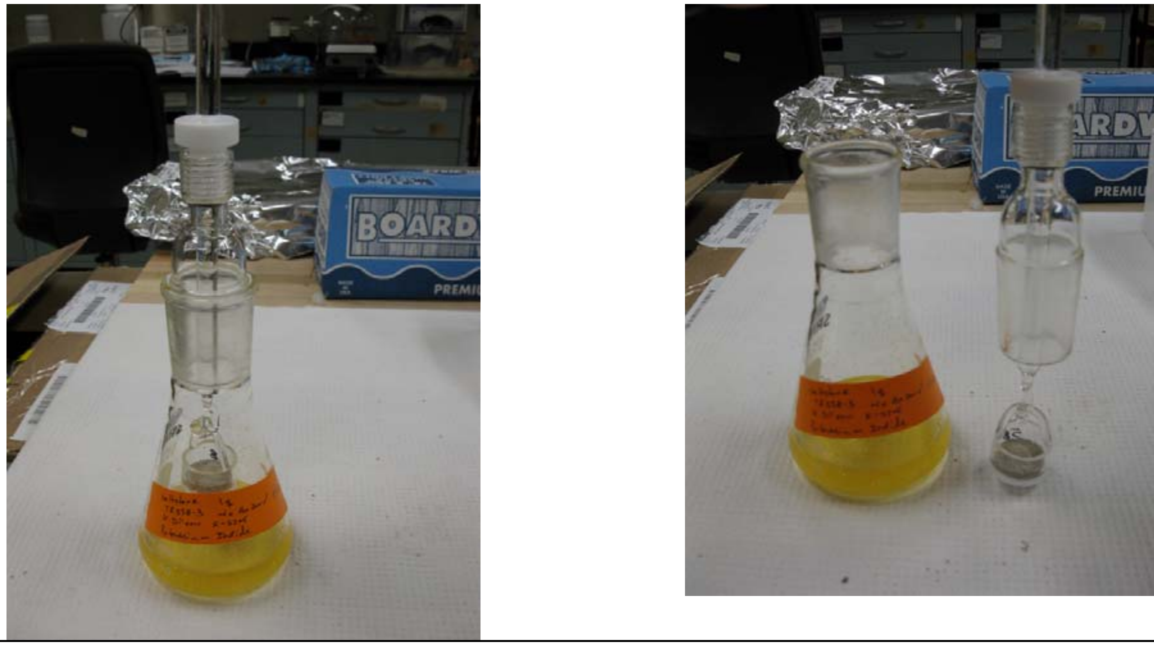
Figure 4. Chilled mirror humidity sensor (a) and sample set prepared for testing (b).

(a) (b)

Figure 5. Saltstone simulant was tested for osmotic potential using the chilled mirror humidity sensor (a and b). The water content of 10 g of simulant was reduced sequentially by boiling to 0.75, 0.50, and 0.35. These photographs clearly show the significant amount of salt contained in the simulant.

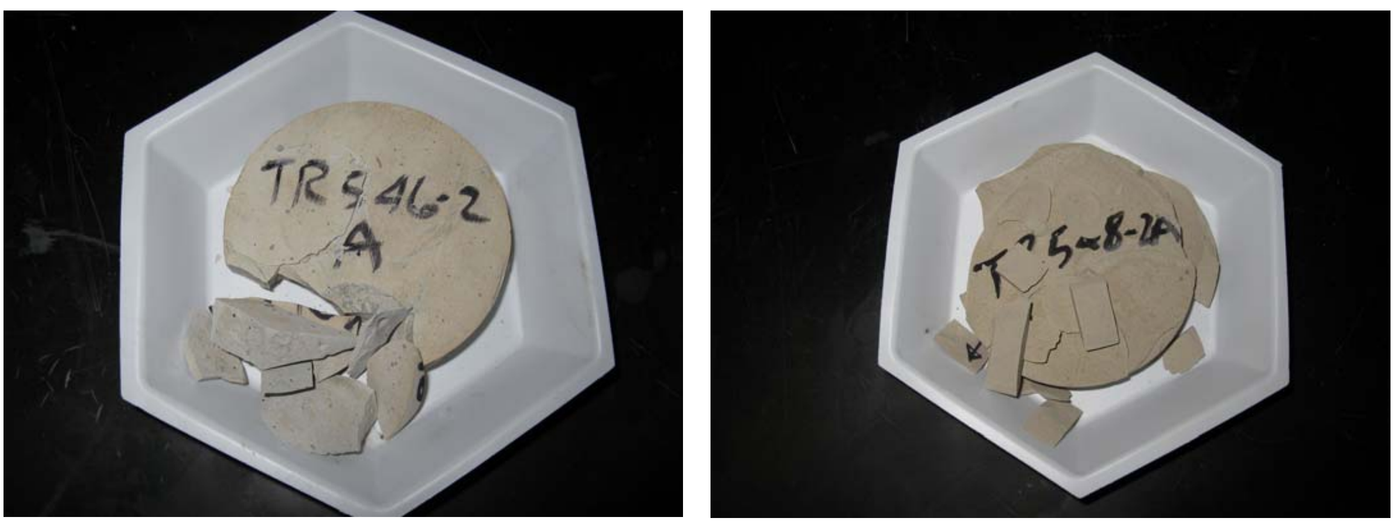
(a) (b)

Figure 6. Samples of each batch of saltstone were crushed and sieved to produce a particle size of < 1 mm for analysis in the chilled mirror humidity sensor (a). Samples were oven dried and then placed in measurement cups for analysis (b). Saltstone simulant was added to each sample prior to analysis.



(a) (b)

Figure 7. Vapor equilibrium apparatus used for confirmation of chilled mirror humidity sensor measurements (a and b). A saturated potassium iodide solution was used to produce a relative humidity of 69% in the headspace of the flask at equilibrium.



(a) (b)

Figure 8. Samples cracked under the high pressure induced in the 50 bar pressure extractor (a and b). This rendered the samples useless and ended testing in the 50 bar pressure extractor.

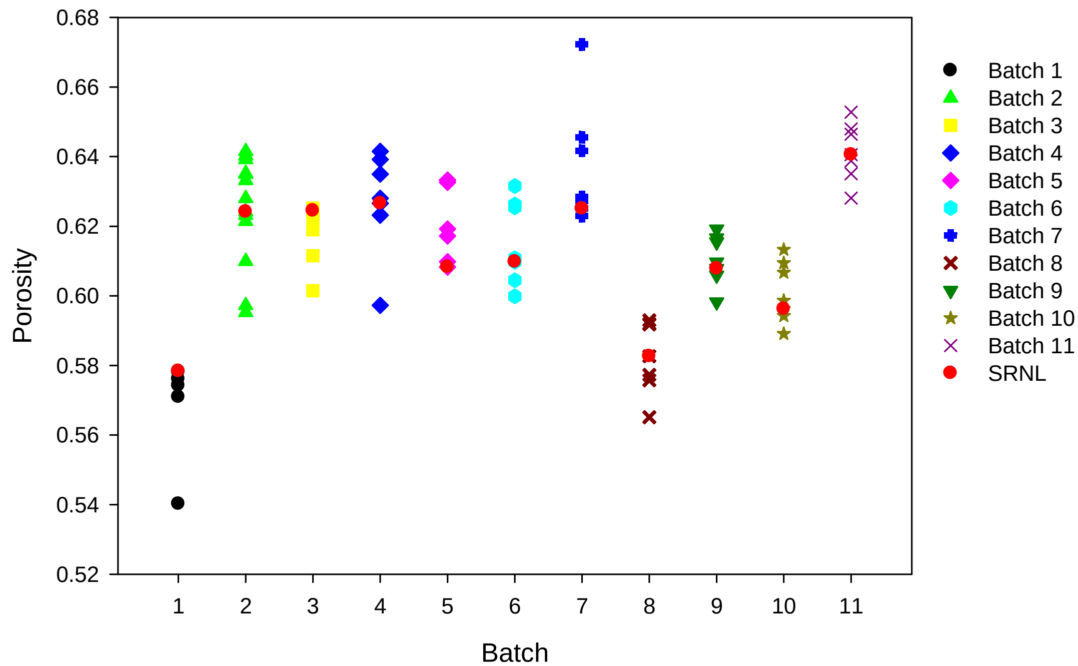


Figure 9. Comparison of saltstone porosity measured by Mactec to that measured by SRNL.

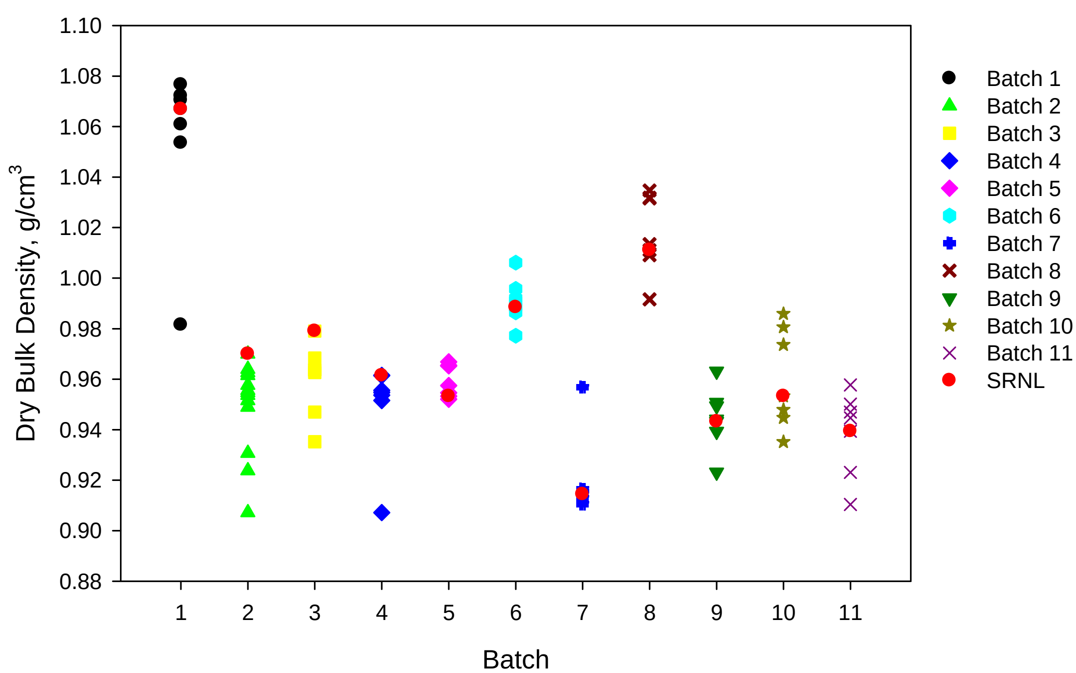


Figure 10. Comparison of dry bulk density measured by Mactec to that measured by SRNL.

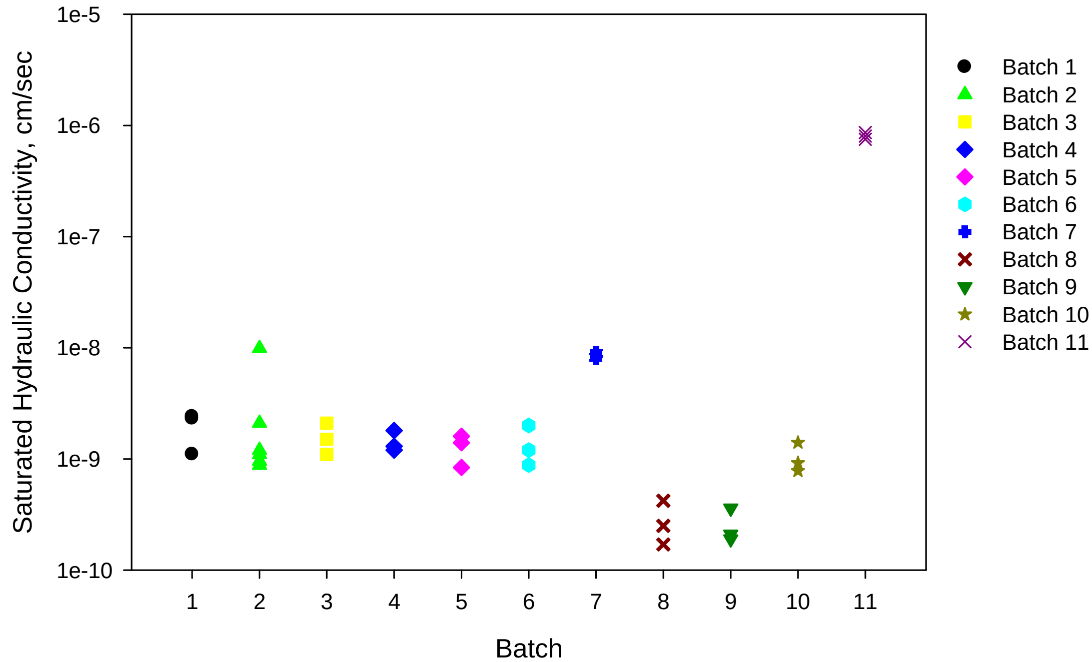


Figure 11. Comparison of saturated hydraulic conductivity as measured by MCT for each batch of saltstone.

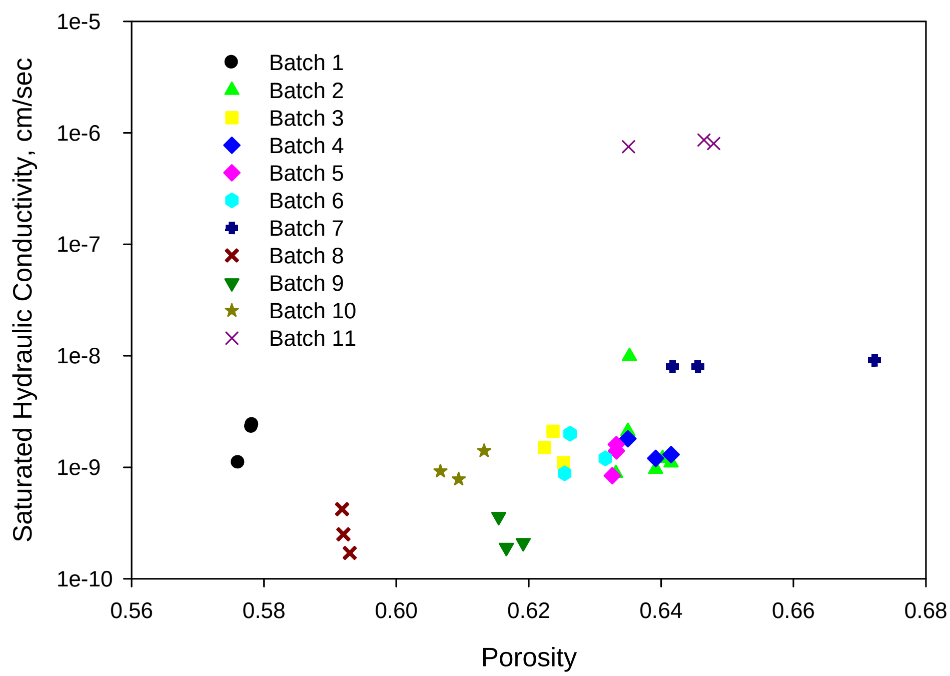


Figure 12. Saturated hydraulic conductivity as a function of porosity for saltstone samples tested at Mactec.

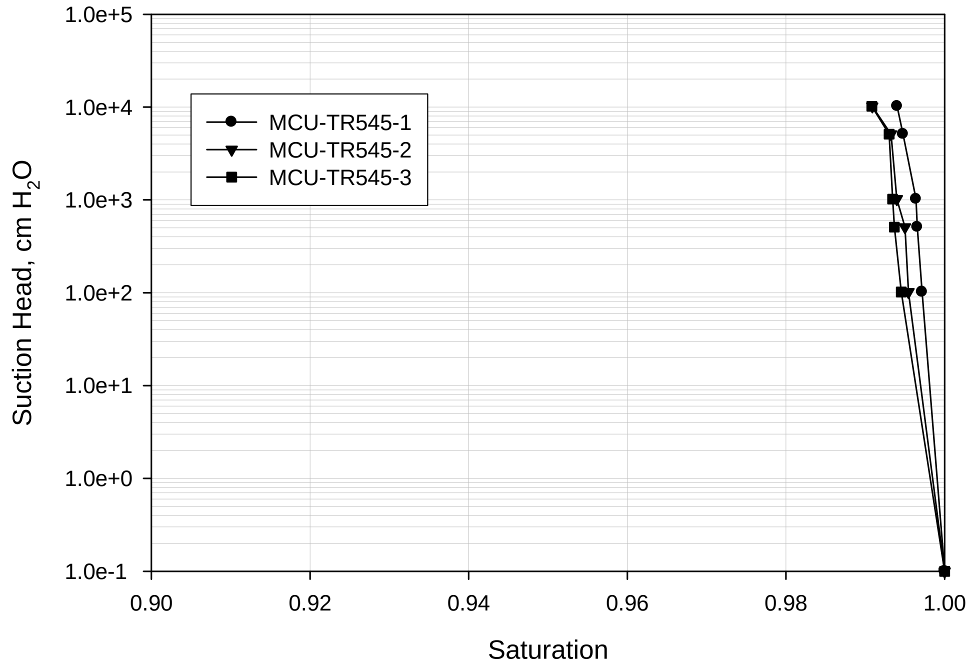


Figure 13. Moisture retention curve for the ARP/MCU saltstone batch TR545 (Control Mix) as measured by Mactec.

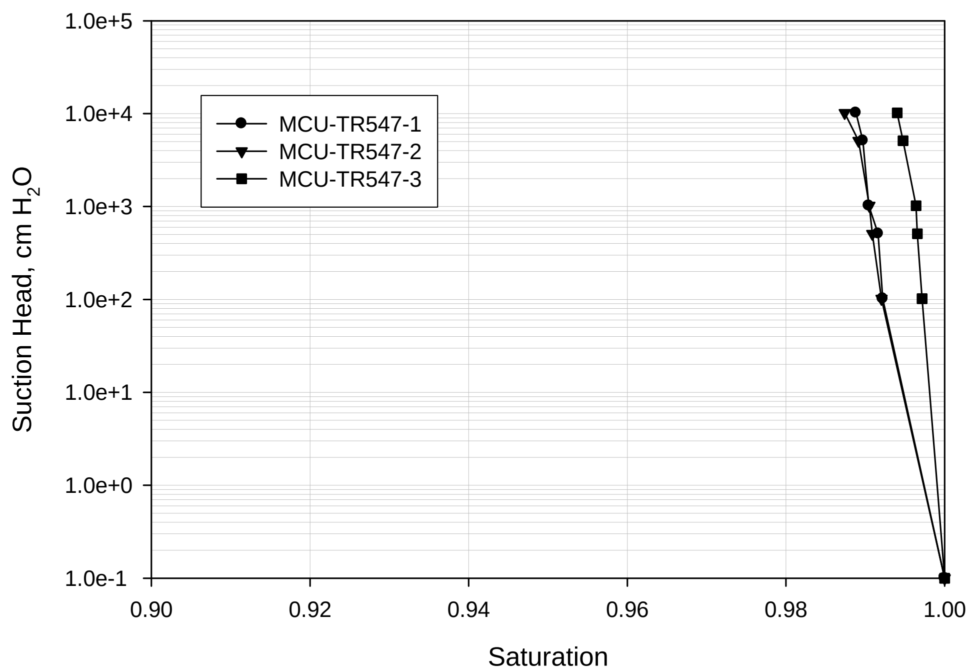


Figure 14. Moisture retention curves for the ARP/MCU saltstone samples batch TR547 (Baseline Mix) as measured by Mactec.

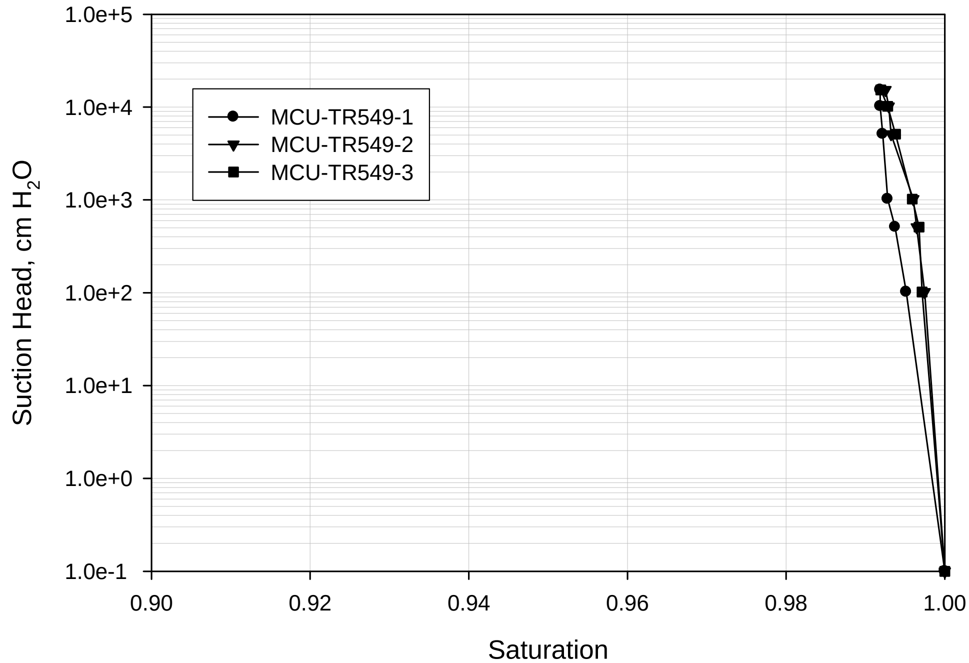


Figure 15. Moisture retention curve for the ARP/MCU saltstone batch TR549 (Baseline Mix with Admixtures) as measured by Mactec.

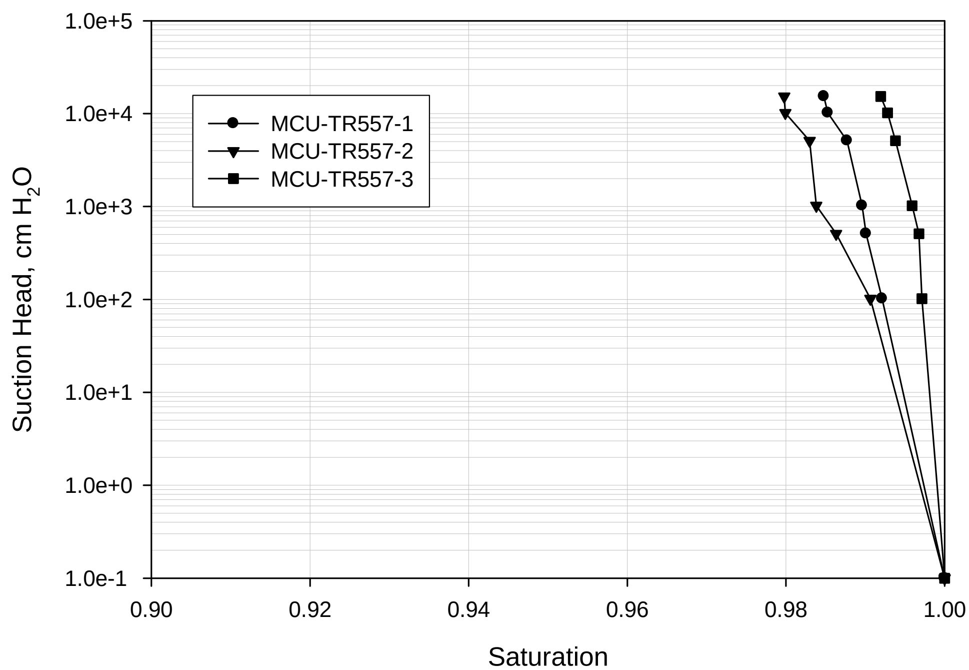


Figure 16. Moisture retention curves for the ARP/MCU saltstone samples batch TR557 (Baseline Mix with Organics) as measured by Mactec.

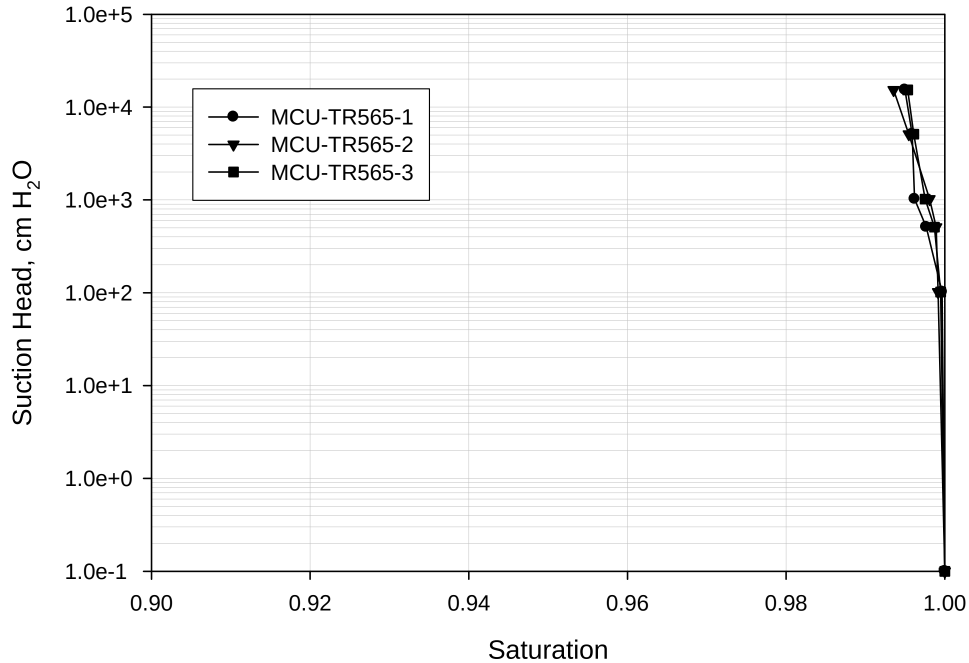


Figure 17. Moisture retention curve for the ARP/MCU saltstone batch TR565 (Baseline Mix with Organics and Admixtures) as measured by Mactec.

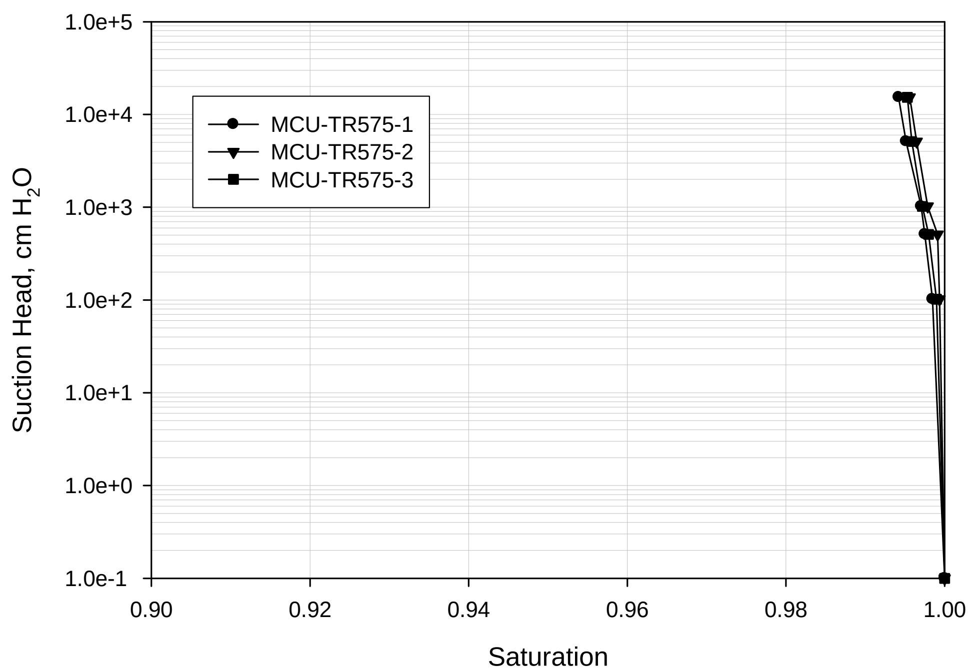


Figure 18. Moisture retention curves for the ARP/MCU saltstone samples batch TR575 (Impact of w/pm ratio) as measured by Mactec.

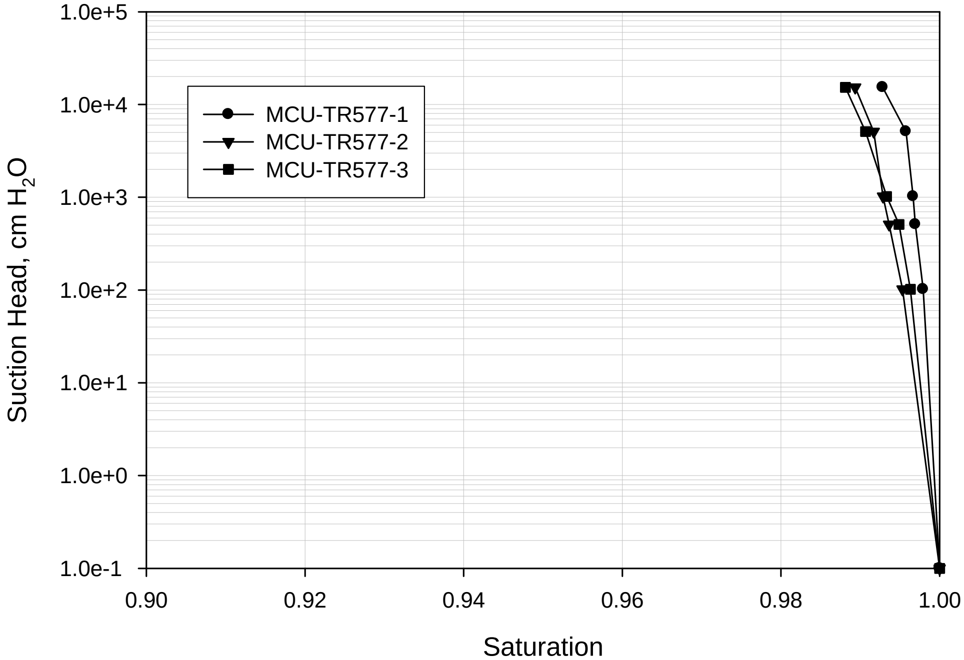


Figure 19. Moisture retention curve for the ARP/MCU saltstone batch TR577 (Impact of w/pm ratio) as measured by Mactec.

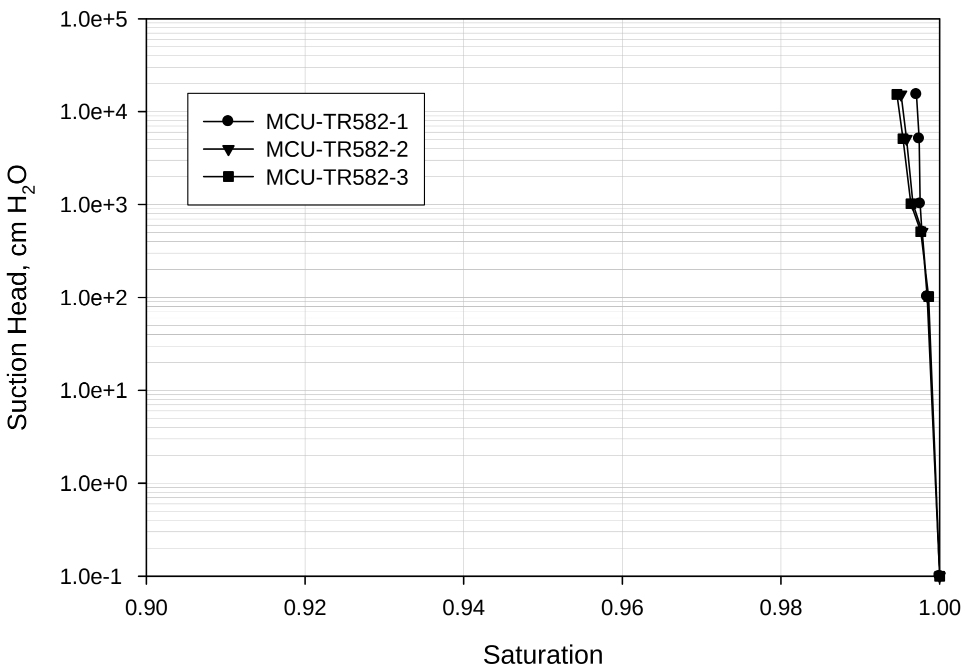


Figure 20. Moisture retention curves for the ARP/MCU saltstone samples batch TR582 (Impact of Aluminate) as measured by Mactec.

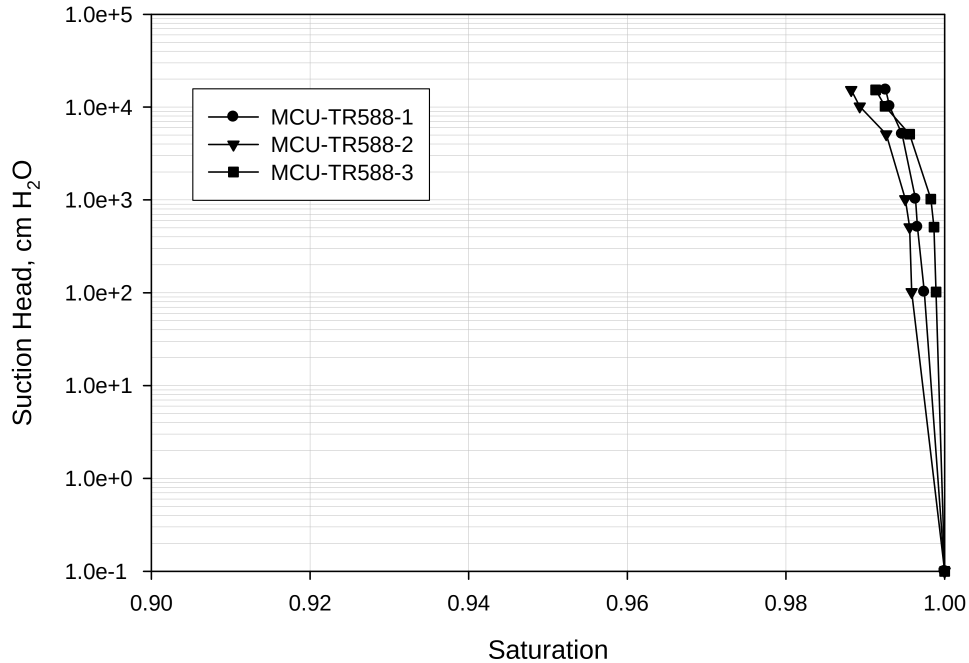


Figure 21. Moisture retention curve for the ARP/MCU saltstone batch TR588 (Impact of Aluminate) as measured by Mactec.

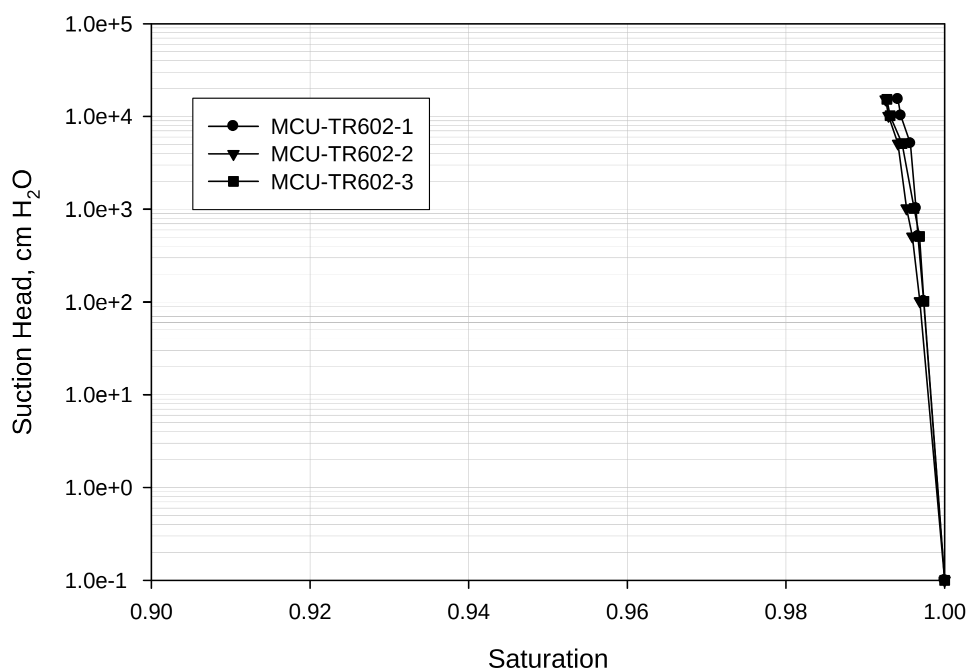


Figure 22. Moisture retention curves for the ARP/MCU saltstone samples batch TR602 (Baseline Mix with Organics, Admixtures, and Increased Aluminate) as measured by Mactec.

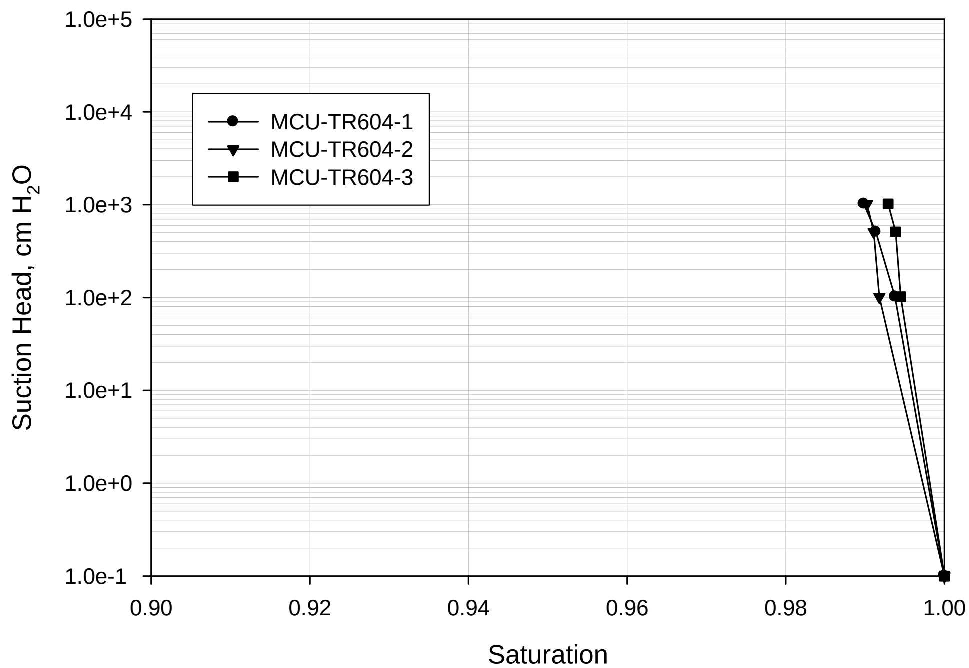


Figure 23. Moisture retention curves for the ARP/MCU saltstone samples batch TR604 (Baseline Mix with Organics and Admixtures Cured at 60° C). Samples cracked at 1 bar.

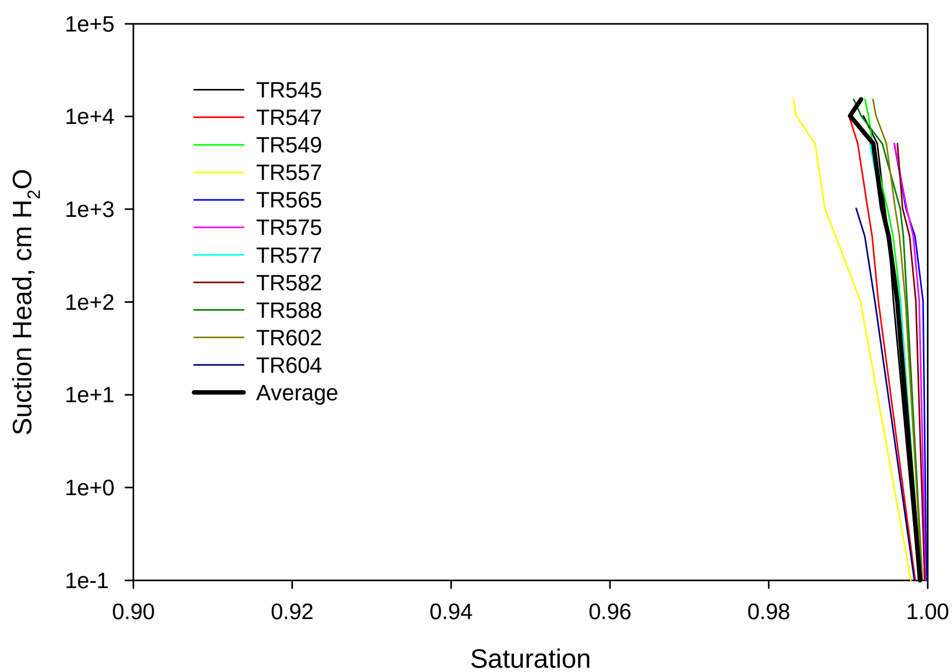


Figure 24. Combined moisture retention curves for the ARP/MCU saltstone samples including average moisture retention curve.

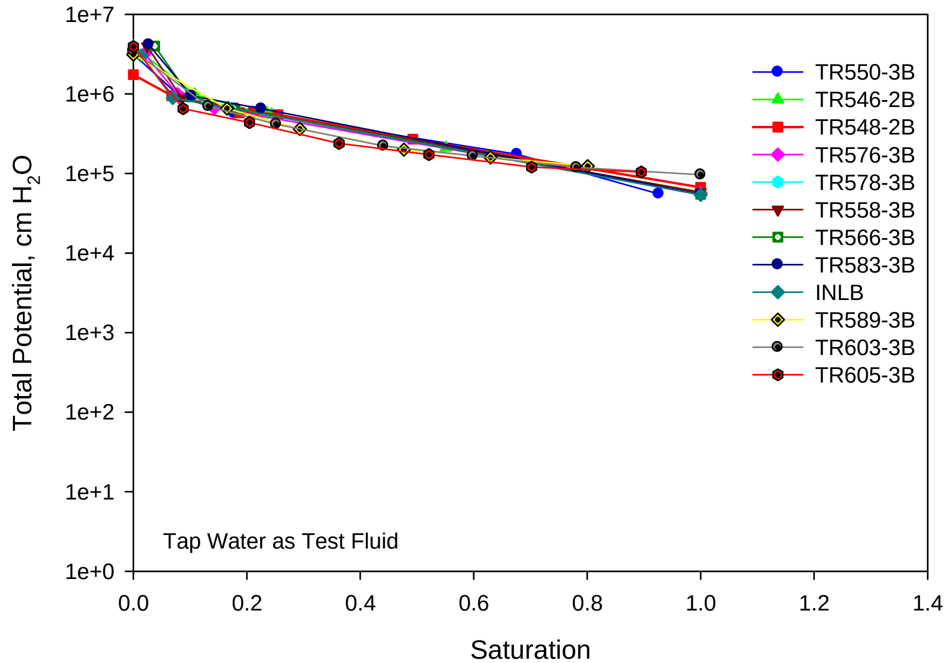


Figure 25. Moisture retention curves for the ARP/MCU saltstone batches as determined by SRNL using a chilled mirror humidity sensor. All measurements were made using tap water as the test fluid.

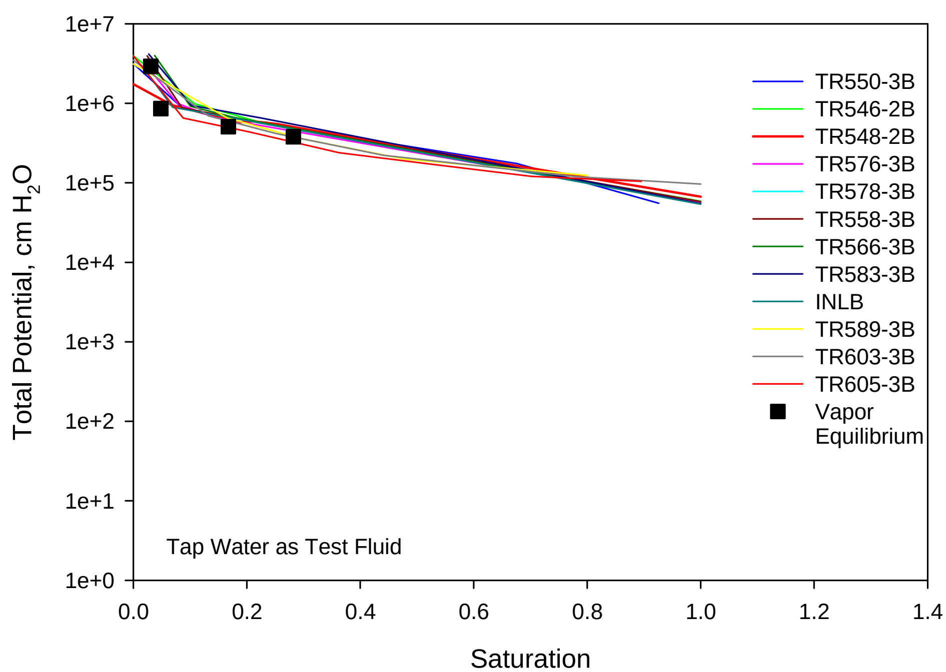


Figure 26. Comparison of moisture retention curves for the ARP/MCU saltstone as determined with a chilled mirror humidity sensor to vapor equilibrium data. All measurements with the chilled mirror humidity sensor were made using tap water as the test fluid.

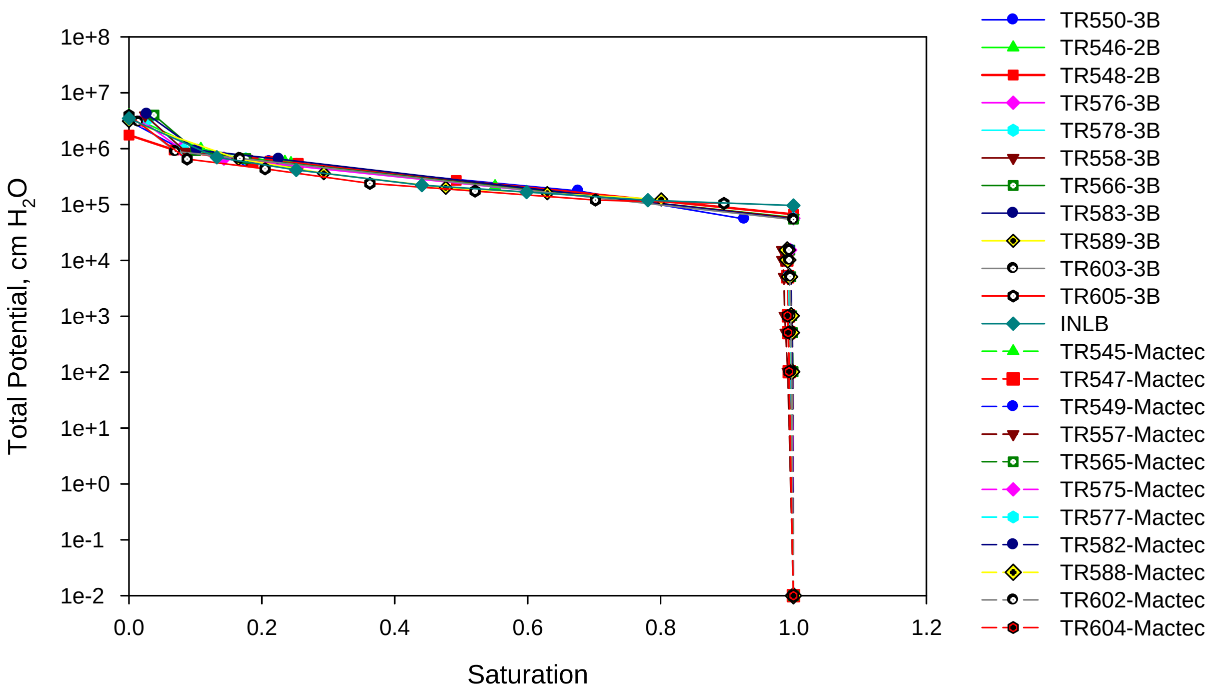


Figure 27. Combined SRNL and MCT moisture retention curves for all ARP/MCU saltstone batches with tap water as the test fluid for the SRNL samples.

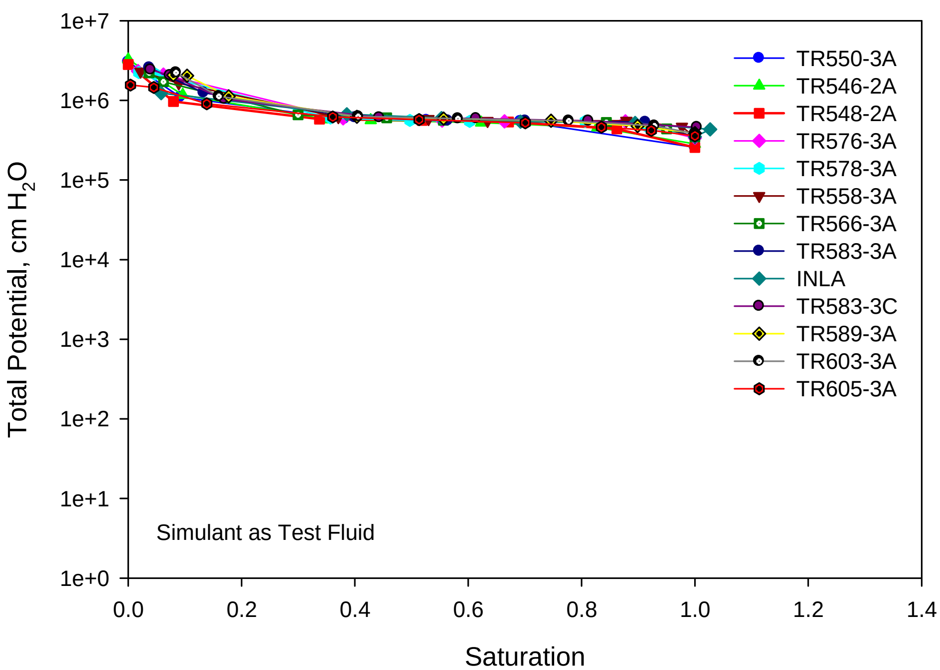


Figure 28. Moisture retention curves for the ARP/MCU saltstone batches as determined by SRNL using a chilled mirror humidity sensor. All measurements were made using saltstone simulant as the test fluid.

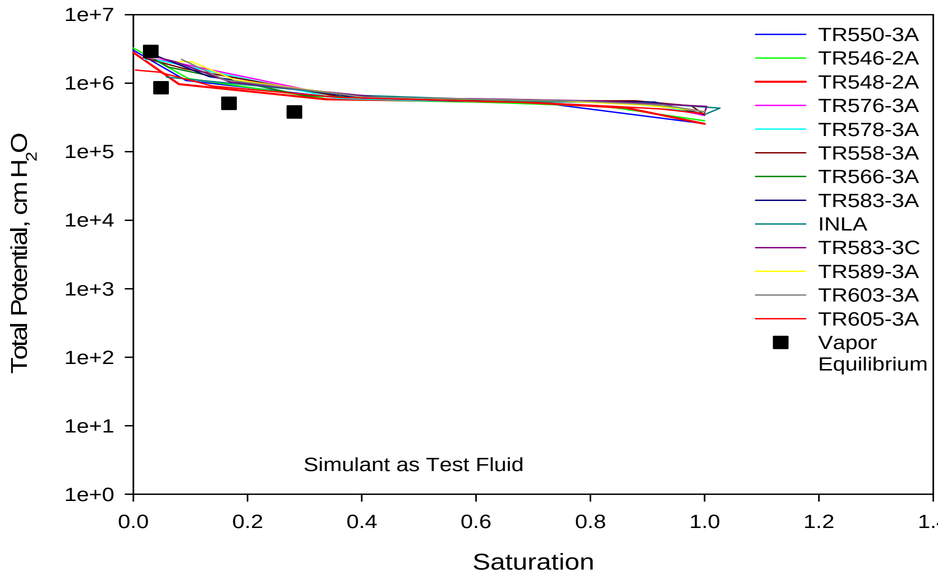


Figure 29. Comparison of moisture retention curves for the ARP/MCU saltstone as determined with a chilled mirror humidity sensor to moisture retention data from vapor equilibrium method. All measurements with the chilled mirror humidity sensor were made using saltstone simulant as the test fluid.

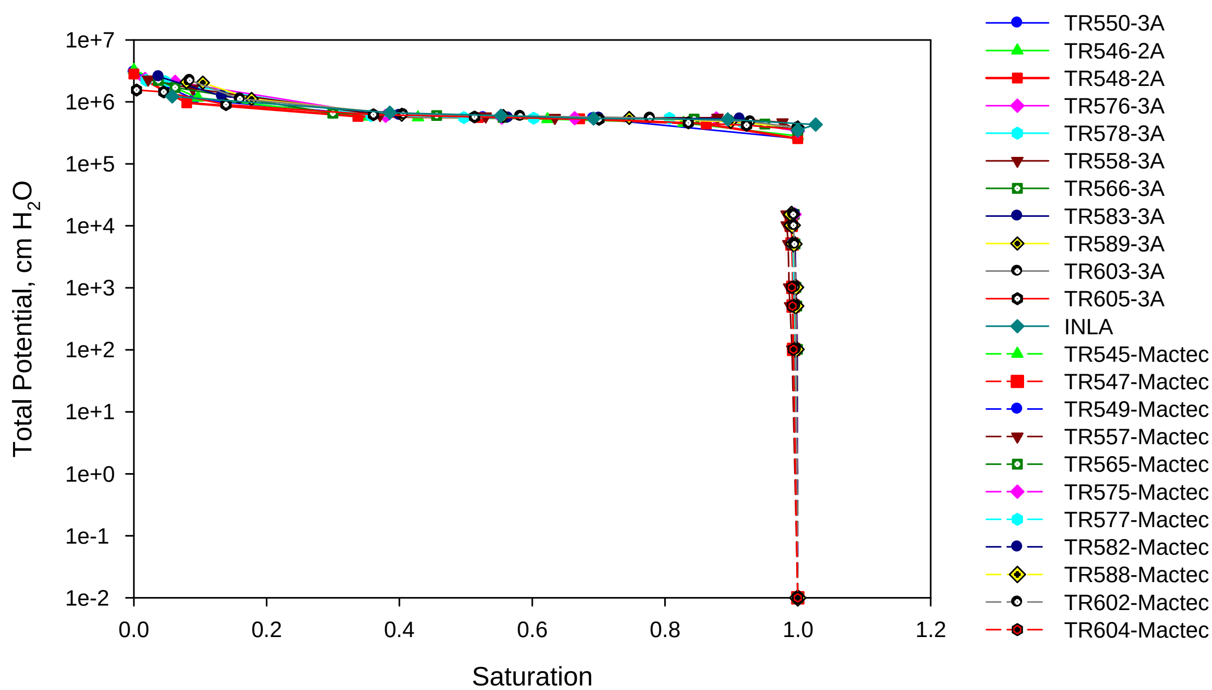


Figure 30. Combined SRNL and MCT moisture retention curves for all ARP/MCU saltstone batches with simulant as the test fluid for the SRNL samples.

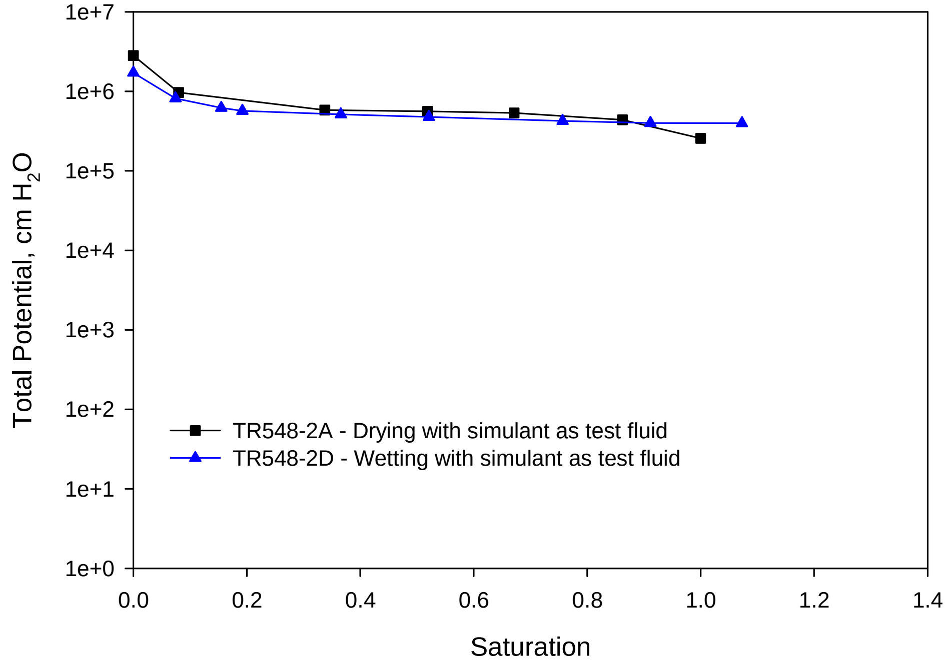


Figure 31. Hysteretic moisture retention curves for the baseline saltstone batch (TR548-2).

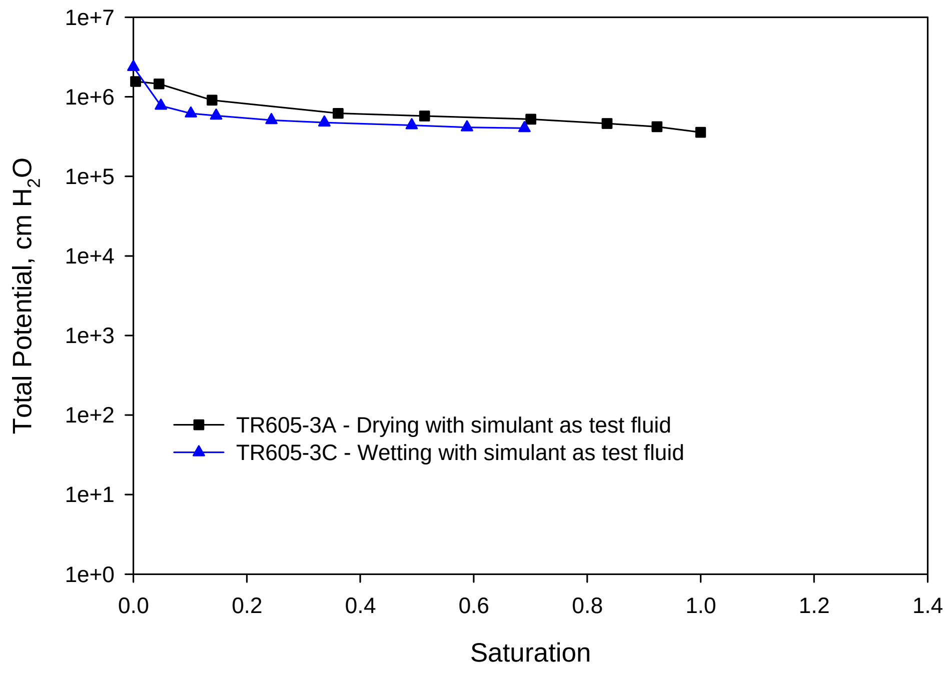


Figure 32. Hysteretic moisture retention curves for the high curing temp saltstone batch (TR605-3).

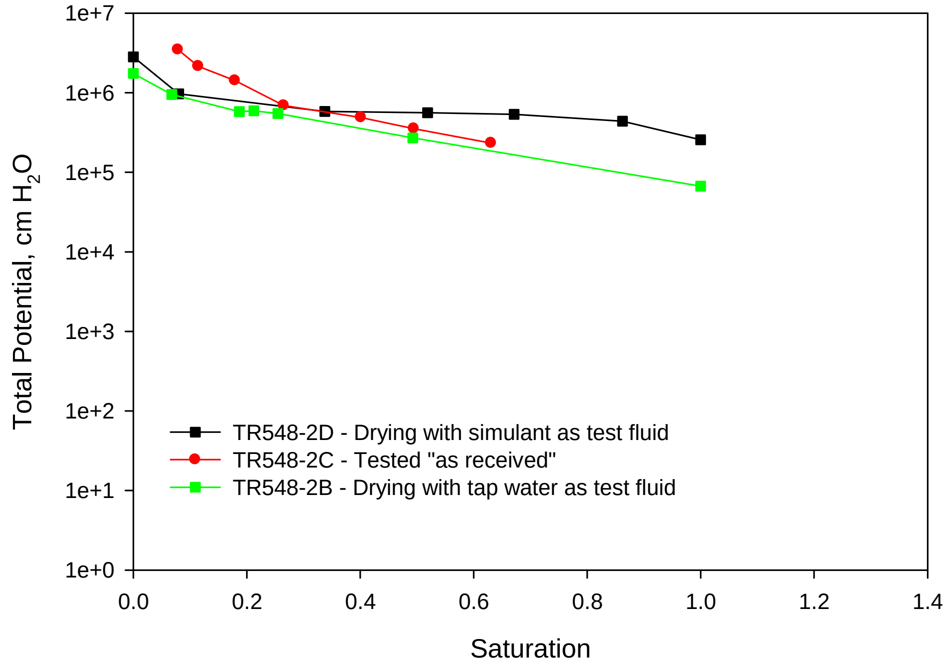


Figure 33. Comparison of moisture retention curves for batch TR548.

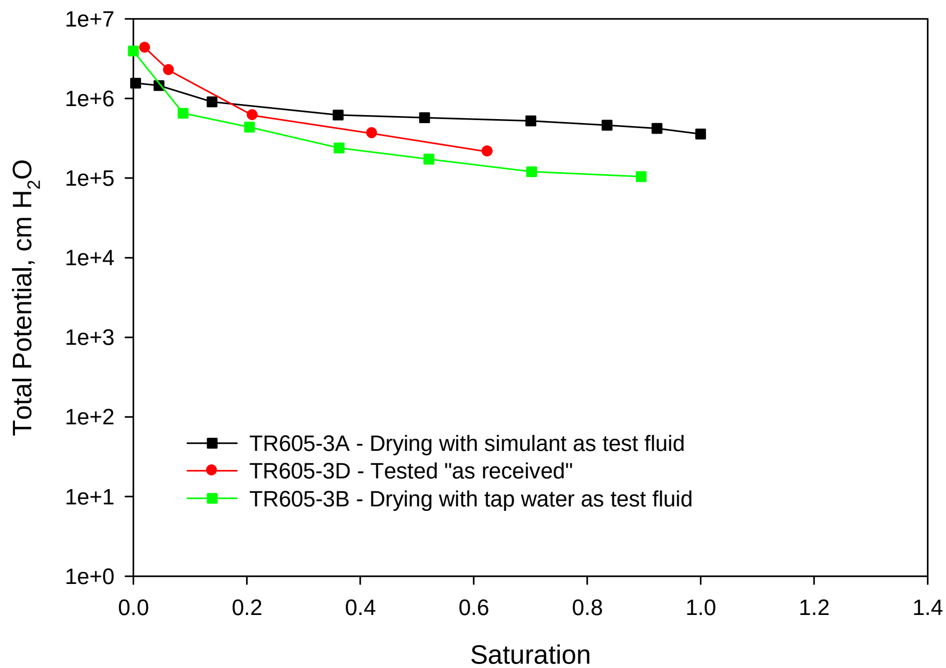


Figure 34. Comparison of moisture retention curves for batch TR605.

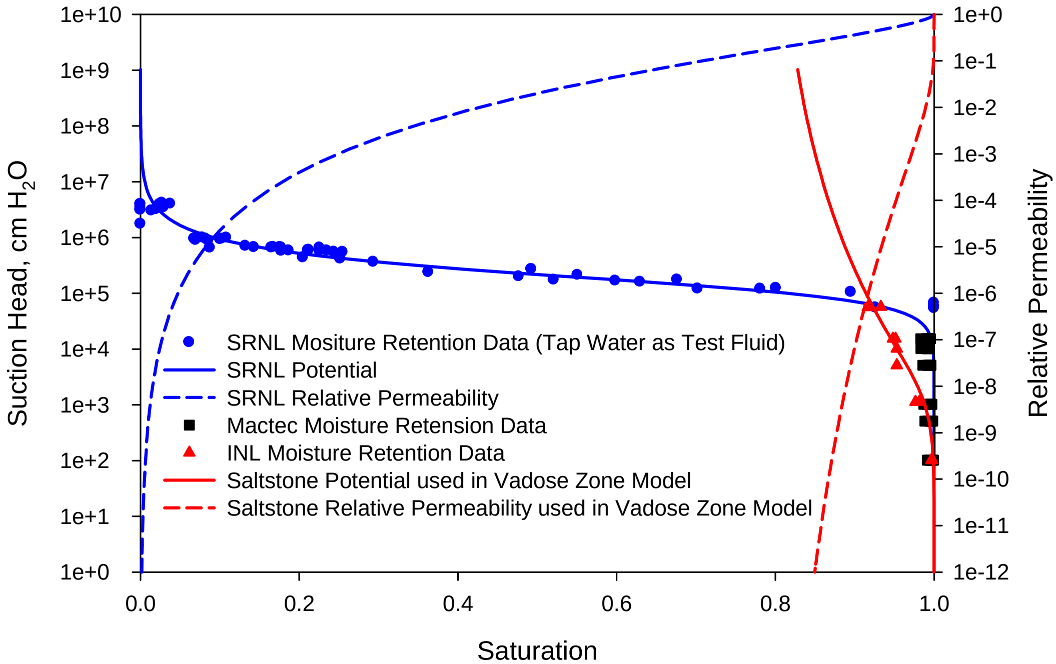


Figure 35. Characteristics curves for ARP/MCU saltstone as determined by SRNL (using tap water as test fluid) and INL. SRNL analysis includes moisture retention data measured by SRNL and Mactec.

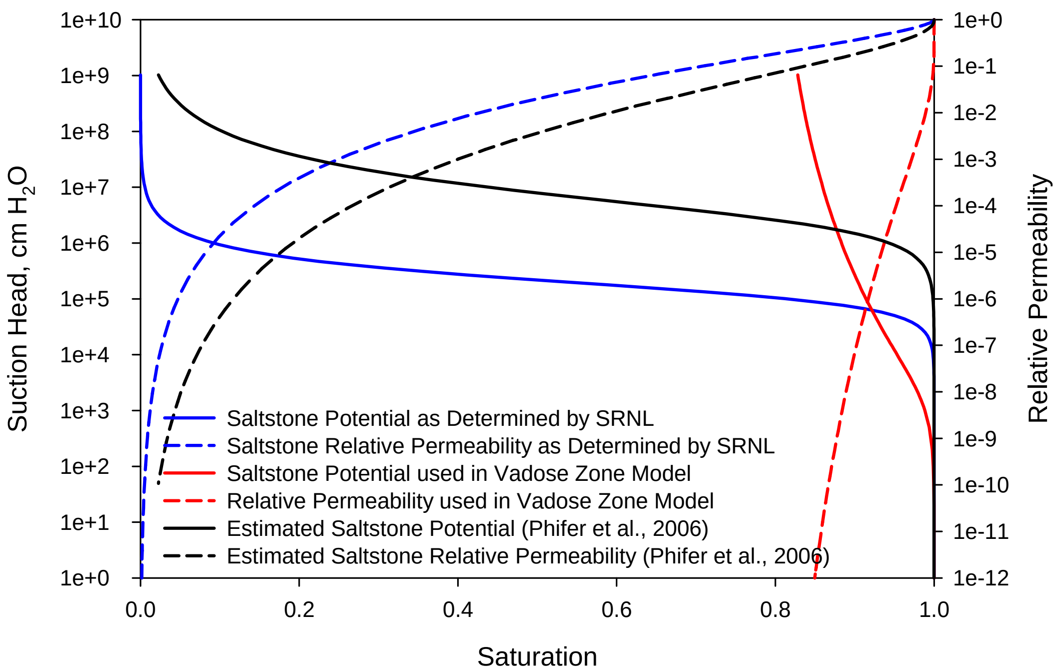


Figure 36. Comparison of characteristics curves for ARP/MCU saltstone as determined by SRNL (using tap water as test fluid) to those currently used in the Z-Area Vadose Zone Model and to those estimated by Phifer et al. (2006).

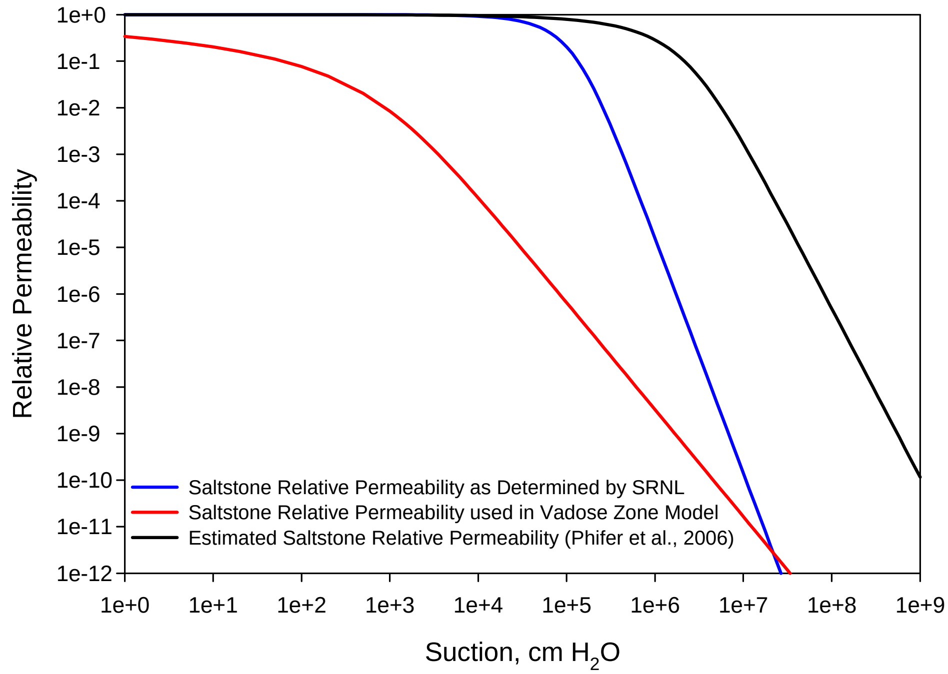


Figure 37. Comparison of relative permeability curve for ARP/MCU saltstone as determined by SRNL (using tap water as test fluid) to the curve currently used in the Z-Area Vadose Zone Model and to the curve estimated by Phifer et al. (2006).

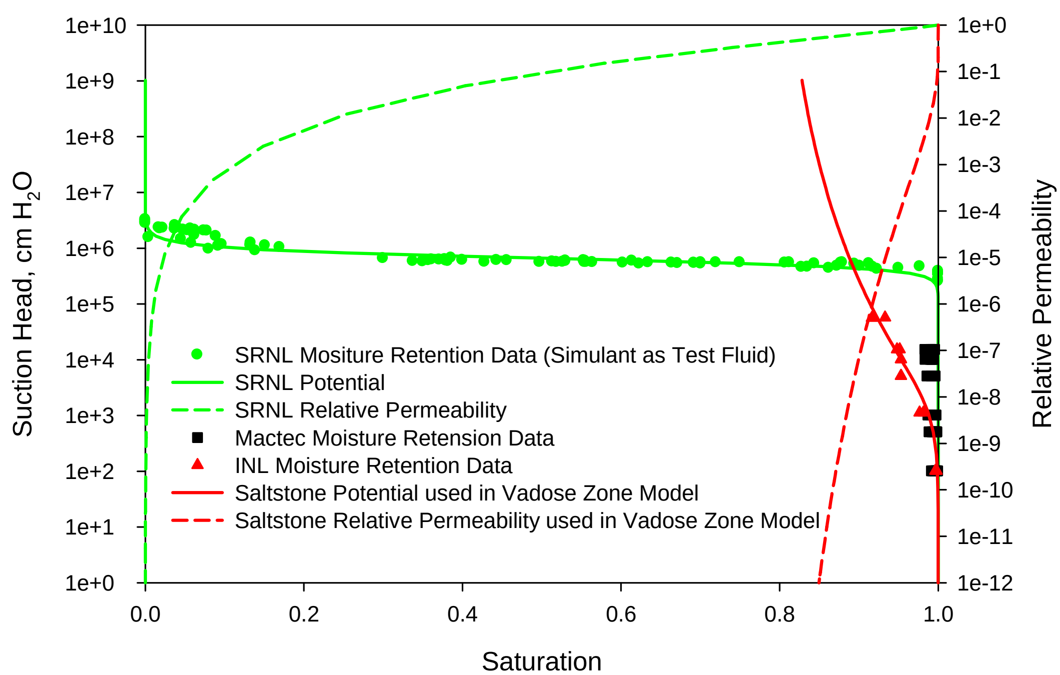


Figure 38. Characteristics curves for ARP/MCU saltstone as determined by SRNL (using simulant as test fluid) and INL. SRNL analysis includes moisture retention data measured by SRNL and Mactec.

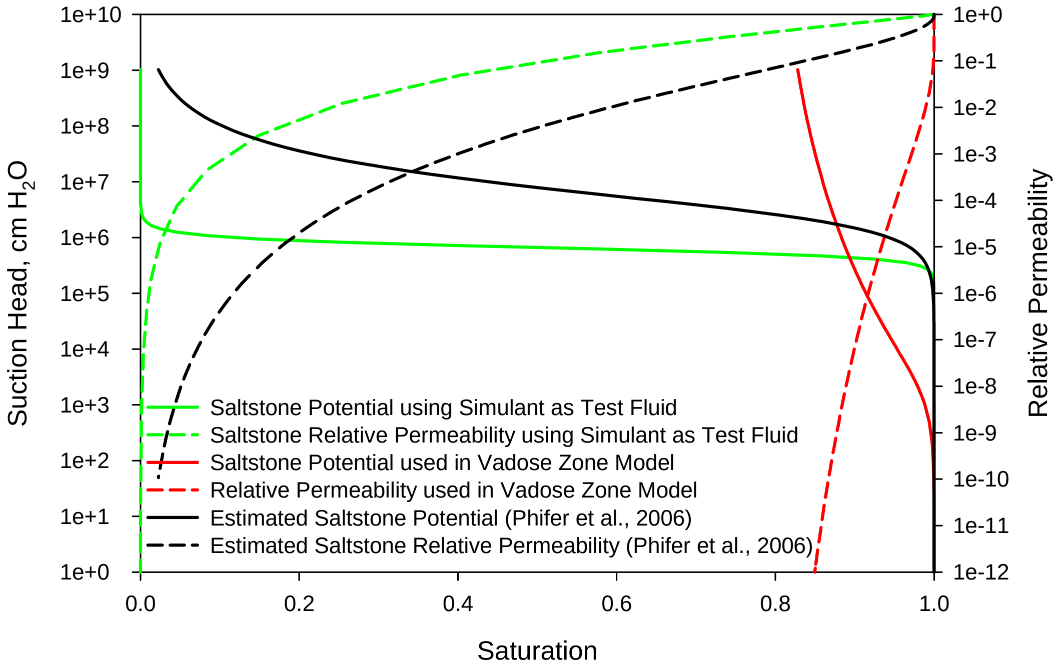


Figure 39. Comparison of characteristics curves for ARP/MCU saltstone as determined by SRNL (using simulant as test fluid) to those currently used in the Z-Area Vadose Zone Model and to those estimated by Phifer et al. (2006).

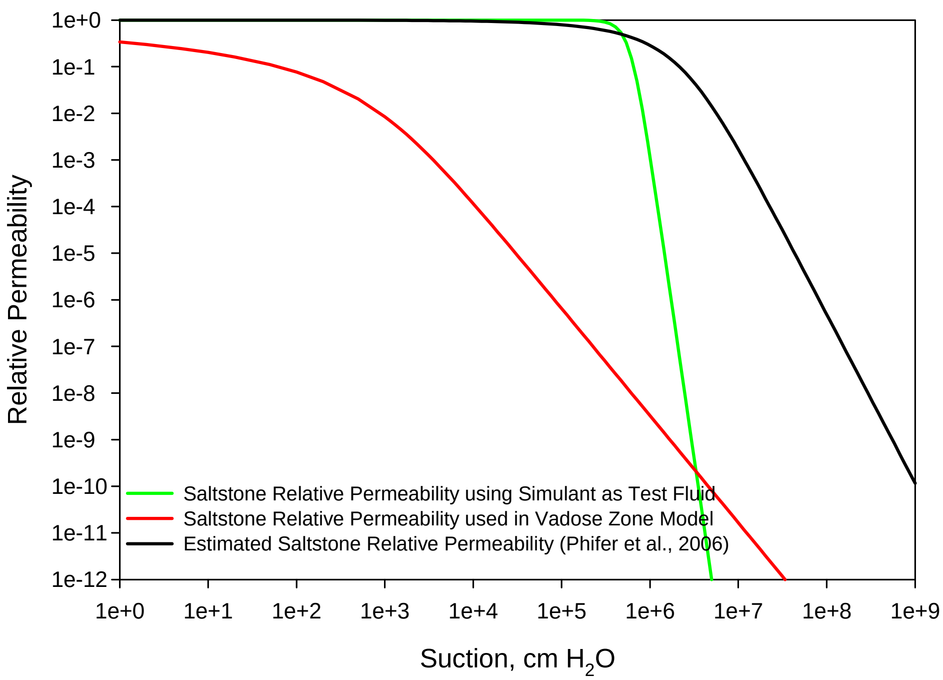


Figure 40. Comparison of relative permeability curve for ARP/MCU saltstone as determined by SRNL (using simulant as test fluid) to the curve currently used in the Z-Area Vadose Zone Model and to the curve estimated by Phifer et al. (2006).

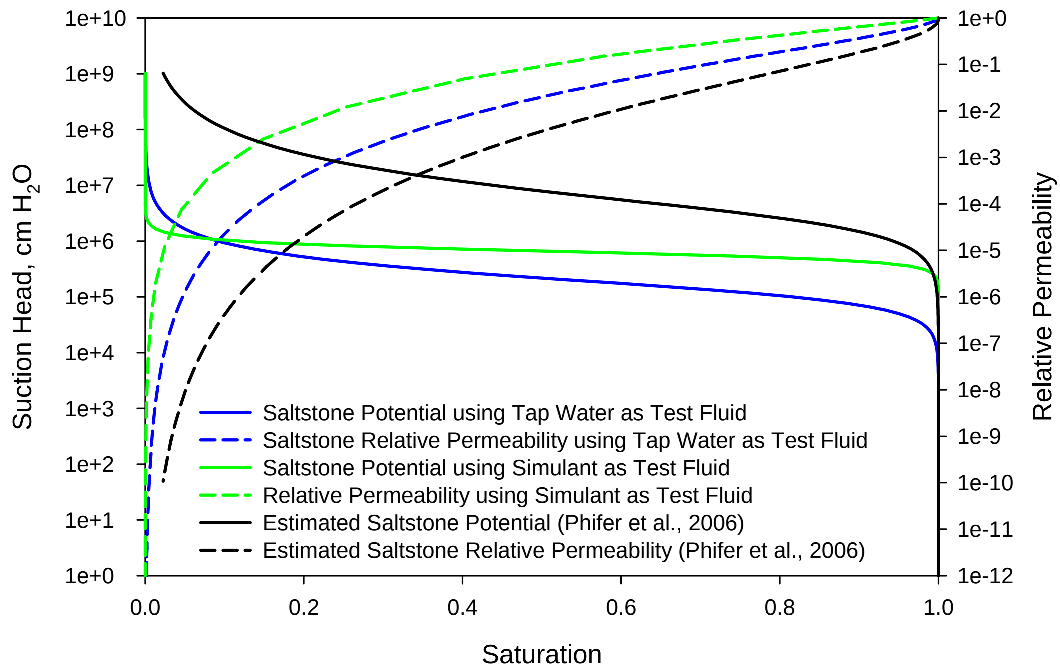


Figure 41. Comparison of relative permeability curve for ARP/MCU saltstone as determined by SRNL using tap water and simulant as the test fluid to the curve estimated by Phifer et al. (2006).

Table 1. Saltstone Mixes that Were Batched and Tested for Hydraulic and Physical Properties.

Batch	Mix ID	Descriptor	w/pm[1]	Aluminate Molarity	Premix BFS[2] (%)	Premix FA[3] (%)	Premix OPC[4] (%)
1	TR545, TR546	Control	0.60	0.054	90	0	10
2	TR547, TR548	Baseline	0.60	0.054	45	45	10
3	TR549, TR550	Baseline with Admixtures	0.60	0.054	45	45	10
4	TR557, TR558	Baseline with Organics	0.60	0.054	45	45	10
5	TR565, TR566	Baseline with Organics and Admixtures	0.60	0.054	45	45	10
6	TR575, TR576	Impact of Water to Premix Ratio	0.55	0.054	45	45	10
7	TR577, TR578	Impact of Water to Premix Ratio	0.65	0.054	45	45	10
8	TR582, TR583	Impact of Increased Aluminate	0.55	0.280	45	45	10
9	TR588, TR589	Impact of Increased Aluminate	0.65	0.280	45	45	10
10	TR602, TR603	Baseline with Organics, Admixtures, and Increased Aluminate	0.60	0.280	45	45	10
11	TR604, TR605	Baseline with Organics and Admixtures at 60^{o} C Cure Temperature	0.60	0.054	45	45	10

[1]Water to premix ratio
[2]BFS – Blast Furnace Slag
[3]FA – Carbon Burnout Fly Ash
[4]Ordinary Portland Cement (Type II)

Table 2. Cementitious Materials Used in the Premix for Each Batch of Simulated Saltstone Grout.

Ingredient	Vendor
Ordinary Portland Cement (Type II)	Holcim
Blast Furnace Slag (Grade 100)	Holcim
Carbon Burnout Fly Ash (Class F)	McMeekin Station

Table 3. Additives (Organics and Admixtures) used in Selected Saltstone Formulations.

Additives	Compound	Quantity
Admixtures	Daratard 17 Set Retarder	1.0 % of premix by mass
	Q2-1383-A Anti Foam Agent	
Organics	0.75 M 1-(2,2,3,3-tetrafluoropropoxy)-3-(4-sec-butylphenoxy)-2-propanol (Cs-7SB) in an Isopar® L diluent 0.003 M tri-n-octylamine (TOA) in an Isopar® L diluent	100 μL/1600 g grout[1]

[1]Grout includes premix and simulant.

Table 4. Recipe for Standard ARP/MCU Simulant Used to Prepare Simulated Saltstone Grout Samples for Hydraulic and Physical Testing.

Ingredient	ARP/MCU Simulant[1]	
	Molarity (Moles/Liter)	**Mass (g/Liter H_2O)**
Sodium Hydroxide, NaOH (50 % by weight)	1.594	127.50
Sodium Nitrate, $NaNO_3$	2.996	254.66
Sodium Nitrite, $NaNO_2$	0.368	25.39
Sodium Carbonate, Na_2CO_3	0.176	18.65
Sodium Sulfate. Na_2SO_4	0.059	8.37
Aluminum Nitrate (9 H_2O)	0.054	20.33
Sodium Phosphate (12 H_2O)	0.012	4.67

[1]The same simulant was used to batch and test each of the grout samples.

Table 5. Recipe for ARP/MCU Simulant with Increased Aluminate Used to Prepare Simulated Saltstone Grout Samples for Hydraulic and Physical Testing (batches TR582, TR588, TR602).

Ingredient	ARP/MCU Simulant[1]	
	Molarity (Moles/Liter)	**Mass (g/Liter H_2O)**
Sodium Hydroxide, NaOH (50 % by weight)	2.497	199.76
Sodium Nitrate, $NaNO_3$	2.319	197.09
Sodium Nitrite, $NaNO_2$	0.368	25.39
Sodium Carbonate, Na_2CO_3	0.176	18.65
Sodium Sulfate. Na_2SO_4	0.059	8.37
Aluminum Nitrate (9 H_2O)	0.280	105.04
Sodium Phosphate (12 H_2O)	0.012	4.67

[1]The same simulant was used to batch and test each of the grout samples that used a higher level of aluminate. The free hydroxide ion and nitrate ion concentrations are the same for both simulants.

Table 6. ARP/MCU Simulant Properties.

	Density (g/ml)	Dynamic Viscosity (cP)	Water to Simulant Ratio (g H_2O/g simulant)	Weight Percent Solids (%)	Salt Content (g/100g wet grout)
ARP/MCU Simulant	1.253	2.49	0.693	30.57	14.38
ARP/MCU Simulant with Increased Aluminate	1.269	2.85	0.676	32.16	15.05

Table 7. Salt Solutions used in Controlled Vapor Pressure Method.

Salt Solution	Relative Humidity (fraction)	$(h_m-h_o)^1$ (bar)	$(h_m-h_o)^1$ (cm)
Sodium Chloride (NaCl)	0.75	-372	-379837
Potassium Iodide (KI)	0.68	-496	-506179
Magnesium Nitrate Hexahydrate $Mg(NO_3)_2*6H_2O$	0.53	-840	-856253
Lithium Chloride (LiCl)	0.11	-2849	-2905106

[1]Total potential which is the sum of matric and osmotic potential.

Table 8. Fresh Properties and Young's Modulus Data for the ARP/MCU Saltstone Grouts.

Batch	Mix Id	Yield Stress (Pa)	Plastic Viscosity (cP)	Gel Time (minutes)	One Day Bleed (volume %)	Set Time (days)	Young's Modulus (GPa)	Days Cured (days)
1	TR545, TR546	11.5	126	25	0	1	8.7	89
2	TR547, TR548	5.8	97	10	0	1	5.2	91
3	TR549, TR550	4.1	76	20	<1	1	5.3	90
4	TR557, TR558	5.8	98	20	0	1	5.8	89
5	TR565, TR566	4.1	75	20	0	1	5	91
6	TR575, TR576	8.6	132	20	0	1	5.7	92
7	TR577, TR578	3.8	68	35	<1	1	4.9	90
8	TR582, TR583	5.6	105	15	<1	6	10.2	90
9	TR588, TR589	2.4	51	30	<1	7	8.6	91
10	TR602, TR603	2.7	63	10	<1	7	8.3	96
11	TR604, TR605	3.2	67	20	0	1	2.9	57

Table 9. Hydraulic Properties of ARP/MCU Saltstone as Measured by MCT (90 day minimum curing period) for Each of the Eleven Formulations Tested.

Batch	Sample Id	Saturated Hydraulic Conductivity[1] (cm/s)	Permeability[2] (darcy)	Dry Bulk Density (g/cm^3)[3]	Porosity[4]	Particle Density (g/cm^3)[5]
1	MCU-TR545-1	2.3E-09	4.7E-06	1.072	0.578	2.541
1	MCU-TR545-2	1.1E-09	2.3E-06	1.070	0.576	2.525
1	MCU-TR545-3	2.4E-09	4.9E-06	1.077	0.578	2.552
2	MCU-TR547-1	1.2E-09	2.5E-06	0.964	0.640	2.679
2	MCU-TR547-2	9.9E-09	2.0E-05	0.958	0.635	2.625
2	MCU-TR547-3	8.8E-10	1.8E-06	0.963	0.633	2.624
2	MCU-TR548-1	9.6E-10	2.0E-06	0.950	0.636	2.609
2	MCU-TR548-2	2.1E-09	4.3E-06	0.951	0.637	2.618
2	MCU-TR548-3	1.1E-09	2.3E-06	0.953	0.637	2.626
3	MCU-TR549-1	2.1E-09	4.3E-06	0.968	0.624	2.573
3	MCU-TR549-2	1.5E-09	3.1E-06	0.963	0.622	2.549
3	MCU-TR549-3	1.1E-09	2.3E-06	0.964	0.625	2.571
4	MCU-TR557-1	1.2E-09	2.5E-06	0.954	0.639	2.643
4	MCU-TR557-2	1.8E-09	3.7E-06	0.952	0.635	2.607
4	MCU-TR557-3	1.3E-09	2.7E-06	0.962	0.642	2.682
5	MCU-TR565-1	8.4E-10	1.7E-06	0.955	0.633	2.598
5	MCU-TR565-2	1.4E-09	2.9E-06	0.957	0.633	2.611
5	MCU-TR565-3	1.6E-09	3.3E-06	0.965	0.633	2.632
6	MCU-TR575-1	2.0E-09	4.1E-06	0.992	0.626	2.654
6	MCU-TR575-2	8.8E-10	1.8E-06	0.991	0.625	2.646
6	MCU-TR575-3	1.2E-09	2.5E-06	1.006	0.632	2.731
7	MCU-TR577-1	9.1E-09	1.9E-05	0.957	0.672	2.919
7	MCU-TR577-2	8.0E-09	1.6E-05	0.913	0.642	2.548
7	MCU-TR577-3	8.0E-09	1.6E-05	0.915	0.646	2.582
8	MCU-TR582-1	4.2E-10	9.7E-07	1.032	0.592	2.527
8	MCU-TR582-2	1.7E-10	3.9E-07	1.035	0.593	2.542
8	MCU-TR582-3	2.5E-10	5.8E-07	1.032	0.592	2.529
9	MCU-TR588-1	1.9E-10	4.4E-07	0.949	0.617	2.476
9	MCU-TR588-2	2.1E-10	4.9E-07	0.963	0.619	2.529
9	MCU-TR588-3	3.6E-10	8.3E-07	0.951	0.615	2.473

Table 9. Hydraulic Properties of ARP/MCU Saltstone as Measured by MCT (90 day minimum curing period) for Each of the Eleven Formulations Tested - continued.

Batch	Sample Id	Saturated Hydraulic Conductivity[1] (cm/s)	Permeability[2] (darcy)	Dry Bulk Density (g/cm^3)[3]	Porosity[4]	Particle Density (g/cm^3)[5]
10	MCU-TR602-1	1.4E-09	3.2E-06	0.986	0.613	2.549
10	MCU-TR602-2	9.2E-10	2.1E-06	0.974	0.607	2.475
10	MCU-TR602-3	7.8E-10	1.8E-06	0.981	0.609	2.511
11	MCU-TR604-1	8.0E-07	1.8E-03	0.958	0.648	2.659
11	MCU-TR604-2	8.6E-07	2.0E-03	0.947	0.646	2.618
11	MCU-TR604-3	7.5E-07	1.7E-03	0.945	0.635	2.533

[1]Saturated hydraulic conductivity relative to the ARP/MCU simulant.
[2]Permeability is independent of the simulant and can be converted to saturated hydraulic conductivity for any solution using the equation in Section 3.2.
[3]Dry bulk density corrected for salt precipitation as described in Section 3.2.
[4]Porosity corrected for salt precipitation as described in Section 3.2.
[5]Particle density calculated as $\rho_s = \rho_b/(1-\eta)$ where ρ_b is dry bulk density and η is porosity.

Table 10. Physical Properties of ARP/MCU Saltstone as Measured by SRNL (90 day minimum curing period) for Each of the Eleven Formulations Tested.

Batch	Sample Id	Lab	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)
1	TR546-2B	SRNL	1.067	0.578	2.530
2	TR548-2B	SRNL	0.970	0.624	2.581
3	TR550-3B	SRNL	0.979	0.624	2.607
4	TR558-3B	SRNL	0.961	0.627	2.575
5	TR566-3B	SRNL	0.953	0.608	2.434
6	TR576-3B	SRNL	0.988	0.610	2.533
7	TR578-3B	SRNL	0.914	0.625	2.439
8	TR583-3B	SRNL	1.011	0.583	2.423
9	TR589-3B	SRNL	0.943	0.608	2.405
10	TR603-3B	SRNL	0.953	0.596	2.361
11	TR605-3B	SRNL	0.939	0.641	2.614

Table 11. Summary Hydraulic Properties for ARP/MCU Saltstone Grout Samples.

Batch	Mix ID	Description	Bulk Density (g/cm^3)[1] Min	Max	Avg[2]	Saturated Hydraulic Conductivity (cm/sec) Min	Max	Avg[2]	Permeability (darcy) Min	Max	Avg[2]	Porosity (fraction)[1] Min	Max	Avg[2]
1	TR545, TR546	Control - BFS/OPC	0.981	1.077	1.055	1.1E-09	2.4E-09	1.9E-09	2.3E-06	4.9E-06	4.0E-06	0.540	0.578	0.571
2	TR547, TR548	Baseline	0.924	0.970	0.951	8.8E-10	9.9E-09	4.0E-09	1.8E-06	2.0E-05	8.2E-06	0.595	0.640	0.623
2	TR548	Baseline (2 inch samples)	0.907	0.956	0.945	9.6E-10	2.1E-09	1.4E-09	2.0E-06	4.3E-06	2.8E-06	0.597	0.637	0.626
3	TR549, TR550	Baseline with Admixtures	0.935	0.979	0.960	1.1E-09	2.1E-09	1.6E-09	2.3E-06	4.3E-06	3.2E-06	0.601	0.625	0.618
4	TR557, TR558	Baseline with Organics	0.907	0.962	0.949	1.2E-09	1.8E-09	1.4E-09	2.5E-06	3.7E-06	2.9E-06	0.597	0.642	0.627
5	TR565, TR566	Baseline with Organics and Admixtures	0.952	0.967	0.959	8.4E-10	1.6E-09	1.3E-09	1.7E-06	3.3E-06	2.6E-06	0.608	0.633	0.622
6	TR575, TR576	Impact of Water to Premix Ratio	0.977	1.006	0.991	8.8E-10	2.0E-09	1.4E-09	1.8E-06	4.1E-06	2.8E-06	0.600	0.632	0.615
7	TR577, TR578	Impact of Water to Premix Ratio	0.911	0.957	0.920	8.0E-09	9.1E-09	8.4E-09	1.6E-05	1.9E-05	1.7E-05	0.623	0.672	0.638
8	TR582, TR583	Impact of Increased Aluminate	0.992	1.035	1.018	1.7E-10	4.2E-10	2.8E-10	3.9E-07	9.7E-07	6.5E-07	0.565	0.593	0.583
9	TR588, TR589	Impact of Increased Aluminate	0.923	0.963	0.945	1.9E-10	3.6E-10	2.5E-10	4.4E-07	8.3E-07	5.9E-07	0.598	0.619	0.610
10	TR602, TR603	Baseline with Organics, Admixtures, and Increased Aluminate	0.935	0.986	0.960	7.8E-10	1.4E-09	1.0E-09	1.8E-06	3.2E-06	2.4E-06	0.589	0.613	0.601
11	TR604, TR605	Baseline with Organics and Admixtures at 60o C Cure Temperature	0.910	0.958	0.939	7.5E-07	8.6E-07	8.0E-07	1.7E-03	2.0E-03	1.9E-03	0.628	0.653	0.641

[1]Includes measurements from the MCT permeability samples, the MCT moisture retention samples, and SRNL moisture retention samples.
[2]Arithmetic average.

Table 12. Summary Statistics for Saturated Hydraulic Conductivity of ARP/MCU Saltstone Grouts.

Batch	**α**	**n**	**Log_{10} Mean**	**Standard Deviation**	**95.0 % Confidence Intervals**		**Geometric Mean (cm/sec)**
1	0.05	3	-8.739	0.191	-8.954	-8.523	1.8E-09
2	0.05	6	-8.772	0.399	-9.092	-8.453	1.7E-09
3	0.05	3	-8.820	0.140	-8.979	-8.661	1.5E-09
4	0.05	3	-8.851	0.093	-8.956	-8.745	1.4E-09
5	0.05	3	-8.908	0.148	-9.076	-8.741	1.2E-09
6	0.05	3	-8.892	0.180	-9.095	-8.688	1.3E-09
7	0.05	3	-8.078	0.032	-8.115	-8.042	8.4E-09
8	0.05	3	-9.583	0.197	-9.806	-9.360	2.6E-10
9	0.05	3	-9.614	0.149	-9.783	-9.445	2.4E-10
10	0.05	3	-8.999	0.131	-9.148	-8.851	1.0E-09
11	0.05	3	-6.096	0.030	-6.129	-6.062	8.0E-07

Table 13. Summary Statistics for Porosity of ARP/MCU Saltstone Grouts.

Batch	**α**	**n**	**Arithmetic Mean (cm^3/cm^3)**	**Standard Deviation**	**95.0 % Confidence Intervals**	
1	0.05	7	0.571	0.014	0.561	0.581
2	0.05	13	0.625	0.015	0.616	0.633
3	0.05	7	0.618	0.009	0.612	0.625
4	0.05	7	0.627	0.015	0.616	0.638
5	0.05	7	0.622	0.011	0.614	0.630
6	0.05	7	0.615	0.012	0.606	0.624
7	0.05	7	0.638	0.018	0.625	0.651
8	0.05	7	0.583	0.010	0.575	0.590
9	0.05	7	0.610	0.007	0.605	0.616
10	0.05	7	0.601	0.009	0.595	0.608
11	0.05	7	0.641	0.008	0.635	0.648

Table 14. Summary Statistics for Dry Bulk Density of ARP/MCU Saltstone Grouts.

Batch	**α**	**n**	**Arithmetic Mean (g/cm³)**	**Standard Deviation**	**95.0 % Confidence Intervals**	
1	0.05	7	1.055	0.033	1.030	1.079
2	0.05	13	0.949	0.018	0.940	0.959
3	0.05	7	0.960	0.014	0.949	0.971
4	0.05	7	0.949	0.019	0.935	0.963
5	0.05	7	0.959	0.006	0.955	0.964
6	0.05	7	0.991	0.009	0.984	0.998
7	0.05	7	0.920	0.016	0.908	0.932
8	0.05	7	1.018	0.016	1.006	1.029
9	0.05	7	0.945	0.012	0.936	0.954
10	0.05	7	0.960	0.020	0.946	0.975
11	0.05	7	0.939	0.017	0.927	0.951

Table 15. Comparison of Saltstone Batches to the Control Mix (Batch 1) using Dunnett's Method.

	Comparison to Batch 1		
Description	**Batch**	**Porosity**	**Ks**
Control	1	NA	NA
Baseline	2	>	-
Baseline with Admixtures	3	>	-
Baseline with Organics	4	>	-
Baseline with Organics and Admixtures	5	>	-
Impact of Water to Premix Ratio	6	>	-
Impact of Water to Premix Ratio	7	>	>
Impact of Increased Aluminate	8	-	<
Impact of Increased Aluminate	9	>	<
Baseline with Organics, Admixtures, and Increased Aluminate	10	>	-
Baseline with Organics and Admixtures at 60° C Cure Temperature	11	>	>

- means not significantly different
> mean significantly greater than control mix (batch 1)
< mean significantly less than control mix (batch 1)

Table 16. Comparison of Saltstone Batches to the Baseline Mix (Batch 2) using Dunnett's Method.

Description	Comparison to Batch 2		
	Batch	Porosity	K_s
Control	1	<	-
Baseline	2	NA	NA
Baseline with Admixtures	3	-	-
Baseline with Organics	4	-	-
Baseline with Organics and Admixtures	5	-	-
Impact of Water to Premix Ratio	6	-	-
Impact of Water to Premix Ratio	7	-	>
Impact of Increased Aluminate	8	<	<
Impact of Increased Aluminate	9	-	<
Baseline with Organics, Admixtures, and Increased Aluminate	10	<	-
Baseline with Organics and Admixtures at 60^o C Cure Temperature	11	-	>

- means not significantly different
> mean significantly greater than baseline mix (batch 2)
< mean significantly less than baseline mix (batch 2)

Table 17. Comparison of Saltstone Batches to the High Curing Temperature Mix (Batch 11) using Dunnett's Method.

Description	Comparison to Batch 11		
	Batch	Porosity	K_s
Control	1	<	<
Baseline	2	<	<
Baseline with Admixtures	3	<	<
Baseline with Organics	4	-	<
Baseline with Organics and Admixtures	5	<	<
Impact of Water to Premix Ratio	6	<	<
Impact of Water to Premix Ratio	7	-	<
Impact of Increased Aluminate	8	<	<
Impact of Increased Aluminate	9	<	<
Baseline with Organics, Admixtures, and Increased Aluminate	10	<	<
Baseline with Organics and Admixtures at 60^o C Cure Temperature	11	NA	NA

- means not significantly different
> mean significantly greater than high curing temperature mix (batch 1)
< mean significantly less than high curing temperature mix (batch 1)

Table 18. Comparison of Saturated Hydraulic Conductivity and Young's Modulus.

Batch	Mix Id	Hydraulic Conductivity Average Value (cm/s)	Young's Modulus (GPa)	Days Cured (days)
1	TR545, TR546	1.9E-09	8.7	89
2	TR547, TR548	4.0E-09	5.2	91
3	TR549, TR550	1.6E-09	5.3	90
4	TR557, TR558	1.4E-09	5.8	89
5	TR565, TR566	1.3E-09	5	91
6	TR575, TR576	1.4E-09	5.7	92
7	TR577, TR578	8.4E-09	4.9	90
8	TR582, TR583	2.8E-10	10.2	90
9	TR588, TR589	2.5E-10	8.6	91
10	TR602, TR603	1.0E-09	8.3	96
11	TR604, TR605	8.0E-07	2.9	57

Table 19. Moisture Retention Data for ARP/MCU Saltstone as measured by MCT (90 day minimum curing period).

Sample Id	Minimum Curing Period (days)	Bulk Density[a] (g/cm³)	Potential (cm)						
			0	-101.97	-509.87	-1,019.74	-5,098.72	-10,197.44	-15,296.16
			(0.00 bars)	(-0.10 bars)	(-0.50 bars)	(-1.0 bars)	(-5.0 bars)	(-10.0 bars)	(-15.0 bars)
			Volumetric Moisture Content[1] (cm³/cm³)						
MCU-TR545-1	90	1.061	0.574	0.573	0.572	0.572	0.571	0.571	NA
MCU-TR545-2	90	1.054	0.571	0.568	0.568	0.568	0.567	0.566	NA
MCU-TR545-3	90	0.981	0.540	0.537	0.537	0.537	0.536	0.535	NA
MCU-TR547-1	90	0.924	0.595	0.591	0.590	0.590	0.589	0.589	NA
MCU-TR547-2	90	0.931	0.610	0.605	0.604	0.604	0.603	0.602	NA
MCU-TR547-3	90	0.949	0.621	0.616	0.615	0.615	0.614	0.613	NA
MCU-TR548-1	90	0.943	0.608	0.610	0.608	0.606	0.606	NA	0.605
MCU-TR548-2	90	0.944	0.604	0.605	0.604	0.604	0.603	NA	0.602
MCU-TR548-3	90	0.952	0.615	0.615	0.614	0.613	0.613	NA	0.613
MCU-TR549-1	90	0.935	0.601	0.599	0.598	0.597	0.597	0.597	0.597
MCU-TR549-2	90	0.947	0.612	0.610	0.609	0.609	0.607	0.607	0.607
MCU-TR549-3	90	0.964	0.619	0.617	0.617	0.616	0.615	0.615	0.614
MCU-TR557-1	90	0.956	0.623	0.618	0.617	0.617	0.616	0.614	0.614
MCU-TR557-2	90	0.955	0.628	0.623	0.621	0.620	0.620	0.619	0.618
MCU-TR557-3	90	0.907	0.597	0.592	0.589	0.588	0.587	0.585	0.585
MCU-TR565-1	90	0.952	0.610	0.610	0.608	0.608	0.607	NA	0.607
MCU-TR565-2	90	0.965	0.619	0.619	0.619	0.618	0.616	NA	0.615
MCU-TR565-3	90	0.967	0.617	0.617	0.616	0.616	0.615	NA	0.614
MCU-TR575-1	90	0.996	0.611	0.610	0.609	0.609	0.608	NA	0.607
MCU-TR575-2	90	0.977	0.600	0.600	0.599	0.599	0.598	NA	0.597
MCU-TR575-3	90	0.986	0.605	0.604	0.603	0.603	0.602	NA	0.602
MCU-TR577-1	90	0.915	0.628	0.627	0.626	0.626	0.626	NA	0.624
MCU-TR577-2	90	0.911	0.623	0.620	0.619	0.619	0.618	NA	0.616
MCU-TR577-3	90	0.916	0.627	0.625	0.624	0.623	0.621	NA	0.620

Table 19. Moisture Retention Data for ARP/MCU Saltstone as measured by MCT (90 day minimum curing period) - continued.

Sample Id	Minimum Curing Period (days)	Bulk Density[a] (g/cm^3)	Potential (cm)						
			0	-101.97	-509.87	-1,019.74	-5,098.72	-10,197.44	-15,296.16
			(0.00 bars)	(-0.10 bars)	(-0.50 bars)	(-1.0 bars)	(-5.0 bars)	(-10.0 bars)	(-15.0 bars)
			Volumetric Moisture Content[1] (cm^3/cm^3)						
MCU-TR582-1	90	1.013	0.577	0.576	0.576	0.576	0.576	NA	0.576
MCU-TR582-2	90	1.009	0.576	0.575	0.574	0.574	0.573	NA	0.573
MCU-TR582-3	90	0.992	0.565	0.564	0.564	0.563	0.563	NA	0.562
MCU-TR588-1	90	0.923	0.598	0.597	0.596	0.596	0.595	0.594	0.594
MCU-TR588-2	90	0.939	0.610	0.607	0.607	0.607	0.605	0.603	0.603
MCU-TR588-3	90	0.944	0.606	0.605	0.605	0.605	0.603	0.601	0.601
MCU-TR602-1	90	0.948	0.599	0.597	0.597	0.597	0.596	0.595	0.595
MCU-TR602-2	90	0.945	0.594	0.592	0.592	0.591	0.591	0.590	0.590
MCU-TR602-3	90	0.935	0.589	0.588	0.587	0.587	0.586	0.585	0.585
MCU-TR604-1[b]	90	0.910	0.628	0.624	0.623	0.622	0.611	0.596	NA
MCU-TR604-2[b]	90	0.950	0.653	0.647	0.647	0.646	0.636	0.621	NA
MCU-TR604-3[b]	90	0.923	0.639	0.635	0.635	0.634	0.625	0.619	NA

[a]Dry bulk density and volumetric moisture content corrected as described in Section 3.2.

[b]TR604 samples cracked after 1 bar applied pressure.

Table 20. Mass of simulant released during pressure extraction testing.

Sample ID	Mass of Simulant Released (g)	Total Mass of Simulant in Sample (g)	Percentage of Simulant Released	Sample ID	Mass of Simulant Released (g)	Total Mass of Simulant in Sample (g)	Percentage of Simulant Released
MCU-TR545-1	0.40	62.29	0.64	MCU-TR575-1	0.49	81.64	0.60
MCU-TR545-2	0.62	63.35	0.98	MCU-TR575-2	0.35	77.10	0.45
MCU-TR545-3	0.42	42.80	0.98	MCU-TR575-3	0.42	86.54	0.49
MCU-TR547-1	0.76	66.56	1.14	MCU-TR577-1	0.73	101.26	0.72
MCU-TR547-2	0.65	50.72	1.28	MCU-TR577-2	1.00	93.45	1.07
MCU-TR547-3	0.71	51.14	1.39	MCU-TR577-3	1.07	89.50	1.20
MCU-TR548-1	0.17	29.78	0.57	MCU-TR582-1	0.26	85.04	0.31
MCU-TR548-2	0.12	28.16	0.43	MCU-TR582-2	0.42	82.06	0.51
MCU-TR548-3	0.13	29.88	0.44	MCU-TR582-3	0.43	76.07	0.57
MCU-TR549-1	0.52	62.54	0.83	MCU-TR588-1	0.61	81.19	0.75
MCU-TR549-2	0.53	69.39	0.76	MCU-TR588-2	0.88	73.81	1.19
MCU-TR549-3	0.65	78.86	0.82	MCU-TR588-3	0.65	73.49	0.88
MCU-TR557-1	1.20	77.42	1.55	MCU-TR602-1	0.49	81.69	0.60
MCU-TR557-2	1.20	77.39	1.55	MCU-TR602-2	0.62	81.51	0.76
MCU-TR557-3	1.45	70.58	2.05	MCU-TR602-3	0.53	71.23	0.74
MCU-TR565-1	0.45	87.77	0.51	MCU-TR604-1	3.82	73.60	5.19
MCU-TR565-2	0.54	81.90	0.66	MCU-TR604-2	4.08	82.55	4.94
MCU-TR565-3	0.36	75.19	0.48	MCU-TR604-3	2.34	74.43	3.14

Table 21. Moisture Retention Data for ARP/MCU Saltstone as measured by SRNL using porous plate pressure extraction system.

Sample ID	Mass Saturated (g)	Applied Pressure 1 bar	4 bar	10 bar	20 bar	40 bar
		Equilibrium Weights (g)				
TR546-2A	109.07	109.19	109.34	110.09	110.09	110.18
TR546-2B	124.63	124.86	125.04	125.87	-	-
TR548-2A	86.19	86.22	85.68	86.45	86.02	cracked
TR548-2B	77.74	77.59	77.16	77.91	-	-
TR550-3A	115.14	115.19	114.86	115.51	115.31	cracked
TR550-3B	101.97	101.92	101.63	102.20	-	-
TR558-3A	108.20	108.50	108.86	108.41	-	-
TR566-3A	120.84	121.33	121.48	121.16	-	-
TR576-3A	119.06	119.33	119.45	119.11	-	-
TR578-3A	129.37	129.53	129.99	129.60	-	-

Table 22. Moisture retention data for ARP/MCU Saltstone as measured by SRNL using chilled mirror humidity sensor with tap water as the test fluid.

Sample ID	Volumetric Moisture Content (cm^3/cm^3)	Saturation (fraction)	Total Potential (bar)	Total Potential (cm H_2O)
TR546-2B	0.578	1.00	57.7	58839.2
TR546-2B	0.319	0.55	206.6	210679.2
TR546-2B	0.141	0.24	536.7	547296.8
TR546-2B	0.136	0.23	565.9	577073.3
TR546-2B	0.131	0.23	558.5	569527.2
TR546-2B	0.063	0.11	965.5	984563.1
TR546-2B	0.000	0.00	3871.7	3948144.0
TR548-2B	0.624	1.00	65.6	66895.2
TR548-2B	0.308	0.49	264.0	269212.5
TR548-2B	0.159	0.25	534.7	545257.3
TR548-2B	0.133	0.21	579.5	590941.8
TR548-2B	0.117	0.19	564.6	575747.6
TR548-2B	0.042	0.07	928.9	947240.5
TR548-2B	0.000	0.00	1705.8	1739479.8
TR550-3B	0.578	0.93	54.2	55270.1
TR550-3B	0.422	0.68	171.1	174478.2
TR550-3B	0.158	0.25	514.3	524454.5
TR550-3B	0.132	0.21	578.3	589718.1
TR550-3B	0.111	0.18	557.8	568813.4
TR550-3B	0.053	0.08	881.0	898394.7
TR550-3B	0.000	0.00	3075.3	3136019.6
TR558-3B	0.627	1.00	56.8	57921.5
TR558-3B	0.111	0.18	643.5	656205.4
TR558-3B	0.054	0.09	860.0	876980.1
TR558-3B	0.015	0.02	3870.9	3947328.2
TR566-3B	0.608	1.00	53.6	54658.3
TR566-3B	0.107	0.18	651.1	663955.5
TR566-3B	0.061	0.10	900.5	918279.7
TR566-3B	0.023	0.04	3909.2	3986384.4

Table 22. Moisture retention data for ARP/MCU Saltstone as measured by SRNL using chilled mirror humidity sensor with tap water as the test fluid - continued.

Sample ID	Volumetric Moisture Content (cm^3/cm^3)	Saturation (fraction)	Total Potential (bar)	Total Potential (cm H_2O)
TR576-3B	0.610	1.00	55.5	56595.8
TR576-3B	0.087	0.14	648.6	661406.1
TR576-3B	0.048	0.08	973.1	992313.2
TR576-3B	0.012	0.02	3107.5	3168855.4
TR578-3B	0.625	1.00	55.6	56697.8
TR578-3B	0.110	0.18	644.1	656817.3
TR578-3B	0.051	0.08	927.4	945710.9
TR578-3B	0.018	0.03	3375.0	3441637.0
TR583-3B	0.583	1.00	53.6	54658.3
TR583-3B	0.131	0.23	636.3	648863.3
TR583-3B	0.060	0.10	920.2	938368.7
TR583-3B	0.016	0.03	4082.4	4163004.1
TR589-3B	0.621	1.02	96.0	97895.5
TR589-3B	0.487	0.80	120.8	123185.1
TR589-3B	0.383	0.63	156.0	159080.1
TR589-3B	0.290	0.48	195.1	198952.1
TR589-3B	0.178	0.29	356.0	363029.0
TR589-3B	0.100	0.17	641.6	654267.9
TR589-3B	0.000	0.00	3049.7	3109914.2
TR603-3B	0.616	1.03	94.1	95957.9
TR603-3B	0.466	0.78	116.7	119004.2
TR603-3B	0.357	0.60	162.9	166116.3
TR603-3B	0.263	0.44	217.0	221284.5
TR603-3B	0.150	0.25	408.4	416463.6
TR603-3B	0.079	0.13	683.2	696689.3
TR603-3B	0.000	0.00	3403.2	3470393.8

Table 22. Moisture retention data for ARP/MCU Saltstone as measured by SRNL using chilled mirror humidity sensor with tap water as the test fluid - continued.

Sample ID	Volumetric Moisture Content (cm^3/cm^3)	Saturation (fraction)	Total Potential (bar)	Total Potential (cm H_2O)
TR605-3B	0.574	0.90	102.2	104217.9
TR605-3B	0.450	0.70	117.6	119921.9
TR605-3B	0.334	0.52	169.5	172846.7
TR605-3B	0.232	0.36	233.1	237702.4
TR605-3B	0.131	0.20	427.4	435838.7
TR605-3B	0.056	0.09	638.3	650902.8
TR605-3B	0.000	0.00	3861.2	3937436.6
INLA-B	0.600	1.00	52.5	53536.6
INLA-B	0.100	0.17	652.4	665281.2
INLA-B	0.042	0.07	871.9	889115.0
INLA-B	0.008	0.01	2956.6	3014976.0

Table 23. Moisture retention data for ARP/MCU Saltstone as measured by SRNL using chilled mirror humidity sensor with simulant as the test fluid.

Sample ID	**Volumetric Moisture Content (cm^3/cm^3)**	**Saturation (fraction)**	**Total Potential (bar)**	**Total Potential (cm H_2O)**
TR546-2A	0.727	1.00	276.7	282163.2
TR546-2A	0.479	0.83	446.3	455111.9
TR546-2A	0.360	0.62	514.3	524454.5
TR546-2A	0.248	0.43	551.4	562287.0
TR546-2A	0.202	0.35	564.2	575339.7
TR546-2A	0.056	0.10	1143.4	1165975.6
TR546-2A	0.000	0.00	3202.5	3265731.1
TR548-2A	0.842	1.00	250.9	255853.8
TR548-2A	0.538	0.86	428.7	437164.4
TR548-2A	0.419	0.67	521.9	532204.5
TR548-2A	0.324	0.52	546.5	557290.3
TR548-2A	0.211	0.34	568.4	579622.7
TR548-2A	0.050	0.08	948.0	966717.6
TR550-3A	0.624	1.00	251.2	256159.8
TR550-3A	0.432	0.69	531.8	542300.0
TR550-3A	0.329	0.53	549.9	560757.4
TR550-3A	0.238	0.38	568.4	579622.7
TR550-3A	0.058	0.09	1071.8	1092961.9
TR550-3A	0.000	0.00	2967.6	3026193.2
TR558-3A	0.697	1.00	336.7	343347.9
TR558-3A	0.612	0.98	458.3	467348.8
TR558-3A	0.551	0.88	542.4	553109.3
TR558-3A	0.397	0.63	540.8	551477.7
TR558-3A	0.332	0.53	569.7	580948.3
TR558-3A	0.232	0.37	602.7	614599.9
TR558-3A	0.056	0.09	1602.2	1633834.3
TR558-3A	0.014	0.02	2250.4	2294832.5

Table 23. Moisture retention data for ARP/MCU Saltstone as measured by SRNL using chilled mirror humidity sensor with simulant as the test fluid - continued.

Sample ID	Volumetric Moisture Content (cm^3/cm^3)	Saturation (fraction)	Total Potential (bar)	Total Potential (cm H_2O)
TR566-3A	0.662	1.00	341.3	348038.7
TR566-3A	0.578	0.95	429.7	438184.1
TR566-3A	0.513	0.84	516.5	526697.9
TR566-3A	0.338	0.56	549.2	560043.6
TR566-3A	0.277	0.46	590.7	602363.0
TR566-3A	0.182	0.30	642.1	654777.8
TR566-3A	0.038	0.06	1677.4	1710519.1
TR566-3A	0.023	0.04	2170.5	2213355.0
TR576-3A	0.724	1.00	329.9	336413.6
TR576-3A	0.535	0.88	531.8	542300.0
TR576-3A	0.405	0.66	533.5	544033.6
TR576-3A	0.338	0.55	546.1	556882.4
TR576-3A	0.231	0.38	582.6	594103.0
TR576-3A	0.038	0.06	2062.4	2103120.6
TR576-3A	0.010	0.02	2288.1	2333276.9
TR578-3A	0.657	1.00	349.2	356094.7
TR578-3A	0.574	0.92	451.0	459904.7
TR578-3A	0.504	0.81	533.6	544135.6
TR578-3A	0.377	0.60	533.6	544135.6
TR578-3A	0.311	0.50	546.6	557392.2
TR578-3A	0.223	0.36	588.0	599609.6
TR578-3A	0.030	0.05	2089.6	2130857.7
TR578-3A	0.012	0.02	2192.0	2235279.5
TR583-3C	0.585	1.00	449.7	458579.0
TR583-3C	0.473	0.81	540.3	550967.8
TR583-3C	0.358	0.61	579.1	590533.9
TR583-3C	0.258	0.44	594.0	605728.1
TR583-3C	0.099	0.17	1016.1	1036162.2
TR583-3C	0.043	0.07	2018.0	2057844.0
TR583-3C	0.023	0.04	2367.7	2414448.6

Table 23. Moisture retention data for ARP/MCU Saltstone as measured by SRNL using chilled mirror humidity sensor with simulant as the test fluid - continued.

Sample ID	Volumetric Moisture Content (cm^3/cm^3)	Saturation (fraction)	Total Potential (bar)	Total Potential (cm H_2O)
TR589-3A	0.638	1.00	379.2	386687.0
TR589-3A	0.530	0.87	467.2	476424.5
TR589-3A	0.437	0.72	541.4	552089.6
TR589-3A	0.322	0.53	580.1	591553.7
TR589-3A	0.229	0.38	609.5	621534.1
TR589-3A	0.092	0.15	1095.4	1117027.9
TR589-3A	0.047	0.08	2001.6	2041120.2
TR589-3A	0.032	0.05	2032.0	2072120.4
TR603-3A	0.650	1.00	373.7	381078.4
TR603-3A	0.537	0.90	468.8	478056.1
TR603-3A	0.447	0.75	539.5	550152.0
TR603-3A	0.331	0.55	575.6	586964.8
TR603-3A	0.226	0.38	614.3	626428.9
TR603-3A	0.079	0.13	1100.1	1121820.7
TR603-3A	0.034	0.06	2185.1	2228243.2
TR605-3A	0.662	1.00	350.5	357420.4
TR605-3A	0.591	0.92	412.4	420542.5
TR605-3A	0.535	0.84	450.5	459394.8
TR605-3A	0.449	0.70	512.1	522211.1
TR605-3A	0.329	0.51	560.3	571362.7
TR605-3A	0.231	0.36	607.0	618984.8
TR605-3A	0.089	0.14	887.4	904921.1
TR605-3A	0.029	0.05	1422.3	1450382.3
TR605-3A	0.003	0.00	1524.9	1555008.1
INLA-A	0.733	1.00	342.4	349160.4
INLA-A	0.616	1.03	422.2	430536.0
INLA-A	0.537	0.89	508.4	518438.0
INLA-A	0.415	0.69	527.3	537711.2
INLA-A	0.332	0.55	587.5	599099.8
INLA-A	0.231	0.39	655.9	668850.3
INLA-A	0.035	0.06	1203.8	1227568.2

Table 24. Special cases of moisture retention data for ARP/MCU Saltstone as measured by SRNL using chilled mirror humidity sensor.

Sample ID	Volumetric Moisture Content (cm^3/cm^3)	Saturation (fraction)	Total Potential (bar)	Total Potential (cm H_2O)
TR548-2C[1]	0.394	0.63	226.9	231380.0
TR548-2C	0.309	0.49	345.5	352321.7
TR548-2C	0.251	0.40	476.6	486010.1
TR548-2C	0.166	0.27	672.9	686185.9
TR548-2C	0.112	0.18	1388.2	1415609.0
TR548-2C	0.072	0.11	2100.5	2141972.9
TR548-2C	0.049	0.08	3399.9	3467028.6
TR548-2D[2]	0.000	0.00	1679.9	1713068.4
TR548-2D	0.046	0.07	799.2	814979.6
TR548-2D	0.097	0.16	607.2	619188.7
TR548-2D	0.120	0.19	554.1	565040.3
TR548-2D	0.228	0.37	501.2	511095.8
TR548-2D	0.325	0.52	466.0	475200.8
TR548-2D	0.472	0.76	415.3	423499.8
TR548-2D	0.569	0.91	391.1	398822.0
TR548-2D	0.670	1.07	389.8	397496.3
TR583-3A[3]	0.679	1.00	340.1	346815.0
TR583-3A	0.532	0.91	521.2	531490.7
TR583-3A	0.408	0.70	540.1	550763.9
TR583-3A	0.329	0.56	543.8	554536.9
TR583-3A	0.233	0.40	596.2	607971.5
TR583-3A	0.078	0.13	1219.2	1243272.2
TR583-3A	0.022	0.04	2511.5	2561087.8

Table 24. Special cases of moisture retention data for ARP/MCU Saltstone as measured by SRNL using chilled mirror humidity sensor - continued.

Sample ID	Volumetric Moisture Content (cm^3/cm^3)	Saturation (fraction)	Total Potential (bar)	Total Potential (cm H_2O)
TR605-3C[4]	0.000	0.00	2311.7	2357342.9
TR605-3C	0.031	0.05	756.7	771640.5
TR605-3C	0.065	0.10	602.6	614497.9
TR605-3C	0.094	0.15	565.4	576563.4
TR605-3C	0.156	0.24	497.1	506914.9
TR605-3C	0.216	0.34	463.0	472141.6
TR605-3C	0.314	0.49	429.2	437674.2
TR605-3C	0.377	0.59	403.8	411772.7
TR605-3C	0.442	0.69	394.4	402187.1
TR605-3D[5]	0.400	0.62	209.2	213330.5
TR605-3D	0.270	0.42	356.0	363029.0
TR605-3D	0.135	0.21	597.0	608787.3
TR605-3D	0.040	0.06	2205.3	2248842.1
TR605-3D	0.013	0.02	4193.1	4275889.8

[1]TR548-2C – Initiated testing at “as received” moisture content.
[2]TR548-2D – Simulant added (wetting) sequentially to saturation as opposed to drying.
[3]TR583-3A – Tested with low aluminate simulant to determine effect of aluminate.
[4]TR605-3C - Simulant added (wetting) sequentially to saturation as opposed to drying.
[5]TR605-3D – Initiated testing at “as received” moisture content.

Table 25. Moisture retention data for ARP/MCU Saltstone as measured by SRNL using vapor equilibrium method.

	Volumetric Moisture Content (cm^3/cm^3)	**Saturation (%)**	**Total Potential (bar)**	**Salt Solution**
TR548-2	0.172	0.29	372.5	NaCl[1]
TR603-3	0.188	0.29	372.5	NaCl
TR605-3	0.165	0.26	372.5	NaCl
TR546-3	0.157	0.27	496.4	KI[2]
TR548-3	0.149	0.24	496.4	KI
TR550-3	0.145	0.23	496.4	KI
TR558-3	0.140	0.23	496.4	KI
TR566-3	0.119	0.20	496.4	KI
TR576-3	0.126	0.21	496.4	KI
TR578-3	0.147	0.23	496.4	KI
TR583-3	0.152	0.24	496.4	KI
TR589-3	0.149	0.24	496.4	KI
TR603-3	0.150	0.25	496.4	KI
TR605-3	0.105	0.16	496.4	KI
INLA	0.134	0.23	496.4	KI
TR548-2	0.052	0.08	839.7	$Mg(NO_3)_2*6H_2O$[3]
TR603-3	0.045	0.08	839.7	$Mg(NO_3)_2*6H_2O$
TR605-3	0.060	0.09	839.7	$Mg(NO_3)_2*6H_2O$
TR548-2	0.007	0.01	2848.9	LiCl[4]
TR603-3	0.023	0.04	2848.9	LiCl
TR605-3	0.015	0.02	2848.9	LiCl

[1]NaCl = sodium chloride
[2]KI = potassium iodide
[3]$Mg(NO_3)_2*6H_2O$ = magnesium nitrate hexahydrate
[4]LiCl = lithium chloride

Table 26. Average moisture retention data for ARP/MCU Saltstone as measured by SRNL using vapor equilibrium method.

Salt Solution	**Relative Humidity[1] (%)**	**Average Saturation (%)**	**Total Potential (bar)**
Sodium chloride, NaCl	75	0.28	372.5
Potassium Iodide, KI	69	0.17	496.4
Magnesium Nitrate Hexahydrate, $Mg(NO_3)_2*6H_2O$	53	0.05	839.7
Lithium Chloride, LiCl	11	0.03	2848.9

[1]At 25^{o} C

Table 27. Van Genuchten Transport Parameters[1,2].

Material	**Test Fluid**	**θ_s (cm^3/cm^{-3})**	**θ_r (cm^3/cm^3)**	**α (1/cm)**	**n**	**m**
ARP/MCU Saltstone	Tap Water	0.615	0.000	7.0E-06	2.22275	0.55011
ARP/MCU Saltstone	Simulant	0.615	0.000	1.6E-06	5.43985	0.81617

[1]Data analyzed using Mualem relationship between n and m where m = 1 – 1/n.
[2]Moisture retention data from SRNL and Mactec measurements were combined for this analysis.

APPENDIX A. MCT DATA SHEETS ON SALTSTONE

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*5/14/2009*
Boring No.	*TR545-1*	Reviewed By	
Sample No.	*TR545-1*	Review Date	
Sample Depth	*N/A*	Lab No.	*9618*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*35.0*
Wet Unit Weight, pcf:	*112.2*
Dry Unit Weight, pcf:	*83.1*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***2.3E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	05/14/09
Boring No.	TR545-1	Reviewed By	
Sample No.	TR545-1	Review Date	
Sample Depth	N/A	Lab No.	9618
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	LJ-56
Location 1	2.936	Location 1	3.012	Wet Soil+Pan, grams	625.72
Location 2	2.947	Location 2	3.015	Dry Soil + Pan, grams	465.56
Location3	2.936	Location 3	3.014	Pan Weight, grams	8.37
Average	2.940	Average	3.014	Moisture Content, %	35.0
Volume, in^3	20.97	Wet Soil + Tare, grams	617.35	Dry Unit Weight, pcf	83.1
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	104.7
Soil Sample Wt., g	617.35	Dry Soil +Tare, grams	457.19	Diameter, in.	N/A
Dry UW, pcf	83.1	Moisture Content, %	35.0	Length, in.	N/A
Saturation, %	104.7			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
21540	1.60	26.90	21.40	5.50	25.6	42.6	33.0	4.64E-09	4.07E-09
100860	1.60	26.90	13.45	13.45	25.5	42.6	19.0	3.11E-09	2.74E-09
150540	1.60	22.30	12.55	9.75	24.2	34.8	17.8	1.74E-09	1.58E-09
180360	1.60	22.30	11.65	10.65	24.3	34.8	16.2	1.66E-09	1.50E-09
237000	1.60	22.30	10.05	12.25	24.2	34.8	13.4	1.57E-09	1.42E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
5	Core	N/A	N/A	Vertical

Avg. k at 20 °C 2.3E-09 cm/sec

a_s = 0.76712 cm^2
A = 46.02 cm^2
L = 7.47 cm
S=L/A= 0.16225 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0003896 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*5/14/2009*
Boring No.	*TR545-2*	Reviewed By	
Sample No.	*TR545-2*	Review Date	
Sample Depth	*N/A*	Lab No.	*9619*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*34.9*
Wet Unit Weight, pcf:	*111.9*
Dry Unit Weight, pcf:	*82.9*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.1E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number 6155-08-0031.04 Tested By JW
Project Name Saltstone Physical Properties Tes Test Date 05/14/09
Boring No. TR545-2 Reviewed By
Sample No. TR545-2 Review Date
Sample Depth N/A Lab No. 9619
Sample Description Grout with MCU (90 days)

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	DB-5
Location 1	3.167	Location 1	3.011	Wet Soil+Pan, grams	664.87
Location 2	3.130	Location 2	3.012	Dry Soil + Pan, grams	494.88
Location3	3.103	Location 3	3.018	Pan Weight, grams	8.43
Average	3.133	Average	3.014	Moisture Content, %	34.9
Volume, in^3	22.35	Wet Soil + Tare, grams	656.44	Dry Unit Weight, pcf	82.9
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	104.0
Soil Sample Wt., g	656.44	Dry Soil +Tare, grams	486.45	Diameter, in.	N/A
Dry UW, pcf	82.9	Moisture Content, %	34.9	Length, in.	N/A
Saturation, %	104.0			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0
Permeant used	MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
27410	1.60	19.90	17.95	1.95	24.4	28.9	25.7	1.78E-09	1.61E-09
84720	1.60	19.90	16.05	3.85	24.6	28.9	22.6	1.21E-09	1.09E-09
94675	1.60	19.90	15.65	4.25	24.4	28.9	21.9	1.21E-09	1.09E-09
104220	1.60	19.90	15.40	4.50	24.6	28.9	21.5	1.18E-09	1.06E-09
112650	1.60	19.90	15.20	4.70	24.8	28.9	21.2	1.15E-09	1.02E-09
171440	1.60	19.90	13.85	6.05	24.5	28.9	19.0	1.0E-09	9.19E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C 1.1E-09 cm/sec

$a_a =$ 0.76712 cm²
$A =$ 46.02 cm²
$L =$ 7.96 cm
$S = L/A =$ 0.17294 1/cm

$a_p =$ 0.031416 cm²
$M_1 =$ 0.03018
$M_2 =$ 1.04095
$C = M_1 S/(G_{Hg}-1) =$ 0.0004152 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*5/14/2009*
Boring No.	*TR545-3*	Reviewed By	
Sample No.	*TR545-3*	Review Date	
Sample Depth	*N/A*	Lab No.	*9620*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*34.9*
Wet Unit Weight, pcf:	*112.4*
Dry Unit Weight, pcf:	*83.4*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***2.4E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	05/14/09
Boring No.	TR545-3	Reviewed By	
Sample No.	TR545-3	Review Date	
Sample Depth	N/A	Lab No.	9620
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	T-2
Location 1	3.022	Location 1	3.014	Wet Soil+Pan, grams	643.79
Location 2	3.007	Location 2	3.012	Dry Soil + Pan, grams	479.55
Location3	3.025	Location 3	3.016	Pan Weight, grams	8.35
Average	3.018	Average	3.014	Moisture Content, %	34.9
Volume, in^3	21.53	Wet Soil + Tare, grams	635.45	Dry Unit Weight, pcf	83.4
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	105.0
Soil Sample Wt., g	635.45	Dry Soil +Tare, grams	471.20	Diameter, in.	N/A
Dry UW, pcf	83.4	Moisture Content, %	34.9	Length, in.	N/A
Saturation, %	105.0			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
8049	1.40	26.90	25.05	1.85	25.4	41.8	38.7	3.90E-09	3.44E-09
21519	1.40	26.90	23.20	3.70	25.6	41.8	35.5	3.04E-09	2.67E-09
99000	1.40	26.90	14.40	12.50	25.5	41.8	20.5	2.88E-09	2.54E-09
150720	1.40	21.90	10.75	11.15	24.2	33.6	14.6	2.22E-09	2.01E-09
180420	1.40	21.90	9.70	12.20	24.3	33.6	12.8	2.14E-09	1.93E-09
237060	1.40	21.90	8.20	13.70	24.2	33.6	10.2	2.0E-09	1.82E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C **2.4E-09 cm/sec**

a_a = 0.76712 cm^2
A = 46.03 cm^2
L = 7.67 cm
S=L/A= 0.16654 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0003998 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*5/19/2009*
Boring No.	*TR547-1*	Reviewed By	
Sample No.	*TR547-1*	Review Date	
Sample Depth	*N/A*	Lab No.	*9621*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*44.0*
Wet Unit Weight, pcf:	*109.4*
Dry Unit Weight, pcf:	*76.0*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.2E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	05/19/09
Boring No.	TR547-1	Reviewed By	
Sample No.	TR547-1	Review Date	
Sample Depth	N/A	Lab No.	9621
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	T-15
Location 1	3.100	Location 1	3.015	Wet Soil+Pan, grams	646.41
Location 2	3.080	Location 2	3.017	Dry Soil + Pan, grams	448.31
Location3	3.090	Location 3	3.011	Pan Weight, grams	8.24
Average	3.090	Average	3.014	Moisture Content, %	45.0
Volume, in^3	22.05	Wet Soil + Tare, grams	633.51	Dry Unit Weight, pcf	76.0
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	111.4
Soil Sample Wt., g	633.51	Dry Soil +Tare, grams	440.07	Diameter, in.	N/A
Dry UW, pcf	76.0	Moisture Content, %	44.0	Length, in.	N/A
Saturation, %	108.8			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
15034	1.40	19.00	18.25	0.75	24.9	28.2	26.9	1.24E-09	1.10E-09
27442	1.40	19.00	17.80	1.20	24.7	28.2	26.2	1.10E-09	9.83E-10
58560	1.40	18.10	15.15	2.95	24.6	26.7	21.8	1.42E-09	1.27E-09
73731	1.40	18.10	14.70	3.40	24.5	26.7	21.1	1.32E-09	1.19E-09
86889	1.40	18.10	13.75	4.35	24.8	26.7	19.5	1.49E-09	1.33E-09
147242	1.40	18.10	11.95	6.15	24.6	26.7	16.5	1.3E-09	1.21E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C 1.2E-09 cm/sec

a_a = 0.76712 cm^2
A = 46.04 cm^2
L = 7.85 cm
S=L/A= 0.17047 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004093 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*5/19/2009*
Boring No.	*TR547-2*	Reviewed By	
Sample No.	*TR547-2*	Review Date	
Sample Depth	*N/A*	Lab No.	*9622*
Sample Description	*Grout with MCU*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.9*
Wet Unit Weight, pcf:	*108.6*
Dry Unit Weight, pcf:	*75.5*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***9.9E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	05/19/09
Boring No.	TR547-2	Reviewed By	
Sample No.	TR547-2	Review Date	
Sample Depth	N/A	Lab No.	9622
Sample Description	Grout with MCU		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-18
Location 1	2.997	Location 1	3.008	Wet Soil+Pan, grams	614.54
Location 2	2.944	Location 2	3.012	Dry Soil + Pan, grams	426.52
Location3	2.948	Location 3	3.014	Pan Weight, grams	8.2
Average	2.963	Average	3.011	Moisture Content, %	44.9
Volume, in^3	21.10	Wet Soil + Tare, grams	601.85	Dry Unit Weight, pcf	75.5
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	109.7
Soil Sample Wt., g	601.85	Dry Soil +Tare, grams	418.32	Diameter, in.	N/A
Dry UW, pcf	75.5	Moisture Content, %	43.9	Length, in.	N/A
Saturation, %	107.1			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
8617	1.40	18.10	14.45	3.65	24.4	27.9	21.5	1.18E-08	1.06E-08
18120	1.40	18.10	11.35	6.75	24.6	27.9	16.2	1.19E-08	1.06E-08
26600	1.40	18.10	9.70	8.40	24.8	27.9	13.3	1.10E-08	9.79E-09
30962	1.40	18.10	8.95	9.15	24.7	27.9	12.0	1.07E-08	9.61E-09
85395	1.40	18.10	3.95	14.15	24.5	27.9	3.3	9.84E-09	8.85E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
5	Core	N/A	N/A	Vertical

Avg. k at 20 °C 9.9E-09 cm/sec

a_s = 0.76712 cm²
A = 45.95 cm²
L = 7.53 cm
S=L/A= 0.16379 1/cm

a_p= 0.031416 cm²
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0003933 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*5/19/2009*
Boring No.	*TR547-3*	Reviewed By	
Sample No.	*TR547-3*	Review Date	
Sample Depth	*N/A*	Lab No.	*9623*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.4*
Wet Unit Weight, pcf:	*108.8*
Dry Unit Weight, pcf:	*75.8*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***8.8E-10***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number 6155-08-0031.04 Tested By JW
Project Name Saltstone Physical Properties Tes Test Date 05/19/09
Boring No. TR547-3 Reviewed By
Sample No. TR547-3 Review Date
Sample Depth N/A Lab No. 9623
Sample Description Grout with MCU (90 days)

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	JW-1
Location 1	2.918	Location 1	3.019	Wet Soil+Pan, grams	613.35
Location 2	2.953	Location 2	3.017	Dry Soil + Pan, grams	426.96
Location3	2.950	Location 3	3.018	Pan Weight, grams	8.21
Average	2.940	Average	3.018	Moisture Content, %	44.5
Volume, in^3	21.03	Wet Soil + Tare, grams	600.52	Dry Unit Weight, pcf	75.8
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	109.6
Soil Sample Wt., g	600.52	Dry Soil +Tare, grams	418.75	Diameter, in.	
Dry UW, pcf	75.8	Moisture Content, %	43.4	Length, in.	
Saturation, %	106.9			Volume, in^3	

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
15398	1.60	20.10	19.45	0.65	24.9	31.1	30.0	9.40E-10	8.38E-10
27626	1.60	20.10	19.00	1.10	24.7	31.1	29.2	8.99E-10	8.05E-10
86400	1.60	20.10	16.45	3.65	24.6	31.1	24.7	1.03E-09	9.28E-10
101531	1.60	20.10	15.95	4.15	24.5	31.1	23.9	1.02E-09	9.15E-10
114779	1.60	20.10	15.45	4.65	24.8	31.1	23.0	1.03E-09	9.17E-10
175146	1.60	20.01	13.70	6.31	24.6	31.0	19.9	9.8E-10	8.8E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C 8.8E-10 cm/sec

a_o = 0.76712 cm^2
A = 46.15 cm^2
L = 7.47 cm
S=L/A= 0.16182 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
C = $M_1S/(G_{Hg}-1)$= 0.0003885 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*7/20/2009*
Boring No.	*TR548-1*	Reviewed By	
Sample No.	*TR548-1*	Review Date	
Sample Depth	*N/A*	Lab No.	*9636*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.8*
Wet Unit Weight, pcf:	*107.9*
Dry Unit Weight, pcf:	*75.0*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***9.6E-10***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	07/20/09
Boring No.	TR548-1	Reviewed By	
Sample No.	TR548-1	Review Date	
Sample Depth	N/A	Lab No.	9636
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	M-3
Location 1	1.789	Location 1	1.993	Wet Soil+Pan, grams	163.31
Location 2	1.775	Location 2	1.991	Dry Soil + Pan, grams	113.59
Location3	1.786	Location 3	1.993	Pan Weight, grams	4.17
Average	1.783	Average	1.992	Moisture Content, %	45.4
Volume, in^3	5.56	Wet Soil + Tare, grams	157.40	Dry Unit Weight, pcf	75.0
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	109.3
Soil Sample Wt., g	157.40	Dry Soil +Tare, grams	109.42	Diameter, in.	N/A
Dry UW, pcf	75.0	Moisture Content, %	43.8	Length, in.	N/A
Saturation, %	105.5			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
9617	1.40	12.65	12.25	0.40	25.1	31.2	30.1	2.12E-09	1.88E-09
20713	1.40	12.65	12.00	0.65	25.1	31.2	29.3	1.62E-09	1.44E-09
54629	1.40	12.20	11.50	0.70	25.4	30.0	27.9	6.91E-10	6.09E-10
66333	1.40	12.20	11.40	0.80	24.3	30.0	27.7	6.54E-10	5.91E-10
72586	1.40	12.20	11.30	0.90	24.1	30.0	27.4	6.76E-10	6.14E-10
82769	1.40	12.20	11.20	1.00	24.0	30.0	27.1	6.6E-10	6.0E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C 9.6E-10 cm/sec

a_s = 0.76712 cm^2
A = 20.11 cm^2
L = 4.53 cm
S=L/A= 0.22521 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0005407 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*7/20/2009*
Boring No.	*TR548-2*	Reviewed By	
Sample No.	*TR548-2*	Review Date	
Sample Depth	*N/A*	Lab No.	*9637*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.9*
Wet Unit Weight, pcf:	*108.0*
Dry Unit Weight, pcf:	*75.1*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***2.1E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	07/20/09
Boring No.	TR548-2	Reviewed By	
Sample No.	TR548-2	Review Date	
Sample Depth	N/A	Lab No.	9637
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	W-28
Location 1	1.922	Location 1	1.986	Wet Soil+Pan, grams	175.94
Location 2	1.940	Location 2	1.988	Dry Soil + Pan, grams	122.31
Location3	1.925	Location 3	1.991	Pan Weight, grams	4.28
Average	1.929	Average	1.988	Moisture Content, %	45.4
Volume, in^3	5.99	Wet Soil + Tare, grams	169.87	Dry Unit Weight, pcf	75.1
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	109.6
Soil Sample Wt., g	169.87	Dry Soil +Tare, grams	118.03	Diameter, in.	N/A
Dry UW, pcf	75.1	Moisture Content, %	43.9	Length, in.	N/A
Saturation, %	105.9			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
71231	1.40	14.00	6.80	7.20	25.3	32.3	13.1	7.45E-09	6.58E-09
7214	1.40	14.40	14.20	0.20	25.2	33.4	32.8	1.31E-09	1.16E-09
15849	1.40	14.40	14.00	0.40	25.1	33.4	32.3	1.21E-09	1.07E-09
24219	1.40	14.40	13.85	0.55	25.1	33.4	31.9	1.09E-09	9.69E-10
93817	1.40	14.40	12.55	1.85	25.3	33.4	28.4	1.00E-09	8.86E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
5	Core	N/A	N/A	Vertical

Avg. k at 20 °C 2.1E-09 cm/sec

$a_a =$ 0.76712 cm^2
$A =$ 20.03 cm^2
$L =$ 4.90 cm
$S = L/A =$ 0.24459 1/cm

$a_p =$ 0.031416 cm^2
$M_1 =$ 0.03018
$M_2 =$ 1.04095
$C = M_1 S/(G_{Hg}-1) =$ 0.0005872 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*7/20/2009*
Boring No.	*TR548-3*	Reviewed By	
Sample No.	*TR548-3*	Review Date	
Sample Depth	*N/A*	Lab No.	*9638*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.7*
Wet Unit Weight, pcf:	*108.1*
Dry Unit Weight, pcf:	*75.2*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.1E-09***

Remarks: ______________________________

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	07/20/09
Boring No.	TR548-3	Reviewed By	
Sample No.	TR548-3	Review Date	
Sample Depth	N/A	Lab No.	9638
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	Z-20
Location 1	1.877	Location 1	1.989	Wet Soil+Pan, grams	169.86
Location 2	1.867	Location 2	1.989	Dry Soil + Pan, grams	118.21
Location3	1.836	Location 3	1.986	Pan Weight, grams	4.26
Average	1.860	Average	1.988	Moisture Content, %	45.3
Volume, in^3	5.77	Wet Soil + Tare, grams	163.77	Dry Unit Weight, pcf	75.2
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	109.7
Soil Sample Wt., g	163.77	Dry Soil +Tare, grams	113.95	Diameter, in.	N/A
Dry UW, pcf	75.2	Moisture Content, %	43.7	Length, in.	N/A
Saturation, %	105.8			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
8135	1.60	12.85	12.75	0.10	25.1	29.9	29.7	6.47E-10	5.74E-10
77749	1.60	12.85	11.80	1.05	25.3	29.9	27.0	7.45E-10	6.58E-10
10000	1.60	11.80	11.70	0.10	25.1	27.1	26.9	5.81E-10	5.16E-10
21004	1.60	11.80	11.40	0.40	25.1	27.1	26.0	1.12E-09	9.97E-10
75701	1.60	11.80	9.45	2.35	25.4	27.1	20.6	2.05E-09	1.81E-09
7494	1.60	12.00	11.70	0.30	24.7	27.7	26.8	2.3E-09	2.1E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C 1.1E-09 cm/sec

a_s = 0.76712 cm^2
A = 20.03 cm^2
L = 4.72 cm
S=L/A= 0.23592 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0005664 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*6/10/2009*
Boring No.	*TR549-1*	Reviewed By	
Sample No.	*TR549-1*	Review Date	
Sample Depth	*N/A*	Lab No.	*9624*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*42.8*
Wet Unit Weight, pcf:	*108.7*
Dry Unit Weight, pcf:	*76.1*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***2.1E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	06/10/09
Boring No.	TR549-1	Reviewed By	
Sample No.	TR549-1	Review Date	
Sample Depth	N/A	Lab No.	9624
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	DB-17
Location 1	3.303	Location 1	3.015	Wet Soil+Pan, grams	678.51
Location 2	3.250	Location 2	3.013	Dry Soil + Pan, grams	475.60
Location3	3.275	Location 3	3..016	Pan Weight, grams	8.39
Average	3.276	Average	3.014	Moisture Content, %	43.4
Volume, in^3	23.37	Wet Soil + Tare, grams	667.08	Dry Unit Weight, pcf	76.1
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	107.8
Soil Sample Wt., g	667.08	Dry Soil +Tare, grams	467.21	Diameter, in.	N/A
Dry UW, pcf	76.1	Moisture Content, %	42.8	Length, in.	N/A
Saturation, %	106.2			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
17340	1.60	20.60	18.90	1.70	23.4	28.7	26.0	2.45E-09	2.26E-09
26990	1.60	20.60	17.80	2.80	23.5	28.7	24.3	2.68E-09	2.46E-09
259053	1.60	20.60	6.40	14.20	24.5	28.7	6.4	2.52E-09	2.27E-09
9710	1.60	19.50	18.00	1.50	24.8	27.0	24.7	4.08E-09	3.64E-09
87116	1.60	19.50	14.45	5.05	24.9	27.0	19.1	1.73E-09	1.54E-09
112503	1.60	19.50	13.30	6.20	25.4	27.0	17.3	1.73E-09	1.52E-09
172337	1.60	19.50	11.80	7.70	25.3	27.0	14.9	1.50E-09	1.32E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C **2.1E-09 cm/sec**

a_a = 0.76712 cm²
A = 46.03 cm²
L = 8.32 cm
S=L/A= 0.18077 1/cm

a_p= 0.031416 cm²
M_1= 0.03018
M_2= 1.04095
$C = M_1 S/(G_{Hg}-1)$= 0.0004340 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*6/10/2009*
Boring No.	*TR549-2*	Reviewed By	
Sample No.	*TR549-2*	Review Date	
Sample Depth	*N/A*	Lab No.	*9625*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.1*
Wet Unit Weight, pcf:	*108.4*
Dry Unit Weight, pcf:	*75.7*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.5E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	06/10/09
Boring No.	TR549-2	Reviewed By	
Sample No.	TR549-2	Review Date	
Sample Depth	N/A	Lab No.	9625
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	DB-22
Location 1	3.008	Location 1	3.016	Wet Soil+Pan, grams	622.36
Location 2	3.014	Location 2	3.016	Dry Soil + Pan, grams	435.88
Location3	3.011	Location 3	3.014	Pan Weight, grams	8.44
Average	3.011	Average	3.015	Moisture Content, %	43.6
Volume, in^3	21.50	Wet Soil + Tare, grams	611.80	Dry Unit Weight, pcf	75.7
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	107.1
Soil Sample Wt., g	611.80	Dry Soil +Tare, grams	427.44	Diameter, in.	N/A
Dry UW, pcf	75.7	Moisture Content, %	43.1	Length, in.	N/A
Saturation, %	105.9			Volume, in^3	N/A

Consolidation	
Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
249660	1.40	22.60	6.00	16.60	24.5	34.8	6.4	2.69E-09	2.42E-09
9825	1.40	20.10	19.20	0.90	24.8	30.7	29.2	2.09E-09	1.86E-09
87269	1.40	20.10	16.40	3.70	24.9	30.7	24.4	1.05E-09	9.39E-10
112670	1.40	20.10	15.00	5.10	25.4	30.7	22.0	1.18E-09	1.04E-09
172434	1.40	20.10	12.20	7.90	25.3	30.7	17.2	1.34E-09	1.18E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
5	Core	N/A	N/A	Vertical

Avg. k at 20 °C 1.5E-09 cm/sec

a_a = 0.76712 cm^2
A = 46.07 cm^2
L = 7.65 cm
S=L/A= 0.16600 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0003986 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*6/10/2009*
Boring No.	*TR549-3*	Reviewed By	
Sample No.	*TR549-3*	Review Date	
Sample Depth	*N/A*	Lab No.	*9626*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.0*
Wet Unit Weight, pcf:	*108.5*
Dry Unit Weight, pcf:	*75.9*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.1E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	06/10/09
Boring No.	TR549-3	Reviewed By	
Sample No.	TR549-3	Review Date	
Sample Depth	N/A	Lab No.	9626
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	HR
Location 1	2.963	Location 1	3.016	Wet Soil+Pan, grams	616.49
Location 2	3.006	Location 2	3.017	Dry Soil + Pan, grams	431.25
Location3	2.952	Location 3	3.013	Pan Weight, grams	8.41
Average	2.974	Average	3.015	Moisture Content, %	43.8
Volume, in^3	21.24	Wet Soil + Tare, grams	604.71	Dry Unit Weight, pcf	75.9
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	107.9
Soil Sample Wt., g	604.71	Dry Soil +Tare, grams	422.84	Diameter, in.	N/A
Dry UW, pcf	75.9	Moisture Content, %	43.0	Length, in.	N/A
Saturation, %	106.0			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
11901	1.40	20.70	19.55	1.15	24.7	32.1	30.1	2.12E-09	1.90E-09
20891	1.40	20.70	19.20	1.50	25.4	32.1	29.5	1.59E-09	1.40E-09
27575	1.40	20.70	18.90	1.80	25.6	32.1	29.0	1.46E-09	1.28E-09
85079	1.40	20.70	17.20	3.50	25.3	32.1	26.1	9.68E-10	8.55E-10
98480	1.40	20.70	16.80	3.90	25.6	32.1	25.4	9.44E-10	8.28E-10
113855	1.40	20.70	16.30	4.40	24.3	32.1	24.5	9.4E-10	8.5E-10
175036	1.40	20.70	15.10	5.60	25.5	32.1	22.4	8.1E-10	7.1E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 1.1E-09 cm/sec

a_a = 0.76712 cm^2

A = 46.07 cm^2

L = 7.55 cm

S=L/A= 0.16394 1/cm

a_p= 0.031416 cm^2

M_1= 0.03018

M_2= 1.04095

$C = M_1 S/(G_{Hg}-1)$= 0.0003936 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*6/17/2009*
Boring No.	*TR557-1*	Reviewed By	
Sample No.	*TR557-1*	Review Date	
Sample Depth	*N/A*	Lab No.	*9627*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.8*
Wet Unit Weight, pcf:	*108.3*
Dry Unit Weight, pcf:	*75.3*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.2E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	06/17/09
Boring No.	TR557-1	Reviewed By	
Sample No.	TR557-1	Review Date	
Sample Depth	N/A	Lab No.	9627
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	LJ-55
Location 1	3.170	Location 1	3.029	Wet Soil+Pan, grams	662.17
Location 2	3.167	Location 2	3.022	Dry Soil + Pan, grams	457.74
Location3	3.162	Location 3	3.020	Pan Weight, grams	8.35
Average	3.166	Average	3.024	Moisture Content, %	45.5
Volume, in^3	22.74	Wet Soil + Tare, grams	646.36	Dry Unit Weight, pcf	75.3
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	110.4
Soil Sample Wt., g	646.36	Dry Soil +Tare, grams	449.39	Diameter, in.	N/A
Dry UW, pcf	75.3	Moisture Content, %	43.8	Length, in.	N/A
Saturation, %	106.4			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
11107	1.40	21.30	20.45	0.85	25.5	31.1	29.7	1.71E-09	1.50E-09
21053	1.40	21.30	19.90	1.40	24.5	31.1	28.8	1.51E-09	1.35E-09
252850	1.40	21.30	12.00	9.30	25.1	31.1	16.0	1.10E-09	9.75E-10
279731	1.40	21.30	11.35	9.95	24.2	31.1	14.9	1.10E-09	9.92E-10
340734	1.40	21.30	10.30	11.00	24.7	31.1	13.2	1.05E-09	9.38E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
5	Core	N/A	N/A	Vertical

Avg. k at 20 °C 1.2E-09 cm/sec

a_s = 0.76712 cm^2
A = 46.33 cm^2
L = 8.04 cm
S=L/A= 0.17361 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004168 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*6/17/2009*
Boring No.	*TR557-2*	Reviewed By	
Sample No.	*TR557-2*	Review Date	
Sample Depth	*N/A*	Lab No.	*9628*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.7*
Wet Unit Weight, pcf:	*107.9*
Dry Unit Weight, pcf:	*75.1*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.8E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	06/17/09
Boring No.	TR557-2	Reviewed By	
Sample No.	TR557-2	Review Date	
Sample Depth	N/A	Lab No.	9628
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	F-230
Location 1	3.240	Location 1	3.019	Wet Soil+Pan, grams	664.75
Location 2	3.248	Location 2	3.014	Dry Soil + Pan, grams	458.94
Location3	3.197	Location 3	3.017	Pan Weight, grams	4.22
Average	3.228	Average	3.017	Moisture Content, %	45.3
Volume, in^3	23.07	Wet Soil + Tare, grams	653.26	Dry Unit Weight, pcf	75.1
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	109.2
Soil Sample Wt., g	653.26	Dry Soil +Tare, grams	454.72	Diameter, in.	N/A
Dry UW, pcf	75.1	Moisture Content, %	43.7	Length, in.	N/A
Saturation, %	105.3			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Initial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
13151	1.60	20.00	18.40	1.60	25.6	28.2	25.7	3.08E-09	2.70E-09
29471	1.60	20.00	17.45	2.55	24.3	28.2	24.1	2.26E-09	2.04E-09
89700	1.60	20.00	14.65	5.35	25.5	28.2	19.7	1.72E-09	1.51E-09
104161	1.60	20.00	14.10	5.90	25.5	28.2	18.8	1.66E-09	1.46E-09
345851	1.60	20.00	8.10	11.90	25.1	28.2	9.2	1.38E-09	1.23E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
5	Core	N/A	N/A	Vertical

Avg. k at 20 °C 1.8E-09 cm/sec

a_a = 0.76712 cm^2
A = 46.11 cm^2
L = 8.20 cm
S=L/A= 0.17783 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004270 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*6/19/2009*
Boring No.	*TR557-3*	Reviewed By	
Sample No.	*TR557-3*	Review Date	
Sample Depth	*N/A*	Lab No.	*9629*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.6*
Wet Unit Weight, pcf:	*108.9*
Dry Unit Weight, pcf:	*75.9*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.3E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	06/19/09
Boring No.	TR557-3	Reviewed By	
Sample No.	TR557-3	Review Date	
Sample Depth	N/A	Lab No.	9629
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	DB-8
Location 1	3.235	Location 1	3.013	Wet Soil+Pan, grams	680.58
Location 2	3.277	Location 2	3.016	Dry Soil + Pan, grams	471.13
Location3	3.253	Location 3	3.016	Pan Weight, grams	8.28
Average	3.255	Average	3.015	Moisture Content, %	45.3
Volume, in³	23.24	Wet Soil + Tare, grams	664.50	Dry Unit Weight, pcf	75.9
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	111.5
Soil Sample Wt., g	664.50	Dry Soil +Tare, grams	462.85	Diameter, in.	N/A
Dry UW, pcf	75.9	Moisture Content, %	43.6	Length, in.	N/A
Saturation, %	107.4			Volume, in³	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
8219	1.40	21.85	20.85	1.00	24.2	31.1	29.5	2.74E-09	2.48E-09
24529	1.40	21.85	20.15	1.70	24.3	31.1	28.4	1.59E-09	1.44E-09
87691	1.40	21.85	17.75	4.10	25.0	31.1	24.6	1.15E-09	1.02E-09
111526	1.40	21.85	17.05	4.80	24.3	31.1	23.5	1.08E-09	9.78E-10
170158	1.40	21.85	15.35	6.50	25.2	31.1	20.8	1.02E-09	9.01E-10
190670	1.40	21.85	14.85	7.00	23.9	31.1	20.0	1.0E-09	9.1E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C **1.3E-09 cm/sec**

a_a = 0.76712 cm²
A = 46.06 cm²
L = 8.27 cm
S=L/A= 0.17950 1/cm

a_p= 0.031416 cm²
M_1= 0.03018
M_2= 1.04095
$C = M_1 S/(G_{Hg}-1)$= 0.0004310 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*6/25/2009*
Boring No.	*TR565-1*	Reviewed By	
Sample No.	*TR565-1*	Review Date	
Sample Depth	*N/A*	Lab No.	*9630*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.0*
Wet Unit Weight, pcf:	*107.7*
Dry Unit Weight, pcf:	*75.3*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***8.4E-10***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number 6155-08-0031.04 Tested By JW
Project Name Saltstone Physical Properties Tes Test Date 06/25/09
Boring No. TR565-1 Reviewed By
Sample No. TR565-1 Review Date
Sample Depth N/A Lab No. 9630
Sample Description Grout with MCU (90 days)

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	SS-29
Location 1	2.972	Location 1	3.016	Wet Soil+Pan, grams	716.40
Location 2	3.076	Location 2	3.021	Dry Soil + Pan, grams	524.49
Location3	3.022	Location 3	3.018	Pan Weight, grams	97.08
Average	3.023	Average	3.018	Moisture Content, %	44.9
Volume, in^3	21.63	Wet Soil + Tare, grams	611.36	Dry Unit Weight, pcf	75.3
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	108.9
Soil Sample Wt., g	611.36	Dry Soil +Tare, grams	427.41	Diameter, in.	N/A
Dry UW, pcf	75.3	Moisture Content, %	43.0	Length, in.	N/A
Saturation, %	104.4			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
68205	1.40	19.30	16.80	2.50	25.1	29.3	25.0	9.20E-10	8.16E-10
80953	1.40	19.30	16.40	2.90	25.0	29.3	24.4	9.11E-10	8.10E-10
93359	1.40	19.30	15.90	3.40	25.0	29.3	23.5	9.42E-10	8.38E-10
169640	1.40	19.30	13.40	5.90	25.0	29.3	19.2	9.89E-10	8.80E-10
245880	1.40	19.30	11.50	7.80	24.6	29.3	16.0	9.82E-10	8.81E-10
336420	1.40	19.30	10.00	9.30	24.6	29.3	13.5	9.2E-10	8.3E-10
426300	1.40	19.30	8.10	11.20	24.6	29.3	10.2	9.9E-10	8.9E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 8.4E-10 cm/sec

a_s = 0.76712 cm^2
A = 46.16 cm^2
L = 7.68 cm
S=L/A= 0.16635 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0003994 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*6/25/2009*
Boring No.	*TR565-2*	Reviewed By	
Sample No.	*TR565-2*	Review Date	
Sample Depth	*N/A*	Lab No.	*9631*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*44.3*
Wet Unit Weight, pcf:	*108.9*
Dry Unit Weight, pcf:	*75.5*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.4E-09***

Remarks: ______________________

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number 6155-08-0031.04 Tested By JW
Project Name Saltstone Physical Properties Tes Test Date 06/25/09
Boring No. TR565-2 Reviewed By
Sample No. TR565-2 Review Date
Sample Depth N/A Lab No. 9631
Sample Description Grout with MCU (90 days)

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	T-11
Location 1	3.113	Location 1	3.015	Wet Soil+Pan, grams	646.53
Location 2	3.137	Location 2	3.015	Dry Soil + Pan, grams	449.02
Location3	3.091	Location 3	3.019	Pan Weight, grams	8.12
Average	3.114	Average	3.016	Moisture Content, %	44.8
Volume, in^3	22.25	Wet Soil + Tare, grams	636.24	Dry Unit Weight, pcf	75.5
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	109.3
Soil Sample Wt., g	636.24	Dry Soil +Tare, grams	440.90	Diameter, in.	N/A
Dry UW, pcf	75.5	Moisture Content, %	44.3	Length, in.	N/A
Saturation, %	108.1			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
68734	1.60	20.80	15.60	5.20	25.0	30.5	21.9	1.98E-09	1.76E-09
16679	1.60	19.70	18.15	1.55	25.0	28.8	26.2	2.31E-09	2.05E-09
85047	1.60	19.70	15.25	4.45	25.1	28.8	21.4	1.43E-09	1.27E-09
12285	1.60	20.65	20.05	0.60	25.0	30.3	29.3	1.12E-09	9.94E-10
24761	1.60	20.65	19.50	1.15	25.0	30.3	28.4	1.08E-09	9.60E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
5	Core	N/A	N/A	Vertical

Avg. k at 20 °C **1.4E-09 cm/sec**

a_s = 0.76712 cm^2
A = 46.10 cm^2
L = 7.91 cm
S=L/A= 0.17155 1/cm

a_p = 0.031416 cm^2
M_1 = 0.03018
M_2 = 1.04095
$C = M_1S/(G_{Hg}-1)$ = 0.0004119 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*6/25/2009*
Boring No.	*TR565-3*	Reviewed By	
Sample No.	*TR565-3*	Review Date	
Sample Depth	*N/A*	Lab No.	*9632*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.9*
Wet Unit Weight, pcf:	*109.4*
Dry Unit Weight, pcf:	*76.1*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.6E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	06/25/09
Boring No.	TR565-3	Reviewed By	
Sample No.	TR565-3	Review Date	
Sample Depth	N/A	Lab No.	9632
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	DB-16
Location 1	3.151	Location 1	3.020	Wet Soil+Pan, grams	654.18
Location 2	3.135	Location 2	3.018	Dry Soil + Pan, grams	455.68
Location3	3.108	Location 3	3.017	Pan Weight, grams	8.25
Average	3.131	Average	3.018	Moisture Content, %	44.4
Volume, in^3	22.41	Wet Soil + Tare, grams	643.71	Dry Unit Weight, pcf	76.1
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	109.9
Soil Sample Wt., g	643.71	Dry Soil +Tare, grams	447.43	Diameter, in.	N/A
Dry UW, pcf	76.1	Moisture Content, %	43.9	Length, in.	N/A
Saturation, %	108.7			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0
Permeant used	MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
6355	1.60	21.10	20.15	0.95	23.9	30.8	29.3	3.39E-09	3.09E-09
22819	1.60	21.10	19.10	2.00	24.7	30.8	27.5	2.05E-09	1.83E-09
259729	1.60	21.10	8.25	12.85	24.8	30.8	9.7	1.84E-09	1.65E-09
24029	1.60	22.80	21.50	1.30	23.4	33.5	31.4	1.14E-09	1.05E-09
84486	1.60	22.80	19.05	3.75	24.8	33.5	27.3	9.96E-10	8.90E-10
99336	1.60	22.80	18.60	4.20	24.8	33.5	26.6	9.6E-10	8.6E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C 1.6E-09 cm/sec

a_a = 0.76712 cm^2
A = 46.16 cm^2
L = 7.95 cm
S=L/A= 0.17229 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004137 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*7/14/2009*
Boring No.	*TR575-1*	Reviewed By	
Sample No.	*TR575-1*	Review Date	
Sample Depth	*N/A*	Lab No.	*9633*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*41.3*
Wet Unit Weight, pcf:	*110.0*
Dry Unit Weight, pcf:	*77.9*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***2.0E-09***

Remarks: ______________________

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	07/14/09
Boring No.	TR575-1	Reviewed By	
Sample No.	TR575-1	Review Date	
Sample Depth	N/A	Lab No.	9633
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-35
Location 1	3.121	Location 1	3.013	Wet Soil+Pan, grams	657.69
Location 2	3.112	Location 2	3.012	Dry Soil + Pan, grams	464.30
Location3	3.151	Location 3	3.013	Pan Weight, grams	8.47
Average	3.128	Average	3.013	Moisture Content, %	42.4
Volume, in^3	22.30	Wet Soil + Tare, grams	644.13	Dry Unit Weight, pcf	77.9
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	110.3
Soil Sample Wt., g	644.13	Dry Soil +Tare, grams	455.83	Diameter, in.	N/A
Dry UW, pcf	77.9	Moisture Content, %	41.3	Length, in.	N/A
Saturation, %	107.4			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_p (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
9627	1.40	22.65	21.20	1.45	25.2	33.6	31.2	3.17E-09	2.81E-09
24010	1.40	22.65	20.05	2.60	25.0	33.6	29.3	2.35E-09	2.09E-09
90996	1.40	22.65	16.90	5.75	25.4	33.6	24.2	1.51E-09	1.33E-09
10625	1.40	20.90	19.40	1.50	24.7	30.9	28.4	3.26E-09	2.92E-09
21155	1.40	20.90	18.85	2.05	24.8	30.9	27.5	2.27E-09	2.03E-09
252924	1.40	20.90	11.45	9.45	24.6	30.9	15.3	1.2E-09	1.0E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C 2.0E-09 cm/sec

a_a = 0.76712 cm^2
A = 45.99 cm^2
L = 7.95 cm
S=L/A= 0.17276 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004148 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*7/14/2009*
Boring No.	*TR575-2*	Reviewed By	
Sample No.	*TR575-2*	Review Date	
Sample Depth	*N/A*	Lab No.	*9634*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*41.3*
Wet Unit Weight, pcf:	*109.9*
Dry Unit Weight, pcf:	*77.8*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***8.8E-10***

Remarks: ______________________________

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	07/14/09
Boring No.	TR575-2	Reviewed By	
Sample No.	TR575-2	Review Date	
Sample Depth	N/A	Lab No.	9634
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	T-9
Location 1	3.079	Location 1	3.020	Wet Soil+Pan, grams	643.91
Location 2	3.035	Location 2	3.020	Dry Soil + Pan, grams	454.69
Location3	3.032	Location 3	3.023	Pan Weight, grams	8.45
Average	3.049	Average	3.021	Moisture Content, %	42.4
Volume, in^3	21.85	Wet Soil + Tare, grams	630.69	Dry Unit Weight, pcf	77.8
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	110.0
Soil Sample Wt., g	630.69	Dry Soil +Tare, grams	446.24	Diameter, in.	N/A
Dry UW, pcf	77.8	Moisture Content, %	41.3	Length, in.	N/A
Saturation, %	107.2			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Initial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
11220	1.60	21.10	20.25	0.85	23.7	31.7	30.2	1.66E-09	1.52E-09
24206	1.60	21.10	19.90	1.20	23.8	31.7	29.6	1.10E-09	1.01E-09
85249	1.60	21.10	18.20	2.90	25.1	31.7	26.8	7.93E-10	7.04E-10
100899	1.60	21.10	17.80	3.30	24.1	31.7	26.1	7.72E-10	7.01E-10
12293	1.60	20.10	19.70	0.40	24.4	30.0	29.4	7.44E-10	6.71E-10
71073	1.60	20.10	17.90	2.20	25.3	30.0	26.3	7.5E-10	6.6E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C 8.8E-10 cm/sec

a_s = 0.76712 cm^2
A = 46.24 cm^2
L = 7.74 cm
S=L/A= 0.16745 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004020 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*7/14/2009*
Boring No.	*TR575-3*	Reviewed By	
Sample No.	*TR575-3*	Review Date	
Sample Depth	*N/A*	Lab No.	*9635*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*41.0*
Wet Unit Weight, pcf:	*111.3*
Dry Unit Weight, pcf:	*78.9*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.2E-09***

Remarks: ____________________

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	07/14/09
Boring No.	TR575-3	Reviewed By	
Sample No.	TR575-3	Review Date	
Sample Depth	N/A	Lab No.	9635
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-11
Location 1	3.105	Location 1	3.002	Wet Soil+Pan, grams	660.30
Location 2	3.154	Location 2	3.002	Dry Soil + Pan, grams	467.05
Location3	3.122	Location 3	3.002	Pan Weight, grams	8.46
Average	3.127	Average	3.002	Moisture Content, %	42.1
Volume, in^3	22.13	Wet Soil + Tare, grams	646.75	Dry Unit Weight, pcf	78.9
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	112.7
Soil Sample Wt., g	646.75	Dry Soil +Tare, grams	458.59	Diameter, in.	N/A
Dry UW, pcf	78.9	Moisture Content, %	41.0	Length, in.	N/A
Saturation, %	109.7			Volume, in^3	N/A

Consolidation	
Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
9116	1.60	19.20	18.60	0.60	25.2	27.9	26.9	1.66E-09	1.47E-09
23468	1.60	19.20	17.50	1.70	25.0	27.9	25.1	1.89E-09	1.68E-09
90812	1.60	19.20	15.60	3.60	25.4	27.9	21.9	1.10E-09	9.70E-10
10706	1.60	19.50	18.70	0.80	24.7	28.3	27.0	1.86E-09	1.66E-09
21155	1.60	19.50	18.30	1.20	24.8	28.3	26.4	1.43E-09	1.28E-09
253002	1.60	19.50	15.15	4.35	24.6	28.3	21.2	4.8E-10	4.3E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C 1.2E-09 cm/sec

a_a = 0.76712 cm²
A = 45.66 cm²
L = 7.94 cm
S=L/A= 0.17393 1/cm

a_p= 0.031416 cm²
M_1= 0.03018
M_2= 1.04095
$C = M_1 S/(G_{Hg}-1)$= 0.0004176 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*8/4/2009*
Boring No.	*TR577-1*	Reviewed By	
Sample No.	*TR577-1*	Review Date	
Sample Depth	*N/A*	Lab No.	*9690*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*46.8*
Wet Unit Weight, pcf:	*111.4*
Dry Unit Weight, pcf:	*75.9*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***9.1E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	08/04/09
Boring No.	TR577-1	Reviewed By	
Sample No.	TR577-1	Review Date	
Sample Depth	N/A	Lab No.	9690
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	F-121
Location 1	3.023	Location 1	3.018	Wet Soil+Pan, grams	642.30
Location 2	3.032	Location 2	3.019	Dry Soil + Pan, grams	435.34
Location3	3.018	Location 3	3.018	Pan Weight, grams	4.29
Average	3.024	Average	3.018	Moisture Content, %	48.0
Volume, in^3	21.64	Wet Soil + Tare, grams	632.77	Dry Unit Weight, pcf	75.9
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	118.4
Soil Sample Wt., g	632.77	Dry Soil +Tare, grams	431.05	Diameter, in.	N/A
Dry UW, pcf	75.9	Moisture Content, %	46.8	Length, in.	N/A
Saturation, %	115.4			Volume, in^3	N/A

Consolidation	
Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
4483	1.40	19.30	17.50	1.80	25.0	29.3	26.2	9.85E-09	8.76E-09
61415	1.40	19.30	5.50	13.80	25.0	29.3	5.8	1.06E-08	9.38E-09
10274	1.40	19.35	15.30	4.05	25.1	29.4	22.5	1.04E-08	9.24E-09
24716	1.40	19.35	11.40	7.95	25.0	29.4	15.8	9.99E-09	8.89E-09
87276	1.40	19.35	3.70	15.65	25.0	29.4	2.7	1.09E-08	9.69E-09
19269	1.40	19.20	12.70	6.50	25.0	29.1	18.1	9.9E-09	8.8E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C **9.1E-09 cm/sec**

a_s = 0.76712 cm^2
A = 46.16 cm^2
L = 7.68 cm
S=L/A= 0.16641 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1 S/(G_{Hg}-1)$= 0.0003995 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*8/4/2009*
Boring No.	*TR577-2*	Reviewed By	
Sample No.	*TR577-2*	Review Date	
Sample Depth	*N/A*	Lab No.	*9691*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*46.8*
Wet Unit Weight, pcf:	*106.3*
Dry Unit Weight, pcf:	*72.4*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***8.0E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Tes	Test Date	08/04/09
Boring No.	TR577-2	Reviewed By	
Sample No.	TR577-2	Review Date	
Sample Depth	N/A	Lab No.	9691
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	F-221
Location 1	3.425	Location 1	3.023	Wet Soil+Pan, grams	696.71
Location 2	3.439	Location 2	3.026	Dry Soil + Pan, grams	472.00
Location3	3.421	Location 3	3.021	Pan Weight, grams	4.3
Average	3.428	Average	3.023	Moisture Content, %	48.0
Volume, in^3	24.61	Wet Soil + Tare, grams	686.55	Dry Unit Weight, pcf	72.4
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	107.9
Soil Sample Wt., g	686.55	Dry Soil +Tare, grams	467.70	Diameter, in.	N/A
Dry UW, pcf	72.4	Moisture Content, %	46.8	Length, in.	N/A
Saturation, %	105.1			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
16526	1.60	19.50	14.55	4.95	25.0	25.8	18.4	9.27E-09	8.25E-09
25568	1.60	19.50	12.60	6.90	25.0	25.8	15.5	9.06E-09	8.05E-09
12060	1.60	20.30	16.30	4.00	25.0	27.0	21.0	9.43E-09	8.38E-09
21300	1.60	20.30	13.65	6.65	25.8	27.0	17.0	9.80E-09	8.56E-09
55903	1.60	21.40	9.45	11.95	25.0	28.6	10.6	7.99E-09	7.11E-09
20780	1.60	20.00	14.00	6.00	25.5	26.6	17.5	9.0E-09	7.9E-09
30443	1.60	20.00	12.05	7.95	25.0	26.6	14.6	8.9E-09	7.9E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 8.0E-09 cm/sec

a_a = 0.76712 cm^2
A = 46.32 cm^2
L = 8.71 cm
S=L/A= 0.18801 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004514 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Tes*	Test Date	*8/4/2009*
Boring No.	*TR577-3*	Reviewed By	
Sample No.	*TR577-3*	Review Date	
Sample Depth	*N/A*	Lab No.	*9692*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	Core
Sample Orientation:	Vertical
Initial Water Content, %:	46.9
Wet Unit Weight, pcf:	106.7
Dry Unit Weight, pcf:	72.6
Compaction, %:	N/A
Hydraulic Conductivity, cm/sec. @20 °C	**8.0E-09**

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number 6155-08-0031.04 — Tested By JW
Project Name Saltstone Physical Properties Tes — Test Date 08/04/09
Boring No. TR577-3 — Reviewed By
Sample No. TR577-3 — Review Date
Sample Depth N/A — Lab No. 9692
Sample Description Grout with MCU (90 days)

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	AB-65
Location 1	3.356	Location 1	3.022	Wet Soil+Pan, grams	684.25
Location 2	3.364	Location 2	3.019	Dry Soil + Pan, grams	462.99
Location3	3.357	Location 3	3.021	Pan Weight, grams	4.22
Average	3.359	Average	3.021	Moisture Content, %	48.2
Volume, in^3	24.07	Wet Soil + Tare, grams	673.94	Dry Unit Weight, pcf	72.6
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	108.9
Soil Sample Wt., g	673.94	Dry Soil +Tare, grams	458.77	Diameter, in.	N/A
Dry UW, pcf	72.6	Moisture Content, %	46.9	Length, in.	N/A
Saturation, %	105.9			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
9421	1.60	20.15	16.70	3.45	24.1	27.3	22.0	1.01E-08	9.19E-09
7543	1.60	19.45	17.00	2.45	25.3	26.3	22.5	9.06E-09	8.00E-09
19255	1.60	19.45	14.15	5.30	25.0	26.3	18.2	8.51E-09	7.57E-09
76271	1.60	19.45	6.05	13.40	25.0	26.3	5.7	8.83E-09	7.86E-09
10279	1.60	19.80	16.60	3.20	25.1	26.8	21.9	8.71E-09	7.73E-09
24717	1.60	19.80	13.30	6.50	25.0	26.8	16.8	8.3E-09	7.4E-09
87270	1.60	19.80	5.40	14.40	25.0	26.8	4.7	8.8E-09	7.8E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 8.0E-09 cm/sec

a_t = 0.76712 cm^2
A = 46.23 cm^2
L = 8.53 cm
S=L/A= 0.18454 1/cm

a_p = 0.031416 cm^2
M_1 = 0.03018
M_2 = 1.04095
$C = M_1S/(G_{Hg}-1)$ = 0.0004431 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Testing*	Test Date	*8/13/2009*
Boring No.	*TR582-1*	Reviewed By	
Sample No.	*TR582-1*	Review Date	
Sample Depth	*N/A*	Lab No.	*9693*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*37.7*
Wet Unit Weight, pcf:	*109.8*
Dry Unit Weight, pcf:	*79.7*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***4.2E-10***

Remarks:

PERMEABILITY TEST

(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Testing	Test Date	08/13/09
Boring No.	TR582-1	Reviewed By	
Sample No.	TR582-1	Review Date	
Sample Depth	N/A	Lab No.	9693
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-29
Location 1	3.200	Location 1	3.023	Wet Soil+Pan, grams	662.23
Location 2	3.127	Location 2	3.017	Dry Soil + Pan, grams	482.90
Location3	3.184	Location 3	3.013	Pan Weight, grams	8.25
Average	3.170	Average	3.018	Moisture Content, %	37.8
Volume, in^3	22.67	Wet Soil + Tare, grams	653.56	Dry Unit Weight, pcf	79.7
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	103.3
Soil Sample Wt., g	653.56	Dry Soil +Tare, grams	474.65	Diameter, in.	N/A
Dry UW, pcf	79.7	Moisture Content, %	37.7	Length, in.	N/A
Saturation, %	103.0			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
21501	1.60	20.20	19.50	0.70	24.8	29.0	27.9	7.79E-10	6.96E-10
259291	1.60	20.20	16.70	3.50	25.2	29.0	23.3	3.52E-10	3.12E-10
277029	1.60	20.20	16.30	3.90	24.9	29.0	22.7	3.72E-10	3.32E-10
346232	1.60	20.20	16.00	4.20	25.5	29.0	22.2	3.24E-10	2.85E-10
31680	1.60	20.20	19.40	0.80	24.6	29.0	27.7	6.06E-10	5.44E-10
179717	1.60	20.20	17.60	2.60	24.5	29.0	24.8	3.7E-10	3.3E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C **4.2E-10 cm/sec**

a_s = 0.76712 cm^2

A = 46.14 cm^2

L = 8.05 cm

S=L/A= 0.17452 1/cm

a_p= 0.031416 cm^2

M_1= 0.03018

M_2= 1.04095

$C = M_1S/(G_{Hg}-1)$= 0.0004190 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Testing*	Test Date	*8/13/2009*
Boring No.	*TR582-2*	Reviewed By	
Sample No.	*TR582-2*	Review Date	
Sample Depth	*N/A*	Lab No.	*9694*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*37.6*
Wet Unit Weight, pcf:	*110.2*
Dry Unit Weight, pcf:	*80.1*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.7E-10***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Testing	Test Date	08/13/09
Boring No.	TR582-2	Reviewed By	
Sample No.	TR582-2	Review Date	
Sample Depth	N/A	Lab No.	9694
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	H-7
Location 1	3.417	Location 1	3.018	Wet Soil+Pan, grams	709.61
Location 2	3.409	Location 2	3.015	Dry Soil + Pan, grams	517.63
Location3	3.352	Location 3	3.014	Pan Weight, grams	8.17
Average	3.393	Average	3.016	Moisture Content, %	37.7
Volume, in^3	24.23	Wet Soil + Tare, grams	701.03	Dry Unit Weight, pcf	80.1
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	104.0
Soil Sample Wt., g	701.03	Dry Soil +Tare, grams	509.46	Diameter, in.	N/A
Dry UW, pcf	80.1	Moisture Content, %	37.6	Length, in.	N/A
Saturation, %	103.7			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
63816	1.60	20.80	20.00	0.80	26.3	28.0	26.8	3.12E-10	2.69E-10
317299	1.60	20.80	18.70	2.10	24.4	28.0	24.8	1.71E-10	1.54E-10
98932	1.60	18.60	18.10	0.50	25.4	24.8	24.0	1.41E-10	1.24E-10
162699	1.60	18.60	17.60	1.00	24.1	24.8	23.3	1.74E-10	1.58E-10
246923	1.60	18.60	17.20	1.40	25.8	24.8	22.7	1.63E-10	1.42E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
5	Core	N/A	N/A	Vertical

Avg. k at 20 °C **1.7E-10 cm/sec**

a_s = 0.76712 cm^2
A = 46.08 cm^2
L = 8.62 cm
S=L/A= 0.18700 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004490 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Testing*	Test Date	*8/13/2009*
Boring No.	*TR582-3*	Reviewed By	
Sample No.	*TR582-3*	Review Date	
Sample Depth	*N/A*	Lab No.	*9695*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*37.7*
Wet Unit Weight, pcf:	*109.9*
Dry Unit Weight, pcf:	*79.8*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***2.5E-10***

Remarks: ______________________________

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number 6155-08-0031.04 Tested By JW
Project Name Saltstone Physical Properties Testing Test Date 08/13/09
Boring No. TR582-3 Reviewed By
Sample No. TR582-3 Review Date
Sample Depth N/A Lab No. 9695
Sample Description Grout with MCU (90 days)

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-28
Location 1	3.365	Location 1	3.029	Wet Soil+Pan, grams	700.38
Location 2	3.353	Location 2	3.019	Dry Soil + Pan, grams	510.70
Location3	3.308	Location 3	3.018	Pan Weight, grams	8.26
Average	3.342	Average	3.022	Moisture Content, %	37.8
Volume, in^3	23.97	Wet Soil + Tare, grams	691.62	Dry Unit Weight, pcf	79.8
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	103.5
Soil Sample Wt., g	691.62	Dry Soil +Tare, grams	502.44	Diameter, in.	N/A
Dry UW, pcf	79.8	Moisture Content, %	37.7	Length, in.	N/A
Saturation, %	103.2			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
21750	1.40	20.50	19.90	0.60	24.8	28.3	27.4	6.73E-10	6.01E-10
259323	1.40	20.50	18.90	1.60	25.2	28.3	25.8	1.55E-10	1.37E-10
277228	1.40	20.50	18.70	1.80	24.9	28.3	25.5	1.64E-10	1.46E-10
346289	1.40	20.50	18.30	2.20	25.5	28.3	24.9	1.62E-10	1.43E-10
20445	1.40	21.60	21.30	0.30	24.5	29.9	29.4	3.36E-10	3.02E-10
84345	1.40	21.60	21.00	0.60	26.3	29.9	29.0	1.6E-10	1.4E-10
337677	1.40	21.60	19.40	2.20	24.4	29.9	26.5	1.6E-10	1.4E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 2.5E-10 cm/sec

a_a = 0.76712 cm^2
A = 46.27 cm^2
L = 8.49 cm
S=L/A= 0.18344 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004404 for 15° to 25°

Remarks:

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Testing*	Test Date	*8/24/2009*
Boring No.	*TR588-1*	Reviewed By	
Sample No.	*TR588-1*	Review Date	
Sample Depth	*N/A*	Lab No.	*9696*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.4*
Wet Unit Weight, pcf:	*107.3*
Dry Unit Weight, pcf:	*74.8*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.9E-10***

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number 6155-08-0031.04 Tested By JW
Project Name Saltstone Physical Properties Testing Test Date 08/24/09
Boring No. TR588-1 Reviewed By
Sample No. TR588-1 Review Date
Sample Depth N/A Lab No. 9696
Sample Description Grout with MCU (90 days)

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	Z-19
Location 1	3.255	Location 1	3.013	Wet Soil+Pan, grams	651.32
Location 2	3.216	Location 2	3.013	Dry Soil + Pan, grams	455.06
Location3	3.184	Location 3	3.014	Pan Weight, grams	4.25
Average	3.218	Average	3.013	Moisture Content, %	43.5
Volume, in^3	22.95	Wet Soil + Tare, grams	646.52	Dry Unit Weight, pcf	74.8
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	104.3
Soil Sample Wt., g	646.52	Dry Soil +Tare, grams	450.81	Diameter, in.	N/A
Dry UW, pcf	74.8	Moisture Content, %	43.4	Length, in.	N/A
Saturation, %	104.0			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
61910	1.60	20.00	19.20	0.80	23.6	28.3	27.0	3.19E-10	2.93E-10
86867	1.60	20.00	19.00	1.00	23.9	28.3	26.7	2.86E-10	2.61E-10
317532	1.60	20.00	17.70	2.30	23.4	28.3	24.6	1.87E-10	1.73E-10
346774	1.60	20.00	17.50	2.50	24.0	28.3	24.3	1.88E-10	1.71E-10
58228	1.60	17.50	17.20	0.30	23.9	24.4	24.0	1.45E-10	1.33E-10
77074	1.60	17.50	17.10	0.40	24.0	24.4	23.8	1.5E-10	1.3E-10
143395	1.60	17.50	16.70	0.80	23.8	24.4	23.2	1.6E-10	1.5E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 1.9E-10 cm/sec

a_o = 0.76712 cm^2
A = 46.01 cm^2
L = 8.17 cm
S=L/A= 0.17767 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004266 for 15° to 25°

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Testing*	Test Date	*8/24/2009*
Boring No.	*TR588-2*	Reviewed By	
Sample No.	*TR588-2*	Review Date	
Sample Depth	*N/A*	Lab No.	*9697*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.3*
Wet Unit Weight, pcf:	*107.7*
Dry Unit Weight, pcf:	*75.2*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***2.1E-10***

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number 6155-08-0031.04 Tested By JW
Project Name Saltstone Physical Properties Testing Test Date 08/24/09
Boring No. TR588-2 Reviewed By
Sample No. TR588-2 Review Date
Sample Depth N/A Lab No. 9697
Sample Description Grout with MCU (90 days)

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	DB-23
Location 1	3.108	Location 1	3.012	Wet Soil+Pan, grams	635.36
Location 2	3.104	Location 2	3.010	Dry Soil + Pan, grams	445.52
Location3	3.130	Location 3	3.010	Pan Weight, grams	8.13
Average	3.114	Average	3.011	Moisture Content, %	43.4
Volume, in^3	22.17	Wet Soil + Tare, grams	626.87	Dry Unit Weight, pcf	75.2
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	105.0
Soil Sample Wt., g	626.87	Dry Soil +Tare, grams	437.39	Diameter, in.	N/A
Dry UW, pcf	75.2	Moisture Content, %	43.3	Length, in.	N/A
Saturation, %	104.8			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
16247	1.40	22.20	21.80	0.40	24.6	33.1	32.4	5.15E-10	4.62E-10
84836	1.40	22.20	21.60	0.60	24.1	33.1	32.1	1.49E-10	1.35E-10
61648	1.40	20.70	20.20	0.50	23.6	30.7	29.8	1.83E-10	1.68E-10
86676	1.40	20.70	20.00	0.70	23.9	30.7	29.5	1.84E-10	1.67E-10
317285	1.40	20.70	18.90	1.80	23.4	30.7	27.7	1.33E-10	1.23E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
5	Core	N/A	N/A	Vertical

Avg. k at 20 °C 2.1E-10 cm/sec

a_a = 0.76712 cm^2
A = 45.93 cm^2
L = 7.91 cm
S=L/A= 0.17221 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1 S/(G_{Hg}-1)$= 0.0004135 for 15° to 25°

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Testing*	Test Date	*8/26/2009*
Boring No.	*TR588-3*	Reviewed By	
Sample No.	*TR588-3*	Review Date	
Sample Depth	*N/A*	Lab No.	*9698*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*43.3*
Wet Unit Weight, pcf:	*107.3*
Dry Unit Weight, pcf:	*74.9*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***3.6E-10***

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Testing	Test Date	08/26/09
Boring No.	TR588-3	Reviewed By	
Sample No.	TR588-3	Review Date	
Sample Depth	N/A	Lab No.	9698
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	K-3
Location 1	3.184	Location 1	3.020	Wet Soil+Pan, grams	643.92
Location 2	3.160	Location 2	3.015	Dry Soil + Pan, grams	450.42
Location3	3.181	Location 3	3.014	Pan Weight, grams	4.27
Average	3.175	Average	3.016	Moisture Content, %	43.4
Volume, in^3	22.69	Wet Soil + Tare, grams	639.22	Dry Unit Weight, pcf	74.9
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	104.2
Soil Sample Wt., g	639.22	Dry Soil +Tare, grams	446.15	Diameter, in.	N/A
Dry UW, pcf	74.9	Moisture Content, %	43.3	Length, in.	N/A
Saturation, %	104.0			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
8801	1.40	22.10	21.80	0.30	24.0	32.3	31.8	7.25E-10	6.60E-10
58274	1.40	21.70	20.65	1.05	23.9	31.6	29.9	3.99E-10	3.64E-10
77059	1.40	21.70	20.50	1.20	24.0	31.6	29.7	3.46E-10	3.15E-10
143457	1.40	21.70	20.10	1.60	23.8	31.6	29.0	2.51E-10	2.29E-10
168951	1.40	21.70	20.00	1.70	23.5	31.6	28.9	2.27E-10	2.09E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
5	Core	N/A	N/A	Vertical

Avg. k at 20 °C 3.6E-10 cm/sec

a_a = 0.76712 cm^2
A = 46.10 cm^2
L = 8.06 cm
S=L/A= 0.17493 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1 S/(G_{Hg}-1)$= 0.0004200 for 15° to 25°

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Testing*	Test Date	*9/2/2009*
Boring No.	*TR602-1*	Reviewed By	
Sample No.	*TR602-1*	Review Date	
Sample Depth	*N/A*	Lab No.	*9699*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*41.5*
Wet Unit Weight, pcf:	*108.5*
Dry Unit Weight, pcf:	*76.7*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.4E-09***

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Testing	Test Date	09/02/09
Boring No.	TR602-1	Reviewed By	
Sample No.	TR602-1	Review Date	
Sample Depth	N/A	Lab No.	9699
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	LJ-22
Location 1	3.213	Location 1	3.013	Wet Soil+Pan, grams	660.28
Location 2	3.202	Location 2	3.012	Dry Soil + Pan, grams	468.37
Location3	3.202	Location 3	3.011	Pan Weight, grams	8.67
Average	3.206	Average	3.012	Moisture Content, %	41.7
Volume, in^3	22.84	Wet Soil + Tare, grams	650.25	Dry Unit Weight, pcf	76.7
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	105.1
Soil Sample Wt., g	650.25	Dry Soil + Tare, grams	459.70	Diameter, in.	N/A
Dry UW, pcf	76.7	Moisture Content, %	41.5	Length, in.	N/A
Saturation, %	104.4			Volume, in^3	N/A

Consolidation	
Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0
Permeant used	MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Initial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
26801	1.40	24.50	21.80	2.70	23.4	35.7	31.3	2.06E-09	1.90E-09
83422	1.40	24.50	17.80	6.70	23.9	35.7	24.9	1.83E-09	1.67E-09
113332	1.40	24.50	16.10	8.40	24.2	35.7	22.2	1.78E-09	1.62E-09
21420	1.40	21.70	20.30	1.40	23.9	31.3	29.1	1.48E-09	1.35E-09
81073	1.40	21.70	17.70	4.00	23.5	31.3	24.9	1.20E-09	1.11E-09
107420	1.40	21.70	16.90	4.80	24.0	31.3	23.6	1.12E-09	1.02E-09
168689	1.40	21.70	15.20	6.50	24.0	31.3	20.9	1.02E-09	9.30E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 1.4E-09 cm/sec

a_a = 0.76712 cm^2
A = 45.97 cm^2
L = 8.14 cm
S=L/A= 0.17713 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004253 for 15° to 25°

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Testing*	Test Date	*9/2/2009*
Boring No.	*TR602-2*	Reviewed By	
Sample No.	*TR602-2*	Review Date	
Sample Depth	*N/A*	Lab No.	*9700*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*41.3*
Wet Unit Weight, pcf:	*108.0*
Dry Unit Weight, pcf:	*76.4*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***9.2E-10***

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Testing	Test Date	09/02/09
Boring No.	TR602-2	Reviewed By	
Sample No.	TR602-2	Review Date	
Sample Depth	N/A	Lab No.	9700
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	F-124
Location 1	3.102	Location 1	3.017	Wet Soil+Pan, grams	629.13
Location 2	3.052	Location 2	3.019	Dry Soil + Pan, grams	446.01
Location3	3.078	Location 3	3.019	Pan Weight, grams	4.36
Average	3.077	Average	3.018	Moisture Content, %	41.5
Volume, in^3	22.02	Wet Soil + Tare, grams	623.97	Dry Unit Weight, pcf	76.4
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	103.7
Soil Sample Wt., g	623.97	Dry Soil +Tare, grams	441.65	Diameter, in.	N/A
Dry UW, pcf	76.4	Moisture Content, %	41.3	Length, in.	N/A
Saturation, %	103.2			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
26490	1.60	20.60	18.90	1.70	23.4	30.6	27.7	1.50E-09	1.38E-09
82920	1.60	20.60	16.90	3.70	23.9	30.6	24.4	1.11E-09	1.01E-09
112909	1.60	20.60	16.10	4.50	24.2	30.6	23.0	1.02E-09	9.23E-10
25890	1.60	19.70	18.50	1.20	23.9	29.1	27.1	1.12E-09	1.02E-09
85555	1.60	19.70	17.50	2.20	23.5	29.1	25.4	6.43E-10	5.92E-10
111801	1.60	19.70	17.00	2.70	24.0	29.1	24.6	6.14E-10	5.58E-10
173150	1.60	19.70	16.10	3.60	24.0	29.1	23.1	5.45E-10	4.96E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 9.2E-10 cm/sec

a_s = 0.76712 cm^2
A = 46.16 cm^2
L = 7.82 cm
S=L/A= 0.16932 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004065 for 15° to 25°

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Testing*	Test Date	*9/2/2009*
Boring No.	*TR602-3*	Reviewed By	
Sample No.	*TR602-3*	Review Date	
Sample Depth	*N/A*	Lab No.	*9701*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*41.1*
Wet Unit Weight, pcf:	*108.7*
Dry Unit Weight, pcf:	*77.0*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***7.8E-10***

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Testing	Test Date	09/02/09
Boring No.	TR602-3	Reviewed By	
Sample No.	TR602-3	Review Date	
Sample Depth	N/A	Lab No.	9701
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	Z-65
Location 1	3.314	Location 1	3.015	Wet Soil+Pan, grams	673.16
Location 2	3.254	Location 2	3.014	Dry Soil + Pan, grams	477.66
Location3	3.275	Location 3	3.016	Pan Weight, grams	4.26
Average	3.281	Average	3.015	Moisture Content, %	41.3
Volume, in^3	23.42	Wet Soil + Tare, grams	668.10	Dry Unit Weight, pcf	77.0
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	104.9
Soil Sample Wt., g	668.10	Dry Soil +Tare, grams	473.40	Diameter, in.	N/A
Dry UW, pcf	77.0	Moisture Content, %	41.1	Length, in.	N/A
Saturation, %	104.4			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
57912	1.40	20.40	18.50	1.90	23.4	28.7	25.7	8.25E-10	7.61E-10
82080	1.40	20.40	17.90	2.50	24.0	28.7	24.7	7.80E-10	7.09E-10
316361	1.40	20.40	11.60	8.80	23.7	28.7	14.8	9.04E-10	8.28E-10
27263	1.40	21.30	20.30	1.00	24.0	30.0	28.4	8.56E-10	7.79E-10
85518	1.40	21.30	18.30	3.00	23.8	30.0	25.3	8.67E-10	7.93E-10
109440	1.40	21.30	17.50	3.80	24.0	30.0	24.0	8.80E-10	8.00E-10

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
6	Core	N/A	N/A	Vertical

Avg. k at 20 °C 7.8E-10 cm/sec

a_s = 0.76712 cm^2
A = 46.06 cm^2
L = 8.33 cm
S=L/A= 0.18093 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004344 for 15° to 25°

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Testing*	Test Date	*9/16/2009*
Boring No.	*TR604-1*	Reviewed By	
Sample No.	*TR604-1*	Review Date	
Sample Depth	*N/A*	Lab No.	*9702*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*45.7*
Wet Unit Weight, pcf:	*109.3*
Dry Unit Weight, pcf:	*75.0*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***8.0E-07***

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number 6155-08-0031.04 — Tested By JW
Project Name Saltstone Physical Properties Testing — Test Date 09/16/09
Boring No. TR604-1 — Reviewed By
Sample No. TR604-1 — Review Date
Sample Depth N/A — Lab No. 9702
Sample Description Grout with MCU (90 days)

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	H-23
Location 1	3.349	Location 1	3.020	Wet Soil+Pan, grams	691.91
Location 2	3.329	Location 2	3.021	Dry Soil + Pan, grams	473.96
Location3	3.315	Location 3	3.019	Pan Weight, grams	4.23
Average	3.331	Average	3.020	Moisture Content, %	46.4
Volume, in^3	23.86	Wet Soil + Tare, grams	684.39	Dry Unit Weight, pcf	75.0
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	111.7
Soil Sample Wt., g	684.39	Dry Soil +Tare, grams	469.73	Diameter, in.	N/A
Dry UW, pcf	75.0	Moisture Content, %	45.7	Length, in.	N/A
Saturation, %	110.0			Volume, in^3	N/A

Consolidation	
Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
120	1.40	18.50	15.00	3.50	23.8	25.4	20.0	8.78E-07	8.02E-07
240	1.40	18.50	11.80	6.70	23.9	25.4	15.0	9.60E-07	8.75E-07
42	1.40	14.00	13.00	1.00	23.7	18.7	17.2	9.02E-07	8.27E-07
80	1.40	12.50	11.00	1.50	23.7	16.5	14.2	8.33E-07	7.63E-07
80	1.40	10.50	9.30	1.20	23.8	13.5	11.7	8.11E-07	7.42E-07
120	1.40	9.00	7.50	1.50	23.9	11.3	9.0	8.4E-07	7.7E-07
111	1.40	7.00	6.00	1.00	23.8	8.3	6.8	8.1E-07	7.4E-07

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 8.0E-07 cm/sec

a_s = 0.76712 cm^2
A = 46.21 cm^2
L = 8.46 cm
S=L/A= 0.18308 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0004396 for 15° to 25°

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Testing*	Test Date	*9/16/2009*
Boring No.	*TR604-2*	Reviewed By	
Sample No.	*TR604-2*	Review Date	
Sample Depth	*N/A*	Lab No.	*9703*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*46.2*
Wet Unit Weight, pcf:	*108.4*
Dry Unit Weight, pcf:	*74.1*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***8.6E-07***

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number 6155-08-0031.04
Project Name Saltstone Physical Properties Testing
Boring No. TR604-2
Sample No. TR604-2
Sample Depth N/A
Sample Description Grout with MCU (90 days)

Tested By JW
Test Date 09/16/09
Reviewed By
Review Date
Lab No. 9703

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	K-4
Location 1	2.924	Location 1	3.028	Wet Soil+Pan, grams	606.36
Location 2	2.935	Location 2	3.024	Dry Soil + Pan, grams	414.00
Location3	2.933	Location 3	3.022	Pan Weight, grams	4.18
Average	2.931	Average	3.025	Moisture Content, %	46.9
Volume, in^3	21.06	Wet Soil + Tare, grams	599.22	Dry Unit Weight, pcf	74.1
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	110.4
Soil Sample Wt., g	599.22	Dry Soil +Tare, grams	409.82	Diameter, in.	N/A
Dry UW, pcf	74.1	Moisture Content, %	46.2	Length, in.	N/A
Saturation, %	108.7			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
90	1.40	18.50	15.20	3.30	23.8	28.9	23.1	9.61E-07	8.78E-07
180	1.40	18.50	12.40	6.10	23.9	28.9	18.2	9.94E-07	9.07E-07
101	1.40	16.00	13.00	3.00	23.6	24.7	19.4	9.19E-07	8.44E-07
68	1.40	12.00	10.50	1.50	23.7	17.9	15.3	9.03E-07	8.28E-07
82	1.40	10.00	8.50	1.50	23.7	14.5	11.9	9.42E-07	8.63E-07
72	1.40	14.50	12.50	2.00	23.6	22.1	18.6	9.27E-07	8.51E-07
64	1.40	12.00	10.50	1.50	23.6	17.9	15.3	9.60E-07	8.82E-07

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 8.6E-07 cm/sec

a_o = 0.76712 cm^2
A = 46.36 cm^2
L = 7.44 cm
S=L/A= 0.16058 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0003855 for 15° to 25°

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.04*	Tested By	*JW*
Project Name	*Saltstone Physical Properties Testing*	Test Date	*9/16/2009*
Boring No.	*TR604-3*	Reviewed By	
Sample No.	*TR604-3*	Review Date	
Sample Depth	*N/A*	Lab No.	*9704*
Sample Description	*Grout with MCU (90 days)*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*45.3*
Wet Unit Weight, pcf:	*107.3*
Dry Unit Weight, pcf:	*73.8*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***7.5E-07***

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

MACTEC

Project Number	6155-08-0031.04	Tested By	JW
Project Name	Saltstone Physical Properties Testing	Test Date	09/16/09
Boring No.	TR604-3	Reviewed By	
Sample No.	TR604-3	Review Date	
Sample Depth	N/A	Lab No.	9704
Sample Description	Grout with MCU (90 days)		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	K-13
Location 1	3.058	Location 1	3.034	Wet Soil+Pan, grams	625.72
Location 2	3.048	Location 2	3.034	Dry Soil + Pan, grams	429.60
Location3	3.013	Location 3	3.027	Pan Weight, grams	4.28
Average	3.040	Average	3.032	Moisture Content, %	46.1
Volume, in^3	21.94	Wet Soil + Tare, grams	617.90	Dry Unit Weight, pcf	73.8
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	107.6
Soil Sample Wt., g	617.90	Dry Soil +Tare, grams	425.32	Diameter, in.	N/A
Dry UW, pcf	73.8	Moisture Content, %	45.3	Length, in.	N/A
Saturation, %	105.7			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	60
Back Pressure, psi	50
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used MCU

Elapsed Time (sec)	z_p (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
109	1.60	18.00	15.00	3.00	23.8	26.7	21.6	7.71E-07	7.05E-07
283	1.60	18.00	11.20	6.80	23.9	26.7	15.2	7.95E-07	7.25E-07
80	1.60	15.00	13.00	2.00	23.6	21.8	18.4	8.40E-07	7.71E-07
77	1.60	12.50	11.00	1.50	23.6	17.7	15.2	7.99E-07	7.34E-07
61	1.60	10.00	9.00	1.00	23.6	13.7	12.0	8.63E-07	7.93E-07
75	1.60	8.50	7.50	1.00	23.6	11.2	9.5	8.68E-07	7.97E-07
97	1.60	7.00	6.00	1.00	23.6	8.8	7.1	8.79E-07	8.07E-07

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 7.5E-07 cm/sec

a_a = 0.76712 cm^2
A = 46.57 cm^2
L = 7.72 cm
S=L/A= 0.16578 1/cm

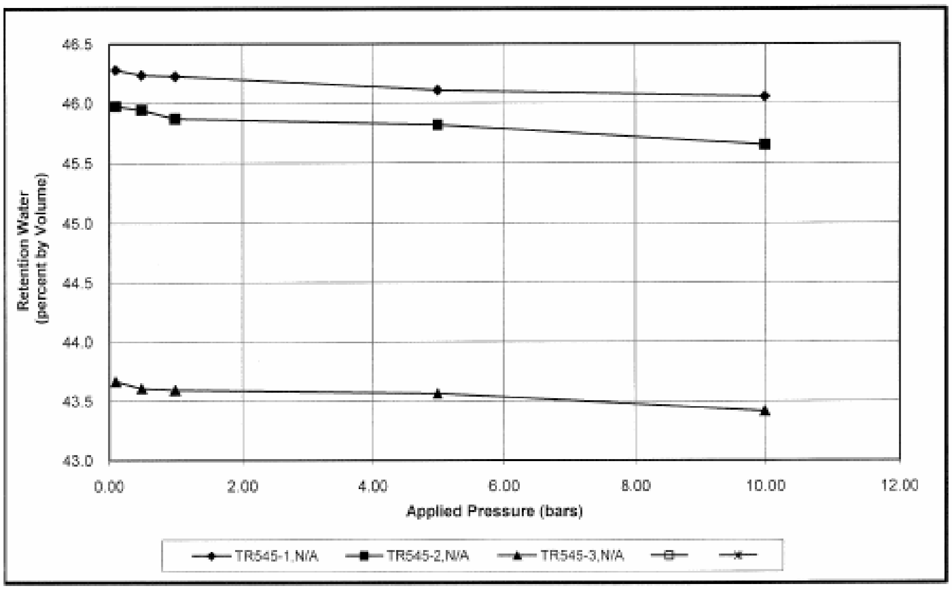
a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0003980 for 15° to 25°

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013, Rev. 12
Delivery Order #4

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testi
Tested By	JW	Test Date	5/14/09
Reviewed By		Review Date	



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	10.0					
			Retained Water (percent by volume)									
TR545-1,N/A	46.5	82.1	46.3	46.2	46.2	46.1	46.1					
TR545-2,N/A	46.3	81.5	46.0	45.9	45.9	45.8	45.7					
TR545-3,N/A	44.0	76.0	43.7	43.6	43.6	43.6	43.4					

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

AC54317N
Specification No. K-SPC-G-0013
Delivery Order #4

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	5/14/2009
Reviewed By		Review Date	

AC54317N
Specification No. K-SPC-G-0013
Delivery Order #4

Boring No.	TR545-1	TR545-2	TR545-3
Sample No.	TR545-1	TR545-2	TR545-3
Depth (ft)	N/A	N/A	N/A
Lab No.	9618	9619	9620
Ring No.	N/A	N/A	N/A
Container Weight. (g)	0.00	0.00	0.00
Container Diameter (cm)	7.65	7.67	7.76
Container Height, (cm)	2.02	2.06	1.43
Container Volume (cm^3)	93.13	95.22	67.65
Wt. of Wet Soil + Container (g)	165.8	168.44	112.19
Wt. of Dry Soil + Container (g)	122.51	124.35	82.40
Moisture Content (%)	35.3	35.5	36.2
Dry Unit Weight (pcf)	82.09	81.49	76.01
Initial Wt.Wet Soil + Container (g)	165.80	168.44	112.19
Initial Wt. Container (g)	0.00	0.00	0.00
Initial Moisture, % by Volume	46.5	46.3	44.0

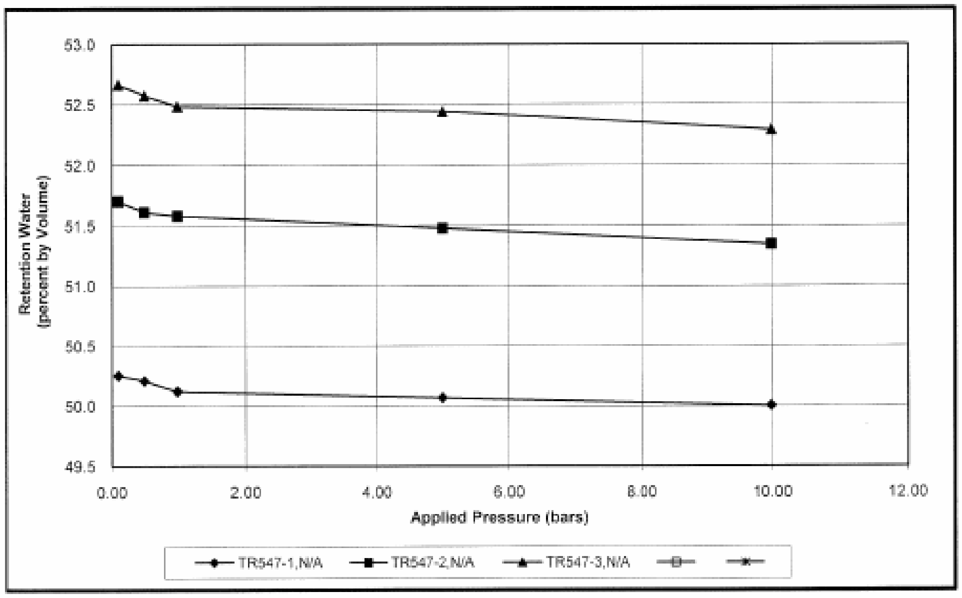
Lab No.							
	Pressure	psi	1.45	7.26	14.5	72.6	145
		bars	0.1	0.50	1.0	5.0	10.0
	Date / Read By		5/15/2009	5/16/2009	5/18/2009	5/19/2009	5/20/2009
9618	Weight of Soil + Ring		165.61	165.57	165.56	165.45	165.4
	Weight of Ring		0	0	0	0	0
	Retained Water (%)		46.3	46.2	46.2	46.1	46.1
9619	Weight of Soil + Ring		168.13	168.1	168.03	167.98	167.82
	Weight of Ring		0	0	0	0	0
	Retained Water (%)		46.0	45.9	45.9	45.8	45.7
9620	Weight of Soil + Ring		111.94	111.9	111.89	111.87	111.77
	Weight of Ring		0	0	0	0	0
	Retained Water (%)		43.7	43.6	43.6	43.6	43.4

No. of Samples 3
No. of Tests per Sample 5

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testi
Tested By	JW	Test Date	5/14/09
Reviewed By		Review Date	



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars)									
			0.10	0.50	1.0	5.0	10.0					
			Retained Water (percent by volume)									
TR547-1,N/A	50.8	72.5	50.3	50.2	50.1	50.1	50.0					
TR547-2,N/A	52.3	73.0	51.7	51.6	51.6	51.5	51.3					
TR547-3,N/A	53.4	74.5	52.7	52.6	52.5	52.4	52.3					

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

AC54317N
Specification No. K-SPC-G-0013
Delivery Order #4

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	5/14/2009
Reviewed By		Review Date	

AC54317N
Specification No. K-SPC-G-0013
Delivery Order #4

Boring No.	TR547-1	TR547-2	TR547-3		
Sample No.	TR547-1	TR547-2	TR547-3		
Depth (ft)	N/A	N/A	N/A		
Lab No.	9621	9622	9623		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.66	7.66	7.65		
Container Height, (cm)	1.98	1.47	1.45		
Container Volume (cm^3)	91.20	67.58	66.84		
Wt. of Wet Soil + Container (g)	152.27	114.46	115.48		
Wt. of Dry Soil + Container (g)	105.91	79.11	79.82		
Moisture Content (%)	43.8	44.7	44.7		
Dry Unit Weight (pcf)	72.47	73.05	74.52		
Initial Wt.Wet Soil + Container (g)	152.27	114.46	115.48		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	50.8	52.3	53.4		

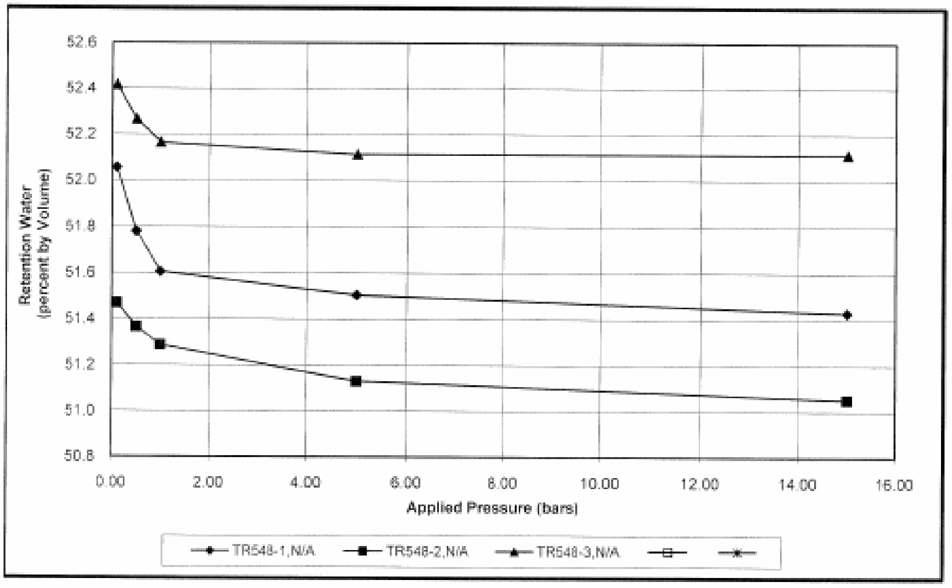
Lab No.	Pressure											
	psi	1.45	7.26	14.5	72.6	145						
	bars	0.1	0.50	1.0	5.0	10.0						
	Date / Read By	5/15/2009	5/16/2009	5/18/2009	5/19/2009	5/20/2009						
9621	Weight of Soil + Ring	151.74	151.7	151.62	151.57	151.51						
	Weight of Ring	0	0	0	0	0						
	Retained Water (%)	50.3	50.2	50.1	50.1	50.0						
9622	Weight of Soil + Ring	114.05	113.99	113.97	113.9	113.81						
	Weight of Ring	0	0	0	0	0						
	Retained Water (%)	51.7	51.6	51.6	51.5	51.3						
9623	Weight of Soil + Ring	115.02	114.96	114.9	114.87	114.77						
	Weight of Ring	0	0	0	0	0						
	Retained Water (%)	52.7	52.6	52.5	52.4	52.3						

No. of Samples 3
No. of Tests per Sample 5

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testi
Tested By	JW	Test Date	7/17/09
Reviewed By		Review Date	



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	15.0					
			Retained Water (percent by volume)									
TR548-1,N/A	51.9	74.0	52.1	51.8	51.6	51.5	51.4					
TR548-2,N/A	51.4	74.1	51.5	51.4	51.3	51.1	51.1					
TR548-3,N/A	52.4	74.8	52.4	52.3	52.2	52.1	52.1					

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water.
When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No 6155-08-0031.04
Tested By JW
Reviewed By

Project Name Saltstone Physical Properties Testing
Test Date 7/17/2009
Review Date

Boring No.	TR548-1	TR548-2	TR548-3
Sample No.	TR548-1	TR548-2	TR548-3
Depth (ft)	N/A	N/A	N/A
Lab No.	9636	9637	9638
Ring No.	N/A	N/A	N/A
Container Weight. (g)	0.00	0.00	0.00
Container Diameter (cm)	5.05	5.04	5.03
Container Height, (cm)	1.99	1.91	1.99
Container Volume (cm^3)	39.90	38.06	39.57
Wt. of Wet Soil + Container (g)	68.03	64.76	68.18
Wt. of Dry Soil + Container (g)	47.34	45.21	47.43
Moisture Content (%)	43.7	43.2	43.7
Dry Unit Weight (pcf)	74.04	74.12	74.80
Initial Wt.Wet Soil + Container (g)	68.03	64.76	68.18
Initial Wt. Container (g)	0.00	0.00	0.00
Initial Moisture, % by Volume	51.9	51.4	52.4

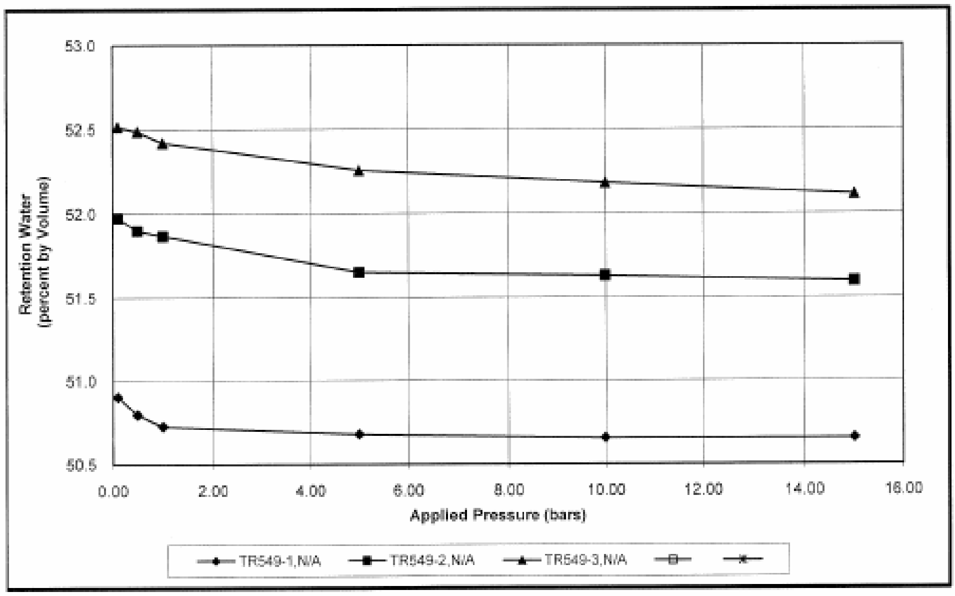
Lab No.							
	Pressure	psi	1.45	7.26	14.51	72.55	217.65
		bars	0.1	0.50	1.0	5.0	15.0
	Date / Read By						
9636	Weight of Soil + Ring		68.11	68	67.93	67.89	67.86
	Weight of Ring		0	0	0	0	0
	Retained Water (%)		52.1	51.8	51.6	51.5	51.4
9637	Weight of Soil + Ring		64.8	64.76	64.73	64.67	64.64
	Weight of Ring		0	0	0	0	0
	Retained Water (%)		51.5	51.4	51.3	51.1	51.1
9638	Weight of Soil + Ring		68.17	68.11	68.07	68.05	68.05
	Weight of Ring		0	0	0	0	0
	Retained Water (%)		52.4	52.3	52.2	52.1	52.1

No. of Samples 3
No. of Tests per Sample 5

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testi
Tested By	JW	Test Date	6/28/09
Reviewed By		Review Date	



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	10.0	15.0				
			Retained Water (percent by volume)									
TR549-1,N/A	51.3	73.4	50.9	50.8	50.7	50.7	50.7	50.7				
TR549-2,N/A	52.2	74.4	52.0	51.9	51.9	51.7	51.6	51.6				
TR549-3,N/A	52.7	75.6	52.5	52.5	52.4	52.3	52.2	52.1				

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

Subcontract No. AC54317N
Spe. No. K-SPC-G-0013
Revision 12 08-13-08
Delivery Order No. 04

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	6/28/2009
Reviewed By		Review Date	

Remarks: Subcontract No. AC54317N
Spe. No. K-SPC-G-0013
Revision 12 08-13-08
Delivery Order No. 04

Boring No.	TR549-1	TR549-2	TR549-3
Sample No.	TR549-1	TR549-2	TR549-3
Depth (ft)	N/A	N/A	N/A
Lab No.	9624	9625	9626
Ring No.	N/A	N/A	N/A
Container Weight. (g)	0.00	0.00	0.00
Container Diameter (cm)	7.65	7.66	7.65
Container Height, (cm)	1.85	2.01	2.26
Container Volume (cm^3)	84.85	92.49	104.00
Wt. of Wet Soil + Container (g)	143.3	158.46	180.87
Wt. of Dry Soil + Container (g)	99.80	110.21	126.02
Moisture Content (%)	43.6	43.8	43.5
Dry Unit Weight (pcf)	73.39	74.36	75.61
Initial Wt Wet Soil + Container (g)	143.30	158.46	180.87
Initial Wt. Container (g)	0.00	0.00	0.00
Initial Moisture, % by Volume	51.3	52.2	52.7

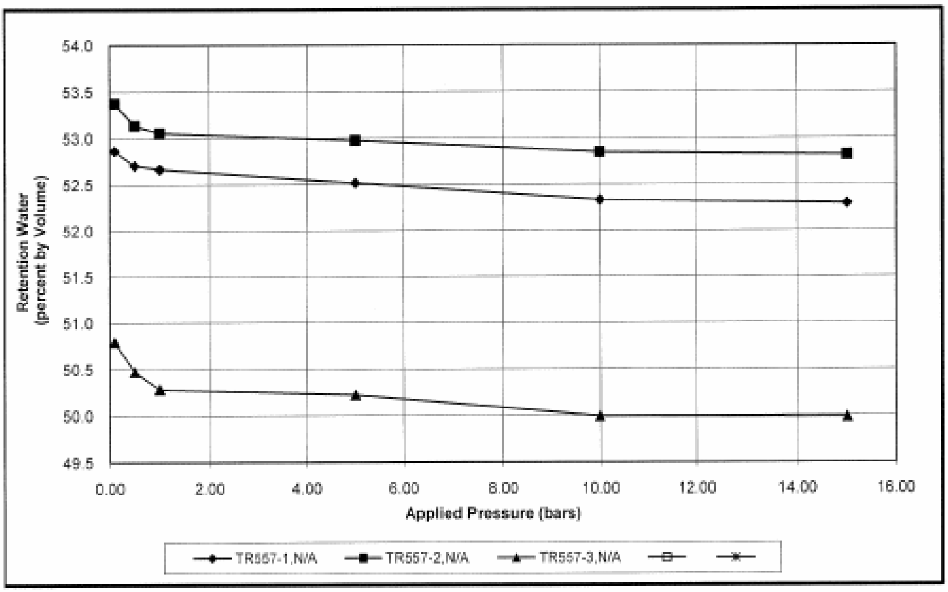
Lab No.							
	Pressure psi	1.45	7.26	14.51	72.55	145	217.65
	bars	0.1	0.50	1.0	5.0	10.0	15.0
	Date / Read By						
9624	Weight of Soil + Ring	142.99	142.9	142.84	142.8	142.78	142.78
	Weight of Ring	0	0	0	0	0	0
	Retained Water (%)	50.9	50.8	50.7	50.7	50.7	50.7
9625	Weight of Soil + Ring	158.28	158.21	158.18	157.98	157.96	157.93
	Weight of Ring	0	0	0	0	0	0
	Retained Water (%)	52.0	51.9	51.9	51.7	51.6	51.6
9626	Weight of Soil + Ring	180.64	180.61	180.54	180.37	180.29	180.22
	Weight of Ring	0	0	0	0	0	0
	Retained Water (%)	52.5	52.5	52.4	52.3	52.2	52.1

No. of Samples 3
No. of Tests per Sample 6

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testi
Tested By	JW	Test Date	6/28/09
Reviewed By		Review Date	



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	10.0	15.0
			Retained Water (percent by volume)					
TR557-1,N/A	53.5	75.0	52.9	52.7	52.7	52.5	52.3	52.3
TR557-2,N/A	54.0	75.0	53.4	53.1	53.1	53.0	52.8	52.8
TR557-3,N/A	51.5	71.2	50.8	50.5	50.3	50.2	50.0	50.0

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	6/28/2009
Reviewed By		Review Date	

Boring No.	TR557-1	TR557-2	TR557-3		
Sample No.	TR557-1	TR557-2	TR557-3		
Depth (ft)	N/A	N/A	N/A		
Lab No.	9627	9628	9629		
Ring No.	N/A	N/A	N/A		
Container Weight, (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.67	7.66	7.66		
Container Height, (cm)	2.19	2.17	2.08		
Container Volume (cm^3)	101.01	99.97	95.85		
Wt. of Wet Soil + Container (g)	175.4	174.11	158.69		
Wt. of Dry Soil + Container (g)	121.38	120.11	109.33		
Moisture Content (%)	44.5	45.0	45.1		
Dry Unit Weight (pcf)	74.98	74.97	71.17		
Initial Wt.Wet Soil + Container (g)	175.40	174.11	158.69		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	53.5	54.0	51.5		

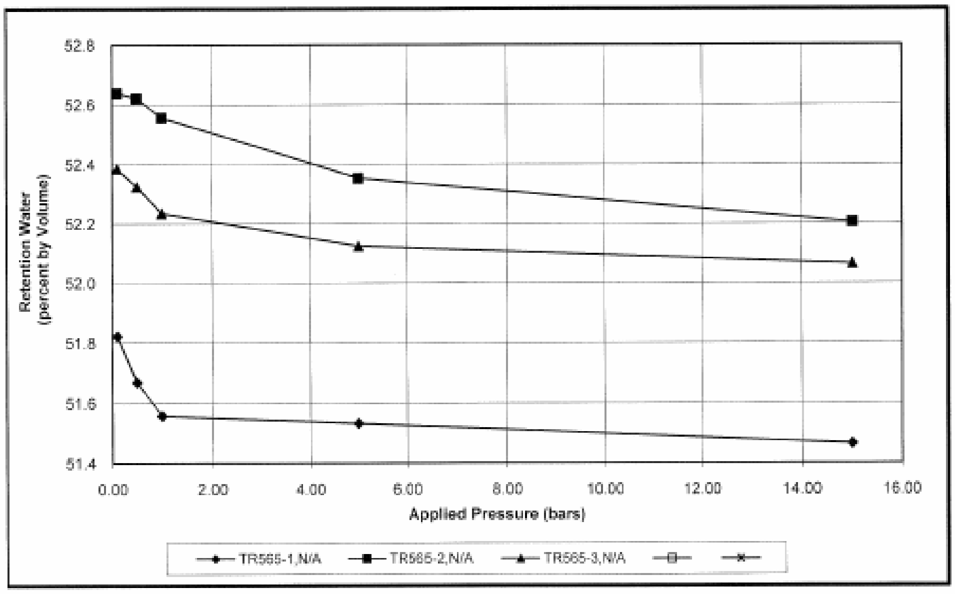
Lab No.								
	Pressure psi	1.45	7.26	14.51	72.55	145	217.65	
	bars	0.1	0.50	1.0	5.0	10.0	15.0	
	Date / Read By							
9627	Weight of Soil + Ring	174.78	174.62	174.58	174.43	174.24	174.2	
	Weight of Ring	0	0	0	0	0	0	
	Retained Water (%)	52.9	52.7	52.7	52.5	52.3	52.3	
9628	Weight of Soil + Ring	173.47	173.23	173.15	173.07	172.94	172.91	
	Weight of Ring	0	0	0	0	0	0	
	Retained Water (%)	53.4	53.1	53.1	53.0	52.8	52.8	
9629	Weight of Soil + Ring	158.02	157.71	157.53	157.47	157.25	157.24	
	Weight of Ring	0	0	0	0	0	0	
	Retained Water (%)	50.8	50.5	50.3	50.2	50.0	50.0	

No. of Samples 3
No. of Tests per Sample 6

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testi
Tested By	JW	Test Date	7/17/09
Reviewed By		Review Date	



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	15.0					
			Retained Water (percent by volume)									
TR565-1,N/A	51.8	74.7	51.8	51.7	51.6	51.5	51.5					
TR565-2,N/A	52.7	75.8	52.6	52.6	52.6	52.4	52.2					
TR565-3,N/A	52.4	75.9	52.4	52.3	52.2	52.1	52.1					

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water.
When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	7/17/2009
Reviewed By		Review Date	

Boring No.	TR565-1	TR565-2	TR565-3		
Sample No.	TR565-1	TR565-2	TR565-3		
Depth (ft)	N/A	N/A	N/A		
Lab No.	9630	9631	9632		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.66	7.67	7.66		
Container Height, (cm)	2.55	2.34	2.16		
Container Volume (cm^3)	117.57	108.00	99.61		
Wt. of Wet Soil + Container (g)	201.77	188.04	173.34		
Wt. of Dry Soil + Container (g)	140.81	131.12	121.12		
Moisture Content (%)	43.3	43.4	43.1		
Dry Unit Weight (pcf)	74.73	75.76	75.88		
Initial Wt.Wet Soil + Container (g)	201.77	188.04	173.34		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	51.8	52.7	52.4		

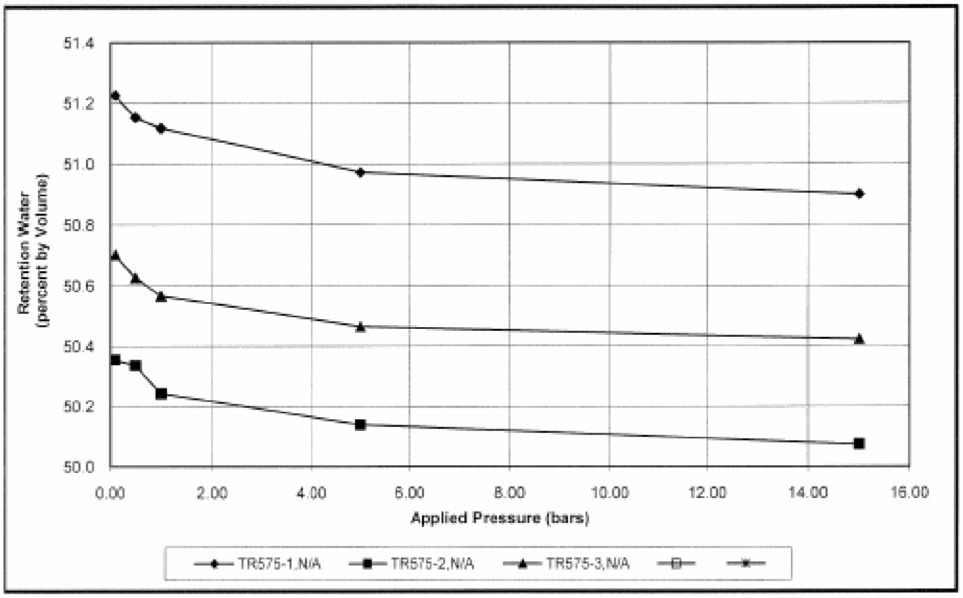
Lab No.							
	Pressure	psi	1.45	7.26	14.51	72.55	217.65
		bars	0.1	0.50	1.0	5.0	15.0
	Date / Read By						
9630	Weight of Soil + Ring		201.74	201.56	201.43	201.4	201.32
	Weight of Ring		0	0	0	0	0
	Retained Water (%)		51.8	51.7	51.6	51.5	51.5
9631	Weight of Soil + Ring		187.97	187.95	187.88	187.66	187.5
	Weight of Ring		0	0	0	0	0
	Retained Water (%)		52.6	52.6	52.6	52.4	52.2
9632	Weight of Soil + Ring		173.3	173.24	173.15	173.04	172.98
	Weight of Ring		0	0	0	0	0
	Retained Water (%)		52.4	52.3	52.2	52.1	52.1

No. of Samples 3
No. of Tests per Sample 5

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testi
Tested By	JW	Test Date	7/17/09
Reviewed By		Review Date	



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	15.0				
			Retained Water (percent by volume)								
TR575-1,N/A	51.3	77.9	51.2	51.2	51.1	51.0	50.9				
TR575-2,N/A	50.4	76.4	50.4	50.3	50.2	50.1	50.1				
TR575-3,N/A	50.8	77.1	50.7	50.6	50.6	50.5	50.4				

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water.
When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	7/17/2009
Reviewed By		Review Date	

Boring No.	TR575-1	TR575-2	TR575-3		
Sample No.	TR575-1	TR575-2	TR575-3		
Depth (ft)	N/A	N/A	N/A		
Lab No.	9633	9634	9635		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.66	7.66	7.65		
Container Height, (cm)	2.40	2.31	2.58		
Container Volume (cm^3)	110.49	106.22	118.36		
Wt. of Wet Soil + Container (g)	194.58	183.64	206.41		
Wt. of Dry Soil + Container (g)	137.85	130.10	146.31		
Moisture Content (%)	41.2	41.2	41.1		
Dry Unit Weight (pcf)	77.85	76.43	77.14		
Initial Wt.Wet Soil + Container (g)	194.58	183.64	206.41		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	51.3	50.4	50.8		

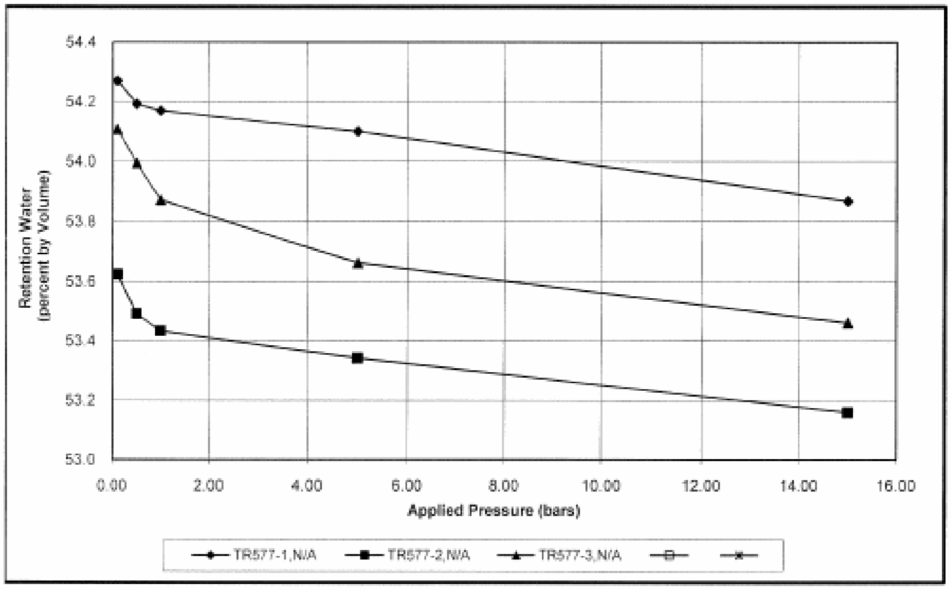
Lab No.	Pressure psi	1.45	7.26	14.51	72.55	217.65					
	bars	0.1	0.50	1.0	5.0	15.0					
	Date / Read By										
9633	Weight of Soil + Ring	194.45	194.37	194.33	194.17	194.09					
	Weight of Ring	0	0	0	0	0					
	Retained Water (%)	51.2	51.2	51.1	51.0	50.9					
9634	Weight of Soil + Ring	183.59	183.57	183.47	183.36	183.29					
	Weight of Ring	0	0	0	0	0					
	Retained Water (%)	50.4	50.3	50.2	50.1	50.1					
9635	Weight of Soil + Ring	206.32	206.23	206.16	206.04	205.99					
	Weight of Ring	0	0	0	0	0					
	Retained Water (%)	50.7	50.6	50.6	50.5	50.4					

No. of Samples 3
No. of Tests per Sample 5

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	8/4/09
Reviewed By		Review Date	



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	15.0					
			Retained Water (percent by volume)									
TR577-1,N/A	54.4	72.3	54.3	54.2	54.2	54.1	53.9					
TR577-2,N/A	54.0	71.8	53.6	53.5	53.4	53.3	53.2					
TR577-3,N/A	54.4	72.3	54.1	54.0	53.9	53.7	53.5					

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water.
When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	8/4/2009
Reviewed By		Review Date	

Boring No.	TR577-1	TR577-2	TR577-3		
Sample No.	TR577-1	TR577-2	TR577-3		
Depth (ft)	N/A	N/A	N/A		
Lab No.	9690	9691	9692		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.66	7.68	7.66		
Container Height, (cm)	2.81	2.60	2.49		
Container Volume (cm^3)	129.34	120.52	114.62		
Wt. of Wet Soil + Container (g)	220.19	203.81	195.12		
Wt. of Dry Soil + Container (g)	149.79	138.74	132.77		
Moisture Content (%)	47.0	46.9	47.0		
Dry Unit Weight (pcf)	72.27	71.83	72.28		
Initial Wt.Wet Soil + Container (g)	220.19	203.81	195.12		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	54.4	54.0	54.4		

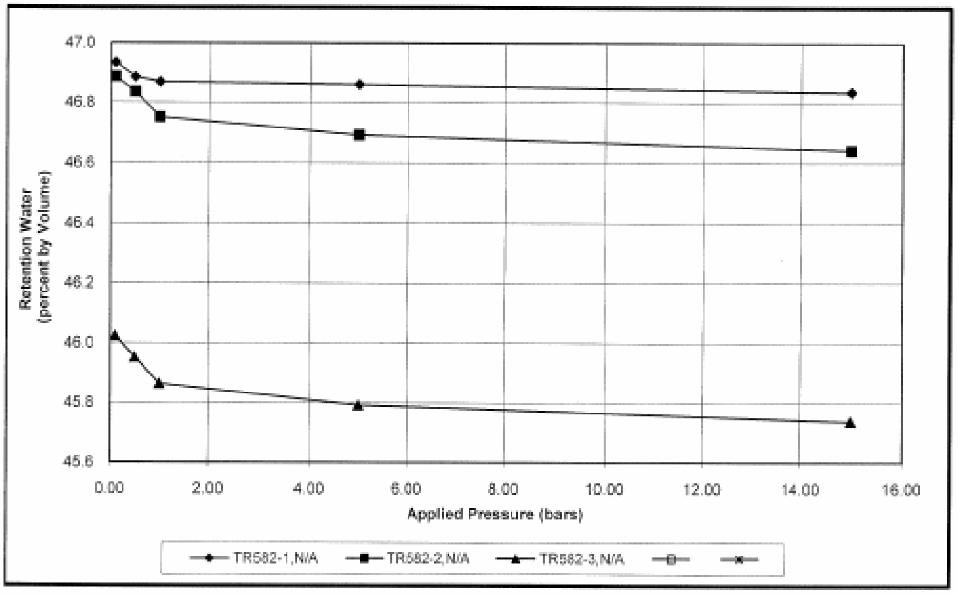
Lab No.							
	Pressure psi	1.45	7.26	14.51	72.55	217.65
	bars	0.1	0.50	1.0	5.0	15.0
	Date / Read By					
9690	Weight of Soil + Ring	219.98	219.88	219.85	219.76	219.46
	Weight of Ring	0	0	0	0	0
	Retained Water (%)	54.3	54.2	54.2	54.1	53.9
9691	Weight of Soil + Ring	203.37	203.21	203.14	203.03	202.81
	Weight of Ring	0	0	0	0	0
	Retained Water (%)	53.6	53.5	53.4	53.3	53.2
9692	Weight of Soil + Ring	194.79	194.66	194.52	194.28	194.05
	Weight of Ring	0	0	0	0	0
	Retained Water (%)	54.1	54.0	53.9	53.7	53.5

No. of Samples 3
No. of Tests per Sample 5

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	8/4/09
Reviewed By		Review Date	



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	15.0
			Retained Water (percent by volume)				
TR582-1,N/A	47.0	79.6	46.9	46.9	46.9	46.9	46.8
TR582-2,N/A	47.0	79.2	46.9	46.8	46.8	46.7	46.6
TR582-3,N/A	46.1	77.8	46.0	46.0	45.9	45.8	45.7

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	8/4/2009
Reviewed By		Review Date	

Boring No.	TR582-1	TR582-2	TR582-3		
Sample No.	TR582-1	TR582-2	TR582-3		
Depth (ft)	N/A	N/A	N/A		
Lab No.	9693	9694	9695		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.66	7.66	7.66		
Container Height, (cm)	2.66	2.57	2.43		
Container Volume (cm^3)	122.36	118.33	111.79		
Wt. of Wet Soil + Container (g)	213.65	205.86	191.02		
Wt. of Dry Soil + Container (g)	156.08	150.25	139.46		
Moisture Content (%)	36.9	37.0	37.0		
Dry Unit Weight (pcf)	79.59	79.23	77.85		
Initial Wt.Wet Soil + Container (g)	213.65	205.86	191.02		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	47.0	47.0	46.1		

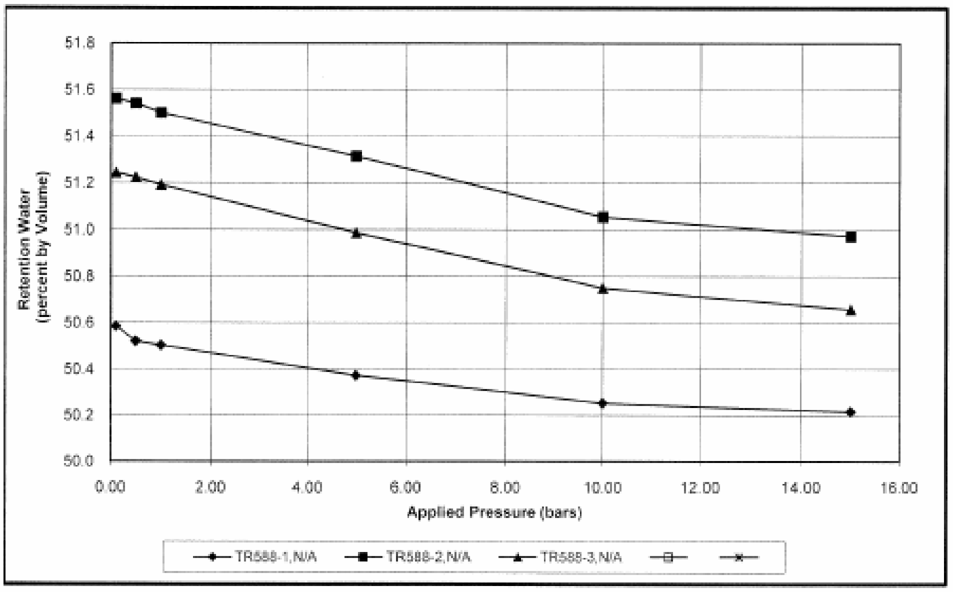
Lab No.							
	Pressure	psi	1.45	7.26	14.51	72.55	217.65
		bars	0.1	0.50	1.0	5.0	15.0
	Date / Read By						
9693	Weight of Soil + Ring		213.51	213.45	213.43	213.42	213.39
	Weight of Ring		0	0	0	0	0
	Retained Water (%)		46.9	46.9	46.9	46.9	46.8
9694	Weight of Soil + Ring		205.73	205.67	205.57	205.5	205.44
	Weight of Ring		0	0	0	0	0
	Retained Water (%)		46.9	46.8	46.8	46.7	46.6
9695	Weight of Soil + Ring		190.91	190.83	190.73	190.65	190.59
	Weight of Ring		0	0	0	0	0
	Retained Water (%)		46.0	46.0	45.9	45.8	45.7

No. of Samples 3
No. of Tests per Sample 5

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	8/31/09
Reviewed By		Review Date	



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	0.10	0.50	1.0	5.0	10.0	15.0				
			Applied Pressure (bars) / Retained Water (percent by volume)									
TR588-1,N/A	50.8	73.3	50.6	50.5	50.5	50.4	50.3	50.2				
TR588-2,N/A	51.9	74.5	51.6	51.5	51.5	51.3	51.1	51.0				
TR588-3,N/A	51.3	74.9	51.2	51.2	51.2	51.0	50.8	50.7				

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	8/31/2009
Reviewed By		Review Date	

Boring No.	TR588-1	TR588-2	TR588-3		
Sample No.	TR588-1	TR588-2	TR588-3		
Depth (ft)	N/A	N/A	N/A		
Lab No.	9696	9697	9698		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.66	7.65	7.66		
Container Height, (cm)	2.36	2.11	2.11		
Container Volume (cm^3)	108.47	96.72	97.20		
Wt. of Wet Soil + Container (g)	182.48	165.68	166.50		
Wt. of Dry Soil + Container (g)	127.40	115.50	116.61		
Moisture Content (%)	43.2	43.4	42.8		
Dry Unit Weight (pcf)	73.29	74.52	74.86		
Initial Wt.Wet Soil + Container (g)	182.48	165.68	166.50		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	50.8	51.9	51.3		

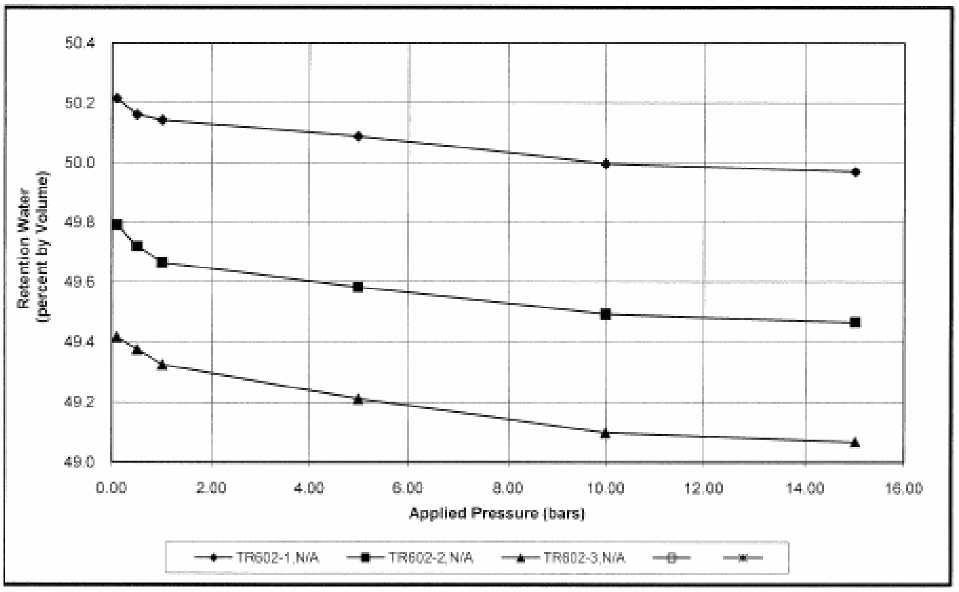
Lab No.	Pressure										
	psi	1.45	7.26	14.51	72.55	145.1	217.65				
	bars	0.1	0.50	1.0	5.0	10.0	15.0				
	Date / Read By										
9696	Weight of Soil + Ring	182.27	182.2	182.18	182.04	181.91	181.87				
	Weight of Ring	0	0	0	0	0	0				
	Retained Water (%)	50.6	50.5	50.5	50.4	50.3	50.2				
9697	Weight of Soil + Ring	165.37	165.35	165.31	165.13	164.88	164.8				
	Weight of Ring	0	0	0	0	0	0				
	Retained Water (%)	51.6	51.5	51.5	51.3	51.1	51.0				
9698	Weight of Soil + Ring	166.42	166.4	166.37	166.17	165.94	165.85				
	Weight of Ring	0	0	0	0	0	0				
	Retained Water (%)	51.2	51.2	51.2	51.0	50.8	50.7				

No. of Samples 3
No. of Tests per Sample 6

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	8/31/09
Reviewed By		Review Date	



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	10.0	15.0				
			Retained Water (percent by volume)									
TR602-1,N/A	50.4	75.1	50.2	50.2	50.1	50.1	50.0	50.0				
TR602-2,N/A	50.0	74.8	49.8	49.7	49.7	49.6	49.5	49.5				
TR602-3,N/A	49.6	74.0	49.4	49.4	49.3	49.2	49.1	49.1				

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	8/31/2009
Reviewed By		Review Date	

Boring No.	TR602-1	TR602-2	TR602-3
Sample No.	TR602-1	TR602-2	TR602-3
Depth (ft)	N/A	N/A	N/A
Lab No.	9699	9700	9701
Ring No.	N/A	N/A	N/A
Container Weight. (g)	0.00	0.00	0.00
Container Diameter (cm)	7.66	7.66	7.65
Container Height, (cm)	2.38	2.40	2.12
Container Volume (cm^3)	109.85	110.54	97.40
Wt. of Wet Soil + Container (g)	187.58	187.79	163.90
Wt. of Dry Soil + Container (g)	132.20	132.49	115.58
Moisture Content (%)	41.9	41.7	41.8
Dry Unit Weight (pcf)	75.10	74.79	74.05
Initial Wt.Wet Soil + Container (g)	187.58	187.79	163.90
Initial Wt. Container (g)	0.00	0.00	0.00
Initial Moisture, % by Volume	50.4	50.0	49.6

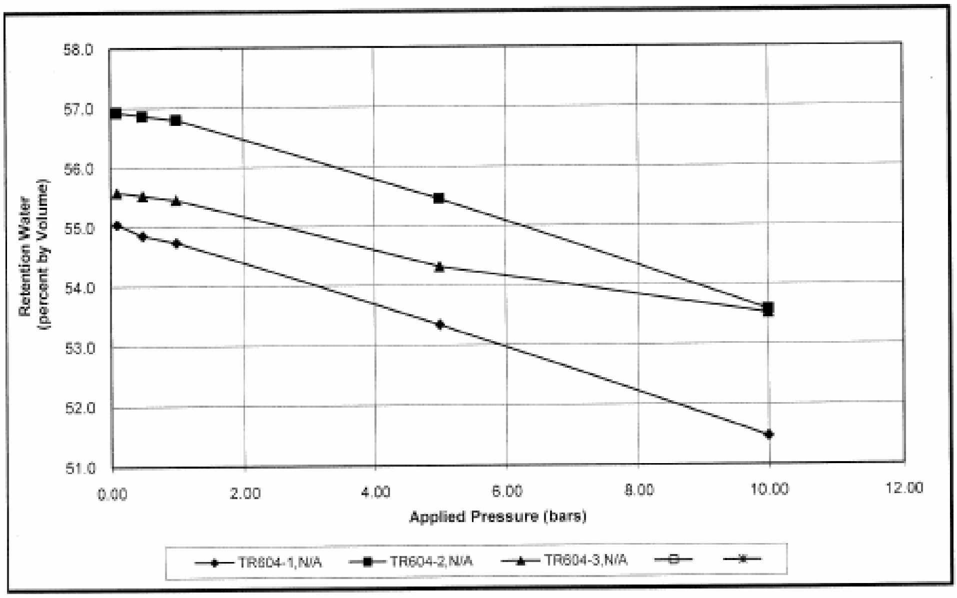
Lab No.	Pressure						
	psi	1.45	7.26	14.51	72.55	145.1	217.65
	bars	0.1	0.50	1.0	5.0	10.0	15.0
	Date / Read By						
9699	Weight of Soil + Ring	187.36	187.3	187.28	187.22	187.12	187.09
	Weight of Ring	0	0	0	0	0	0
	Retained Water (%)	50.2	50.2	50.1	50.1	50.0	50.0
9700	Weight of Soil + Ring	187.53	187.45	187.39	187.3	187.2	187.17
	Weight of Ring	0	0	0	0	0	0
	Retained Water (%)	49.8	49.7	49.7	49.6	49.5	49.5
9701	Weight of Soil + Ring	163.71	163.67	163.62	163.51	163.4	163.37
	Weight of Ring	0	0	0	0	0	0
	Retained Water (%)	49.4	49.4	49.3	49.2	49.1	49.1

No. of Samples 3
No. of Tests per Sample 6

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	8/31/09
Reviewed By		Review Date	



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	10.0					
			Retained Water (percent by volume)									
TR604-1,N/A	55.5	71.3	55.0	54.9	54.7	53.3	51.5					
TR604-2,N/A	57.6	74.4	56.9	56.9	56.8	55.5	53.6					
TR604-3,N/A	56.0	72.6	55.6	55.5	55.5	54.3	53.5					

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

Subcontract No. AC54317N
Spe. No. K-SPC-00013
Rev 12, 08-13-08
Delivery Order No.5

Note: Samples cracked at 1 bar and started to crumble at 5 bars.

MACTEC

Water Retention Test
(ASTM D3152-72 (2000))

Project No	6155-08-0031.04	Project Name	Saltstone Physical Properties Testing
Tested By	JW	Test Date	8/31/2009
Reviewed By		Review Date	

Subcontract No. AC54317N
Spe. No. K-SPC-00013
Rev 12, 08-13-08
Delivery Order No.5

Boring No.	TR604-1	TR604-2	TR604-3		
Sample No.	TR604-1	TR604-2	TR604-3		
Depth (ft)	N/A	N/A	N/A		
Lab No.	9702	9703	9704		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.69	7.69	7.68		
Container Height, (cm)	2.03	2.19	2.01		
Container Volume (cm^3)	93.95	101.49	93.35		
Wt. of Wet Soil + Container (g)	159.47	179.44	160.89		
Wt. of Dry Soil + Container (g)	107.29	120.98	108.59		
Moisture Content (%)	48.6	48.3	48.2		
Dry Unit Weight (pcf)	71.26	74.38	72.59		
Initial Wt.Wet Soil + Container (g)	159.47	179.44	160.89		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	55.5	57.6	56.0		

Lab No.												
	Pressure psi	1.45	7.26	14.51	72.55	145.1						
	bars	0.1	0.50	1.0	5.0	10.0						
	Date / Read By											
9702	Weight of Soil + Ring	159.01	158.83	158.72	157.41	155.65						
	Weight of Ring	0	0	0	0	0						
	Retained Water (%)	55.0	54.9	54.7	53.3	51.5						
9703	Weight of Soil + Ring	178.76	178.7	178.63	177.27	175.36						
	Weight of Ring	0	0	0	0	0						
	Retained Water (%)	56.9	56.9	56.8	55.5	53.6						
9704	Weight of Soil + Ring	160.48	160.43	160.36	159.29	158.55						
	Weight of Ring	0	0	0	0	0						
	Retained Water (%)	55.6	55.5	55.5	54.3	53.5						

No. of Samples 3
No. of Tests per Sample 5

APPENDIX B. CALCULATIONS TO CORRECT FOR SALT PRECIPITATION

The purpose of this appendix is to demonstrate the calculations that were used to correct the raw laboratory measurements of dry bulk density, porosity, and moisture retention for the saltstone grout samples. For each of these measurements, the sample is ultimately oven dried and it is necessary to correct for salt precipitation that occurs during this process. For each type of saltstone, the amount of salt added per 100 gram of wet grout was measured and this information was used to make the corrections. The corrections were made saltstone formulation.

Dry bulk density was calculated based on the following equations.

$$M_{liquid} = M_{sat} - M_{dry} + S$$

$$\rho_{dry} = \frac{M_{sat} - M_{liquid}}{V_{total}}$$

M_{liquid} = mass of interstitial liquid in sample
M_{sat} = mass of saturated sample
M_{dry} = mass of oven dried sample
S = known salt content of grout (g salt/100g grout)
V_{total} = total volume of sample
ρ_{dry} = dry bulk density

For sample MCU-TR545-1:

M_{sat} = 617.35 g
M_{dry} = 457.19 g
S = 14.38 (grams of salt per 100 gram of grout for low aluminate simulant)
V_{total} = 343.64 cm^3

$$M_{liquid} = 617.35\,g - 457.19\,g + \frac{14.38\,g\ salt}{100\,g\ grout} * 617.35\,g\ grout$$

$$M_{liquid} = 248.93\,g$$

$$\rho_{dry} = \frac{617.35\,g - 248.93\,g}{343.64\,cm^3}$$

$$\rho_{dry} = 1.07\frac{g}{cm^3}$$

Porosity was calculated as:

$$V_{liquid} = \frac{M_{liquid}}{\rho_{liquid}}$$

$$\phi = \frac{V_{voids}}{V_{total}} = \frac{V_{liquid}}{V_{total}}$$

M_{liquid} = mass of interstitial liquid in sample
V_{voids} = total volume of voids
V_{liquid} = volume of interstitial liquid in sample
V_{total} = total volume of sample
ρ_{liquid} =density of interstitial liquid
ϕ = corrected porosity

For sample MCU-TR545-1:

M_{liquid} = 248.93 g
ρ_{liquid} = 1.253 g/cm^3
V_{total} = 343.64 cm^3

$$V_{liquid} = \frac{M_{liquid}}{\rho_{liquid}}$$

$$V_{liquid} = \frac{248.93\,g}{1.253\ \frac{g}{cm^3}}$$

$$V_{liquid} = 198.67\,cm^3$$

$$\phi = \frac{198.67\,cm^3}{343.64\,cm^3}$$

$$\phi = 0.578$$

The following equations were used to determine the initial simulant mass and moisture content (i.e., porosity) of the moisture retention samples.

1) Determine the total simulant mass within sample:

$$M_{salt} = M_{sat} * S$$

$$M_{water-oven} = M_{pressure-final} - M_{dry}$$

$$M_{water-pressure} = M_{liquid-pressure} * \chi_{wil}$$

$$M_{water} = M_{water-pressure} + M_{water-oven}$$

$$M_{liquid} = M_{salt} + M_{water}$$

$$V_{liquid} = \frac{M_{liquid}}{\rho_{liquid}}$$

$$\phi = \frac{V_{voids}}{V_{total}} = \frac{V_{liquid}}{V_{total}}$$

M_{salt} = mass of salt in sample, g
M_{sat} = total mass of saturated sample, g
S = known salt content of grout (g salt/100g grout)
$M_{water-oven}$ = mass of water removed by oven drying, g
$M_{pressure-final}$ = final mass of sample following pressure extraction, g
M_{dry} = mass of oven dried sample, g
$M_{water-pressure}$ = mass of water removed by pressure extraction, g
$M_{liquid-pressure}$ = mass of interstitial liquid removed by pressure extraction, g
χ_{wil}= mass fraction of water in interstitial liquid, fraction
M_{water} = mass of water in sample, g
M_{liquid} = mass of interstitial liquid in sample at saturation, g
V_{liquid} = volume of interstitial liquid in sample, cm^3
V_{voids} = total volume of voids, cm^3
V_{total} = total volume of sample, cm^3
ϕ = porosity, fraction
ρ_{liquid} =density of interstitial liquid, g/cm^3

For MCU-TR545-1:

M_{sat} = 165.80 g
$M_{pressure\text{-}final}$ = 165.40 g
M_{dry} = 122.51 g
χ_{wil}= 0.693
V_{total} = 93.13 cm^3
ϕ = porosity, fraction
ρ_{liquid} =1.253 g/cm^3
S = 14.38 (grams of salt per 100 gram of grout for low aluminate simulant)

$$M_{liquid-pressure} = 165.80\,g - 165.40\,g$$
$$M_{liquid-pressure} = 0.40\,g$$

$$M_{water-pressure} = 0.40\,g * \frac{0.693\,g\ water}{1\,g\ simulant}$$
$$M_{water-pressure} = 0.28\,g$$

$$M_{salt} = 165.80\,g * \frac{14.38\,g\ salt}{100\,g\ grout}$$
$$M_{salt} = 23.84\,g$$

$$M_{water-oven} = 165.40\,g - 122.51\,g$$
$$M_{water-oven} = 42.89\ g$$

$$M_{liquid} = 0.28\,g + 23.84\,g + 42.89$$
$$M_{liquid} = 67.01\,g$$

$$V_{liquid} = \frac{67.01\,g}{1.253\,\frac{g}{cm^3}}$$
$$V_{liquid} = 53.48\,cm^3$$

$$\phi = \frac{53.48\,cm^3}{93.13\,cm^3}$$

$$\phi = 0.574$$

2) Determine the volumetric moisture content of the samples at each pressure increment. In this example, the volumetric liquid content at 15 bars is determined.

$$M_{solid} = M_{sat} - M_{liquid}$$

$$V_{liquid} = \frac{M_{sample} - M_{solid}}{\rho_{liquid}}$$

$$\theta_{liquid} = \frac{V_{liquid}}{V_{total}}$$

M_{sat} = total mass of saturated sample, g
M_{sample} = mass of sample at each pressure increment, g
M_{liquid} = mass of interstitial liquid in sample at saturation, g
M_{solid}= corrected final dry weight of sample, g
ρ_{liquid} =density of interstitial liquid, g/cm^3
V_{liquid} = volume of liquid in sample at each pressure increment, cm^3
V_{total} = total volume of sample, cm^3
θ_{liquid} = volumetric moisture content of sample at each pressure increment, fraction

For MCU-TR545-1

M_{sat} = 165.80 g
M_{sample} = mass of sample at each pressure increment, g
M_{liquid} =67.01 g
ρ_{liquid} =1.253 g/cm^3
V_{total} = 93.13 cm^3

For 0.1 bar pressure increment:

$$M_{solid} = 165.80\,g - 67.01\,g$$

$$M_{solid} = 98.79\,g$$

$$V_{liquid} = \frac{165.61\,g - 98.79\,g}{1.253\,\frac{g}{cm^3}}$$

$$V_{liquid} = 53.33\,cm^3$$

$$\theta_{liquid} = \frac{53.33\,cm^3}{93.13\,cm^3}$$

$$\theta_{liquid} = 0.573$$

APPENDIX C. RECOMMENDED CHARACTERISTIC CURVE DATA

Table C.1. Recommended Characteristic Curves for ARP/MCU Saltstone with Tap Water as Test Fluid.

Saturation	Suction Head (cm)	Saturation	Relative Permeability kr
1.0000000000000E+00	0.00E+00	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	5.00E-02	1.0000000000000E+00	1.000000E+00
9.9999999999999E-01	1.00E-01	9.9999999999999E-01	9.999999E-01
9.9999999999995E-01	2.00E-01	9.9999999999995E-01	9.999999E-01
9.9999999999959E-01	5.00E-01	9.9999999999959E-01	9.999996E-01
9.9999999999808E-01	1.00E+00	9.9999999999808E-01	9.999990E-01
9.9999999999106E-01	2.00E+00	9.9999999999106E-01	9.999977E-01
9.9999999993145E-01	5.00E+00	9.9999999993145E-01	9.999929E-01
9.9999999968001E-01	1.00E+01	9.9999999968001E-01	9.999834E-01
9.9999999850634E-01	2.00E+01	9.9999999850634E-01	9.999612E-01
9.9999998855082E-01	5.00E+01	9.9999998855082E-01	9.998811E-01
9.9999994655726E-01	1.00E+02	9.9999994655726E-01	9.997224E-01
9.9999975053881E-01	2.00E+02	9.9999975053881E-01	9.993522E-01
9.9999808784485E-01	5.00E+02	9.9999808784485E-01	9.980138E-01
9.9999107448551E-01	1.00E+03	9.9999107448551E-01	9.953652E-01
9.9998782280125E-01	1.15E+03	9.9998782280125E-01	9.945018E-01
9.9998338651267E-01	1.32E+03	9.9998338651267E-01	9.934778E-01
9.9997733408656E-01	1.52E+03	9.9997733408656E-01	9.922632E-01
9.9996907680936E-01	1.75E+03	9.9996907680936E-01	9.908228E-01
9.9995781155394E-01	2.01E+03	9.9995781155394E-01	9.891146E-01
9.9994244272170E-01	2.31E+03	9.9994244272170E-01	9.870890E-01
9.9992147579581E-01	2.66E+03	9.9992147579581E-01	9.846874E-01
9.9989287220538E-01	3.06E+03	9.9989287220538E-01	9.818405E-01
9.9985385148412E-01	3.52E+03	9.9985385148412E-01	9.784662E-01
9.9980062166849E-01	4.05E+03	9.9980062166849E-01	9.744679E-01
9.9972801206397E-01	4.65E+03	9.9972801206397E-01	9.697313E-01
9.9962897331703E-01	5.35E+03	9.9962897331703E-01	9.641223E-01
9.9949389739071E-01	6.15E+03	9.9949389739071E-01	9.574833E-01
9.9930969357902E-01	7.08E+03	9.9930969357902E-01	9.496293E-01
9.9905853492210E-01	8.14E+03	9.9905853492210E-01	9.403447E-01
9.9871616094907E-01	9.36E+03	9.9871616094907E-01	9.293787E-01
9.9824958621917E-01	1.08E+04	9.9824958621917E-01	9.164415E-01
9.9761401868084E-01	1.24E+04	9.9761401868084E-01	9.012006E-01
9.9674873767529E-01	1.42E+04	9.9674873767529E-01	8.832786E-01
9.9557162161378E-01	1.64E+04	9.9557162161378E-01	8.622529E-01
9.9397195907659E-01	1.88E+04	9.9397195907659E-01	8.376596E-01
9.9180114488311E-01	2.16E+04	9.9180114488311E-01	8.090033E-01
9.8886089562615E-01	2.49E+04	9.8886089562615E-01	7.757770E-01
9.8488879250077E-01	2.86E+04	9.8488879250077E-01	7.374952E-01
9.7954140015192E-01	3.29E+04	9.7954140015192E-01	6.937473E-01
9.7237611326674E-01	3.79E+04	9.7237611326674E-01	6.442749E-01
9.6283450267463E-01	4.35E+04	9.6283450267463E-01	5.890771E-01
9.5023250804509E-01	5.01E+04	9.5023250804509E-01	5.285402E-01

Table C.1. Recommended Characteristic Curves for ARP/MCU Saltstone with Tap Water as Test Fluid.

Saturation	Suction Head (cm)	Saturation	Relative Permeability kr
9.3376634424756E-01	5.76E+04	9.3376634424756E-01	4.635762E-01
9.1254670951991E-01	6.62E+04	9.1254670951991E-01	3.957349E-01
8.8567562629328E-01	7.61E+04	8.8567562629328E-01	3.272298E-01
8.5237596911534E-01	8.76E+04	8.5237596911534E-01	2.608084E-01
8.1216870507671E-01	1.01E+05	8.1216870507671E-01	1.994198E-01
7.6506602668438E-01	1.16E+05	7.6506602668438E-01	1.457074E-01
7.1171915165270E-01	1.33E+05	7.1171915165270E-01	1.014676E-01
6.5344900453462E-01	1.53E+05	6.5344900453462E-01	6.729045E-02
5.9211694065609E-01	1.76E+05	5.9211694065609E-01	4.254856E-02
5.2985705286801E-01	2.03E+05	5.2985705286801E-01	2.573189E-02
4.6875420049036E-01	2.33E+05	4.6875420049036E-01	1.495209E-02
4.1057014489739E-01	2.68E+05	4.1057014489739E-01	8.393371E-03
3.5658542114947E-01	3.08E+05	3.5658542114947E-01	4.577624E-03
3.0756703298801E-01	3.54E+05	3.0756703298801E-01	2.438743E-03
2.6382876061445E-01	4.07E+05	2.6382876061445E-01	1.275314E-03
2.2533703027079E-01	4.68E+05	2.2533703027079E-01	6.573255E-04
1.9182368663313E-01	5.39E+05	1.9182368663313E-01	3.350581E-04
1.6288327106378E-01	6.20E+05	1.6288327106378E-01	1.693561E-04
1.3804656748731E-01	7.13E+05	1.3804656748731E-01	8.506100E-05
1.1683086283208E-01	8.19E+05	1.1683086283208E-01	4.252116E-05
9.8771209287686E-02	9.42E+05	9.8771209287686E-02	2.118127E-05
8.3437800854304E-02	1.08E+06	8.3437800854304E-02	1.052368E-05
7.0443974647856E-02	1.25E+06	7.0443974647856E-02	5.218526E-06
5.9448297934286E-02	1.43E+06	5.9448297934286E-02	2.584117E-06
5.0153180980634E-02	1.65E+06	5.0153180980634E-02	1.278271E-06
4.2301635406401E-02	1.90E+06	4.2301635406401E-02	6.318309E-07
3.5673200834322E-02	2.18E+06	3.5673200834322E-02	3.121287E-07
3.0079654739868E-02	2.51E+06	3.0079654739868E-02	1.541299E-07
2.5360853905128E-02	2.88E+06	2.5360853905128E-02	7.608662E-08
2.1380888065520E-02	3.31E+06	2.1380888065520E-02	3.755198E-08
1.8024624305692E-02	3.81E+06	1.8024624305692E-02	1.853047E-08
1.5194661149778E-02	4.38E+06	1.5194661149778E-02	9.142984E-09
1.2808678299418E-02	5.04E+06	1.2808678299418E-02	4.510777E-09
1.0797151263414E-02	5.80E+06	1.0797151263414E-02	2.225291E-09
9.1013930976451E-03	6.67E+06	9.1013930976451E-03	1.097746E-09
7.6718840061265E-03	7.67E+06	7.6718840061265E-03	5.415039E-10
6.4668511108118E-03	8.82E+06	6.4668511108118E-03	2.671102E-10
5.4510637553242E-03	1.01E+07	5.4510637553242E-03	1.317563E-10
4.5948133721414E-03	1.17E+07	4.5948133721414E-03	6.498994E-11
3.8730507070713E-03	1.34E+07	3.8730507070713E-03	3.205654E-11
3.2646567870425E-03	1.54E+07	3.2646567870425E-03	1.581190E-11
2.7518273049435E-03	1.77E+07	2.7518273049435E-03	7.799181E-12
2.3195530273723E-03	2.04E+07	2.3195530273723E-03	3.846912E-12

Table C.1. Recommended Characteristic Curves for ARP/MCU Saltstone with Tap Water as Test Fluid.

Saturation	Suction Head (cm)	Saturation	Relative Permeability kr
1.9551814022627E-03	2.35E+07	1.9551814022627E-03	1.897467E-12
1.6480467721487E-03	2.70E+07	1.6480467721487E-03	9.359130E-13
1.3891585155975E-03	3.10E+07	1.3891585155975E-03	4.616320E-13
1.1709380785558E-03	3.57E+07	1.1709380785558E-03	2.276963E-13
9.8699725361634E-04	4.10E+07	9.8699725361634E-04	1.123092E-13
8.3195125113725E-04	4.72E+07	8.3195125113725E-04	5.539554E-14
7.0126111133217E-04	5.43E+07	7.0126111133217E-04	2.732335E-14
5.9110085716941E-04	6.24E+07	5.9110085716941E-04	1.347699E-14
4.9824550711927E-04	7.18E+07	4.9824550711927E-04	6.647401E-15
4.1997667432556E-04	8.25E+07	4.1997667432556E-04	3.278768E-15
3.5400299168538E-04	9.49E+07	3.5400299168538E-04	1.617221E-15
2.9839303515870E-04	1.09E+08	2.9839303515870E-04	7.976790E-16
2.5151878278176E-04	1.25E+08	2.5151878278176E-04	3.934476E-16
2.1200795484050E-04	1.44E+08	2.1200795484050E-04	1.940642E-16
1.7870384038011E-04	1.66E+08	1.7870384038011E-04	9.572033E-17
1.5063143422013E-04	1.91E+08	1.5063143422013E-04	4.721313E-17
1.2696889328200E-04	2.19E+08	1.2696889328200E-04	2.328742E-17
1.0702347669609E-04	2.52E+08	1.0702347669609E-04	1.148630E-17
9.0211265380954E-05	2.90E+08	9.0211265380954E-05	5.665506E-18
7.6040067408816E-05	3.34E+08	7.6040067408816E-05	2.794456E-18
6.4095008722582E-05	3.84E+08	6.4095008722582E-05	1.378339E-18
5.4026387375711E-05	4.41E+08	5.4026387375711E-05	6.798523E-19
4.5539435726935E-05	5.08E+08	4.5539435726935E-05	3.353306E-19
3.8385690875155E-05	5.84E+08	3.8385690875155E-05	1.653986E-19
3.2355720700132E-05	6.71E+08	3.2355720700132E-05	8.158125E-20
2.7272992559758E-05	7.72E+08	2.7272992559758E-05	4.023917E-20
2.2988705146064E-05	8.88E+08	2.2988705146064E-05	1.984758E-20
1.9377432198909E-05	1.02E+09	1.9377432198909E-05	9.789629E-21

Table C.2. Recommended Characteristic Curves for ARP/MCU Saltstone with Simulant as Test Fluid.

Saturation	Suction Head (cm)	Saturation	Relative Permeability kr
1.0000000000000E+00	0.00E+00	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	5.00E-02	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	1.00E-01	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	2.00E-01	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	5.00E-01	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	1.00E+00	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	2.00E+00	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	5.00E+00	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	1.00E+01	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	2.00E+01	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	5.00E+01	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	1.00E+02	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	2.00E+02	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	5.00E+02	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	1.00E+03	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	1.15E+03	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	1.32E+03	1.0000000000000E+00	1.000000E+00
1.0000000000000E+00	1.52E+03	1.0000000000000E+00	1.000000E+00
9.9999999999999E-01	1.75E+03	9.9999999999999E-01	1.000000E+00
9.9999999999998E-01	2.01E+03	9.9999999999998E-01	1.000000E+00
9.9999999999995E-01	2.31E+03	9.9999999999995E-01	1.000000E+00
9.9999999999990E-01	2.66E+03	9.9999999999990E-01	1.000000E+00
9.9999999999978E-01	3.06E+03	9.9999999999978E-01	1.000000E+00
9.9999999999953E-01	3.52E+03	9.9999999999953E-01	1.000000E+00
9.9999999999899E-01	4.05E+03	9.9999999999899E-01	1.000000E+00
9.9999999999784E-01	4.65E+03	9.9999999999784E-01	1.000000E+00
9.9999999999538E-01	5.35E+03	9.9999999999538E-01	1.000000E+00
9.9999999999011E-01	6.15E+03	9.9999999999011E-01	1.000000E+00
9.9999999997885E-01	7.08E+03	9.9999999997885E-01	1.000000E+00
9.9999999995477E-01	8.14E+03	9.9999999995477E-01	1.000000E+00
9.9999999990326E-01	9.36E+03	9.9999999990326E-01	1.000000E+00
9.9999999979308E-01	1.08E+04	9.9999999979308E-01	1.000000E+00
9.9999999955743E-01	1.24E+04	9.9999999955743E-01	9.999999E-01
9.9999999905339E-01	1.42E+04	9.9999999905339E-01	9.999999E-01
9.9999999797532E-01	1.64E+04	9.9999999797532E-01	9.999998E-01
9.9999999566945E-01	1.88E+04	9.9999999566945E-01	9.999996E-01
9.9999999073745E-01	2.16E+04	9.9999999073745E-01	9.999993E-01
9.9999998018848E-01	2.49E+04	9.9999998018848E-01	9.999988E-01
9.9999995762546E-01	2.86E+04	9.9999995762546E-01	9.999977E-01
9.9999990936580E-01	3.29E+04	9.9999990936580E-01	9.999957E-01
9.9999980614403E-01	3.79E+04	9.9999980614403E-01	9.999921E-01
9.9999958536475E-01	4.35E+04	9.9999958536475E-01	9.999852E-01
9.9999911314393E-01	5.01E+04	9.9999911314393E-01	9.999724E-01

Table C.2. Recommended Characteristic Curves for the ARP/MCU Saltstone with Simulant as Test Fluid.

Saturation	Suction Head (cm)	Saturation	Relative Permeability kr
9.9999810312024E-01	5.76E+04	9.9999810312024E-01	9.999486E-01
9.9999594280477E-01	6.62E+04	9.9999594280477E-01	9.999041E-01
9.9999132217635E-01	7.61E+04	9.9999132217635E-01	9.998211E-01
9.9998143934957E-01	8.76E+04	9.9998143934957E-01	9.996661E-01
9.9996030186318E-01	1.01E+05	9.9996030186318E-01	9.993765E-01
9.9991509457791E-01	1.16E+05	9.9991509457791E-01	9.988350E-01
9.9981841672249E-01	1.33E+05	9.9981841672249E-01	9.978222E-01
9.9961170385072E-01	1.53E+05	9.9961170385072E-01	9.959272E-01
9.9916988815913E-01	1.76E+05	9.9916988815913E-01	9.923817E-01
9.9822635287331E-01	2.03E+05	9.9822635287331E-01	9.857554E-01
9.9621488040968E-01	2.33E+05	9.9621488040968E-01	9.734087E-01
9.9194269770889E-01	2.68E+05	9.9194269770889E-01	9.505681E-01
9.8294037778987E-01	3.08E+05	9.8294037778987E-01	9.089688E-01
9.6428202560058E-01	3.54E+05	9.6428202560058E-01	8.356165E-01
9.2689823825243E-01	4.07E+05	9.2689823825243E-01	7.143630E-01
8.5679751030067E-01	4.68E+05	8.5679751030067E-01	5.370438E-01
7.4010894005148E-01	5.39E+05	7.4010894005148E-01	3.276664E-01
5.7889332389957E-01	6.20E+05	5.7889332389957E-01	1.493476E-01
4.0354649836719E-01	7.13E+05	4.0354649836719E-01	4.905621E-02
2.5389745466653E-01	8.19E+05	2.5389745466653E-01	1.210564E-02
1.4867275425633E-01	9.42E+05	1.4867275425633E-01	2.450537E-03
8.3463342168125E-02	1.08E+06	8.3463342168125E-02	4.419231E-04
4.5827574904167E-02	1.25E+06	4.5827574904167E-02	7.500763E-05
2.4887629603973E-02	1.43E+06	2.4887629603973E-02	1.235479E-05
1.3444496389964E-02	1.65E+06	1.3444496389964E-02	2.005880E-06
7.2446582825600E-03	1.90E+06	7.2446582825600E-03	3.234520E-07
3.8992365200442E-03	2.18E+06	3.8992365200442E-03	5.199002E-08
2.0974968559428E-03	2.51E+06	2.0974968559428E-03	8.344036E-09
1.1280042242711E-03	2.88E+06	1.1280042242711E-03	1.338216E-09
6.0655136038269E-04	3.31E+06	6.0655136038269E-04	2.145523E-10
3.2613683987344E-04	3.81E+06	3.2613683987344E-04	3.439323E-11
1.7535600552681E-04	4.38E+06	1.7535600552681E-04	5.512918E-12
9.4283578111704E-05	5.04E+06	9.4283578111704E-05	8.836402E-13
5.0693112283543E-05	5.80E+06	5.0693112283543E-05	1.416324E-13
2.7255909608683E-05	6.67E+06	2.7255909608683E-05	2.270107E-14
1.4654528706872E-05	7.67E+06	1.4654528706872E-05	3.638553E-15
7.8792118017082E-06	8.82E+06	7.8792118017082E-06	5.831905E-16
4.2363669755486E-06	1.01E+07	4.2363669755486E-06	9.347420E-17
2.2777408811797E-06	1.17E+07	2.2777408811797E-06	1.498211E-17
1.2246585903147E-06	1.34E+07	1.2246585903147E-06	2.401342E-18
6.5845445057303E-07	1.54E+07	6.5845445057303E-07	3.848887E-19
3.5402704164424E-07	1.77E+07	3.5402704164424E-07	6.169021E-20
1.9034748012165E-07	2.04E+07	1.9034748012165E-07	9.887745E-21

Table C.2. Recommended Characteristic Curves for the ARP/MCU Saltstone with Simulant as Test Fluid.

Saturation	Suction Head (cm)	Saturation	Relative Permeability kr
1.0234292531945E-07	2.35E+07	1.0234292531945E-07	1.584814E-21
5.5026073064435E-08	2.70E+07	5.5026073064435E-08	2.540150E-22
2.9585520499154E-08	3.10E+07	2.9585520499154E-08	4.071369E-23
1.5907059584692E-08	3.57E+07	1.5907059584692E-08	6.525613E-24
8.5526480632064E-09	4.10E+07	8.5526480632064E-09	1.045931E-24
4.5984481606358E-09	4.72E+07	4.5984481606358E-09	1.676423E-25
2.4724185222102E-09	5.43E+07	2.4724185222102E-09	2.686979E-26
1.3293296206338E-09	6.24E+07	1.3293296206338E-09	4.306655E-27
7.1473224472651E-10	7.18E+07	7.1473224472651E-10	6.902653E-28
3.8428556297923E-10	8.25E+07	3.8428556297923E-10	1.106353E-28
2.0661638677091E-10	9.49E+07	2.0661638677091E-10	1.773524E-29
1.1109012514359E-10	1.09E+08	1.1109012514359E-10	2.841796E-30
5.9729124573731E-11	1.25E+08	5.9729124573731E-11	4.556287E-31
3.2114180425422E-11	1.44E+08	3.2114180425422E-11	7.310047E-32
1.7266628160997E-11	1.66E+08	1.7266628160997E-11	1.170254E-32
9.2836386948273E-12	1.91E+08	9.2836386948273E-12	1.884411E-33
4.9914752673472E-12	2.19E+08	4.9914752673472E-12	2.978527E-34
2.6837349194148E-12	2.52E+08	2.6837349194148E-12	4.848221E-35
1.4429467706276E-12	2.90E+08	1.4429467706276E-12	7.832516E-36
7.7582005875552E-13	3.34E+08	7.7582005875552E-13	1.313670E-36
4.1713026136483E-13	3.84E+08	4.1713026136483E-13	1.990198E-37
2.2427578790035E-13	4.41E+08	2.2427578790035E-13	2.334918E-38
1.2058494359470E-13	5.08E+08	1.2058494359470E-13	4.280229E-39
6.4834143524216E-14	5.84E+08	6.4834143524216E-14	3.138502E-39
3.4858963658406E-14	6.71E+08	3.4858963658406E-14	0.000000E+00
1.8742398392048E-14	7.72E+08	1.8742398392048E-14	0.000000E+00
1.0077106735832E-14	8.88E+08	1.0077106735832E-14	0.000000E+00
5.4180942076458E-15	1.02E+09	5.4180942076458E-15	0.000000E+00

APPENDIX D. DESIGN CHECK DOCUMENTATION

Re: Design Check of SRNL-STI-2009-00419
W02 Jones to: Kenneth Dixon 03/15/2010 07:41 AM

Ken,

I've completed the requested design check, checking at least 10 percent of the calculations and transcriptions. No errors have been noted. The logic, assumptions, interpretations, and conclusions are reasonable. Several editorial suggestions will be delivered to you in marked-up hard copy.

Bill

Kenneth Dixon/SRNL/Srs

Kenneth Dixon/SRNL/Srs
03/11/2010 02:46 PM

To W02 Jones/SRNL/Srs@Srs
cc
Subject Design Check of SRNL-STI-2009-00419

Bill,

Please perform a design check on the document SRNL-STI-2009-00419_DRAFT_P.doc which is titled "HYDRAULIC AND PHYSICAL PROPERTIES OF ARP/MCU SALTSTONE GROUTS". Elements of this design check should include but are not limited to:

- verify that data from the laboratory reports have been accurately entered into the spreadsheets and report tables
- verify the correction for salt content on the saltstone samples in the spreadsheets
- check the calculations in the spreadsheets for accuracy
- verify that the logic in determining the van Genuchten transport parameters is sound
- verify that the assumptions, interpretations, and conclusions of the report are reasonable

Files associated with the design check may be found at the following path:

\\wg02\KLD\Salt10_DesignCheck

We can meet to discuss the file structure for the spreadsheets to speed the design check process. I will also provide hard copies of the lab sheets and strength reports. The charge code for your time is LWSDFPROP.

Thanks,
Ken
5-5205

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