THESIS

PREDICTING WATER CONTENT AND SATURATION IN MINE TAILINGS WITH AN ELECTROMAGNETIC SOIL MOISTURE SENSOR

Submitted by

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In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Summer 2023

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ABSTRACT

PREDICTING WATER CONTENT AND SATURATION IN MINE TAILINGS WITH AN ELECTROMAGNETIC SOIL MOISTURE SENSOR

The degree of saturation of mine tailings plays an important role in geotechnical and geochemical stability of a tailings facility, and as such, reliable measurements of in situ tailings saturation aid in evaluating the stability of a tailings facility. However, measuring in situ saturation in tailings facilities is a common challenge in the tailings industry. The objectives of this study were to (1) evaluate the ability of an electromagnetic soil moisture sensor to predict the volumetric water content and degree of saturation of mine tailings and (2) conduct proof-of-concept tests to assess the potential for electromagnetic sensors to be used as a tool in tailings engineering practice. To meet these objectives, laboratory-scale testing was conducted using an electromagnetic soil moisture sensor embedded in moist-tamped and slurry-deposited specimens of a single hardrock mine tailings prepared at varying volumetric water content, degree of saturation, and dry density. Certain specimens were subjected to changes in mass-volume properties and sensor performance was evaluated for timeliness and accuracy of response.

The results of this study indicate an electromagnetic soil moisture sensor can be used to predict the volumetric water content and degree of saturation in hardrock mine tailings with a useful degree of accuracy depending on the application and precision required. During the proof-of concept tests performed, error in predicted volumetric water content was less than about 1.5% to 3.8%, error in predicted saturation was predominantly less than 5%, and temporal response to changes in moisture was equivalent to a sensor insertion rate of approximately 27 mm/s. Based on the findings of this study, electromagnetic sensor technology offers a viable tool to predict the degree of saturation within tailings facilities and can be incorporated into innovative approaches to address the challenges encountered in different types of tailings facilities.

ACKNOWLEDGMENTS

I would sincerely like to thank my wife, Carly, for her love and support throughout my time as a graduate student. My first day of graduate school began eight days after we returned from our honeymoon, and the patience she has shown me during this unconventional start to our marriage truly exemplifies her wonderful soul.

To my advisor, Dr. Christopher Bareither, and committee member, Dr. Joseph Scalia, thank you for introducing me to the fascinating world of mine tailings and for giving me the opportunity to dramatically change my life forever. Your guidance and support throughout my graduate education will lay the foundation for what I hope will be a long and fulfilling career as a tailings engineer. I would also like to thank Dr. Jay Ham for introducing me to the exciting future of sensor technology, and for serving as a member of my committee.

To my fellow Geo-Environmental Warriors, Sam Jacob, Justin Primus, Heath Orcutt, Joe Binder, Esther Clement, Kendall Monley, and Holly Proulx, thank you so much for the wonderful memories these past two years. I consider myself truly honored to know you as friends and colleagues. As we strike out towards an exciting yet unknown future, I hope we remain close and continue to lean on each other because life's greatest achievements cannot be accomplished nor enjoyed alone. I hope to see you all one day at the top of the mountain.

Financial support for this project was provided by the TailEng Group. I am truly grateful to have been affiliated with such an intelligent and ambitious group of individuals who seek to advance the state of engineering practice in tailings.

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CHAPTER 1: INTRODUCTION

Natural porous media, such as soil, generally consists of a combination of solid particles, air, and water. In a given volume of porous medium, the degree of saturation (commonly reported as a percentage) is the ratio of the volume of water to the volume of the void space that exists between solid particles (Holtz et al., 2011). Knowing the degree of saturation of a porous medium is important to understanding and predicting mechanical, hydraulic, and chemical behavior.

A common type of porous media encountered at nearly all mining sites is mine tailings. Tailings are a byproduct of the mining process, consisting of processed rock, soil, and/or residual chemicals that remain following the separation of valuable commodities (The Mining Association of Canada, 2021). Particles of tailings are typically fine-sand and silt-sized and are generally angular due to crushing and grinding of ore processing. When mining an ore body, a relatively small fraction of the total mined material is economically viable to extract. For example, the global average mined ore grades for copper were about 0.62% in 2010 and future decrease is projected (Northey et al., 2014). Consequently, a considerable amount of byproduct (e.g., tailings) is produced in the mining process and is stored in perpetuity in a tailings facility. Characteristics of tailings facilities vary as a function of location, climate, and tailings properties, among many factors (Morrison, 2022). However, nearly all tailings facilities include an impoundment that contains a combination of tailings and water that must be properly designed, constructed, and managed throughout each phase of the facility lifecycle to minimize risk to people and the environment (Global Industry Standard on Tailings Management, 2020).

The degree of saturation of mine tailings plays an important role in geotechnical stability of a tailings facility. The depositional methods of tailings and significant size of tailings impoundments render the tailings in many facilities in a normally consolidated, or slightly over-consolidated, state meaning the effective stress experienced by the tailings is equal to, or near, the maximum historical stress. Normally consolidated and slightly over-consolidated porous

media (e.g., tailings) exhibit contractive tendencies (reduction in void volume) when subject to increases in stress caused by static or cyclic loads (Holtz et al., 2011). When tailings exhibit an elevated degree of saturation, the contractive behavior results in development of positive pore water pressures resulting in a decrease in effective stress and loss of strength. Aghazamani (2022) reported positive pore water pressures generated in tailings specimens prepared at degrees of saturation of approximately 80% and above. Rodriguez et al. (2021) conducted an in-depth study on flow failures in tailings dams and reported that maintaining saturation below 80% is the most influential factor to enhance geotechnical stability.

The degree of saturation in mine tailings also plays an important role in geochemical stability of a tailings facility. Certain tailings are rich in sulfide-bearing minerals, such as pyrite, and when contacted by the combination of air and water, generate acidic pore fluid that can drain into the surrounding environment. Acid mine drainage from oxidation of sulfide-bearing minerals is an extremely harmful source of environmental contamination (Banks et al., 1997). Aachib et al. (2004) report that the diffusion of oxygen into unsaturated porous media (e.g., tailings) decreases exponentially at saturation above 85%, which implies that mitigation of acid generation in sulfide-rich tailings requires a high degree of saturation.

The balance between maintaining tailings at a high degree of saturation to mitigate acid generation while also remaining unsaturated for better geotechnical stability implies that reliable measurements of in situ tailings saturation are fundamental for evaluating geotechnical and geochemical stability. Tailings saturation is important for all types of tailings management strategies, ranging from slurry deposition to filtered stacks. Reducing saturation in slurry deposited tailings requires adequate drainage and surficial drying to facilitate water removal. Although filtered tailings aim to reduce the amount of water stored within tailings, the potential to develop saturated zones within a filtered stack is site specific and a current knowledge gap in practice. Regardless of the management strategy adopted for any tailings facility, there is a need

to determine in situ tailings saturation to assess stability (Zandarín et al., 2009). Measuring in situ saturation in tailings facilities is a common challenge in the tailings industry.

The alternatives for determining the degree of saturation within a tailings facility currently used in practice are limited. The only direct measurement of tailings saturation is destructive sampling coupled with weight-volume calculations, which requires careful sampling and subsequent laboratory evaluation. This technique yields a point measurement at a given location and time and is not readily scalable to the vast size of tailings facilities or the need for real-time monitoring. Commonly used field tools to assess the moisture regime in a tailings facility include instrumentation networks, such as vibrating wire piezometers, and direct push measurement techniques, such as pore pressure dissipation tests and shear wave velocity from CPT and field resistivity probes (e.g., Contreras et al. 2020). However, these methods are used primarily to identify the phreatic surface or boundary between saturated and unsaturated zones within a tailings facility and are not necessarily used to determine variations in the degree of saturation within unsaturated tailings. Soil moisture sensors exploit a surrogate property (e.g., dielectric permittivity) of the surrounding medium to which the sensor is sensitive, and the sensor output can be correlated to volumetric water content via an empirical or theoretical relationship (Evett et al., 2012).

The most appropriate method for evaluating the degree of saturation within a tailings facility depends on the site-specific challenges presented by the characteristics of the site and project scope. For example, a direct push or probe-based technique may be more feasible than installing an instrumentation network when evaluating spatial variations in saturation within an existing tailings facility. In contrast, an instrumentation network containing soil moisture sensors may be more suitable for monitoring spatial and temporal variations in saturation of a tailings facility under construction. The objectives of this study were to (1) evaluate the ability of an electromagnetic soil moisture sensor to predict the volumetric water content and degree of saturation of mine tailings and (2) conduct proof-of-concept tests to assess the potential for

electromagnetic sensors to be used as a tool in tailings engineering practice. A single hardrock mine tailings from a precious metal mine was used in this study. Following an assessment of the electromagnetic sensor, proof-of-concept tests were implemented to evaluate how the sensor may perform as a push-probe technique for existing tailings facilities as well as embedded within a deforming medium that represents a growing filtered tailings stack.

CHAPTER 2: SATURATION MEASUREMENT TECHNIQUES AND DIRECTION OF STUDY

A literature review was conducted to identify different methods and tools that could be used to determine the degree of saturation in mine tailings. The literature review yielded numerous potential methods, and available technologies were categorized into the list included in Appendix A. The list of potential methods was extensive and represented an as-complete-as-possible compilation of available techniques that can serve to determine the degree of saturation in porous media.

A survey of current practitioners with expertise in tailings and porous media was conducted to determine the extent to which the various methods and technologies were currently being used in practice, with particular emphasis on mine tailings applications. A summary of the survey results is included in Appendix B. The results of the survey and knowledge gained from the initial literature review identified three methods / technologies as promising alternatives warranting further study: (i) cone penetration test (CPT); (ii) geophysical methods; and (iii) electromagnetic sensors.

Electromagnetic sensors were selected as the subject of this study for several reasons. Electromagnetic sensors are based on a well-tested principle of operation and have been implemented and researched within the agricultural community for many years. Furthermore, electromagnetic sensors can be designed to be durable, corrosion resistant, wirelessly capable, and compatible with different micro-controllers. Finally, certain types of electromagnetic sensors can be manufactured relatively inexpensively. The combination of these qualities of electromagnetic sensors allows them to be incorporated into an extensive network for monitoring spatial and temporal variations in volumetric water content or degree of saturation across a tailings facility. Where a large sensor network may not be feasible or appropriate, such as at an existing or legacy tailings facility, the vision was for this study to assess future research

potential with electromagnetic sensor technology that could be incorporated into a probe-based application, such as a CPT.

CHAPTER 3: FOCUSED LITERATURE REVIEW

A focused literature review was conducted to identify previous studies incorporating electromagnetic sensors in applications relevant to a tailings facility. Several studies used electromagnetic soil moisture sensors in monitoring networks for earthen slopes. Li et al. (2005) used electromagnetic sensors to determine spatial and temporal variations in volumetric water content of a saprolite slope and compared the sensor data to precipitation events. Greco et al. (2010) and Peranic et al. (2022) used electromagnetic sensors to monitor variations in model slopes constructed in a laboratory environment and subjected to simulated rainfall events. The study performed by Peranic et al. (2022) included the Teros 10 and Teros 12 soil moisture sensors. The results of these studies generally concluded that the electromagnetic sensors responded appropriately to the infiltration of surface water from precipitation events. However, the studies did not specifically focus on the accuracy of the sensors when predicting volumetric water content.

Several studies used electromagnetic soil moisture sensors to monitor variations in volumetric water content within the unsaturated zone of existing tailings impoundments (Basson et al., 2021; Blanco et al., 2013; Cheong et al., 2012). Additionally, electromagnetic soil moisture sensors have been used to monitor the desiccation process of a column of tailings prepared in a laboratory environment (Garino Libardi et al., 2022). Electromagnetic sensors embedded in existing tailings facilities captured variations in volumetric water content that generally reflected the infiltration of surface water from periodic precipitation events (Basson et al., 2021; Cheong et al., 2012). The study performed by Blanco et al. (2013) concluded that the performance of electromagnetic sensors can be negatively impacted by the extreme salinity of certain acid-generating tailings facilities. While the various studies identified showed that the sensors were generally able to capture variations in volumetric water content within certain tailings facilities, the studies did not specifically address the accuracy of the sensor-predicted water content. Instead,

the primary focus of the studies was to determine seasonal effects of rainfall on tailings water quality (Cheong et al., 2012), develop a conceptual desiccation model (Garino Libardi et al., 2022), or develop a wireless data acquisition system (Basson et al., 2021).

Woyshner (1992) installed electromagnetic soil moisture sensors at various locations and depths within the unsaturated zone of an existing sulfide ore tailings facility and monitored temporal variations in volumetric water content over a period of about two months. Laboratory testing was conducted to develop a material-specific calibration for the sensor which was used to predict volumetric water content during the field monitoring program. Sensor predicted volumetric water content was periodically compared to values determined from direct sampling and indicated an average error of +1.1%, standard deviation of 2.2%, and a maximum error of 5.5%. The study concluded the sensor responded appropriately to fluctuations in volumetric water content due to infiltration from precipitation events, and the sensor data was used to develop a water balance model within the unsaturated zone of the tailings.

Testing on laboratory-prepared specimens of iron mine tailings has been conducted using the Teros 12 sensor (Landim et al., 2023), which is a more recent variant of the sensor used during this study. Laboratory specimens were prepared in PVC molds using moist-tamped methods, and a material-specific calibration relating raw sensor output to the volumetric water content of the tailings was developed. Testing indicated the manufacturer calibration resulted in a substantial error when predicting volumetric water content in the iron mine tailings. Additionally, test results indicated an increase in specimen dry density resulted in an increase in the raw sensor output value reported in millivolts.

Narayanan and Sathian (2021) used a Teros 12 soil moisture sensor to determine the volumetric water content at three different depth intervals within a laterite soil deposit. Sensor-predict values of volumetric water content were compared to values determined from direct measurement of representative field samples. The manufacturer calibration was used to predict volumetric water content from sensor output and resulted in errors of about -5%, -12%, and +3%

at the three depth intervals, respectively. The greatest error (-12%) was observed at a depth interval that exhibited significantly low dry density when compared to the other two depth intervals. A material-specific calibration was developed for each depth interval, and calibration specimens were prepared at the respective in-situ field dry densities. The material and density-specific calibrations were then used to predict volumetric water content from sensor output, and the error in sensor-predicted volumetric water content was reduced ranging from 1.7% to 3.9%. The results of this study highlight the importance of performing a material specific calibration and suggest that sensor accuracy is affected by variations in dry density.

CHAPTER 4: MATERIALS AND METHODS

4.1 Experimental Program Overview

Table 1 summarizes the various tests performed as part of this study. All testing was conducted on a single hardrock tailings material and included the preparation of both moist-tamped and slurry-deposited test specimens in either a small or large test mold. Each of the testing programs were conducted in sequential order as presented from top to bottom in the table. The first three tests were performed to evaluate the ability and behavior of the electromagnetic sensor in question when predicting the volumetric water content and degree of saturation of mine tailings. The second three tests are considered proof-of-concept tests performed to evaluate sensor response to variations in volumetric water content, degree of saturation, and dry density.

A critical first step in the successful implementation of the electromagnetic sensor requires calibration testing to relate raw sensor output to predicted values of volumetric water content and degree of saturation. Performing testing on numerous specimens prepared at a wide range of volumetric water contents and degrees of saturation using multiple sensors allowed for a robust calibration equation to be developed. Following calibration testing, additional specimens were prepared at random to evaluate the accuracy of the calibration equations and validate the ability of the sensor to predict volumetric water content and degree of saturation in tailings. Several series of moist-tamped specimens were then tested to further understand and characterize the behavior of sensor output as the dry density of the tailings medium varied. After the ability and behavior of the sensor had been evaluated and characterized, proof-of-concept testing was performed. During proof-of-concept testing, the sensor was subjected to dynamic changes in specimen volumetric water content, saturation, and dry density via rapid insertion, specimen compression, and infiltration of water. The equations developed and the insights gained during the preceding sensor evaluation testing programs were implemented during proof-of-concept testing to assess the timeliness and accuracy of sensor response to the induced change in

conditions. Details and discussion regarding specimen preparation, testing procedures, and results for the various tests performed are discussed herein.

4.2 Mine Tailings

Hardrock mine tailings from a precious metal mine was used in this study and was considered representative of common hardrock mine tailings in practice. Particle size analysis yielded 14% fine sand and 86% fine-grained (i.e., silt and clay that pass the No. 200 sieve), by mass. The tailings had low plasticity with a liquid limit of 30 and a plasticity index of 9. The particle size and plasticity testing indicated lean clay classification, with symbol of CL per the Unified Soil Classification System (USCS). The specific gravity of the tailings was 2.72. Standard Proctor compaction testing (ASTM D698) yielded a maximum dry density of 1.69 Mg/m^3 and optimum gravimetric water content of 15.8%. Particle size, plasticity, and compaction test results were extracted from Aghazamani (2022) and specific gravity and shrinkage limit were conducted as part of this study.

The testing performed in this study required a considerable amount of mine tailings. Due to limitations of the amount of available tailings, recycling of test specimens was necessary to complete the experimental scope with a single-controlled tailings material. Prior to specimen preparation for a given experiment, any previously used tailings were processed to promote consistency in specimen preparation. Pre-test processing consisted of oven-drying tailings for ≥ 24 h, lightly breaking dried clods, and passing the tailings through a No. 40 sieve (0.425 mm). This procedure yielded uniform, oven-dried tailings with all clods and particles of fine sand and smaller. Pre-test processing rendered the tailings workable for mixing with water and subsequent hydration to target water contents for testing.

4.3 Teros 10 Soil Moisture Sensor

The Teros 10 sensor is a commercially available soil moisture sensor manufactured by the METER Group, Inc. (Pullman, WA, USA). A picture and schematic of the Teros 10 sensor are shown in Figure 1. The Teros 10 is an electromagnetic sensor, which is sensitive to the dielectric permittivity of the surrounding medium and can be used to provide a prediction of apparent dielectric permittivity, volumetric water content, or degree of saturation. The sensor operates by supplying a 70-MHz oscillating electromagnetic wave to charge a pair of stainless-steel waveguides (needles). The charge time is proportional to the dielectric permittivity of the surrounding medium (METER Group, 2021). A microprocessor within the sensor body measures the charge time and produces an output in the form of an analog signal based on the dielectric permittivity. This raw output signal, reported by the sensor in millivolts (mV), can be used to calibrate the mV signal to volumetric water content and/or degree of saturation. Additional information regarding dielectric permittivity and soil moisture sensor principals of operation are discussed in previous studies (Bobrov et al., 2019; Peddinti et al., 2020; Seyfried & Grant, 2007; Topp et al., 1980).

For this study, an ESP32 Adafruit Feather micro-controller was used to operate the Teros 10 sensor and record output values. Pictures of the ESP32 Adafruit Feather, a pin-out diagram, and a wiring diagram are shown in Figure 2. The micro-controller is inexpensive, versatile and can be programmed to operate numerous analog and digital sensors. The ESP32 was programmed using the Arduino IDE software platform, and the code used for each of the various tests performed during this study is included in Appendix C.

Testing conducted in this study was performed using up to three separate Teros 10 sensors. When more than one sensor was used, testing for each sensor was conducted simultaneously. The three sensors were wired to a single micro-controller to allow for simultaneous data collection. During testing, raw output from each sensor was reported in millivolts (mV) and saved to a .csv file for post-test processing. The micro-controller was

programmed to report the average of a specified number of measurements as a single output value to smooth noise in the raw sensor output.

The number of sensors used, specified number of measurements averaged to produce a single reported sensor output, and the total number of reported output values obtained from each sensor in each of the tests is summarized in Table 2. Additionally, the approximate test run-time required to obtain the desired number of sensor output values for each test is included in the table.

Examples of raw sensor output for different tests conducted in this study are shown in Figure 3. The sensor output versus output number trends in Figures 3a and 3b are representative of testing conducted on tailings specimens prepared to a target water content and dry density that did not change during the test. Post-test data processing for these tests generally consisted of determining a representative output value in mV for each sensor that was coupled with a physical measurement of volumetric water content, degree of saturation, and dry density directly measured from the prepared specimens. Calibration, accuracy, and characterization of density affects testing (Table 1), incorporated sensor data processing to determine a single representative output value for each test based on an arithmetic average. The sensor output with respect to elapsed time trends in Figures 3c, 3d, and 3e are representative of proof-of-concept testing intended to assess the sensor response to variations in volumetric water content, degree of saturation, and dry density (Table 1). Proof-of-concept testing incorporated an evaluation of the rate of change in sensor output or all reported output values individually.

The sensor output shown in Figure 3a was collected for a test that included monitoring all three sensors simultaneously. The sensor output signal exhibited a slight decay with time until reaching a point when the sensor output remained relatively consistent. In the multi-sensor experiments, steady sensor output was reached by approximately the 500^{th} reported output value, which corresponded to an elapsed time of approximately 4 hours. Therefore, when using three

sensors, the representative sensor output for each test was determined by taking the average of all output values reported beyond the 500th value.

Interestingly, no required equilibration time in sensor signal was needed for tests conducted with only one sensor. The absence of sensor output decay with time when only one sensor was used was not fully understood. Regardless, when performing testing during the characterization of density affects, the average of all output values reported beyond the 500th value was still used to determine the representative output value for each test to maintain consistency.

4.4 Test Molds

Customized test molds were fabricated to facilitate the laboratory tests performed in this study and needed to accommodate the volume of influence of the sensor. Schematics depicting the approximate volume of influence of the Teros 10 sensor are presented in Figure 4. The volume of influence delineates the three-dimensional space of the sensor measurement. Two test molds were used in this study, a 100-mm-diameter “small mold” and a 300-mm-diameter “large-mold,” both of which were larger than the sensor volume of influence to ensure negligible impact on sensor output. The test molds were water-tight, durable, and allowed for consistent, accurate measurements of specimen volume and mass to support preparation of tailings specimens at different target volumetric water contents, degrees of saturation, and/or dry densities. In addition, the test molds were designed to accommodate slurry-deposited specimens and moist-tamped specimens prepared at considerably dense states to capture a robust spectrum of potential water contents and dry densities.

4.4.1 Small Mold

Pictures of the small mold as well as a schematic of the approximate sensor volume of influence within the mold are shown in Figure 5. The small mold consisted of a 100-mm diameter,

Schedule 40 PVC pipe cut to a length of 150 mm. A flat end cap was placed at one end of the mold and sealed using PVC primer and cement. A narrow slot was made down the longitudinal axis of one side of the mold starting at the open end to allow access for the sensor cord. A dashed line was drawn on the inside of the mold to aid in specimen preparation (Figure 5a) and is referred to herein as the target total volume line. Discussion of specimen preparation and the target total volume line is presented subsequently.

4.4.2 Large Mold

Pictures of the large mold as well as a schematic of the approximate sensor volume of influence within the mold are shown in Figure 6. The large mold was fabricated from a 300-mm-diameter PVC pipe cut to a length of approximately 360 mm. A flat end cap was placed over one end of the mold and sealed using silicone caulk. Several drilled holes approximately 11 mm in diameter were made along the longitudinal axis of one side of the mold to allow access for the sensor cord. During testing, the drilled holes were sealed to prevent specimen loss. Numerous markings were made within the mold to aid in specimen preparation. Discussion of specimen preparation in the large mold is presented subsequently.

4.5 General Sensor Testing Methodology

This section discusses general methodologies for the various tests performed during this study based on the testing mold used. Additional details regarding specimen preparation and data processing are presented in subsequent sections.

4.5.1 Small Mold

The small mold was used to conduct calibration, accuracy, characterization of density affects, and sensor temporal response testing (Table 1). Each test specimen prepared in the small mold can be divided into two general zones referred to as the control volume and the cover. A

cross-section of a test specimen prepared in the small mold depicting the two zones is shown in Figure 7. The target total volume line was the boundary between the control volume and cover and served as a guide during specimen preparation to compact tailings within the control volume to the targeted total volume. Creating a specimen with the desired volumetric water content and dry density was achieved by calculating the mass of dry tailings and deionized water needed to occupy the control volume.

Prior to testing, the internal dimensions and mass of the empty mold were measured for mass-volume calculations. Moisture-conditioned tailings in the control volume were placed and compacted in uniform lifts or tailings slurry was poured into the mold until the target total volume line was reached. Prior to inserting the sensor, the combined total mass of the mold and compacted tailings was measured. The depth from the top of the mold to the top of the control volume was computed as the average of at least four caliper measurements spaced equidistance around the perimeter of the mold. After mass-volume measurements were recorded for the control volume, the sensor was carefully inserted into the center of the mold, the cover was constructed by placing and compacting moisture-conditioned tailings in uniform lifts or pouring additional tailings slurry, and the mold was sealed with flexible plastic wrap and tape. Sensor output was recorded for a desired period of time, after which, the cover material and sensor were removed from the mold. A representative sample of the control volume was collected within the zone of influence of the sensor to determine the gravimetric water content.

The mass-volume measurements and gravimetric water content taken from the control volume were used to compute the actual volumetric water content, degree of saturation, and dry density of the control volume to the nearest 0.1% or 0.01 g/cm^3, as appropriate. The control volume occupied the majority of the sensor volume of influence and is expected to have a dominating effect on sensor output. Therefore, the representative sensor output for each test was related only to the mass-volume properties determined for the control volume when using the small mold.

The sensor body and power cord confounded total volume and mass measurements of the cover, and thus, as-prepared mass-volume parameters of the cover were not determined. Similar volumetric water contents and dry densities in the cover as to the control volume, were prepared using moisture-conditioned tailings prepared to the same gravimetric water content as the control volume, and efforts were made to compact the cover tailings with a similar degree of compaction energy. Based on the reported volume of influence for the Teros 10 sensor (Figure 4), a portion of the volume of influence likely extends into the cover and could have influenced sensor output. Although the mass-volume characteristics of the cover potentially differed from the control volume, the impact was assumed to be negligible based on the majority of the sensor volume of influence residing within the control volume.

4.5.2 Large Mold

The large mold was used to conduct proof-of-concept testing to assess sensor response to specimen compression and infiltration (see Table 1). Specimens prepared in the large mold can be divided into three general zones referred to as the primary, secondary, and buffer zones. A cross-section of a test specimen prepared in the large mold that depicts the three zones is shown in Figure 8. Similar to the small mold, the target total volume lines inside the mold served as a guide during specimen preparation and formed the boundary between zones. A calculated mass of dry tailings and deionized water needed to occupy each zone was determined based on the desired volumetric water content and dry density. The pre-determined quantity of moisture conditioned tailings was compacted to the targeted total volume line for each zone to achieve the desired volumetric water content and dry density throughout the specimen.

Prior to testing, internal dimensions and mass of the empty mold were measured for mass-volume calculations. The primary zone was constructed first by placing and compacting moisture-conditioned tailings in uniform lifts until the first target total volume line was reached. The sensor was then inserted into the primary zone, and the secondary zone was then constructed around

the sensor in uniform lifts until the second target total volume line was reached. Finally, the buffer zone was constructed in the same manner as the primary zone. After the specimen was constructed, the combined total mass of the mold, compacted tailings, and sensor was measured. Additionally, the depth from the top of the mold to the top of the specimen was determined by taking an average of eight caliper measurements spaced relatively equidistance around the perimeter of the mold. Measurements from the constructed specimen were used to determine the initial mass-volume properties of the specimen prior to compression.

Pictures showing a large mold specimen being prepared for compression testing are presented in Figure 9. After specimen construction and measurement of initial conditions, a sheet of 4-mil plastic was placed on top of the specimen to prevent loss of water within the specimen during compression. A plastic load platen, approximately 12.5-mm thick, and an aluminum loading plate, approximately 45-mm thick, were then placed on top of the specimen.

Vertical load was applied to the surface of the test specimen in the large mold via an air-cylinder connected to a vertical load rod. Pictures showing the load press and instrumentation used during compression testing are shown in Figure 10. After the prepared specimen and mold were centered below the load rod, the load rod was lowered to be in contact with the aluminum loading plate and a linear potentiometer was positioned to measure vertical deformation during testing. At the conclusion of the test set-up, measurements from the top of the mold to the top of the plastic load platen were taken at eight locations around the perimeter of the specimen to determine the total volume of the specimen immediately prior to compression.

Incremental loads were applied to the specimen during compression testing until the maximum load for the test was achieved. A load cell positioned at the top of the load rod provided continuous measurement of the applied load throughout a given test. Specimen deformation and Teros 10 sensor output were recorded continuously to monitor changes in specimen volume and associated changes in sensor output. Following compression testing, the specimen was

deconstructed, and five samples were taken to determine a representative gravimetric water content.

There were two compression tests conducted in this study in the large mold. Both tests were conducted on similarly prepared specimens to a target dry density of 1.36 g/cm^3 and target volumetric moisture content of 15%. After completing Compression Test 2, water was added incrementally to the top of the specimen to observe the sensor response as the wetting front infiltrated through the specimen. A thin, heat-bonded, non-woven geotextile was placed on top of the prepared specimen for Compression Test 2 in-place of the 4-mil plastic to allow water to infiltrate into the specimen. Water was added to the specimen surface while under the final applied load in Compression Test 2 to simulate a layer within a filtered tailings stack that is compressed from stack raising and then subjected to downward migration of liquid via gravity flow. Specimen deformation was recorded throughout the water infiltration period to correct volumetric water content and saturation calculations for comparison with predictions made via the Teros 10 sensor. At the conclusion of testing, excess water was removed from the specimen surface, total mass of the specimen and mold was measured, and samples were collected to determine the gravimetric water content.

4.6 Specimen Preparation

Specimen preparation methods were generally similar across the various tests performed. The following subsections include descriptions of specimen preparation methods employed to create the various test specimens evaluated as part of this study.

4.6.1 Moist-Tamped Specimen Preparation

Preparation of all moist-tamped specimens began by measuring a pre-determined amount of dry processed tailings and deionized water. The tailings and water were combined and sealed in plastic bags, and then thoroughly mixed within the bags until the tailings and water appeared

visibly uniform. Tailings clods were broken up during the mixing process to the extent practical. Tailings were allowed to moisture condition for at least 16 h prior to testing, which was found to be sufficient via trial and error to provide time for moisture equilibration. Tailings for small-mold specimens were moisture conditioned in two separate bags, one for the control volume and one for the cover. Tailings for the large-mold specimens were moisture conditioned in separate plastic bags for each compacted lift.

Pictures of moist-tamped specimens in the small mold and large mold are shown in Figures 11 and 12, respectively. Moisture-conditioned tailings were placed into the testing molds in loose lifts approximately 25-mm thick. Each loose lift was compacted in a relatively uniform manner prior to placing the subsequent lift. Efforts to maintain consistent compaction energy for each lift were made to the extent practical.

4.6.2 Slurry-Deposited Specimen Preparation

Preparation of all slurry-deposited test specimens began by measuring a pre-determined amount of deionized water in a clean 20-L bucket. Dry processed tailings were then gradually mixed with the deionized water using a power drill equipped with a mixing attachment. After the desired amount of dry processed tailings had been added, the slurry was blended with the mixing drill until the tailings appeared to be well dispersed and the resulting slurry visibly uniform. After mixing, the prepared tailings slurry was carefully transferred from the bucket to the small mold using a ladle or beaker. When multiple specimens were prepared from the same bucket of slurry tailings, the mixing drill was used to re-disperse the tailings immediately prior to preparation of each specimen.

Pictures of a slurry-deposited specimen prepared in the small mold are shown in Figure 13. The tailings slurry was poured into the mold until the targeted total volume line was reached. A rubber spatula was used, as needed, to ensure a relatively uniform specimen surface was created. Once the targeted total volume line had been reached and necessary mass-volume

measurements had been taken, the sensor was inserted into the specimen. Given the low strength of the slurry tailings, zip ties were used to keep the sensor in position during testing. The sensor was then covered with additional tailings slurry. Duct tape and a liberal amount of vacuum grease were used to minimize material loss and seepage from the sensor cord access slot on the side of the mold. Specimen preparation was concluded by placing plastic wrap over the top of the mold to prevent evaporation, and rubber bands were used to ensure a good seal was maintained.

4.7 Supplemental Testing

Two supplemental tests were performed to aid in developing the overall testing program: (i) zero-effective stress void ratio test and (ii) shrinkage limit test. The zero-effective stress void ratio test was used to determine an upper boundary of volumetric water content and associated dry density for slurry-deposited tailings. Specimens prepared at a higher volumetric water content and lower dry density than those determined during this test will likely not be achievable for an extended period of time because self-weight consolidation and settlement from subsequent tailings deposition would occur. Thus, slurry-deposited specimens that were eventually created for sensor calibration testing had target volumetric water contents below the upper-bound determined from the zero-effective stress void ratio test such that specimen mass and volume remained consistent throughout a given test.

The shrinkage limit test characterizes the relationship between volumetric water content and void ratio (or dry density) of a specimen starting from a slurry-deposited state and desiccating to a state that could be reasonably replicated using moist-tamped methods. The purpose of the shrinkage limit test was to aid in identifying target volumetric water contents and associated dry densities for specimens that can be achieved following slurry deposition.

4.7.1 Zero Effective Stress Void Ratio Test

Pictures of the three test specimens prepared for the zero-effective stress void ratio test are shown in Figure 14. The tailings slurry was prepared at a gravimetric water content intended to yield settlement of the solid tailings particles from suspension and development of supernatant water in each of the test specimens. Test specimens were prepared in 1,000 mL beakers and sealed with plastic wrap to prevent evaporation. The test specimens were monitored over a period of 2 d, during which the suspended solid particles in each of the specimens settled to the bottom of the beakers and supernatant water developed. Testing was terminated for a given specimen when consolidation of the settled particles under self-weight showed no visible change over a period of about 24 h.

Upon completion of apparent sediment consolidation, the supernatant water was removed from each specimen using a syringe. Care was used during removal of the supernatant water to minimize removal loss of solid particles. After removal of the supernatant, the total mass and gravimetric water content of the saturated tailings remaining in each beaker was determined. Given the known specific gravity of the tailings and assuming a density of water = 1 g/cm^3, the dry density and volumetric water content of the saturated tailings was computed. Specific details regarding data processing and the results of the zero-effective stress void ratio test are in Appendix D.

4.7.2 Shrinkage Limit Test

Pictures of prepared specimens for shrinkage limit testing are shown in Figure 15. A tailings slurry was prepared at a gravimetric water content intended to yield a relatively fluid slurry that would self-level during specimen preparation. After thorough mixing, the slurry was poured into three brass rings placed on small tin trays. A very thin layer of vacuum grease was applied to the surface of the tin trays and interior of the brass rings prior to specimen preparation to prevent the specimens from sticking to the rings or trays during shrinkage.

After the shrinkage limit test specimens were prepared, the total mass of each specimen was measured, and the specimens were left to dry in the open air via evaporation. Each of the specimens was monitored during the drying process, and periodic measurements of total mass and volume change were collected until no appreciable change in specimen total mass was observed between measurements, which indicated that desiccation under atmospheric conditions had stopped. Specimens were subsequently oven-dried to determine the mass of solid particles within each specimen, and a final measurement of the specimen volume was obtained. Given the known specific gravity of the tailings and assuming a density of water = 1 g/cm^3, the volumetric water content, dry density, void ratio, and degree of saturation were computed for each mass / volume measurement made during desiccation. Specific details regarding data processing and the results of the shrinkage limit testing are presented in Appendix D.

Table 1. Summary of testing programs conducted during this study including the test mold used, specimen preparation method, and number of tests performed for each program.

Test Program Name	Test Mold	Specimen Preparation	No. of Tests Performed
Calibration Testing	Small	Moist-tamped & Slurry-deposited	48
Accuracy Testing	Small	Moist-tamped	6
Characterization of Density Effects on Sensor Output	Small	Moist-tamped	36
Sensor Temporal Response to Variation in Water Content	Small	Moist-tamped	9
Sensor Response to Specimen Compression	Large	Moist-tamped	2
Sensor Response to Specimen Infiltration	Large	Moist-tamped	1

Table 2. Summary of testing conducted with the Teros 10 sensor, number of sensors used, number of sensor measurements averaged for a single output value, number of total output values collected per test, and approximate test duration.

Test Name	Number of Sensors Used	Number of Measurements Averaged to Produce One Reported Output	Total Number of Reported Output Values Collected Per Test	Approximate Test Run-Time
Calibration	3	100,000	≥ 1,000	8 hrs.
Accuracy	3	100,000	≥ 1,000	8 hrs.
Characterization of Density Affects	1	100,000	≥ 1,000	3 hrs.
Sensor Temporal Response to Variation in Volumetric Water Content	1	1,000	≥ 1,000 [a]	2 to 3 min.
Sensor Response to Specimen Compression	1	1,000	1,500 to >4,000 [b]	1 hr.
Sensor Response to Specimen Infiltration	1	5,000	>119,000	7 days

[a] Output reported after full sensor insertion.

[b] Number of output values reported after each load application.

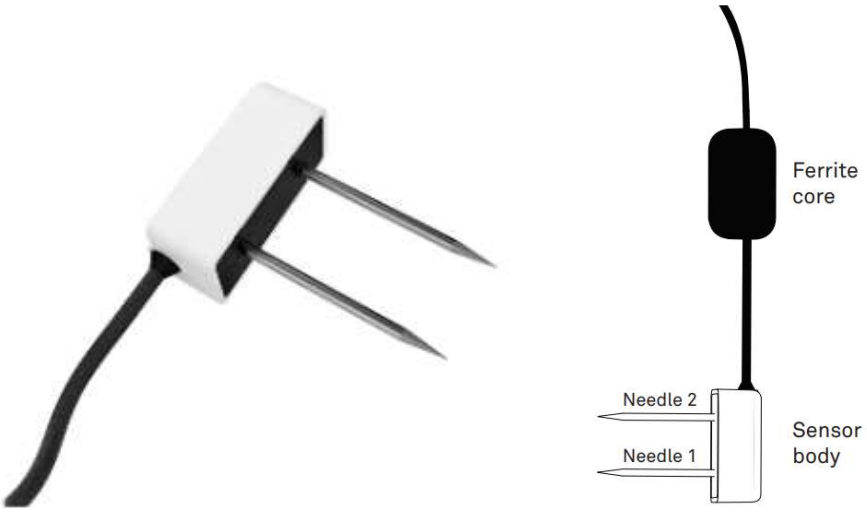


Figure 1. Picture of Teros 10 soil moisture sensor and schematic of components.

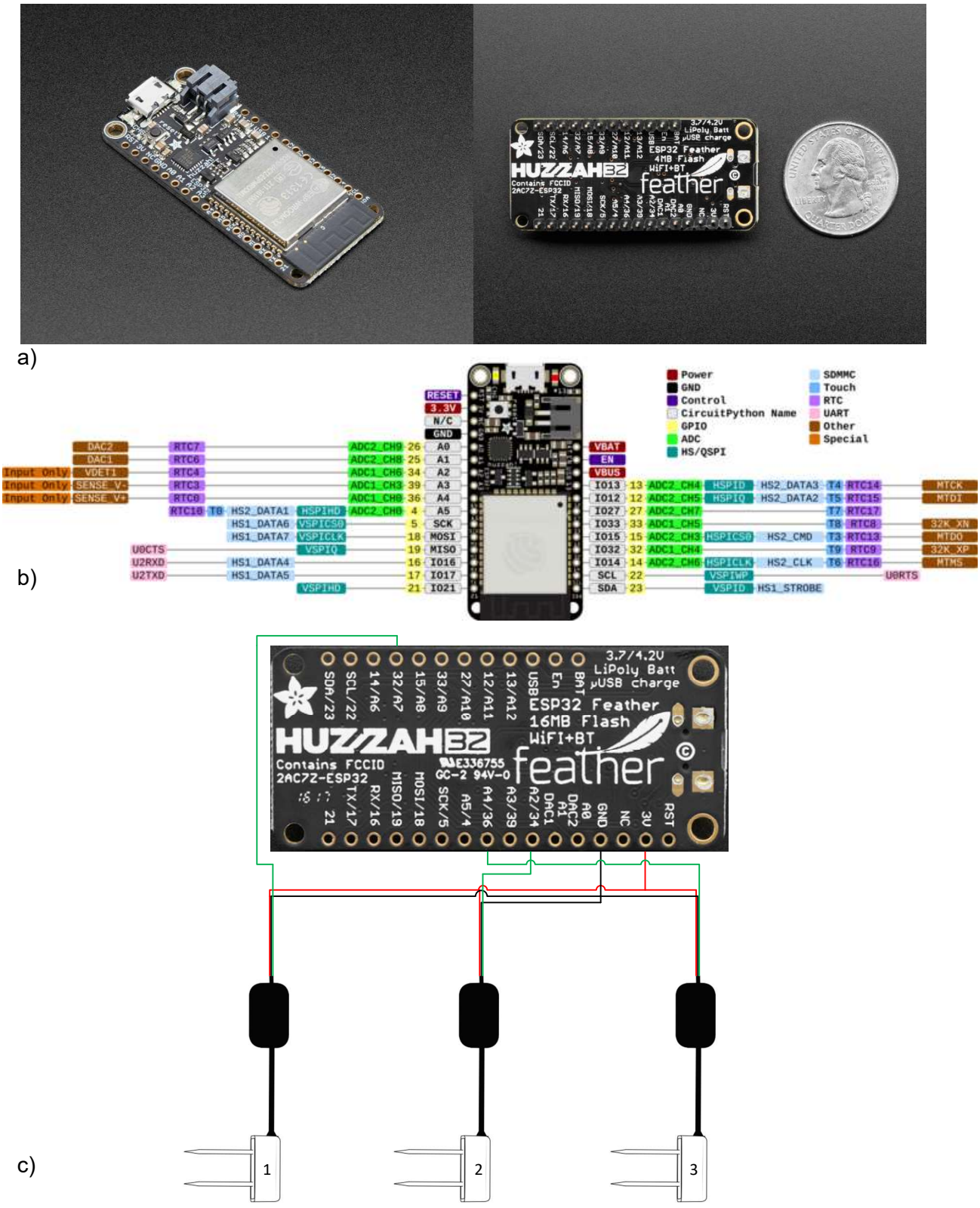
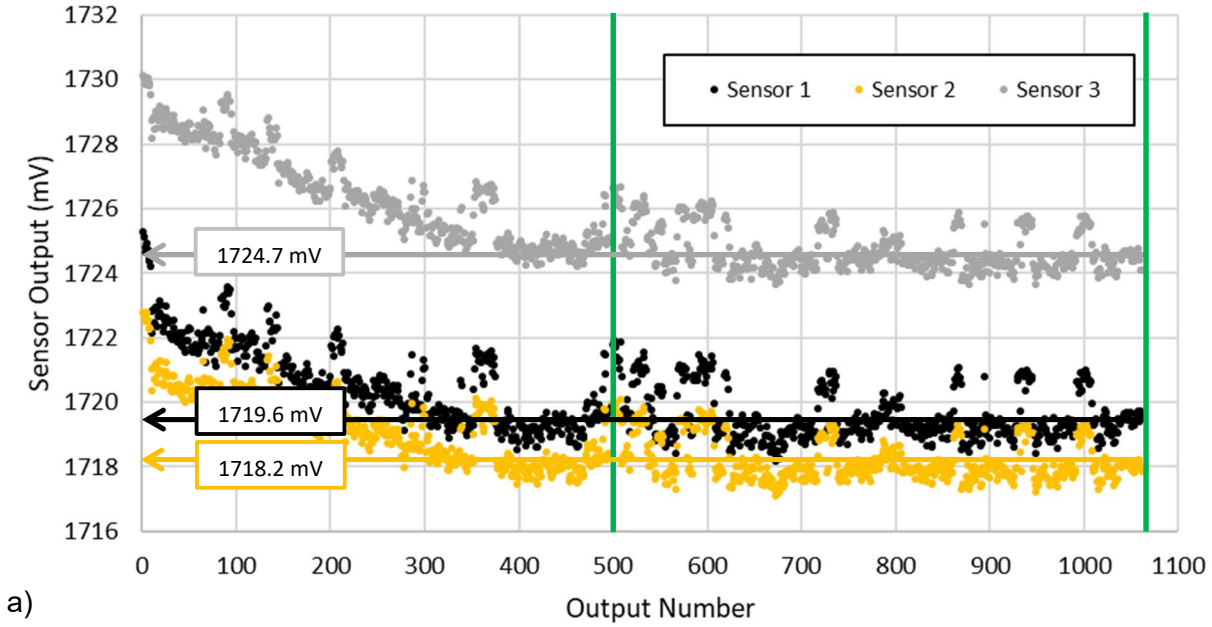
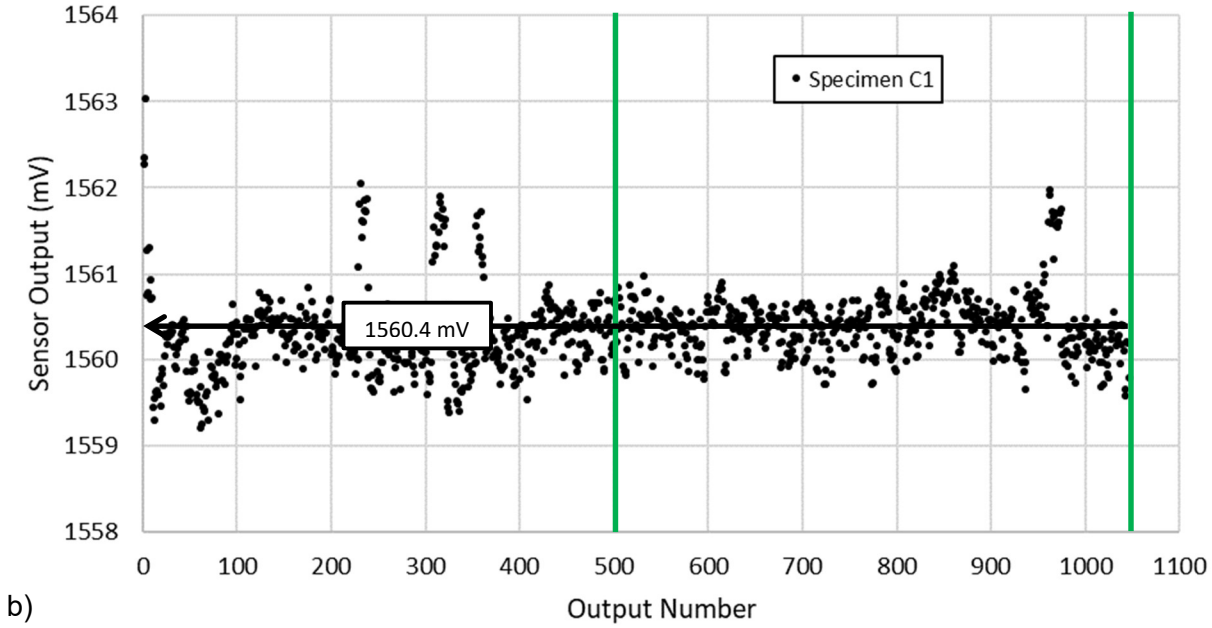


Figure 2. a) Pictures of the ESP32 Adafruit Feather micro-controller used for sensor testing. b) ESP32 Adafruit Feather micro-controller Pin-Out Diagram. c) Micro-Controller and sensor wiring sketch.

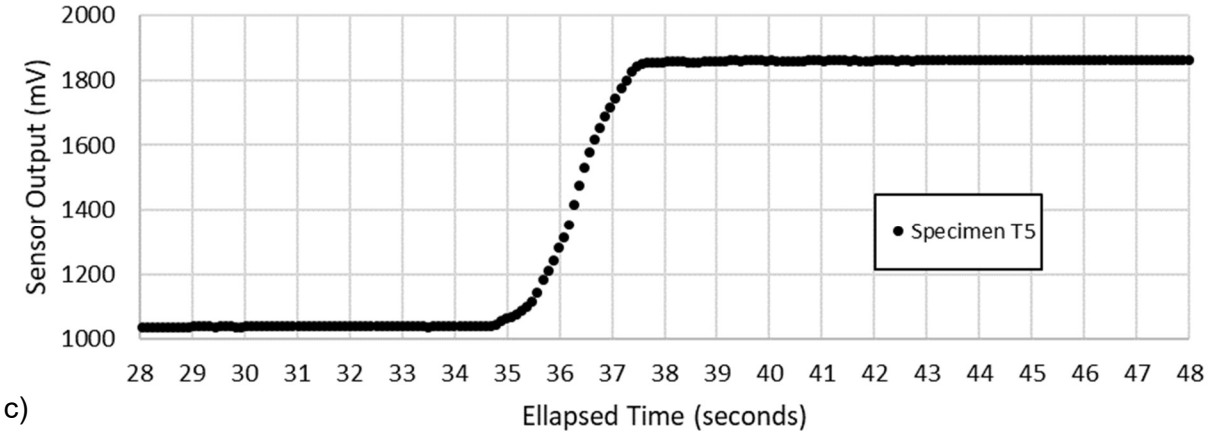


a)

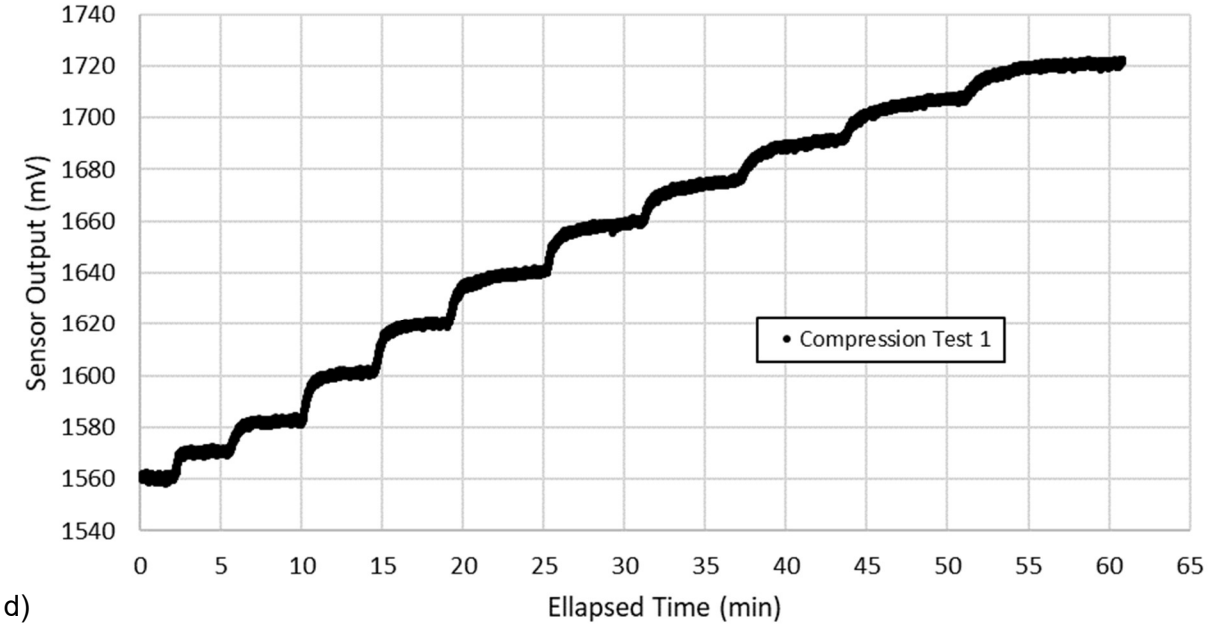


b)

Figure 3. a) Sensor data from calibration test specimen M-05. b) Sensor data from Characterization of Density Affects testing specimen C-1. c) Sensor data from Temporal Response testing specimen T5. d) Sensor data from Compression Test 1. e) Sensor data from Infiltration Test.

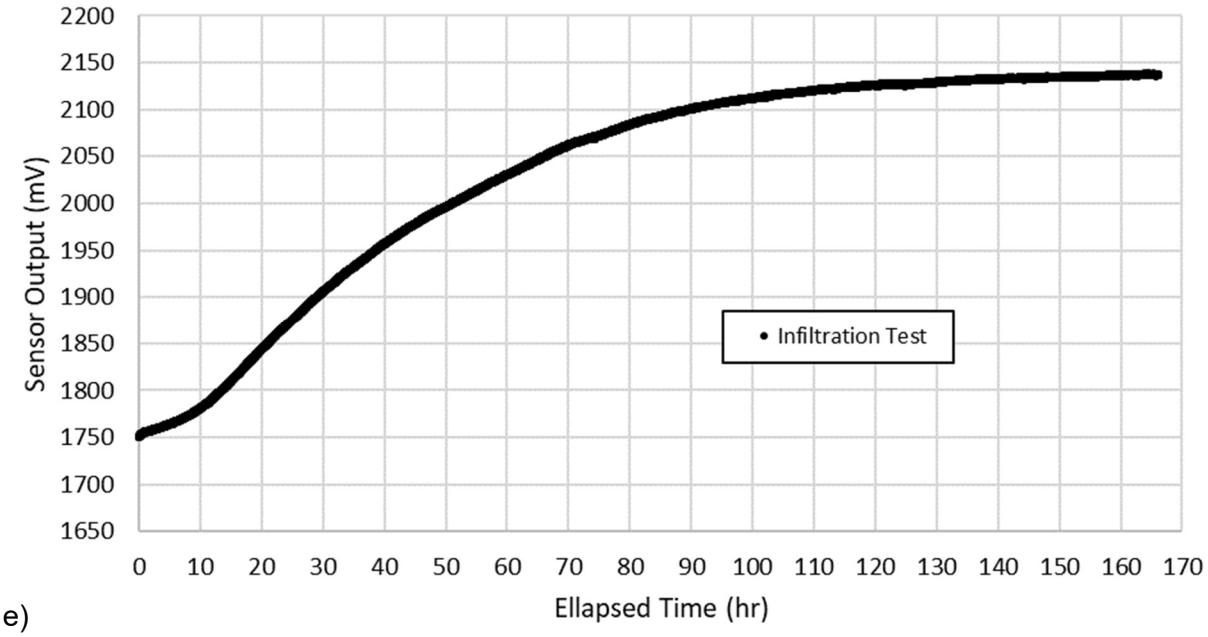


c)



d)

Figure 3 Cont. a) Sensor data from calibration test specimen M-05. b) Sensor data from Characterization of Density Affects testing specimen C-1. c) Sensor data from Temporal Response testing specimen T5. d) Sensor data from Compression Test 1. e) Sensor data from Infiltration Test.



e)

Figure 3 Cont. a) Sensor data from calibration test specimen M-05. b) Sensor data from Characterization of Density Affects testing specimen C-1. c) Sensor data from Temporal Response testing specimen T5. d) Sensor data from Compression Test 1. e) Sensor data from Infiltration Test.

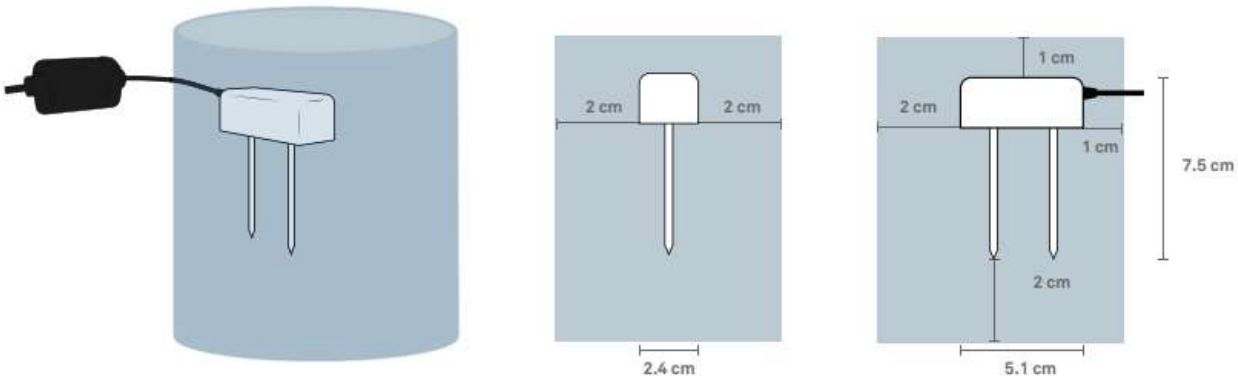
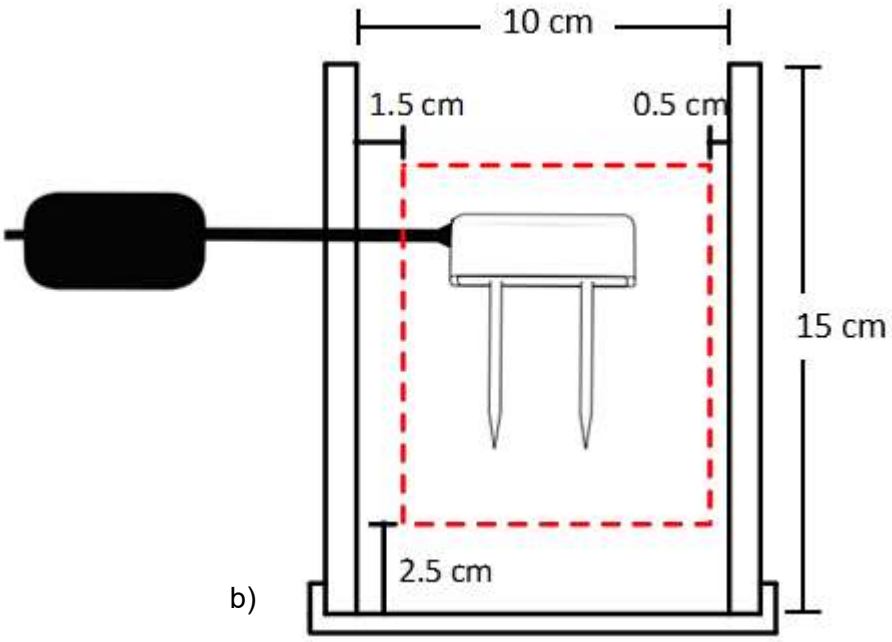


Figure 4. Teros 10 Volume of Influence (from Teros 10 User's Manual)

a)



b)

Figure 5. a) Pictures of the small mold. b) Schematic showing Teros 10 sensor volume of influence relative to small mold. Dimensions shown and scale are approximate.

a)

b)

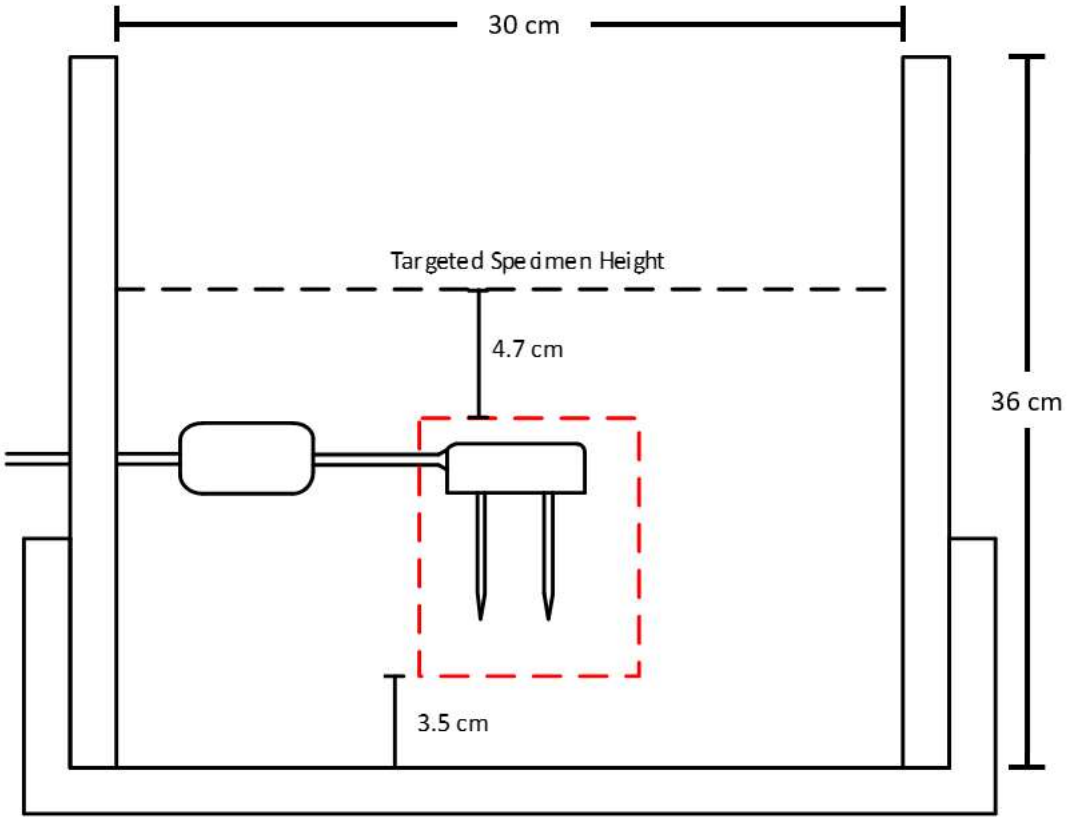


Figure 6. a) Pictures of the large mold. b) Schematic of Tero 10 sensor volume of influence relative to large mold. Dimensions shown and scale are approximate.

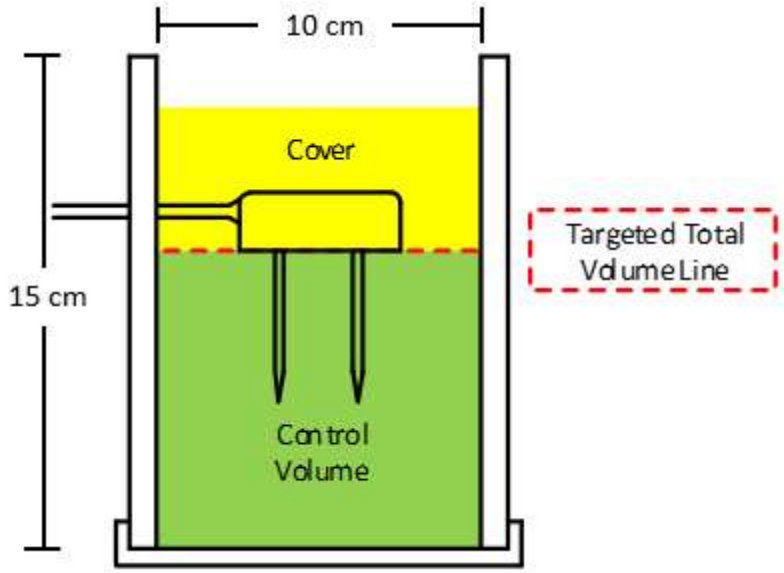


Figure 7. Cross-section of small mold depicting specimen zones.

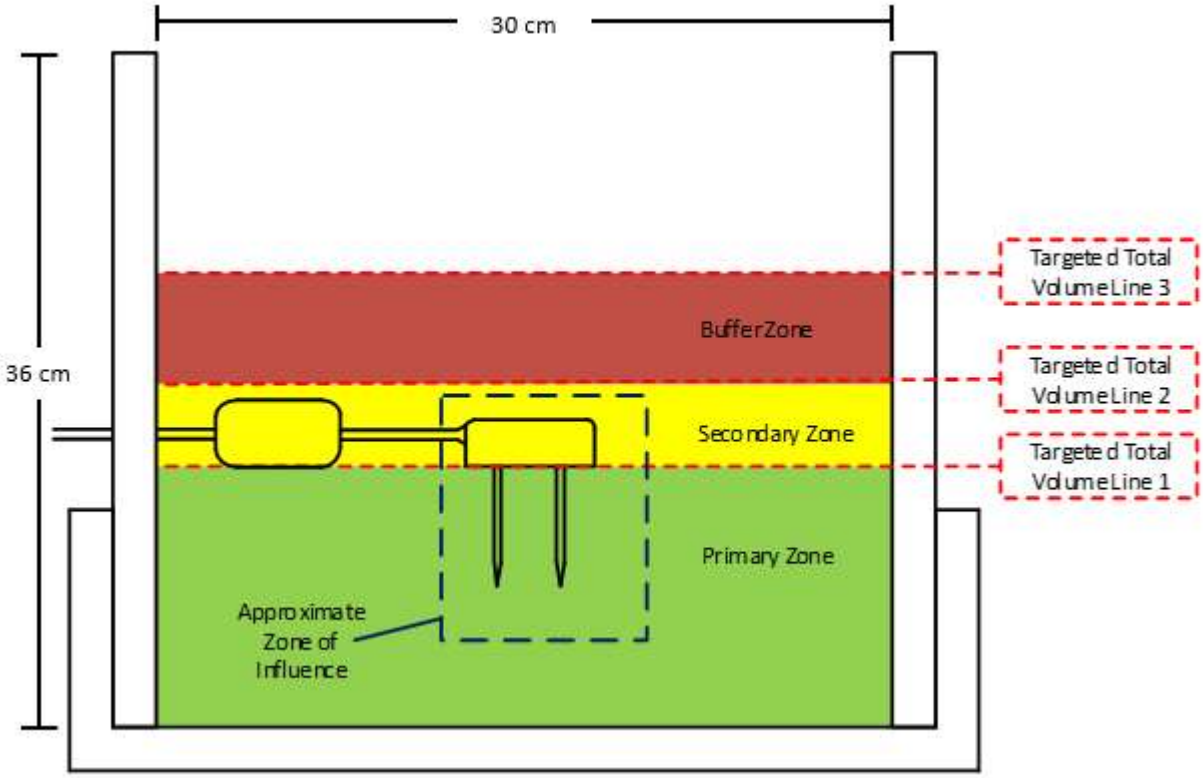


Figure 8. Cross-section of large mold depicting specimen zones.

Figure 9. Specimen constructed in large mold being prepared for compression testing.

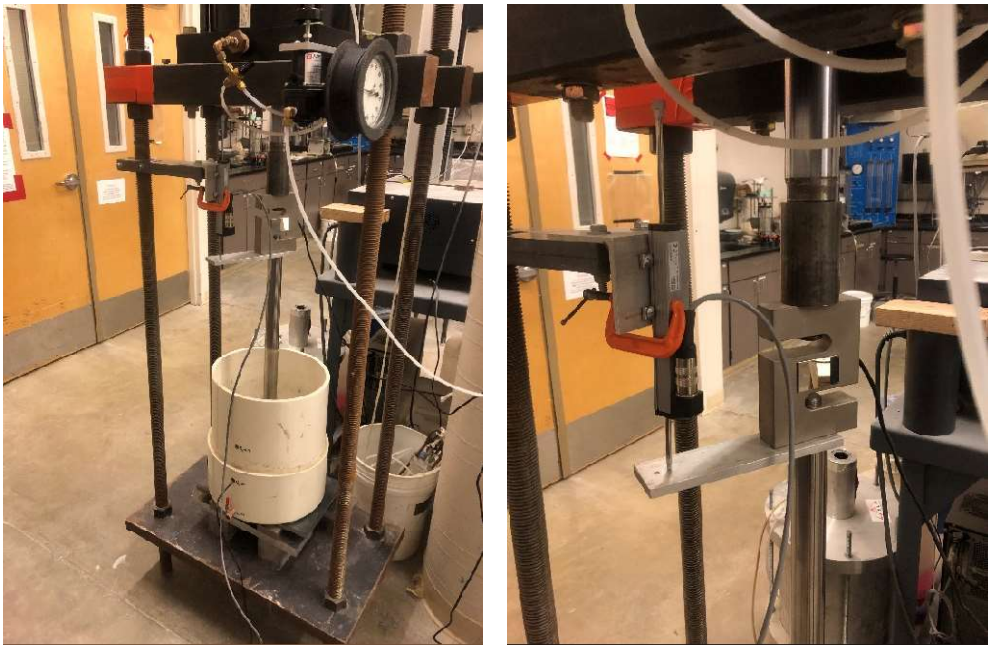


Figure10. Picture of load press with prepared specimen, load cell, and linear potentiometer.

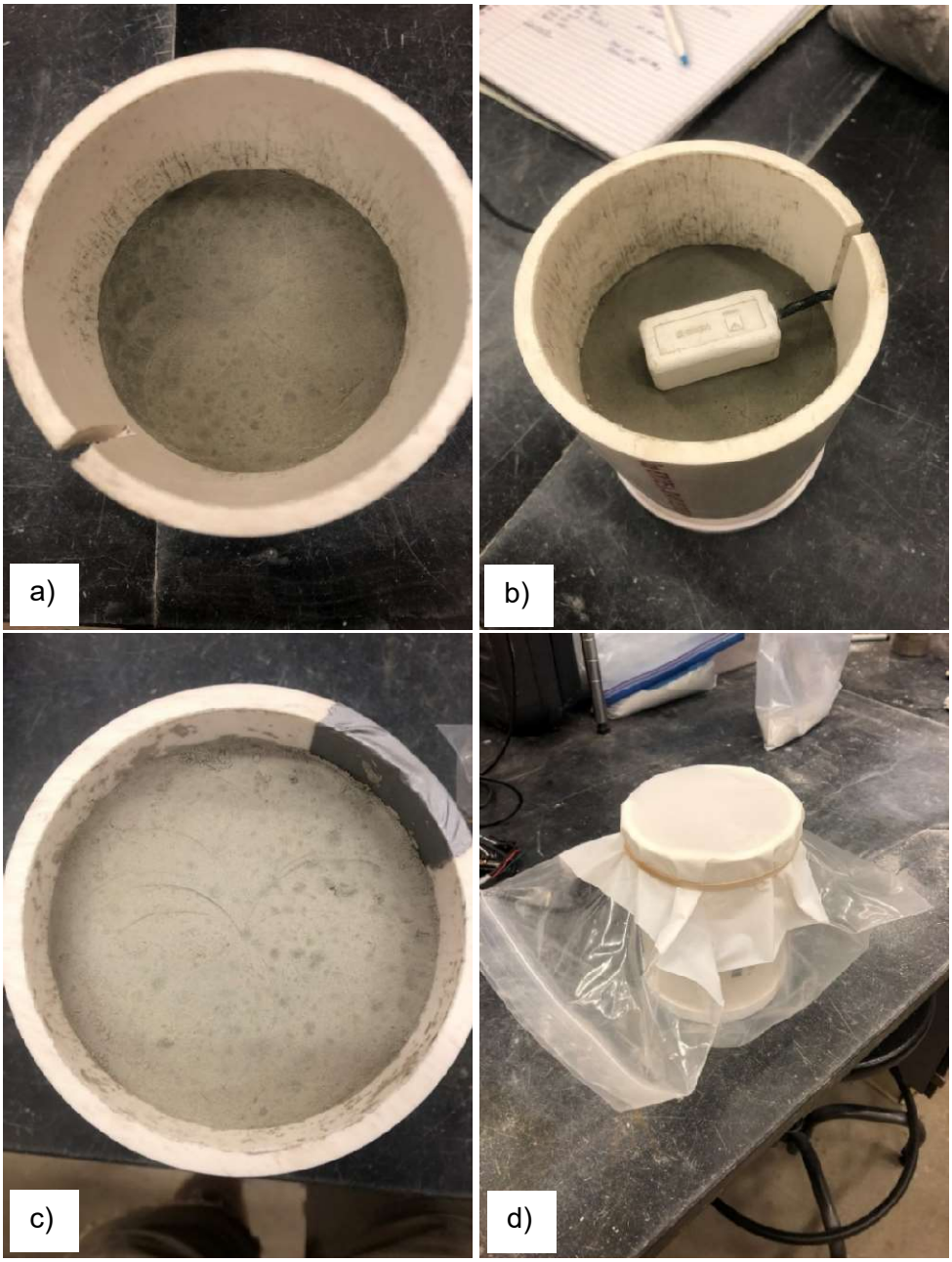


Figure 11. Moist-tamped specimen preparation in the small mold. a) Specimen control volume prior to inserting sensor. b) Specimen control volume immediately after sensor insertion. c) Specimen after cover construction. d) Specimen sealed following cover construction.

Figure 12. Moist-tamped specimen preparation in the large mold. a) Empty mold with sensor prior to specimen preparation. b) Specimen primary zone immediately prior to sensor insertion. c) Specimen primary zone immediately after sensor insertion. d) Specimen after secondary zone construction. e) Specimen after buffer zone construction.

Figure 13. Slurry-deposited specimen preparation in the small mold. a) Specimen control volume prior to inserting sensor. b) Specimen control volume immediately after sensor insertion. c) After sensor insertion, vacuum grease and duct tape are used to prevent loss of slurry. d) Specimen after cover construction. e) Specimens sealed with plastic upon completion of specimen preparation.

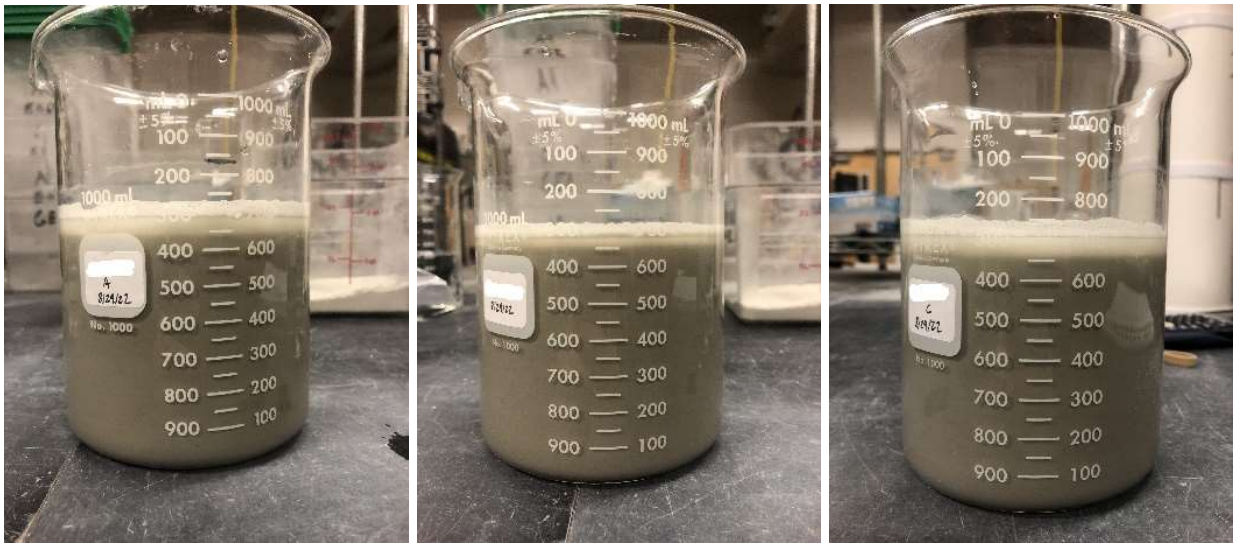


Figure 14. Specimens for Zero Effective Stress Void Ratio Test.

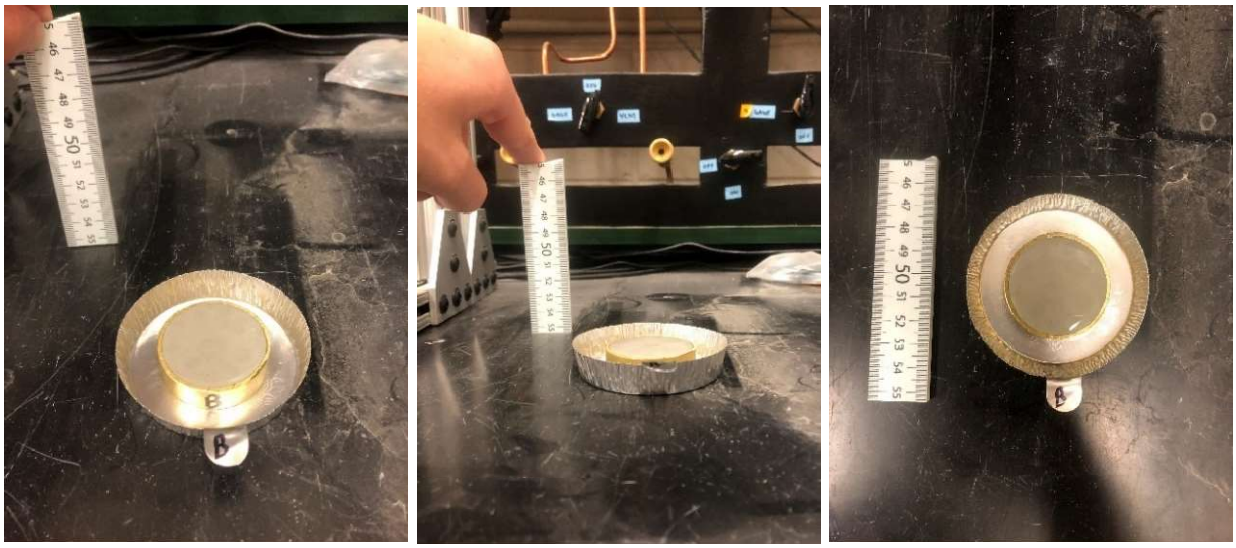


Figure 15. Slurry-deposited specimens prepared for shrinkage limit testing.

CHAPTER 5: RESULTS AND DISCUSSION

5.1 Calibration Testing

Calibration testing of the Teros 10 sensor to the mine tailings was conducted via relating raw sensor output to physical measurements of volumetric water content and degree of saturation. Moist-tamped and slurry-deposited specimens were prepared in the small mold, as described in *Specimen Preparation* and *General Sensor Testing Methodology*, to capture the full spectrum of the tailings continuum.

A summary of the target volumetric water contents and dry densities for each test performed during the calibration testing is in Table 3. Three different Teros 10 sensors were used during each calibration test to account for potential variations between sensors. Thus, three separate test specimens were prepared for each target volumetric water content and associated dry density.

Volumetric water content, degree of saturation, and dry density for each test specimen were determined at the end of the tests. A summary of the relevant values obtained from a specific calibration test is in Table 4. Collection and processing of sensor output was performed as described under the *Teros 10 Soil Moisture Sensor* section above. Detailed data processing for all calibration tests is included in Appendix D.

Relationships between volumetric water content and degree of saturation versus sensor output in millivolts for each specimen tested during the calibration process of the Teros 10 sensor are shown in Figure 16. The calibration equations developed for volumetric water content and degree of saturation are included in the figures. Calibration equations for volumetric water content and degree of saturation were fit to each data set using the curve-fitting app in MatLab.

A third-order polynomial was used for the volumetric water content calibration curve, which is consistent with the calibration curve developed by METER Group (i.e., Teros 10 manufacturer) as well as other studies on electromagnetic sensors (Bhuyan et al., 2020; Kanso et al., 2020;

Narayanan & Sathian, 2021; Topp et al., 1980). The degree of saturation calibration curve is a linear relationship. Further details regarding the accuracy and sensitivity of each calibration are presented in subsequent sections.

The METER Group calibration curve, shown in Figure 16a, to convert millivolt sensor output to volumetric water content was developed for use in mineral soils via calibration testing on a wide variety of soil types. Therefore, the calibration is considered general and may not provide the desired level of accuracy for site specific applications (e.g., mine tailings applications). In the case of the mine tailings evaluated herein, the mineral soils calibration curve overpredicts volumetric water content for a given sensor output. Overpredictions of volumetric water content when using the mineral soils calibration curve ranged from 5.7% to 12.3%. Similar errors were reported by Narayanan and Sathian (2021) when using the manufacturer calibration on laterite soils, and Landim et al. (2023) reported an overprediction of approximately 20% when using the manufacturer calibration on iron ore tailings. The METER Group does not provide a general calibration to degree of saturation for the Teros 10 sensor.

Results of the calibration testing indicated that two distinctly different sensor outputs can be measured for a given volumetric water content depending on the dry density of a prepared specimen. Relationships between volumetric water content and degree of saturation versus sensor output in millivolts for test specimens prepared to a volumetric water content of approximately 16% are shown in Figure 17. The two sets of specimens have essentially equivalent volumetric water contents; however, the sensor produces a higher millivolt output for specimens prepared at a greater dry density. Landim et al. (2023) also noted an increase in raw sensor output for specimens prepared at higher dry densities, and Narayanan and Sathian (2021) concluded that sensor accuracy when predicting volumetric water content is affected by dry density of the surrounding medium. In contrast, the degree of saturation calibration appears unaffected by variations in dry density, particularly at lower degrees of saturation. The change in sensor output resulting from varying dry density was attributed to a change in the volumetric

proportions of the air, water, and solid particles surrounding the sensor, which in turn changes the average dielectric permittivity of the specimen. The effects of variations in dry density on sensor behavior are discussed further in *Characterization of Density Affects*.

Sensor calibration testing required preparation of tailings specimens over a broad range of densities and volumetric water contents (e.g., Figure 16). Examples of loosely compacted (i.e., low density) specimens at volumetric water contents of 25% to 30% are shown in Figure 18 and display a porous macro-structure observed in some of the test specimens. The compaction energy required to achieve certain target dry densities was insufficient to fully remold the tailings clods. Consequently, for a given dry density, specimens exhibited a porous macro-structure as the volumetric water content was increased. The observed porous macro-structure was deemed non-representative of field conditions because (i) equipment used to compact filtered tailings remolds tailings clods via kneading action and/or higher compaction energy and (ii) slurry deposited tailings would not produce a clod-like structure. Therefore, the calibration tests targeting dry densities of 1.44 g/cm^3 and 1.60 g/cm^3 were terminated at target volumetric water contents of 25% and 30%, respectively, due to the porous macro-structure.

Modified calibration curves were developed after excluding data points obtained from specimens exhibiting a porous macro-structure to evaluate the influence of the structure on the calibrations. The modified calibration curves with the excluded data points highlighted are shown in Figure 19. The modified calibration equations developed for volumetric water content and degree of saturation are also included in the figures.

When compared to the calibrations developed using the full data set, the modified calibrations yielded a negligible difference in predicted volumetric water content and degree of saturation. The predicted volumetric water content varied by ≤ 1%, and the predicted degree of saturation varied between 0.2% and 2.5%. The negligible variation observed between the modified and full-data calibrations was due, in part, to the robust amount of test specimens prepared during calibration testing. If a calibration were performed using only several data points,

specimens exhibiting a porous macro-structure could have a more pronounced effect on sensor calibration. In light of the minimal impact on the sensor calibrations, conversions of sensor output to volumetric water content and degree of saturation for all subsequent analyses were based on calibration curves developed using the full set of data points (see Figure 16).

5.2 Accuracy Testing

Testing was conducted to determine the accuracy of the calibration curve. A total of six moist-tamped specimens were prepared in the small mold to different gravimetric water contents ranging between 5% and 20%. Compaction energy was varied between specimens and final mass and volume measurements used to compute volumetric water content and dry density. All three of the Teros 10 sensors were used during testing to account for variations that can occur between sensors. Measured volumetric water content and degree of saturation of each specimen were compared to predicted values computed from representative raw sensor output for each test. Data processing for all accuracy testing is included in Appendix D.

Results of the accuracy testing performed using the Teros 10 sensor are presented in Figure 20 and summarized in Table 5. Residual values (i.e., predicted minus measured) of volumetric water content and degree of saturation are presented on the second y-axis of each plot. Predicted volumetric water contents had an average error of +0.2% and a standard deviation of 1.5% which is consistent with electromagnetic sensor performances achieved during previous studies (Narayanan & Sathian, 2021, Wyoshner, 1992). Predicted degrees of saturation had an average error of -1.8% and a standard deviation of 4.7%. There was no bias observed in the volumetric water content predictions (Figure 20a); however, the two highest degrees of saturation were underpredicted by approximately 8% (Figure 20b). Additional data points at the high range of saturation would help to further evaluate bias and accuracy with the calibration equations.

5.3 Characterization of Density Affects

Mine tailings in a tailings facility, whether in the embankment or impoundment, can have spatial and temporal variation in dry density. As shown in Figure 17, variation in specimen dry density can produce distinctly different sensor output for a given volumetric water content. Previous studies using electromagnetic sensors have also concluded that variations in dry density do effect sensor output and the accuracy of sensor-predicted volumetric water content to some degree (Landim et al., 2023; Narayanan & Sathian, 2021). A general understanding of the dielectric permittivity of porous media and sensor function can help explain the sensor behavior. Porous media, such as tailings, can be separated into air, water, and solid phases, whereby each has a unique dielectric permittivity. The Teros 10 sensor output is representative of the weighted average dielectric permittivity of the three phases occupying the total volume of influence of the sensor. Therefore, the sensor output is unique to a specific combination of air, water, and solid particles present within the volume of influence. If the volumetric proportions of the three phases change within the sensor volume of influence, the weighted average dielectric permittivity will also change and yield a different sensor output.

For the purpose of discussion, sketches of two specimens prepared at the same volumetric water content but different dry densities are shown in Figure 21. An increase in specimen dry density is reflected by an increase in solid particle volume and an equivalent decrease in air volume within the total volume. The dielectric permittivity of granite, for example, ranges from about 7 to 9, and the dielectric permittivity of air is 1 (Noborio, 2001). Consequently, increasing dry density produces an increase in the weighted average dielectric permittivity, and even though the two specimens have the same volumetric water content, they will have unique sensor outputs (Figure 17).

The effect of varying dry density on sensor output was evaluated using moist-tamped specimens prepared in the small mold. A summary of volumetric water content, degree of saturation, and dry density targeted for each test is in Table 6. A broad range of dry density was targeted for each volumetric water content. All testing was conducted using a single Teros 10

sensor. All data processing for the characterization of density affects testing is included in Appendix D.

Relationships between sensor output and specimen dry density for target volumetric water contents of 15%, 20%, and 25% are shown in Figure 22. For a given volumetric water content, a linear increase in sensor output was observed with increasing dry density. Furthermore, the slope between sensor output and dry density was generally consistent for the three volumetric water contents evaluated. The behavior suggests the change in sensor output resulting from a change in dry density is constant and independent of volumetric water content. Therefore, sensor prediction of volumetric water content should exhibit consistent sensitivity to dry density regardless of actual volumetric water content.

The relationship between sensor output and dry density for tailings specimens prepared to target degrees of saturation of 30%, 45%, and 60% are shown in Figure 23. For a given degree of saturation, the relationship between sensor output and dry density can also be characterized as linear. Specimens prepared at a degree of saturation of 30% exhibited negligible change in sensor output for the range of dry density. As the degree of saturation increased, the slope of the linear relationship between sensor output and dry density decreased (slope shown as *m* in Figure 23).

The results in Figure 23 suggest that changes in dry density have a more pronounced effect on sensor output for a given degree of saturation as saturation increases. At a lower degree of saturation (e.g., 30%), variations in dry density had little effect on sensor output. Therefore, sensor prediction of saturation would be unaffected by changes in dry density at low degrees of saturation. However, at higher degrees of saturation, variations in dry density had a more pronounced effect on sensor output, thus making sensor prediction of saturation more sensitive to changes in dry density at elevated saturation levels. To better explain the sensor behavior resulting from changes in dry density for a given value of volumetric water content or degree of

saturation, an exercise was conducted using hypothetical, idealized specimens. The results of this exercise and additional discussion regarding sensor behavior are included in Appendix E.

One-to-one plots of predicted (via equations in Figure 16) versus measured volumetric water content and degree of saturation are shown in Figure 24. Understanding the effect of variations in dry density on sensor output provides insight into potential errors in predicted volumetric water content and degree of saturation. When using the sensor in a field application to estimate volumetric water content or degree of saturation, the potential error due to variations in dry density would depend, in part, on the range of anticipated dry densities throughout the duration of the project. A wider variation in dry density would yield greater potential error in predicted values of volumetric water content and degree of saturation. For all three volumetric water contents tested, the dry density of the specimens varied by about 0.32 g/cm^3, resulting in approximately 3% to 5% variation in predicted volumetric water content. Specimens prepared at 30% saturation varied in dry density by approximately 0.32 g/cm^3, and the predicted degree of saturation varied less than 1%. Specimens prepared at 60% saturation had a smaller variation in dry density of approximately 0.24 g/cm^3, and the predicted degree of saturation varied by approximately 10%.

5.4 Sensor Temporal Response to Variations in Volumetric Water Content

An important consideration of a sensor used to predict volumetric water content and/or saturation in a tailings facility is the sensor response time to changes in moisture. For example, a relevant application of electromagnetic sensor would be integration in a cone penetration test (CPT) such that a continuous profile of volumetric water content and/or saturation with depth in a tailings facility could be developed. Integrating an electromagnetic sensor in a CPT would be worthwhile if the sensor could rapidly equilibrate to the moisture regime in the zone of influence as the cone penetrated the subsurface.

Probe insertion tests were conducted to evaluate the temporal signal response and measurement equilibration of the electromagnetic sensor. The testing was conducted using a

single Teros 10 sensor and data processing for these tests are included in Appendix D. Nine moist-tamped specimens were prepared in the small mold to target dry densities ranging from 1.52 g/cm^3 to 1.68 g/cm^3 and target volumetric water contents ranging from 5% to 30%. Each test was conducted by inserting the sensor into the specimens and recording sensor output before, during, and after insertion to evaluate the speed at which the sensor responded. Sensor insertion times were measured using a stopwatch and varied from 1.6 to 4.0 s. The temporal assessment of sensor output combined with approximate sensor insertion times yielded an understanding of the sensor response time to variations in volumetric water and degree of saturation. One caveat in the probe insertion tests was that the sensor was not covered with tailings following insertion.

Results from the probe insertion tests are presented in Table 7 and in Figure 25. The elapsed time between stable sensor output reported before and after insertion and the rate of change in sensor output during insertion are indicative of the sensor response time to variations in volumetric water content and degree of saturation. The approximate sensor insertion time was essentially equivalent to the sensor response time reported by the micro-controller, indicating an immediate sensor response with insertion into the tailings. For example, Specimens T5 and T8 in Figure 25c were inserted at different rates into specimens prepared at the same volumetric water content and dry density. The sensors equilibrate at the same millivolt output, but at different elapsed times consistent with the different rates of insertion (Table 7).

The observed sensor behavior suggests the sensor can respond to changes in volumetric water content and degree of saturation at rates similar to the rate of insertion during testing. Based on the approximate insertion times and the length of the sensor wave guides, the maximum rate of insertion was approximately 27 mm/s. The standard of practice for CPT recommends a piezocone be pushed at a constant rate of 20 mm/s (Robertson et al., 2015). Therefore, results from the sensor insertion testing indicate an electromagnetic sensor incorporated into a CPT application should be able to respond to variations in volumetric water content and degree of saturation quickly enough to provide a near continuous profile of the moisture regime. The micro-

controller used during testing could be programed to report sensor output at an even faster rate by reducing the number of measurements averaged to produce one reported sensor output.

5.5 Sensor Response to Specimen Compression

Tailings deposited within an impoundment increase the vertical stress on the underlying tailings, which produces compression and/or consolidation over time. Filtered tailings are initially placed and compacted in an unsaturated state, and if compressed, would experience an increase in degree of saturation. The sensor response to specimen compression was evaluated to simulate the behavior of stacked filtered tailings and observe the ability of the sensor to predict volumetric water content and degree of saturation under such conditions. Two experiments were conducted on moist-tamped specimens prepared in the large mold to a target dry density 1.36 g/cm^3, which is approximately 80% Standard Proctor maximum dry density. The specimens were prepared at a target volumetric water content of 15%.

A summary of the applied loading schedule during compression testing for each specimen is shown in Table 8. A single load application was intended to simulate placement of approximately 4 m of filtered tailings compacted at optimum water content and 80% of maximum dry density (Standard effort). Each applied load was maintained long enough to allow for immediate deformation to reach apparent completion before the subsequent load was applied. Temporal trends of volumetric water content and degree of saturation for the two compression experiments (Test 1 and Test 2) are shown in Figure 26. Sensor output and vertical deformation of the specimen were recorded continuously during load application. The sequential stepped increase in volumetric water content and degree of saturation observed in Figure 26 was identical to the temporal compression behavior (data not shown). Data processing for compression tests is included in Appendix D.

The volumetric water content and degree of saturation predicted by the Teros 10 sensor (i.e., Predicted in Figure 26) were compared to actual values determined from direct measurement

of specimen volume based on continuously recorded deformation. Calculations of actual volumetric water content and degree of saturation (i.e., Measured in Figure 26) assumed specimens experienced no loss of solid particles or water during compression. Additionally, positive pore water pressure was assumed to not develop based on the final degree of saturation of the specimen.

The standard deviation shown in Figure 26 was determined via the accuracy testing discussed previously. Throughout the compression process, the volumetric water content and degree of saturation predicted by the sensor remained within one standard deviation of the measured value, except for the predicted saturation for Test 2 during the first four load applications. The greater error in predicted saturation during Test 2 was believed to be due to density heterogeneity within the specimen created during specimen preparation. During specimen preparation for Test 2, the primary zone and/or secondary zone of the specimen (Figure 8), which encompass the sensor volume of influence, may have been prepared at a greater dry density than the buffer zone. This heterogeneity within the specimen would have resulted in a higher degree of saturation within the sensor volume of influence as compared to the overall average saturation determined from mass-volume measurements. Any density heterogeneity within the specimen would be reduced during compression and should reduce the error in sensor predictions as each subsequent load is applied. The test results generally appear to reflect this trend.

The sensor behavior observed during testing suggests the sensor responds timely to changes in volumetric water content and degree of saturation induced by compression of the surrounding tailings, and a reasonable degree of accuracy was observed throughout specimen compression. The behavior observed in the predicted saturation for Test 2 highlights an important consideration for the use of sensor networks incorporated in a tailings facility. The sensor volume of influence is relatively small, and when compared to the scale of a tailings impoundment, each sensor in a network would provide an isolated point value of predicted saturation at any given

time. Potential heterogeneity in volumetric water content or saturation that exists between sensor volumes of influence will not be detected. Consequently, the stratified nature of conventional tailings facilities and the presence of thin layers of tailings with unique particle size distributions (e.g., layered slimes in sandy tailings) present a potential shortcoming for a sensor network. Reducing the spacing of sensors and/or staggering sensor elevations within a sensor network could reduce the likelihood of undetected and/or uncertain zones of saturation within a tailings impoundment.

5.6 Sensor Response to Specimen Infiltration

During the lifetime of any tailings facility, impounded tailings will be subject to some degree of variation in moisture due to drain down, desiccation, and/or infiltration. Unsaturated tailings may experience an increase in saturation and become re-saturated, which is important to geotechnical and geochemical stability throughout the life of a facility. Data collected during previous studies have shown that electromagnetic sensors embedded in existing tailings facilities or in columns of tailings can capture variations in volumetric water content and respond accordingly to desiccation or surface water infiltration from precipitation (Basson et al., 2021; Cheong et al., 2012; Garino Libardi et al., 2022). However, these studies did not focus on the accuracy of electromagnetic sensors to respond to such conditions. An infiltration test was conducted in the large mold on the specimen from Compression Test 2 at the end of compression to simulate a potential wetting event and observe the accuracy of sensor response to surface water infiltration.

Water was poured on the surface of the compressed specimen in four daily increments of approximately 600 mL, and the specimen remained under the final applied stress during infiltration. Sensor output was recorded throughout the wetting process and the test concluded when the signal showed negligible change for 24 h, which occurred about 4 d after the final water application.

Temporal trends of predicted volumetric water content and degree of saturation (Figure 16) during the infiltration test are shown in Figure 27. The initial volumetric water content and degree of saturation computed based on mass and volume at the end of compression, and final volumetric water content and degree of saturation based on end-of-test measurements on exhumed samples are also shown in Figure 27. Due to uncertainty in the amount of water that infiltrated into the specimen, continuous direct calculation of volumetric water content and degree of saturation during testing was not possible. Therefore, the accuracy of the sensor response to specimen infiltration was only evaluated by comparing sensor predictions to the measurements at the beginning and conclusion of the infiltration test. Data processing for infiltration testing is included in Appendix D.

Results from infiltration testing indicate the calibration for degree of saturation performed well, and the saturation predicted by the sensor was generally within about one standard deviation of the direct measurement. However, the calibration for volumetric water content produced an over-prediction of about 8.3% at the completion of infiltration. The discrepancy in volumetric water content could be due, in part, to the higher dry density of the specimen at the end of infiltration when compared to the dry densities of specimens prepared for sensor calibration. The average dry density of moist-tamped specimens prepared during calibration testing was 1.55 g/cm^3, and at completion of infiltration testing, the dry density of the specimen was 1.75 g/cm^3. As discussed previously, an increase in dry density increases sensor output for a given volumetric water content.

A correction for density effects was applied to reduce the error in predicted volumetric water content. The following equation was developed based on results of the *Characterization of Density Affects* to correct the raw sensor output:

$$mV_{corrected} = mV_{raw} - m_{avg.}(\rho_i - \rho_{avg.}) \quad (1)$$

where $mV_{corrected}$ = sensor output corrected for dry density, mV_{raw} = raw (uncorrected) sensor output, $m_{avg.}$= average slope of line relating dry density to sensor output for a given volumetric water content (see Figure 22), ρ_i = specimen dry density during testing, and $\rho_{avg.}$ = average dry density of all moist-tamped specimens prepared during sensor calibration. The corrected sensor output was then used to predict the volumetric water content based on the calibration equation developed during this study (Figure 16).

The calibration equation for volumetric water content is assumed to be representative of the average dry density of the moist-tamped specimens prepared during the calibration process. If the specimen dry density at a given point in time during infiltration is known, the specimen density state relative to the average dry density of specimens during calibration can be determined. The relationship between the change in specimen dry density and resulting change in sensor output for a given volumetric water content (represented by the variable *m* in Figure 22) can be used in conjunction with the relative density state of the specimen to approximate an increase or decrease in sensor millivolt output due to variations in dry density at a given volumetric water content. Test results presented in Figure 22 and the exercise conducted in Appendix E, suggest *m* is consistent regardless of volumetric water content provided the specimen remains unsaturated. Therefore, the average value of *m* for the three volumetric water contents tested during the *Characterization of Density Affects* was used along with the relative specimen density state to correct the sensor output.

The temporal trend of the predicted volumetric water content during the infiltration test is reproduced in Figure 28 along with the prediction that incorporates the density-corrected sensor output. The applied correction reduced the error by 4.5%, which corresponded to a final error of 3.8% between predicted and measured volumetric water content at the completion of infiltration. The remaining error in the sensor prediction of volumetric water content could be due partly to heterogeneity within the specimen. Additionally, preparing all moist-tamped specimens at the

same target dry density during calibration testing could help to further improve the correction to sensor output because this would reduce uncertainty in specimen density state relative to the average specimen dry density during calibration.

The gradual and steady change in predicted volumetric water content and degree of saturation during infiltration suggests the sensor response was likely similar to the rate of moisture infiltration. However, the accuracy of the sensor predictions at intermediate points during specimen infiltration is unknown, and more sophistication and control in the approach and equipment used during testing would be required to more appropriately assess temporal accuracy of the sensor to infiltration. The advantage of knowing the accuracy of the sensor at intermediate points during specimen infiltration would depend on the intended application of the sensor in the field.

Table 3. Summary of test specimens prepared during calibration testing including the targeted dry density and volumetric water content of each test specimen.

Targeted Dry Density	Targeted Volumetric Water Content										
	0%	5%	10%	15%	20%	25%	30%	35%	40%	50%	60%
1.44 g/cm^3	3	3	3	3	3	3					
1.60 g/cm^3		3	3	3	3	3	3				
1.68 g/cm^3								3			
1.76 g/cm^3									3		
N/A										3	3
Method of Preparation	Moist-Tamped									Slurry-Deposited	

Table 4. Summary of processed values obtained from a single calibration test, including representative sensor output values and specimen mass-volume properties determined from direct measurement for Calibration Test M-05.

Value	Specimen A	Specimen B	Specimen C
Representative Raw Sensor Output	1719.56 mV (Sensor 1)	1718.18 mV (Sensor 2)	1724.69 mV (Sensor 3)
Volumetric Water Content [a]	20.4%	20.5%	20.7%
Degree of Saturation [a]	43.9%	44.8%	44.9%
Dry Density [a]	1.46 g/cm^3	1.47 g/cm^3	1.47 g/cm^3

[a] Determined from specimen mass and volume measurement

Table 5. Summary of results from accuracy testing.

Test No.	Average Raw Sensor Output (mV)	Volumetric Water Content (%)			Degree of Saturation (%)			Dry Density (g/cm^3)
		Predicted	Measured	Error	Predicted	Measured	Error	
1	1326.94	7.9	7.0	0.9	14.5	15.4	-0.9	1.48
2	1515.41	13.3	12.5	0.9	29.9	29.0	0.9	1.55
3	1588.28	14.9	15.9	-1.0	35.9	33.0	2.9	1.41
4	1817.07	20.2	22.6	-2.4	54.7	51.9	2.7	1.54
5	2094.77	32.8	30.8	1.9	77.4	85.2	-7.8	1.74
6	2119.08	34.5	33.5	1.0	79.4	88.0	-8.6	1.69

Table 6. Summary of test specimens prepared during characterization of density affects testing including the targeted dry density and volumetric water content or degree of saturation of each test specimen.

Volumetric Water Content or Degree of Saturation	Targeted Dry Density					
	1.36 g/cm^3	1.44 g/cm^3	1.52 g/cm^3	1.60 g/cm^3	1.68 g/cm^3	1.76 g/cm^3
θ = 15%	1	1	1	1	1	
θ = 20%		1	1	1	1	1
θ = 25%		1	1	1	1	1
S = 30%	1	1	1	1	1	
S = 45%		2	2	2	2	
S = 60%			2	2	2	2

Table 7. Summary of test results from evaluation of sensor temporal response to variations in volumetric water content.

Specimen ID	Target Volumetric Water Content (%)	Target Dry Density (g/cm^3)	Approximate Sensor Insertion Time (sec.)	Approximate Sensor Response Time (sec.)	Approximate Sensor Insertion Rate[b] (cm/s)
T1	5	1.44	3	2.9	1.4
T2	10	1.52	4	3	1.1
T3	15	1.52	4	3.2	1.1
T4	20	1.52	2	2.1	2.2
T5	25	1.60	3	2.6	1.4
T6	30	1.68	3	2.7	1.4
T7	20	1.52	2.1[a]	1.8	2.0
T8	25	1.60	1.6[a]	1.4	2.7
T9	30	1.68	1.6[a]	1.3	2.7

[a] Sensor insertion time recorded by an additional person operating a stopwatch.

[b] Based on wave guide (needle) length of 43 mm

Table 8. Specimen loading program targeted during testing to evaluate sensor response to specimen compression.

Target Applied Stress	Duration Sustained
0 kPa	2 to 5 min.
67 kPa	2.5 to 7 min.
134 kPa	3.5 to 7 min.
200 kPa	3.5 to 7 min.
267 kPa	3.5 to 7 min.
334 kPa	5 to 7 min.
401 kPa	5 to 7 min.
467 kPa	5 to 7 min.
534 kPa	5.5 to 7 min.
601 kPa	6 to 7 min.
668 kPa	7 min.

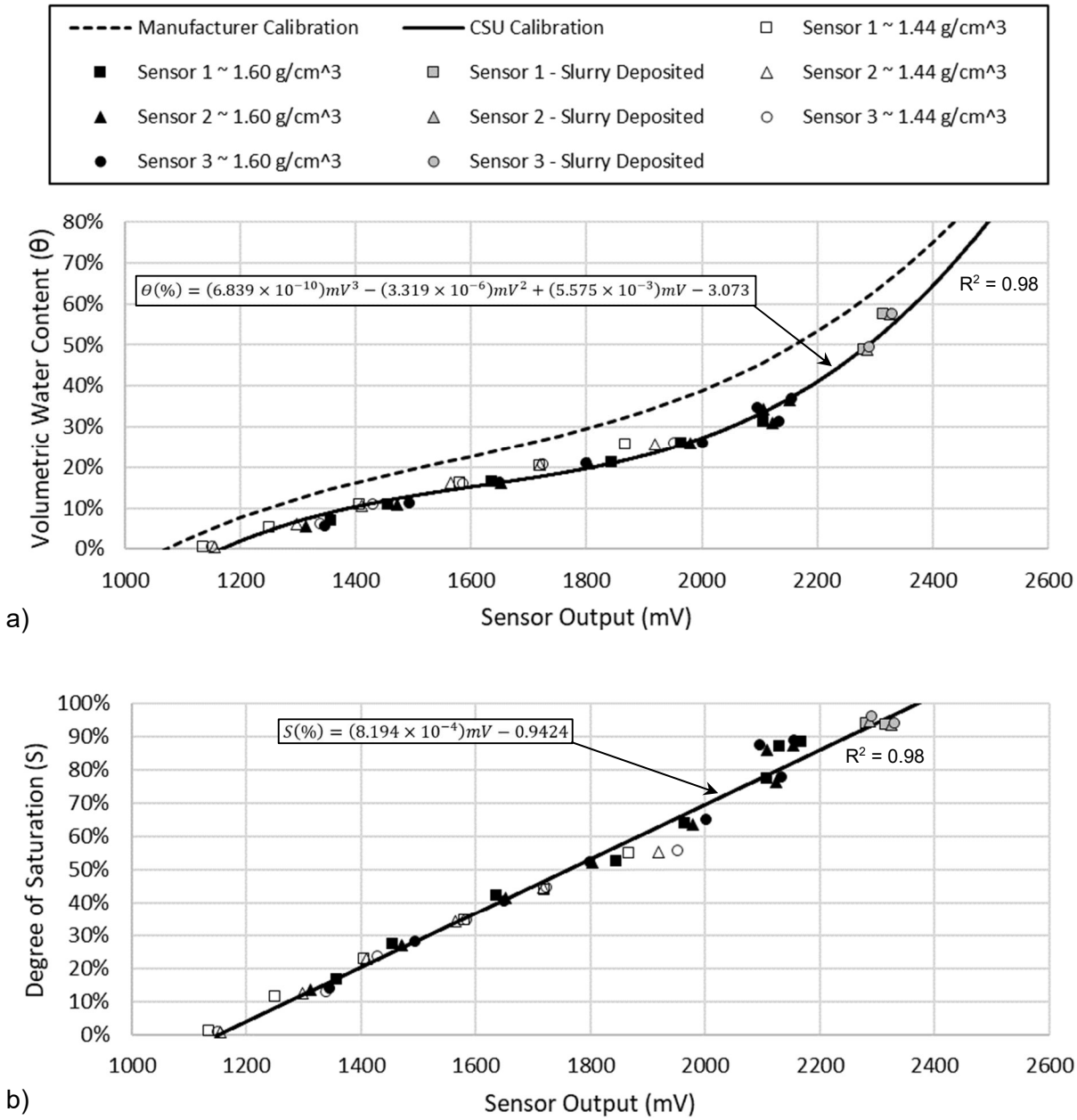


Figure 16. Results from calibration testing of (a) volumetric water content and (b) degree of saturation versus sensor output in millivolts (mV).

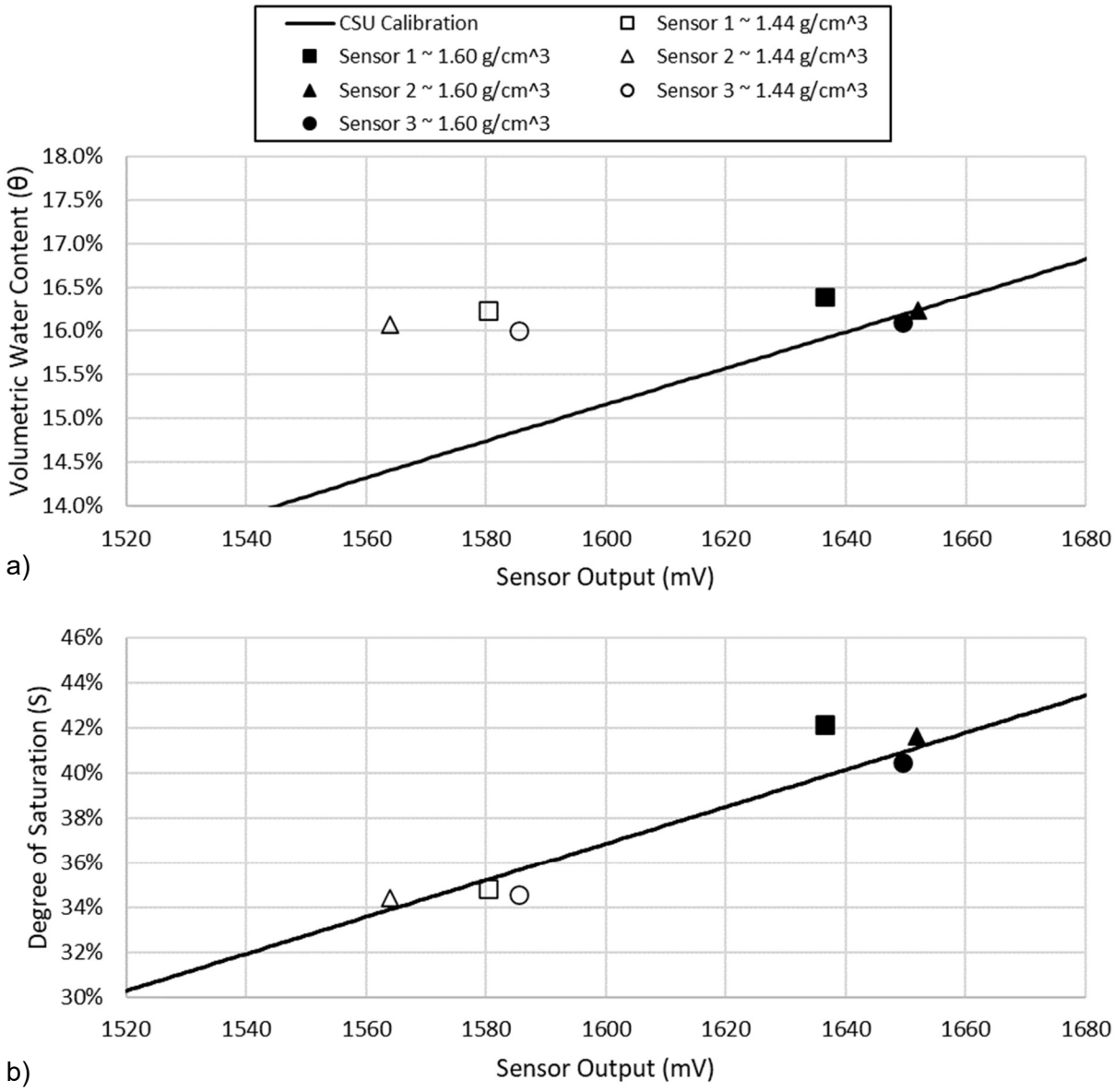


Figure 17. Calibration test results of specimens prepared at the same volumetric water content but two different dry densities. Plot a) shows the relationship between sensor output and volumetric water content, and plot b) shows the relationship between sensor output and degree of saturation for the same specimens.

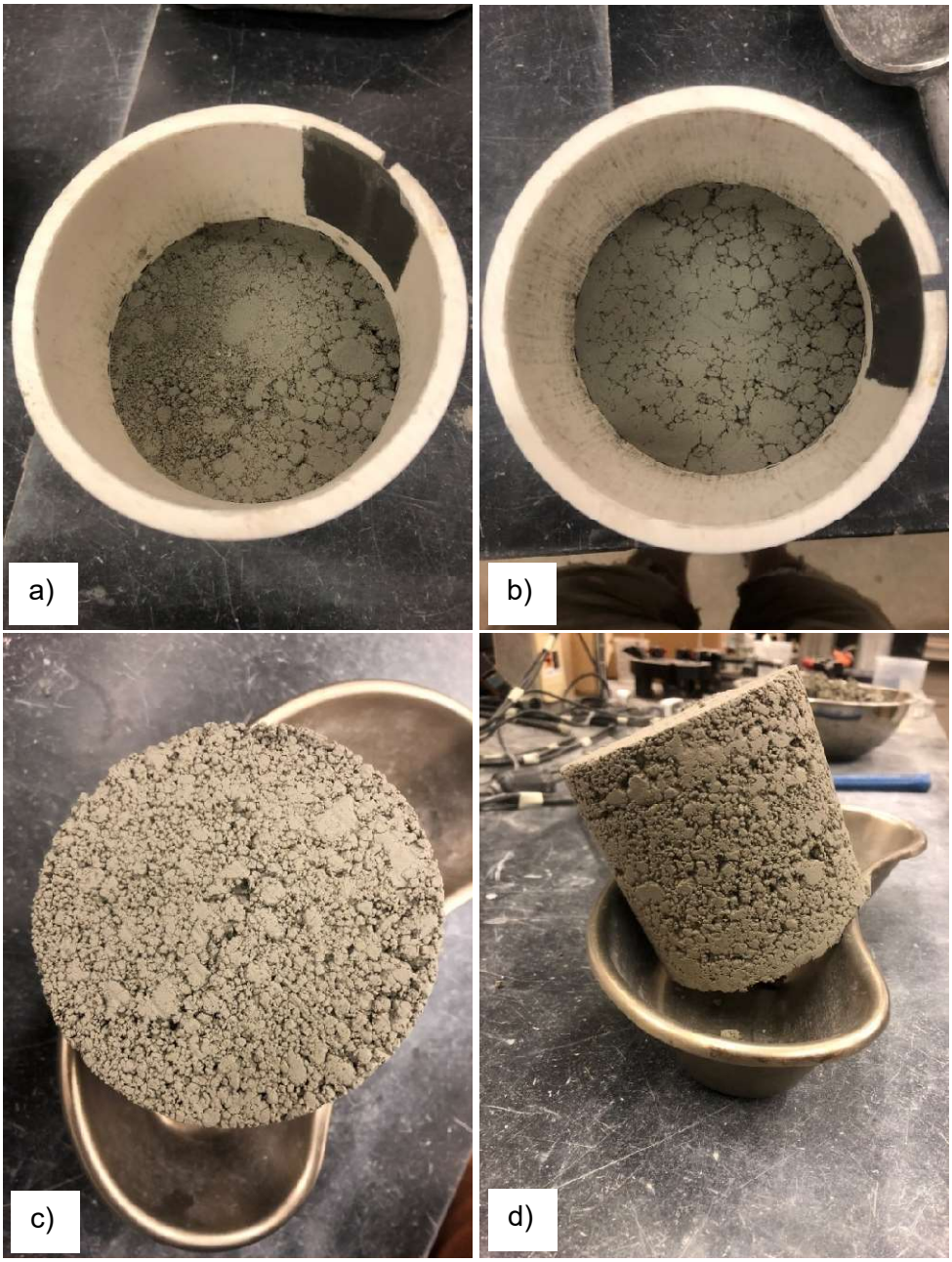


Figure 18. Photos of specimens exhibiting porous macro-structure. Photo a) shows a specimen targeting a volumetric water content of 25% with a dry density of 1.44 g/cm^3. Photo b) shows a specimen targeting a volumetric water content of 30% with a dry density of 1.60 g/cm^3. Photos c) and d) show a specimen prepared at a volumetric water content of 25% and a dry density of about 1.52 g/cm^3.

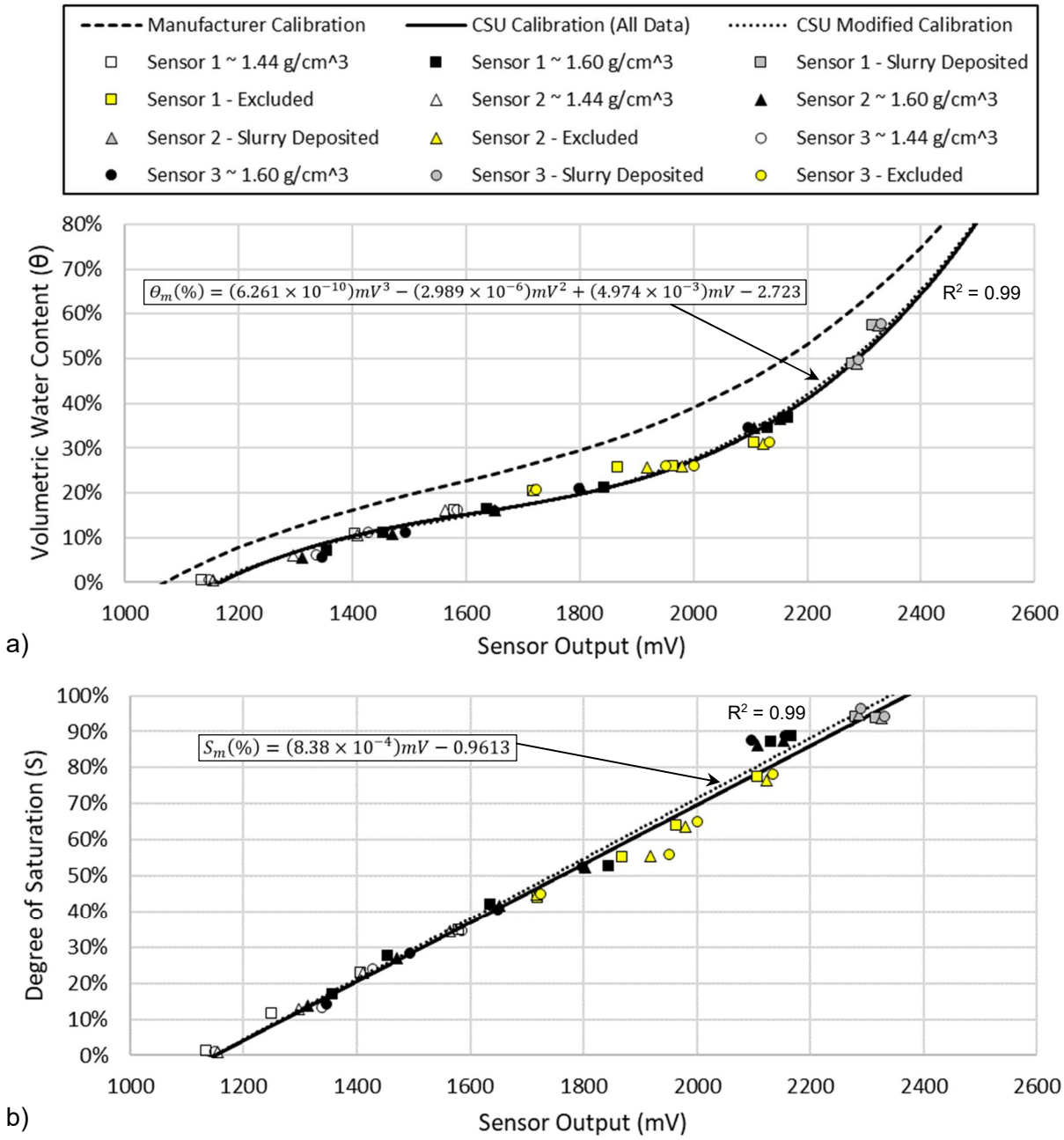
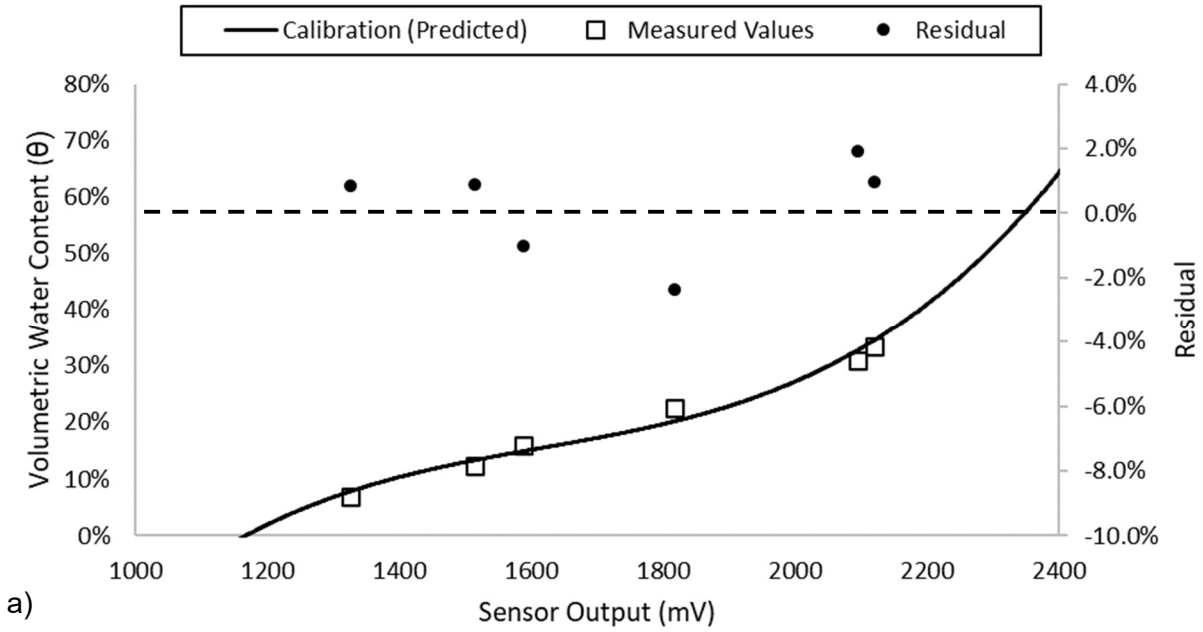
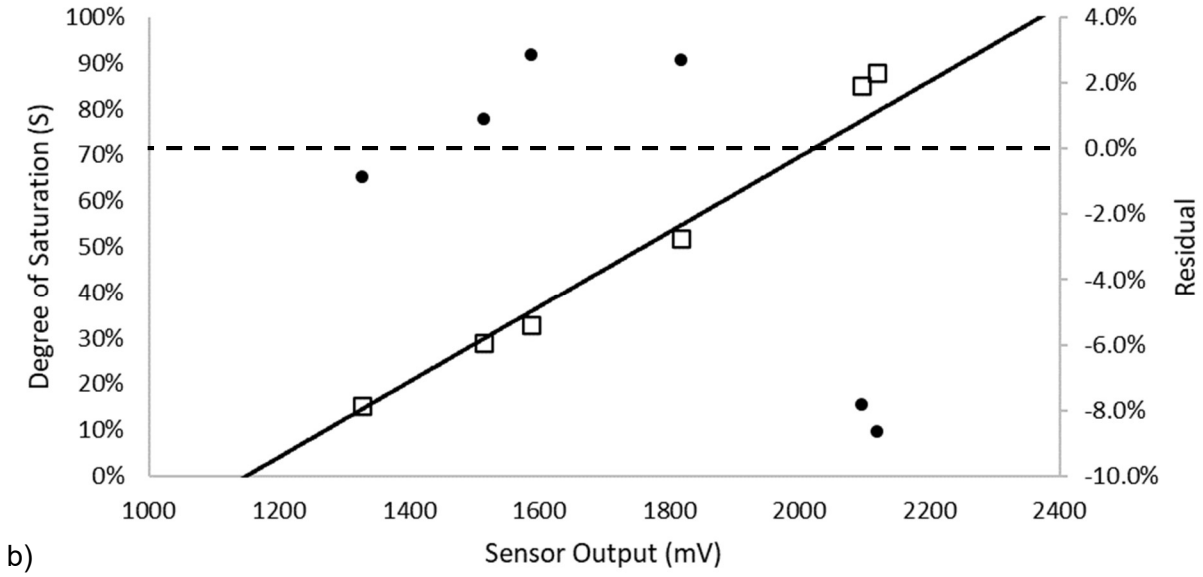


Figure 19. Plots showing excluded test points and modified calibration for (a) volumetric water content and (b) degree of saturation.



a)



b)

Figure 20. Accuracy test results for a) volumetric water content calibration and b) degree of saturation calibration.

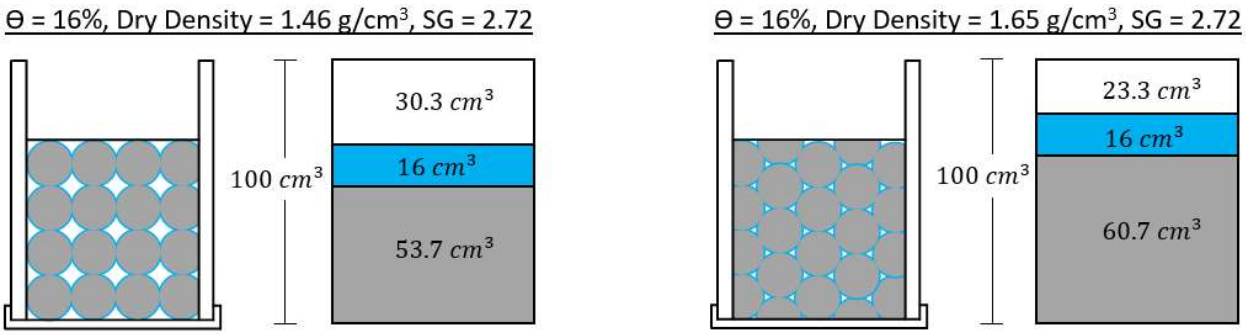


Figure 21. Sketches depicting two specimens prepared at the same volumetric water content but different dry densities.

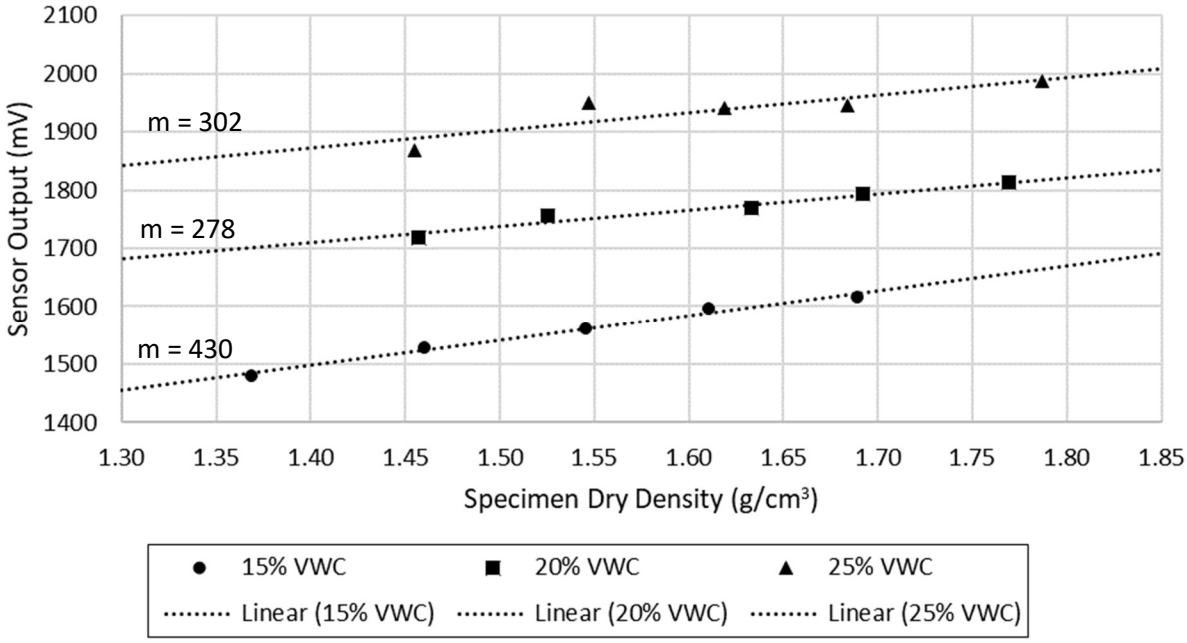


Figure 22. Plot showing the relationship between sensor output and specimen dry density for constant values of volumetric water content.

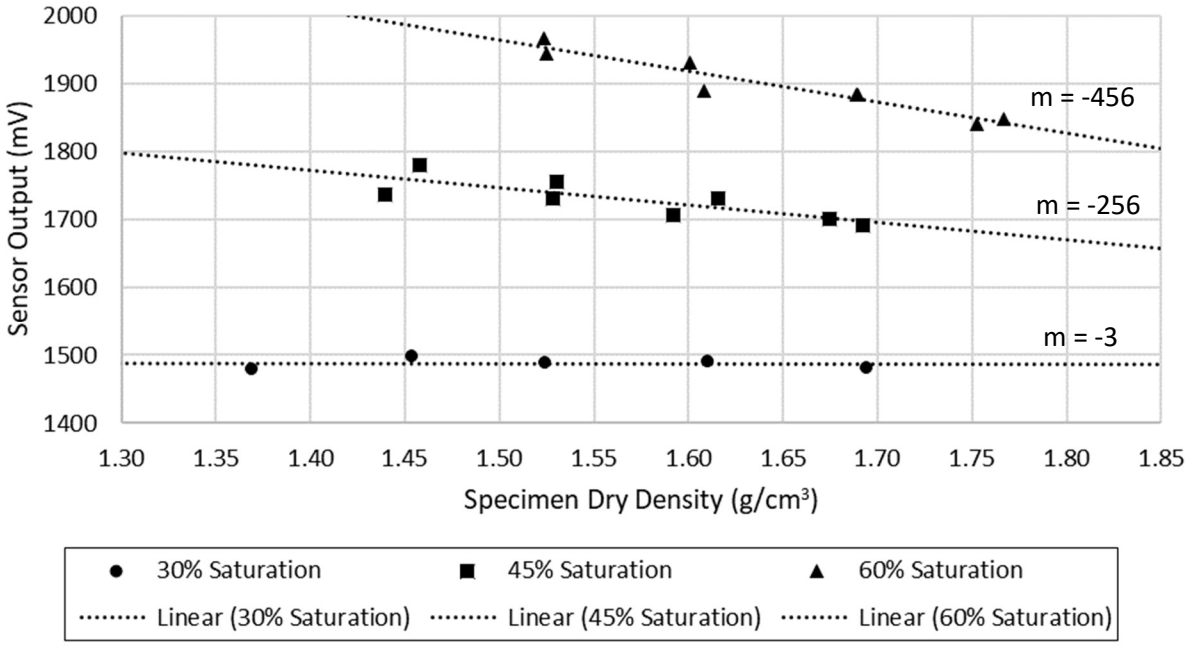
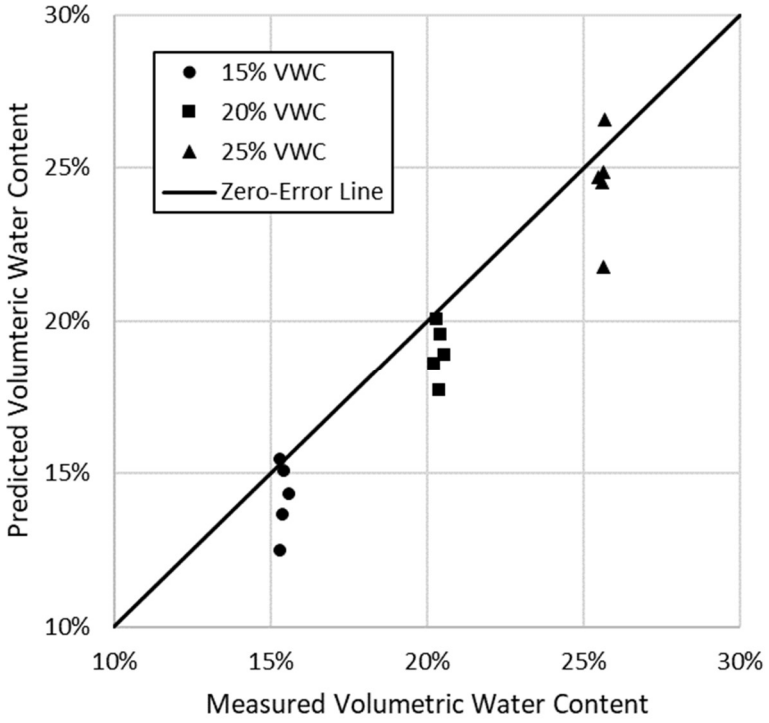


Figure 23. Plot showing the relationship between sensor output and specimen dry density for constant values of degree of saturation.

a)



b)

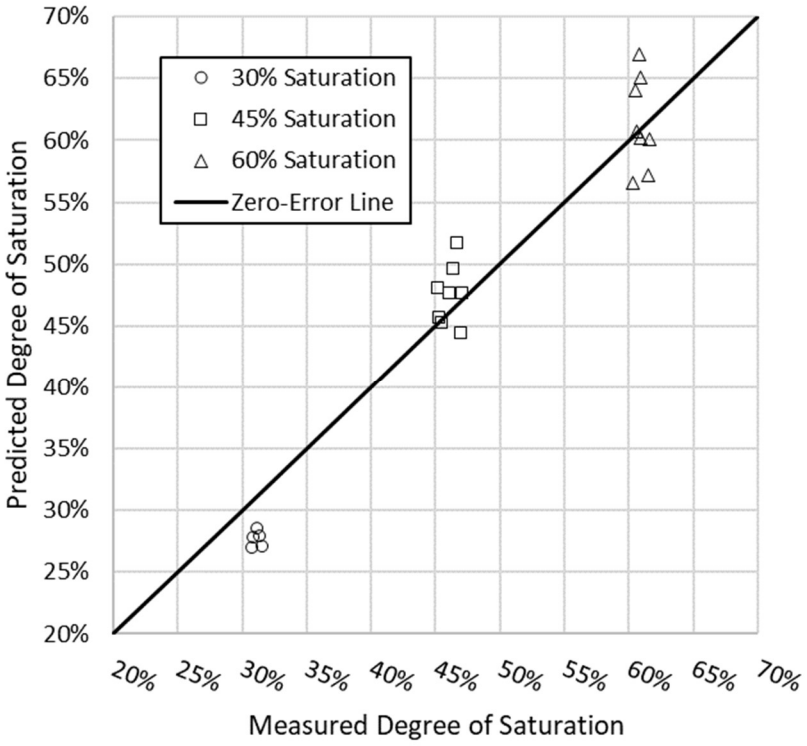
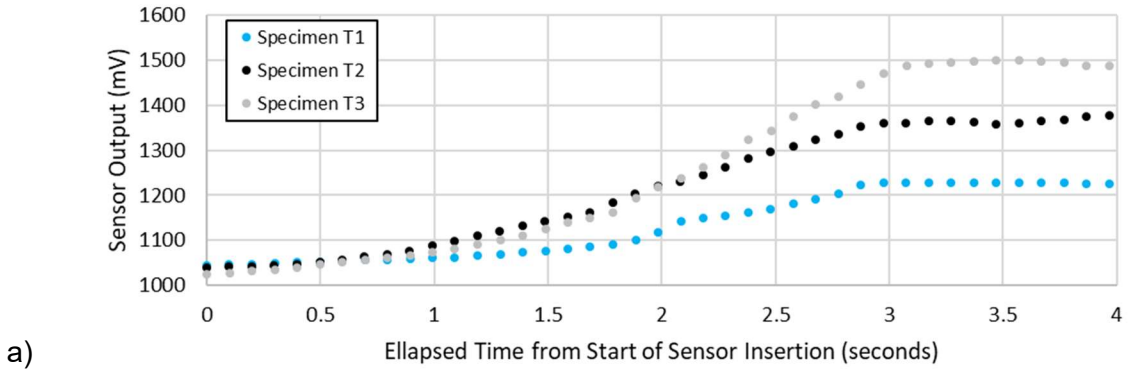
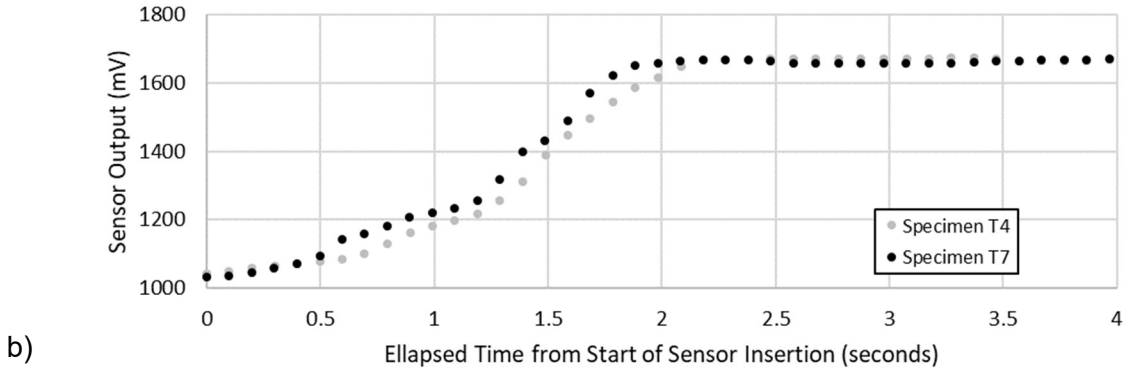


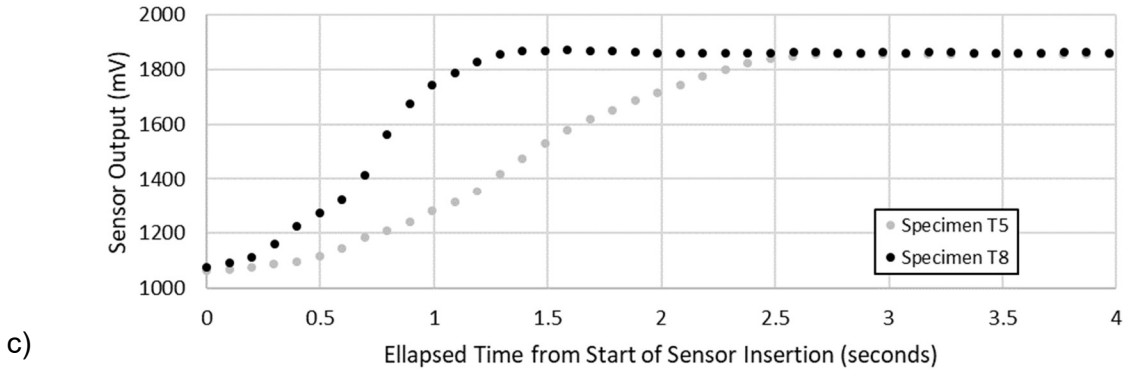
Figure 24. a) Predicted vs. Measured volumetric water content during Characterization of Density Affects testing. b) Predicted vs. Measured degree of saturation during Characterization of Density Affects testing.



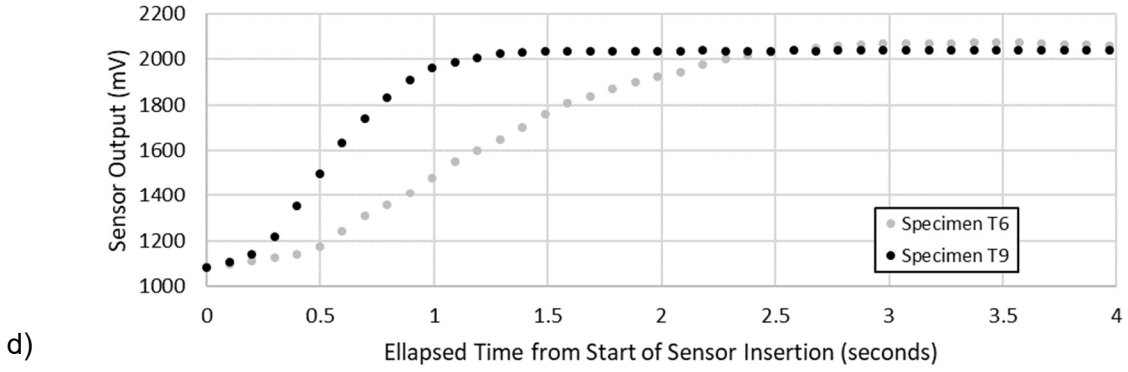
a)



b)

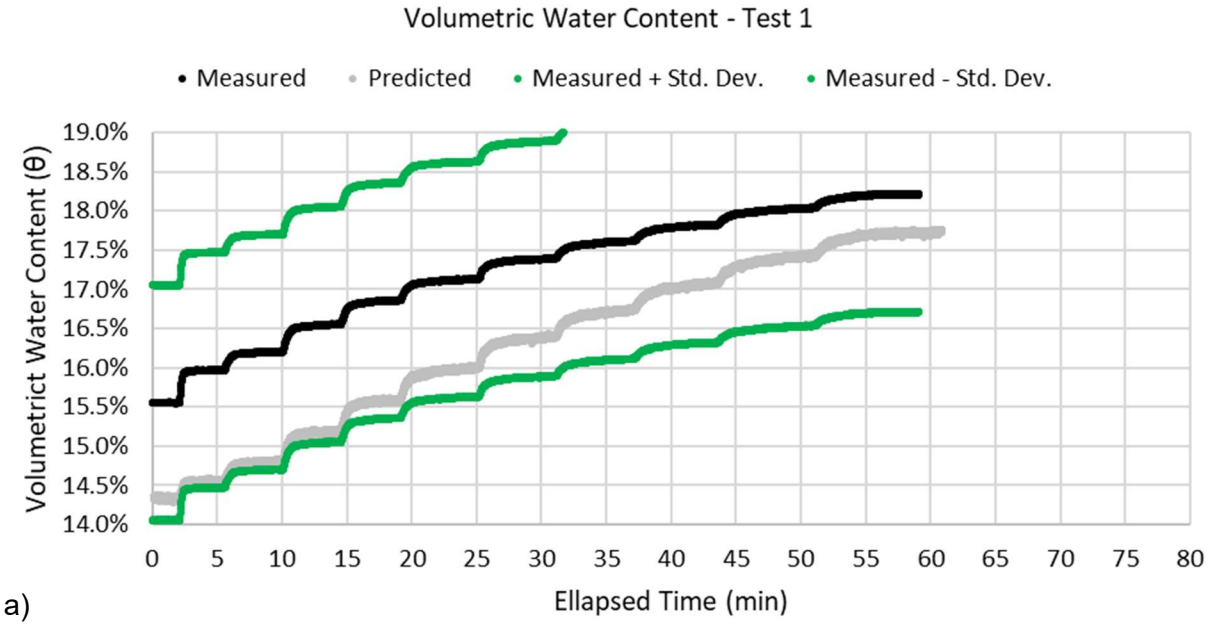


c)

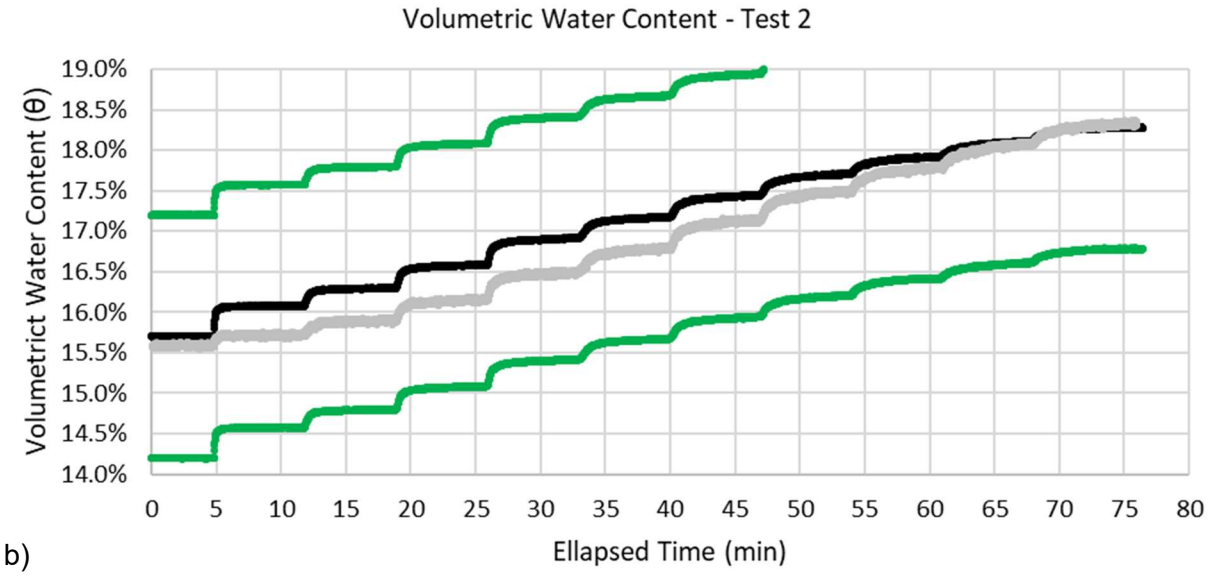


d)

Figure 25. Sensor output with respect to elapsed time during sensor insertion into test specimens.

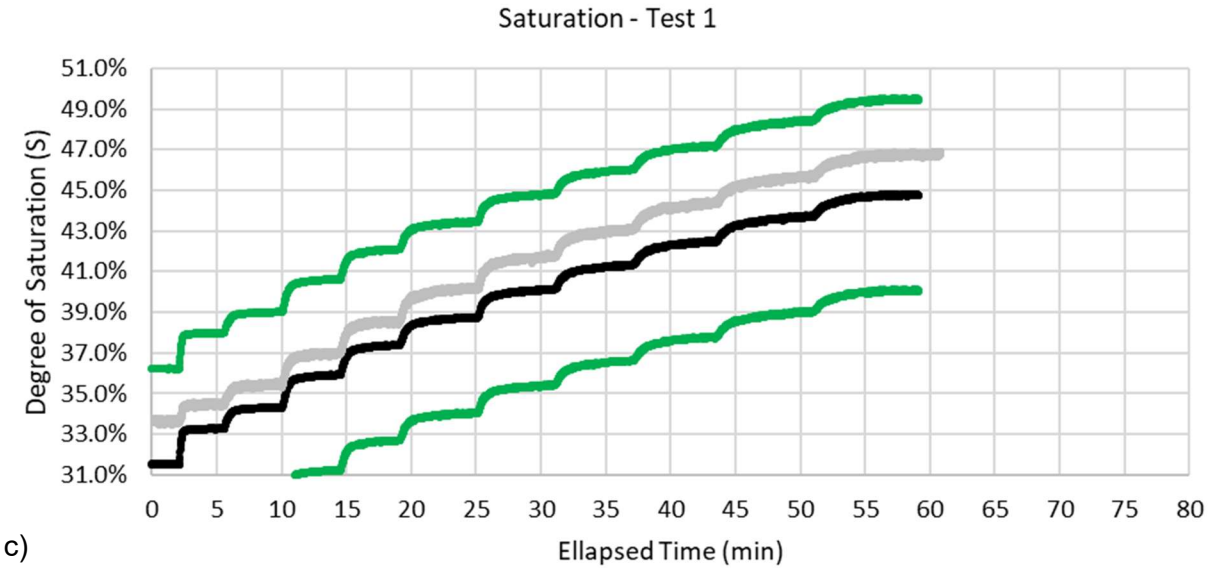


a)

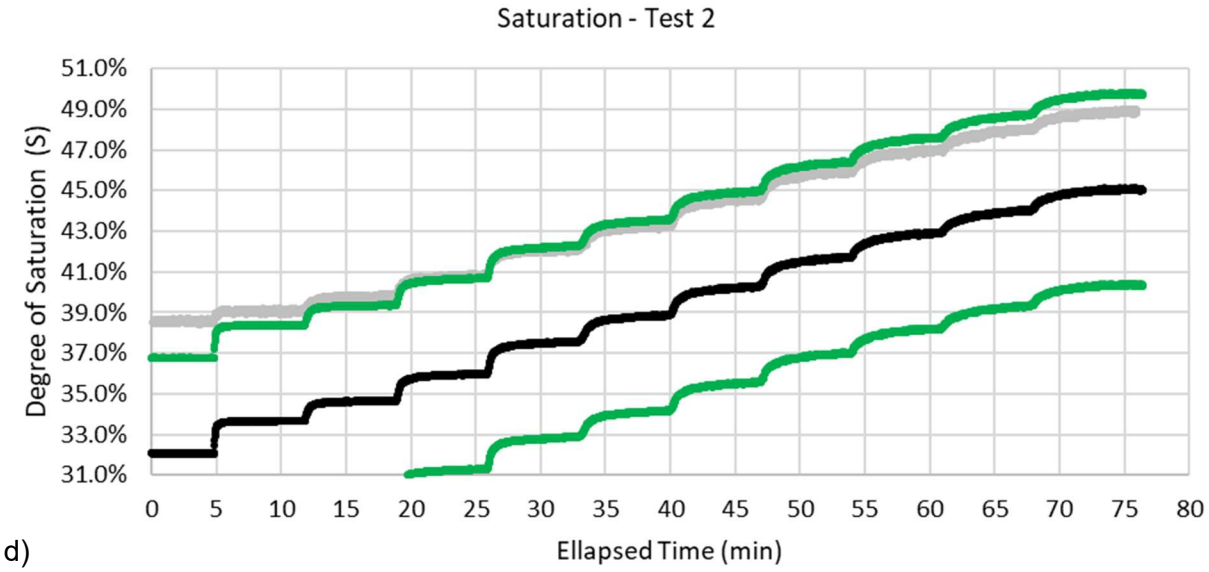


b)

Figure 26. Results from sensor response to specimen compression. Standard deviation presented is based on results from accuracy testing.



c)



d)

Figure 26 Cont. Results from sensor response to specimen compression. Standard deviation presented is based on results from accuracy testing.

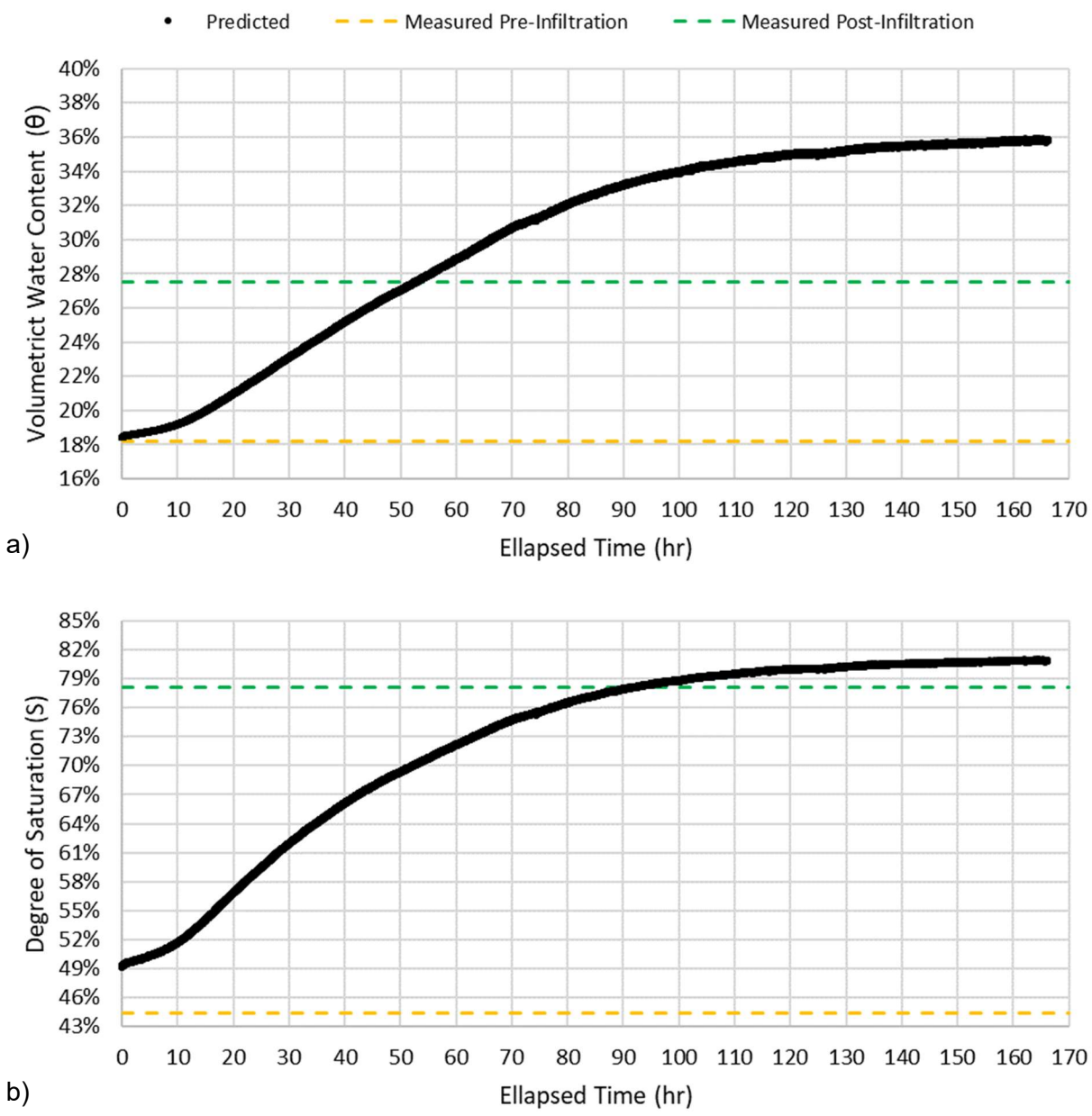


Figure 27. Results of sensor response to infiltration.

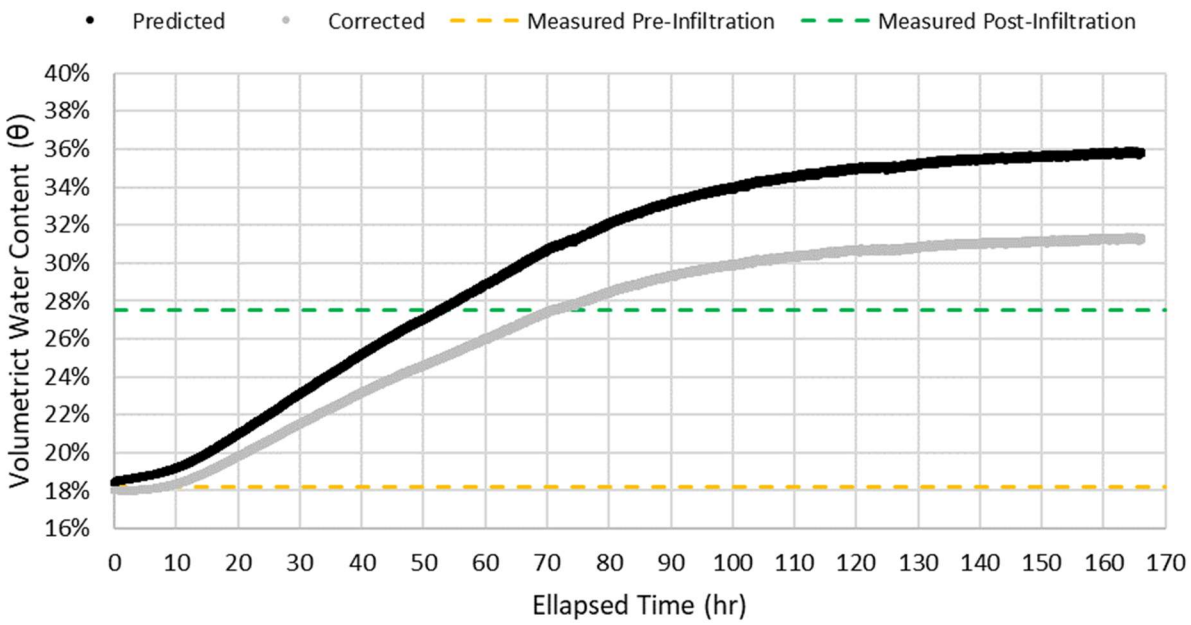


Figure 28. Results of sensor response to infiltration showing predicted volumetric water content corrected for density affects.

CHAPTER 6: CONCLUSIONS

The scope of work in this study suggests that an electromagnetic soil moisture sensor can be used to predict the volumetric water content and degree of saturation in mine tailings with a useful degree of accuracy depending on the application and precision required. The following conclusions were drawn from this study.

- A material-specific calibration is important to obtain accurate predictions of volumetric water content and degree of saturation relative to using the manufacturer's general calibration for mineral soils. The manufacturer's general calibration overpredicted volumetric water content by 5.7% to 12.3% for the tailings tested.
- Sensor output is affected by variations in dry density of the surrounding medium. The effect of dry density on sensor output appeared generally consistent for different volumetric water contents, whereas the effect of dry density on sensor output increased as the degree of saturation increased.
- Sensor output reflected the average dielectric permittivity of the materials within the sensor volume of influence weighted by the volume of each material. The volumetric fractions of air, water and solid phases explained the observed change in sensor output for a given volumetric water content but differing dry densities.
- An electromagnetic sensor should respond to variations in moisture at a fast enough rate to provide continuous data if incorporated into a probe-based application, such as a CPT. Results from insertion testing (Table 7) indicate sensor temporal response to changes in volumetric water content and degree of saturation on the order of 27 mm/s were achieved.
- An electromagnetic sensor should respond to changes in volumetric water content and saturation induced by compression and/or infiltration of unsaturated tailings to a useful degree of accuracy. During specimen compression, error in predicted volumetric water

content was less than 1.5%, and error in predicted saturation was predominantly less than 5%. After specimen infiltration, the error in predicted saturation was also less than 5%, and the error in predicted volumetric water was 3.8% when corrected for dry density effects.

- Understanding the effects of variations in dry density on sensor output can be utilized to correct sensor output for density affects and reduce potential error in sensor predicted values. Correcting sensor output for the effects of dry density resulted in a 4.5% decrease in the error of predicted volumetric water content at the end of infiltration testing.

Calibrating an electromagnetic sensor to predict the degree of saturation in tailings can offer benefits when assessing geotechnical and geochemical stability of a tailings facility. The following recommendations and areas of potential future work were developed from the study:

- The potential error in predicted volumetric water content and degree of saturation due to variations in tailings dry density will depend, in part, on the range of dry density the sensor will be subjected to in a field application. The potential range of tailings dry density at a given facility should be considered when developing sensor calibrations. During calibration, preparing specimens at a dry density near the middle of the expected range of dry densities should help to reduce potential error in predicted values.
- When performing laboratory calibration of a sensor, efforts should be made to mimic field conditions to the extent possible to reduce potential error in predicted values of volumetric water content and degree of saturation.
- Due to the horizontally stratified nature of tailings typically encountered within a conventional tailings facility, designing a probe-based sensor to have a relatively thin volume of influence vertically may improve accuracy and resolution in predicted values of volumetric water content and saturation.

- If a probe-based sensor were to be developed to predict a vertical profile of saturation in tailings, consideration should be given to correcting for variation in saturation due to changes in dry density induced by probe advancement. The change in dry density and resulting variation in saturation brought on by probe advancement would depend on the initial dry density of the tailings prior to probe insertion.

Future study involving a more focused and robust characterization of the effects of dry density on sensor output to develop a density correction process that can be implemented in tailings engineering practice would be very beneficial in advancing the successful application of sensor technology in tailings facilities. Additionally, laboratory-scale proof-of-concept testing of a probe-based sensor with the goal of producing a vertical profile of volumetric water content and saturation in tailings would be a critical next step in expanding the application of sensor technology in tailings engineering practice and addressing current challenges within the tailings engineering community. Finally, evaluating sensor performance on a variety of tailings materials would be beneficial to further understand the effects of material properties on sensor performance and the importance of developing material-specific calibrations for different types of tailings.

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APPENDIX A

LIST OF POTENTIAL METHODS FOR DETERMINING THE DEGREE OF SATURATION IN POROUS MEDIA

Available Methods for Determining Degree of Saturation in Porous Media		
Category	**Method**	**Examples**
Invasive Methods		
Gravimetric	In-Situ Sampling with Shelby Tube	
Penetration Testing	Cone Penetration Test with Pore Pressure Sensor (CPTu)	
	Cone Penetration Test with Seismic Sensor (SCPT)	
	Cone Penetration Test with Electrical Resistivity Sensor (RCPT)	
	Dilatometer Test (DMT)	
	Seismic Dilatometer Test (SDMT)	
	Dynamic Probe (DP)	
	Field Velocity Probe (FVP)	
	Field Velocity Resistivity Probe (FVRP)	
Sensors - Electromagnetic	Frequency Domain Reflectometry (FDR) or Capacitance Sensors	ECH$_2$O, Theta Probe, Hydra Probe, Teros T10, 11 or 12, etc.
	Time Domain Reflectometry (TDR) Sensors	TDR100, 200 or 300, CS600-Series sensors, SoilVUE10, etc.
	Time Domain Transmissometry (TDT) Sensors	
	Other EM Sensors	Time Domain Cone Penetrometer, Virrib Sensor
Sensors – Electrical Resistance	Gypsum Block	
	Nylon Block	
	Fiberglas Block	
	Electrical Resistance Sensor Array System	
Sensors – Nuclear	Neutron Probe	
	Gamma Densitometry	
Sensors – Thermal Conductivity	Dual-Probe Heat-Capacity Sensor	
	Actively Heated Fiber Optics	
Sensors – Fiber Optic	Optical Fiber Long Period Gratings (LPG)	
Sensors – Matric Suction/Potential	Tensiometers	Teros 21, 31 or 32, MPS-2 or 6, CSL229, etc.
Cross-hole/Down-hole Testing	Cross-hole/Down-hole Seismic Testing	
	Cross-hole/Down-hole Ground Penetrating Radar (GPR)	
Other	Passive Wick Fluxmeter	
Non-Invasive Methods		
Surface Geophysics	Electrical Resistivity (Wenner 4-Pin)	
	Electrical Resistivity Tomography (ERT)	
	Seismic Refraction (ReMi)	
Remote Sensing	Satellite-Based Sensors	Microwave Radiometer, Infrared, Scatterometer, etc.
	Airborne Sensors	
	Cosmic Ray Neutron Sensor	
	Ground Penetrating Radar (GPR)	
Data Banks	Global Soil Moisture Data Bank	
	International Soil Moisture Network (ISMN)	

APPENDIX B

RESULTS FROM SURVEY OF PRACTIONERS

General Survey Details

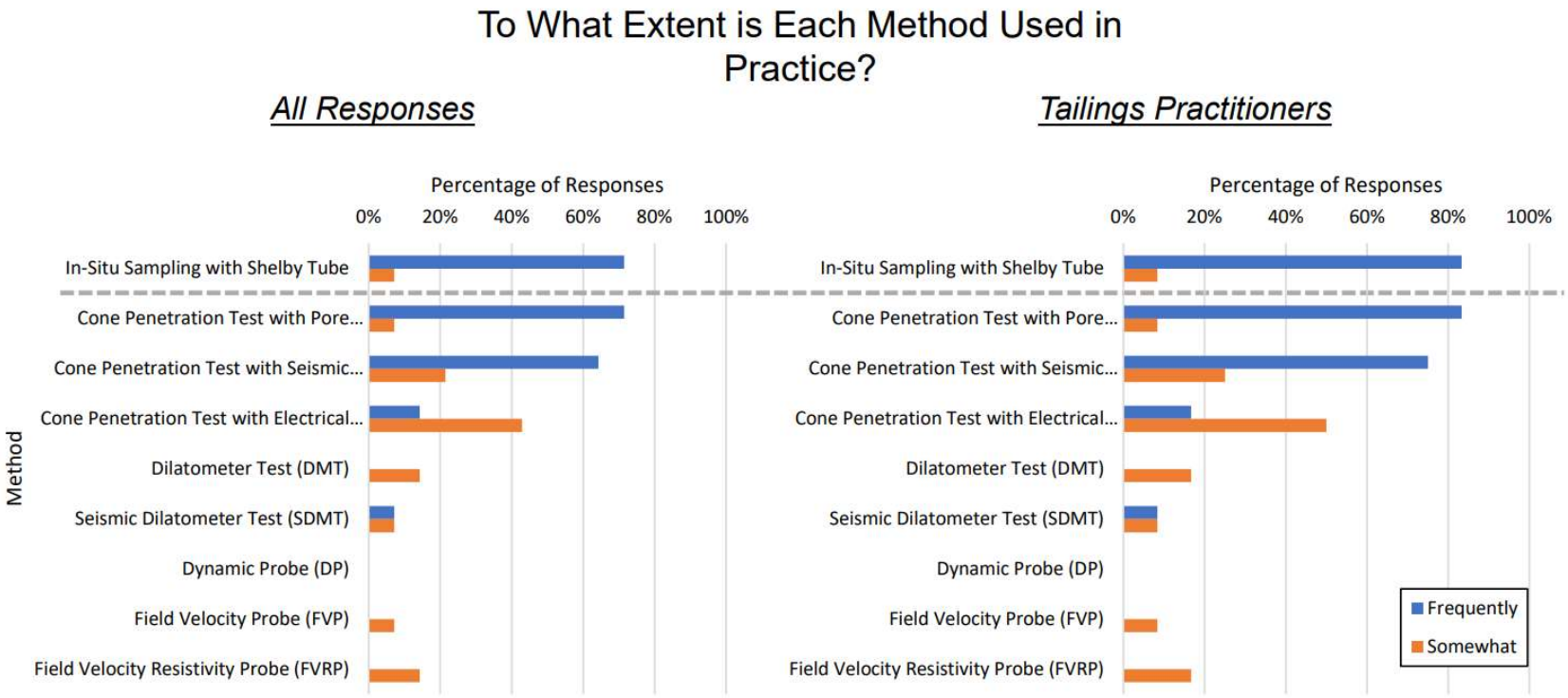
Question:

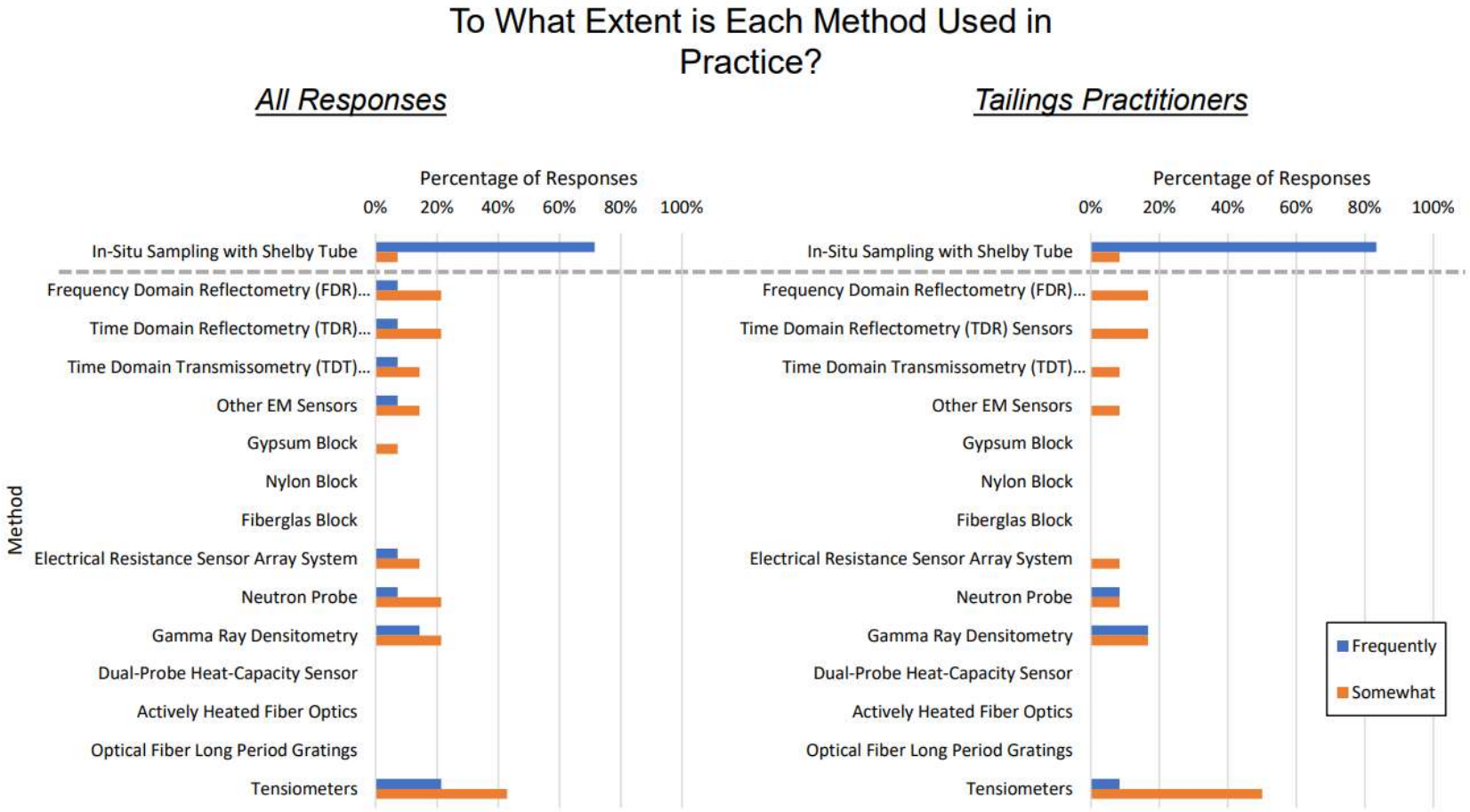
"To what extent is the listed method currently used in practice for determining the degree of saturation in porous media, particularly in regard to mine tailings?"

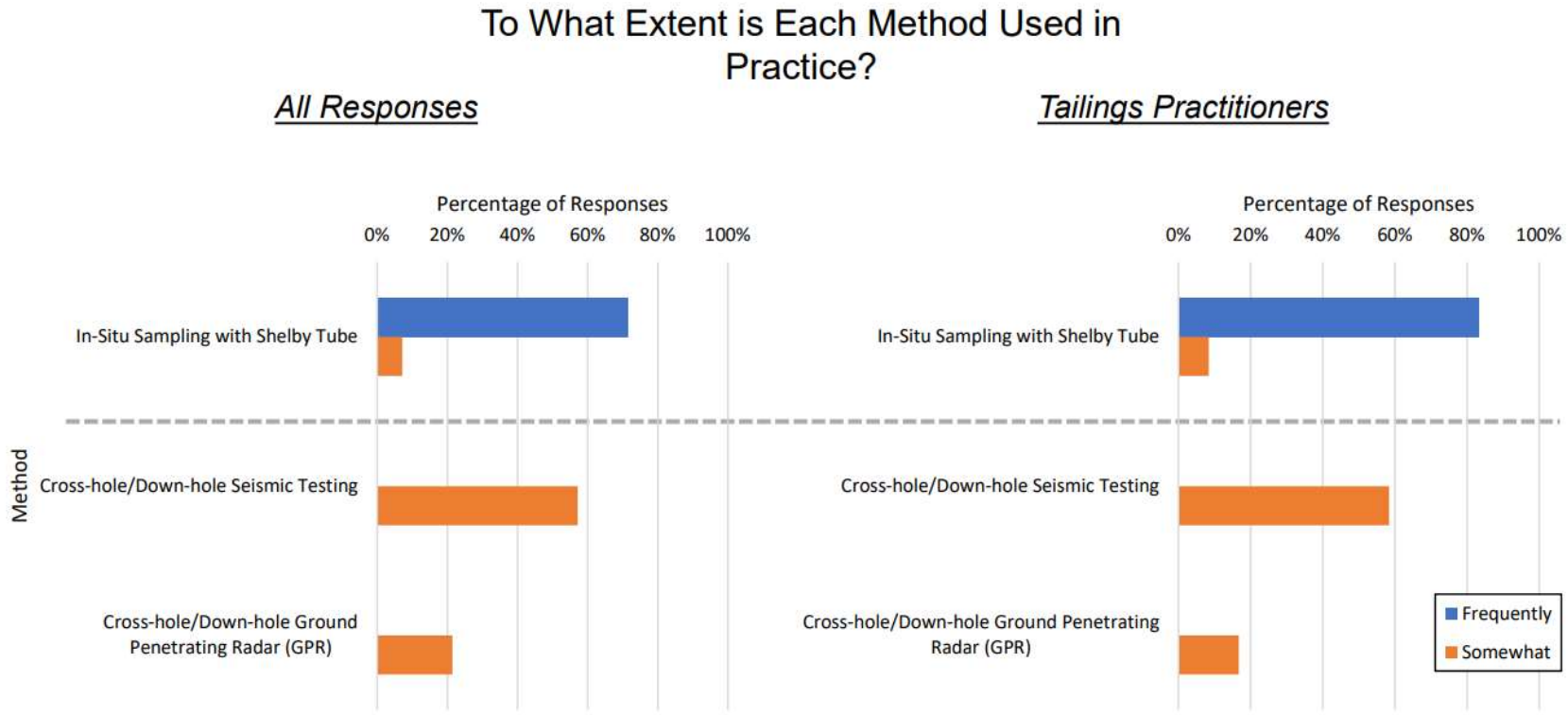
> "Note: If you do not have experience with mine tailings, please answer the question based on your field of experience".

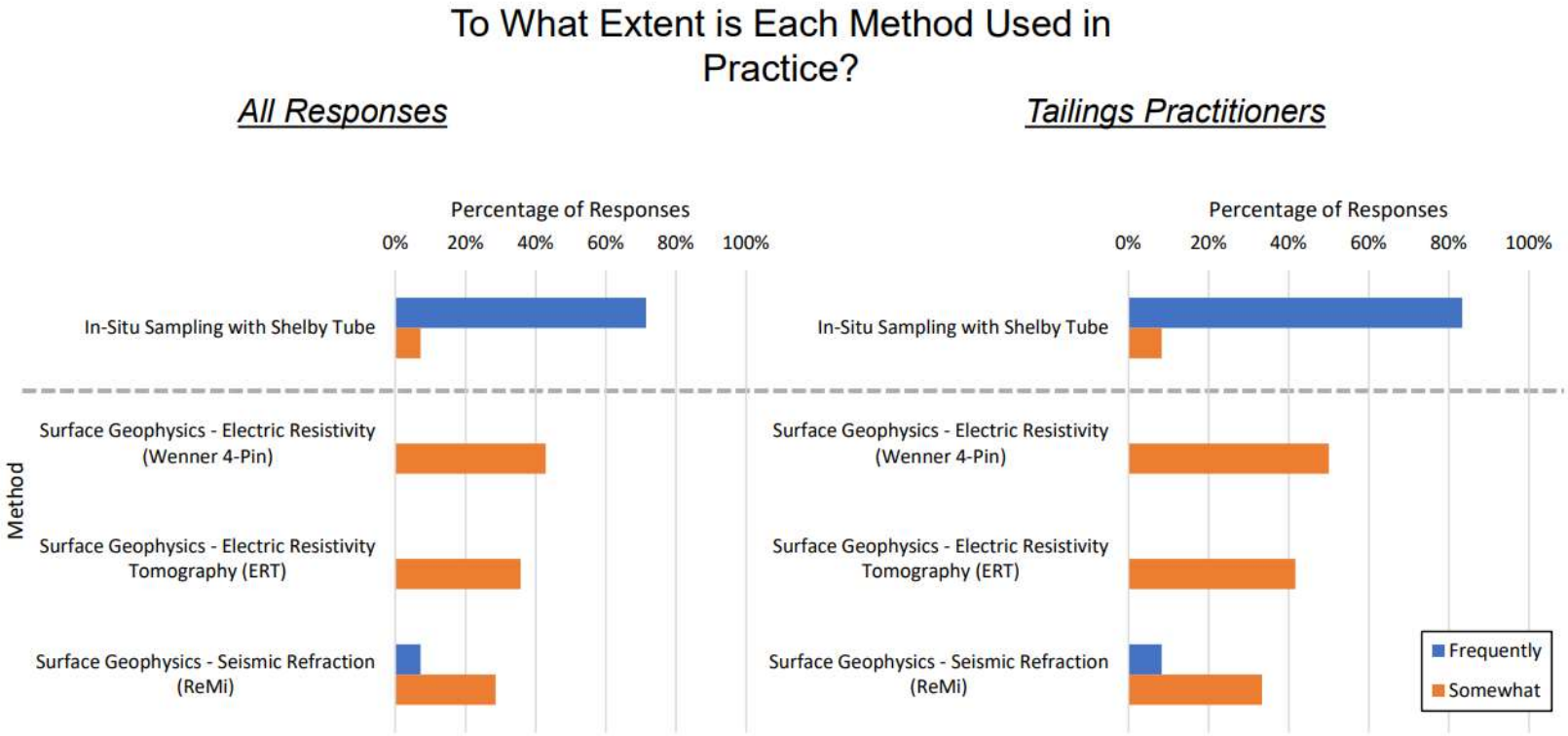
Response Details:

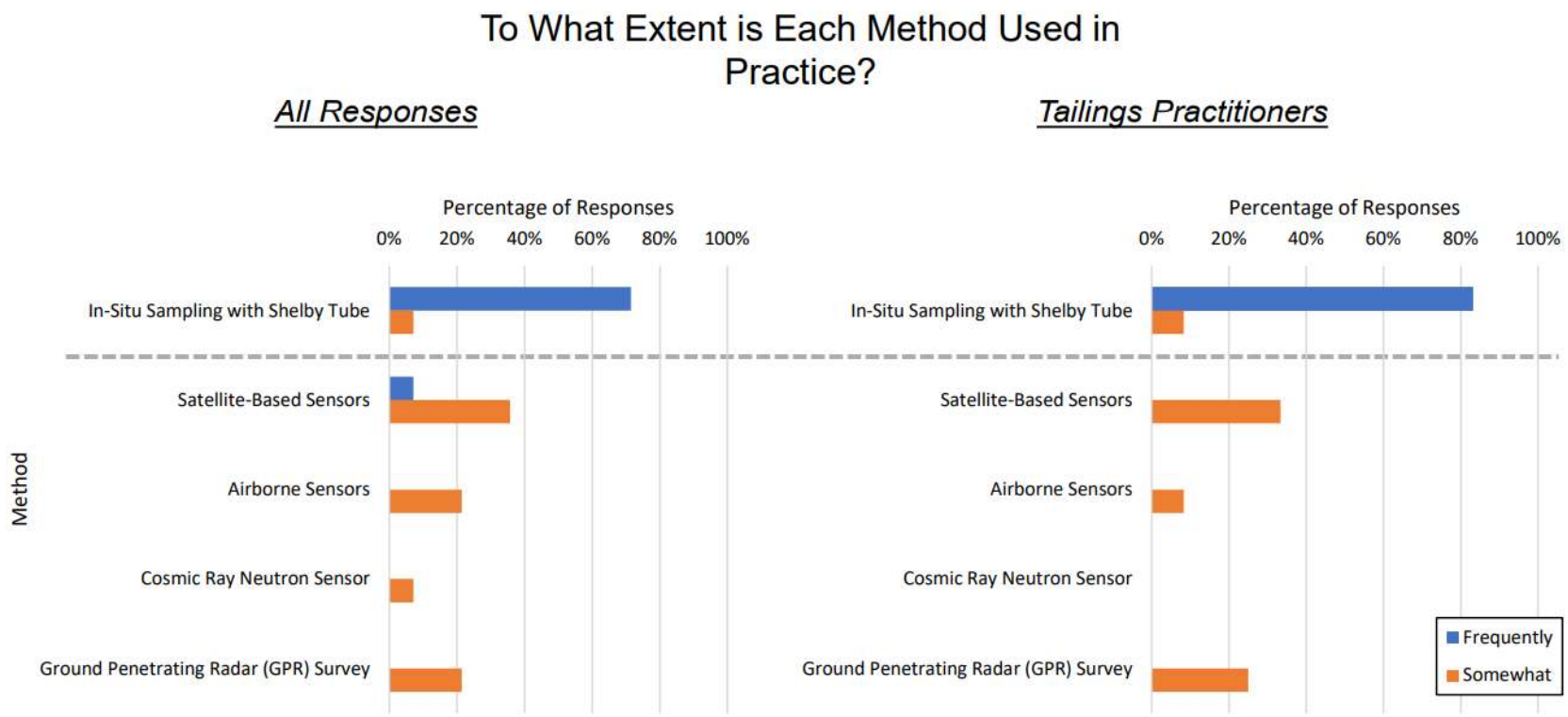
- Total Recipients Polled: 39
- Total Responses: 14
- 12 of 14 Responses from individuals ***familiar with mine tailings***
- 2 of 14 responses from individuals ***with experience in the Agriculture***

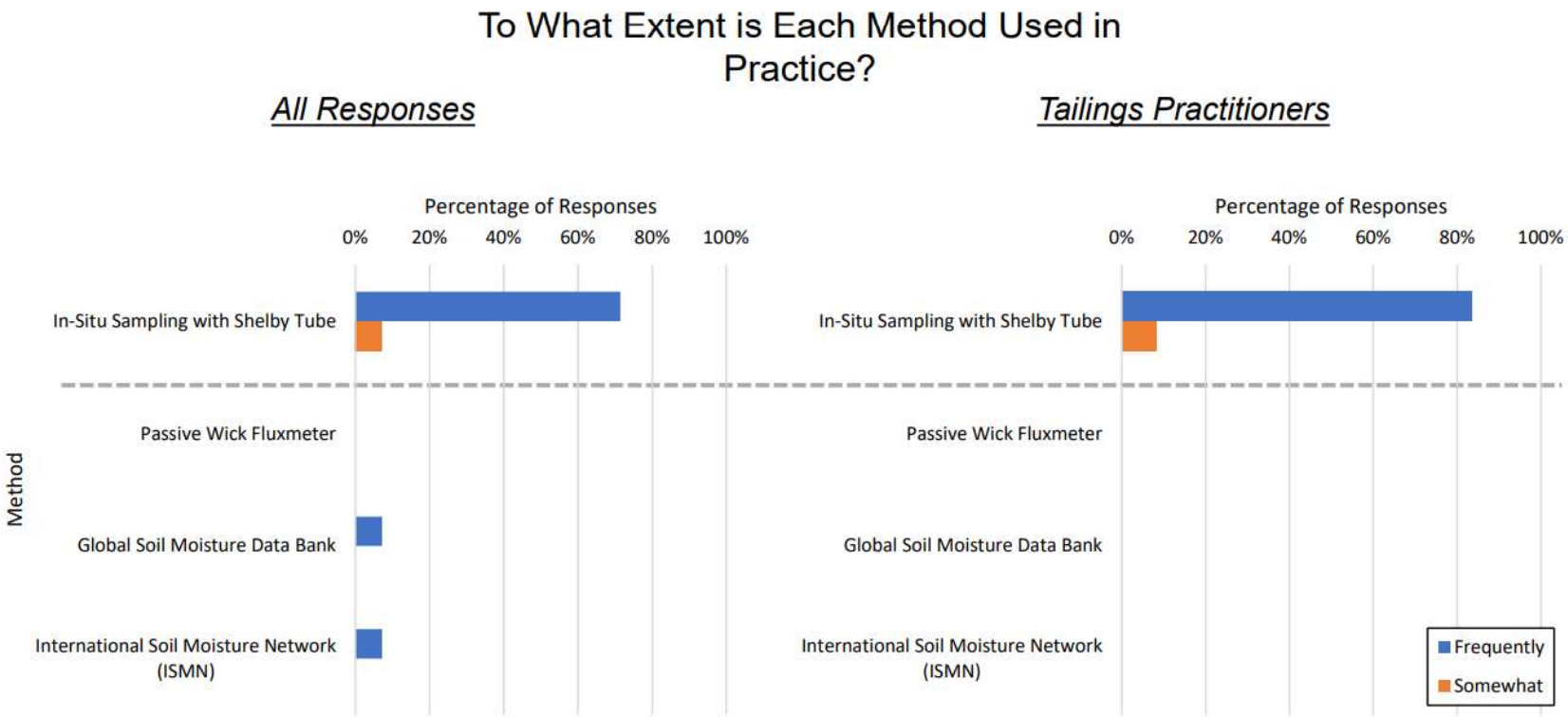

To What Extent is Each Method Used in Practice?
All Responses
Tailings Practitioners
Percentage of Responses
0%
20%
40%
60%
80%
100%
Method
In-Situ Sampling with Shelby Tube
Cone Penetration Test with Pore...
Cone Penetration Test with Seismic...
Cone Penetration Test with Electrical...
Dilatometer Test (DMT)
Seismic Dilatometer Test (SDMT)
Dynamic Probe (DP)
Field Velocity Probe (FVP)
Field Velocity Resistivity Probe (FVRP)
Frequently
Somewhat

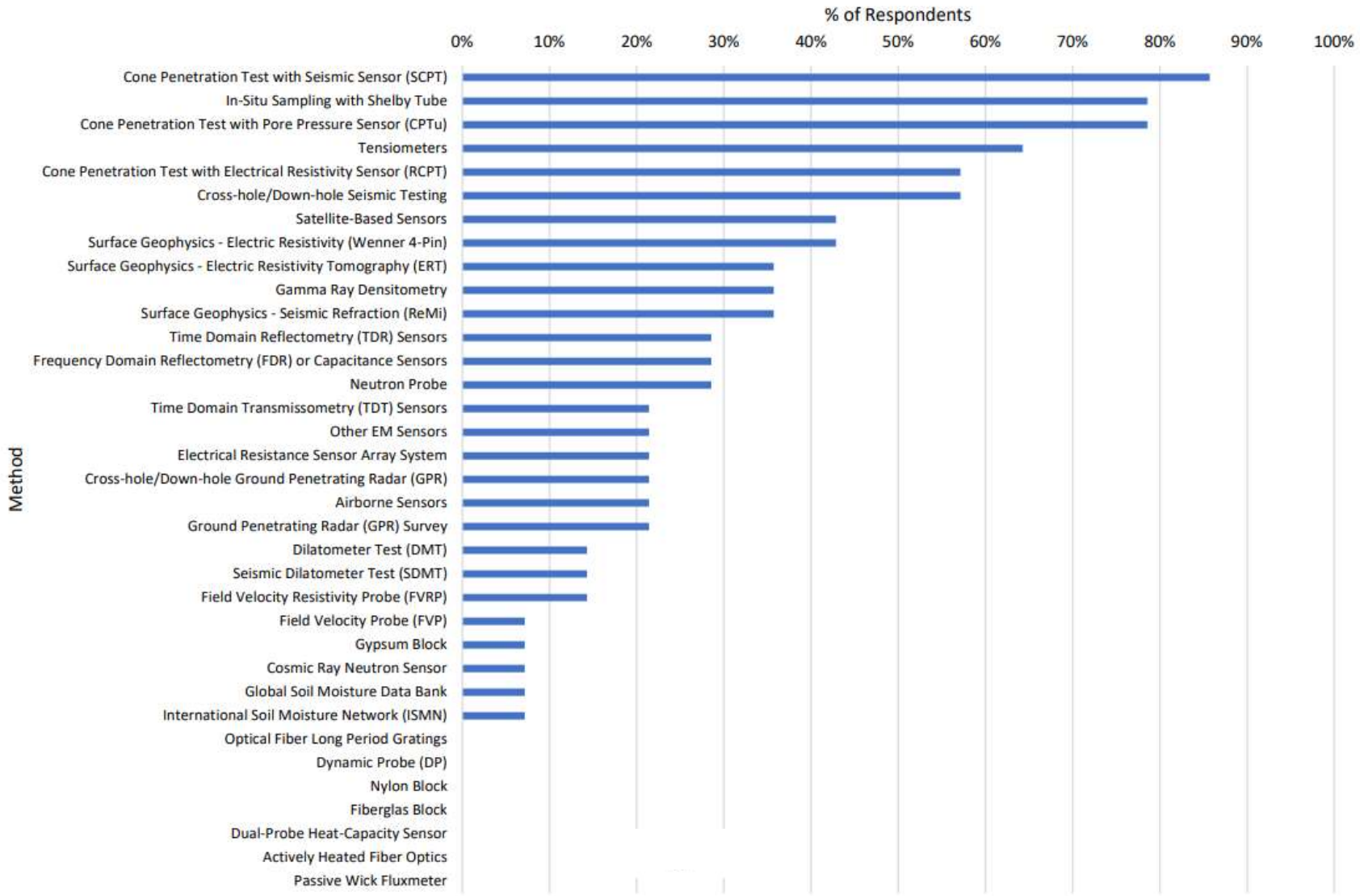

To What Extent is Each Method Used in Practice?
All Responses
Tailings Practitioners
Percentage of Responses
0%
20%
40%
60%
80%
100%
Method
In-Situ Sampling with Shelby Tube
Frequency Domain Reflectometry (FDR)...
Time Domain Reflectometry (TDR)...
Time Domain Transmissometry (TDT)...
Other EM Sensors
Gypsum Block
Nylon Block
Fiberglas Block
Electrical Resistance Sensor Array System
Neutron Probe
Gamma Ray Densitometry
Dual-Probe Heat-Capacity Sensor
Actively Heated Fiber Optics
Optical Fiber Long Period Gratings
Tensiometers
Time Domain Reflectometry (TDR) Sensors
Frequently
Somewhat

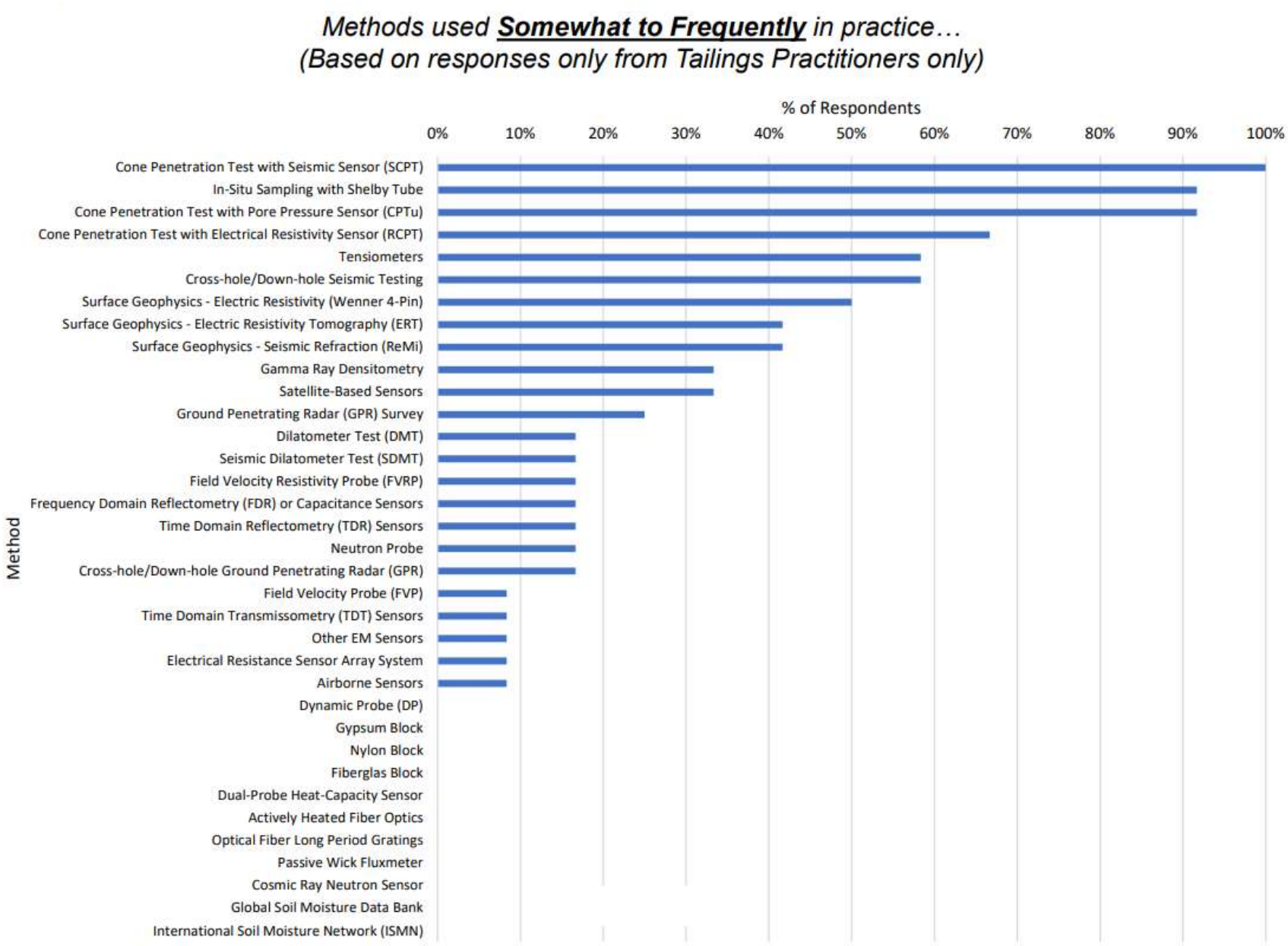

To What Extent is Each Method Used in Practice?
All Responses
Tailings Practitioners
Percentage of Responses
0%
20%
40%
60%
80%
100%
Method
In-Situ Sampling with Shelby Tube
Cross-hole/Down-hole Seismic Testing
Cross-hole/Down-hole Ground Penetrating Radar (GPR)
Frequently
Somewhat


To What Extent is Each Method Used in Practice?
All Responses
Tailings Practitioners
Percentage of Responses
0%
20%
40%
60%
80%
100%
Method
In-Situ Sampling with Shelby Tube
Surface Geophysics - Electric Resistivity (Wenner 4-Pin)
Surface Geophysics - Electric Resistivity Tomography (ERT)
Surface Geophysics - Seismic Refraction (ReMi)
Frequently
Somewhat


To What Extent is Each Method Used in Practice?
All Responses
Tailings Practitioners
Percentage of Responses
0%
20%
40%
60%
80%
100%
Method
In-Situ Sampling with Shelby Tube
Satellite-Based Sensors
Airborne Sensors
Cosmic Ray Neutron Sensor
Ground Penetrating Radar (GPR) Survey
Frequently
Somewhat


To What Extent is Each Method Used in Practice?
All Responses
Tailings Practitioners
Percentage of Responses
0%
20%
40%
60%
80%
100%
Method
In-Situ Sampling with Shelby Tube
Passive Wick Fluxmeter
Global Soil Moisture Data Bank
International Soil Moisture Network (ISMN)
Frequently
Somewhat


Methods used Somewhat to Frequently in practice…
(Based on all responses)
% of Respondents
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Method
Cone Penetration Test with Seismic Sensor (SCPT)
In-Situ Sampling with Shelby Tube
Cone Penetration Test with Pore Pressure Sensor (CPTu)
Tensiometers
Cone Penetration Test with Electrical Resistivity Sensor (RCPT)
Cross-hole/Down-hole Seismic Testing
Satellite-Based Sensors
Surface Geophysics - Electric Resistivity (Wenner 4-Pin)
Surface Geophysics - Electric Resistivity Tomography (ERT)
Gamma Ray Densitometry
Surface Geophysics - Seismic Refraction (ReMi)
Time Domain Reflectometry (TDR) Sensors
Frequency Domain Reflectometry (FDR) or Capacitance Sensors
Neutron Probe
Time Domain Transmissometry (TDT) Sensors
Other EM Sensors
Electrical Resistance Sensor Array System
Cross-hole/Down-hole Ground Penetrating Radar (GPR)
Airborne Sensors
Ground Penetrating Radar (GPR) Survey
Dilatometer Test (DMT)
Seismic Dilatometer Test (SDMT)
Field Velocity Resistivity Probe (FVRP)
Field Velocity Probe (FVP)
Gypsum Block
Cosmic Ray Neutron Sensor
Global Soil Moisture Data Bank
International Soil Moisture Network (ISMN)
Optical Fiber Long Period Gratings
Dynamic Probe (DP)
Nylon Block
Fiberglas Block
Dual-Probe Heat-Capacity Sensor
Actively Heated Fiber Optics
Passive Wick Fluxmeter


Methods used Somewhat to Frequently in practice…
(Based on responses only from Tailings Practitioners only)
% of Respondents
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Method
Cone Penetration Test with Seismic Sensor (SCPT)
In-Situ Sampling with Shelby Tube
Cone Penetration Test with Pore Pressure Sensor (CPTu)
Cone Penetration Test with Electrical Resistivity Sensor (RCPT)
Tensiometers
Cross-hole/Down-hole Seismic Testing
Surface Geophysics - Electric Resistivity (Wenner 4-Pin)
Surface Geophysics - Electric Resistivity Tomography (ERT)
Surface Geophysics - Seismic Refraction (ReMi)
Gamma Ray Densitometry
Satellite-Based Sensors
Ground Penetrating Radar (GPR) Survey
Dilatometer Test (DMT)
Seismic Dilatometer Test (SDMT)
Field Velocity Resistivity Probe (FVRP)
Frequency Domain Reflectometry (FDR) or Capacitance Sensors
Time Domain Reflectometry (TDR) Sensors
Neutron Probe
Cross-hole/Down-hole Ground Penetrating Radar (GPR)
Field Velocity Probe (FVP)
Time Domain Transmissometry (TDT) Sensors
Other EM Sensors
Electrical Resistance Sensor Array System
Airborne Sensors
Dynamic Probe (DP)
Gypsum Block
Nylon Block
Fiberglas Block
Dual-Probe Heat-Capacity Sensor
Actively Heated Fiber Optics
Optical Fiber Long Period Gratings
Passive Wick Fluxmeter
Cosmic Ray Neutron Sensor
Global Soil Moisture Data Bank
International Soil Moisture Network (ISMN)

APPENDIX C

MICRO-CONTROLLER CODE

```
//CODE USED FOR CALIBRATION AND ACCURACY TESTING//

//LIBRARIES TO INCLUDE
  #include <Arduino.h>    //Base Arduino Library
  #include "Statistic.h"  //Stats Library

//DEFINE VARIABLES
  double analogPin7 = A7; //Assigning a variable name to physical microcontroller pins
  double analogPin2 = A2;
  double analogPin4 = A4;
  Statistic myStats1; //Identify variables needed for Stats Function
  Statistic myStats2;
  Statistic myStats3;
  const int numReadings= 100000; //Each individual measumrent will be the average of this many recordings
  double T10_1; //Sensor 1 connected to pin A7
  double T10_2; //Sensor 2 connected to pin A2
  double T10_3; //Sensor 3 connected to pin A4

//HEADER INFO
   String Test_ID = "M-05";
   String Dry_UW = "90 pcf";
   String Mst_Cnt = "20";
   String Date = "8/9/2022";

void setup() {

//TURN ON SERIAL PRINTER AND PRINT 3 BLANK LINES
    Serial.begin(9600);
    Serial.println();
    Serial.println();
    Serial.println();

//REFRESHING CODE TO GIVE MICROCONTROLLER TIME TO STABILIZE - Zana
    for(uint8_t t = 4; t > 0; t--) {
    Serial.printf("[SETUP] WAIT %d...\n", t);
    Serial.flush();
    delay(1000);
    }

//INITIALLY CLEAR THE myStats VARIABLES
    myStats1.clear();
    myStats2.clear();
    myStats3.clear();
```

```
//PRINT HEADER
   delay(3000);
   Serial.println();
   Serial.print("Test ID:, ");
   Serial.println(Test_ID);
   Serial.print("Target Dry UW:, ");
   Serial.println(Dry_UW);
   Serial.print("Target Vol. Mst. Con.:, ");
   Serial.println(Mst_Cnt);
   Serial.print("Date:, ");
   Serial.println(Date);
   Serial.println();
   Serial.println("Specimen A, Specimen B, Specimen C");
   delay(1000);

}

void loop() {

//BEGIN TAKING READINGS AND SUMMING THEM
   myStats1.add(analogRead(analogPin7));
   myStats2.add(analogRead(analogPin2));
   myStats3.add(analogRead(analogPin4));

//ONCE numReadings IS ACHIEVED, AVERAGE THE READINGS
   if (myStats1.count() == numReadings){
   T10_1= myStats1.average();
   T10_2= myStats2.average();
   T10_3= myStats3.average();

//PRINT MEASUREMENTS TO SERIAL MONITOR
    Serial.print(T10_1);
    Serial.print(",");
    Serial.print(T10_2);
    Serial.print(",");
    Serial.println(T10_3);

//CLEAR THE myStats VARIABLES
   myStats1.clear();
   myStats2.clear();
   myStats3.clear();
   delay(500);

}
}
```

```
//CODE USED FOR CHARACTERIZATION OF DENSITY AFFECTS//

//LIBRARIES TO INCLUDE
  #include <Arduino.h>    //Base Arduino Library
  #include "Statistic.h"  //Stats Library

//DEFINE VARIABLES
  double analogPin7 = A7; //Assigning a variable name to physical microcontroller pins
  Statistic myStats1; //Identify variables needed for Stats Function
  const int numReadings= 100000; //Each individual measumrent will be the average of this many recordings
  double T10_1; //Sensor 1 connected to pin A7

//HEADER INFO
   String Test_ID = "Specimen E5A";
   String Dry_UW = "105, pcf";
   String Mst_Cnt = "45, %";
   String Date = "03/09/23";

void setup() {

//TURN ON SERIAL PRINTER AND PRINT 3 BLANK LINES
    Serial.begin(9600);
    Serial.println();
    Serial.println();
    Serial.println();

//REFRESHING CODE TO GIVE MICROCONTROLLER TIME TO STABILIZE - Zana
    for(uint8_t t = 4; t > 0; t--) {
    Serial.printf("[SETUP] WAIT %d...\n", t);
    Serial.flush();
    delay(1000);
    }

//INITIALLY CLEAR THE myStats VARIABLES
    myStats1.clear();

 //PRINT HEADER
    delay(3000);
    Serial.println();
    Serial.print("Test ID:, ");
    Serial.println(Test_ID);
    Serial.print("Target Dry UW:, ");
    Serial.println(Dry_UW);
    Serial.print("Target Degree of Sat.:, ");
    Serial.println(Mst_Cnt);
    Serial.print("Date:, ");
    Serial.println(Date);
    Serial.println();
    Serial.println("Raw mV Outputs");
    delay(1000);

 }
```

```
void loop() {

//BEGIN TAKING READINGS AND SUMMING THEM
   myStats1.add(analogRead(analogPin7));

//ONCE numReadings IS ACHIEVED, AVERAGE THE READINGS
   if (myStats1.count() == numReadings){
   T10_1= myStats1.average();

//PRINT MEASUREMENTS TO SERIAL MONITOR
    Serial.println(T10_1);

//CLEAR THE myStats VARIABLES
   myStats1.clear();
   delay(500);

}
}
```

```
//CODE USED FOR SENSOR INSERTION AND COMPRESSION TESTING//

//LIBRARIES TO INCLUDE
  #include <Arduino.h>    //Base Arduino Library
  #include "Statistic.h"  //Stats Library

//DEFINE VARIABLES
  double analogPin7 = A7; //Assigning a variable name to physical microcontroller pins
  Statistic myStats1; //Identify variables needed for Stats Function
  const int numReadings= 1000; //Each individual measumrent will be the average of this many recordings
  double T10_1; //Sensor 1 connected to pin A7

//HEADER INFO
   String Test_ID = "Compression Test #2";
   String Dry_UW = "85, pcf";
   String Mst_Cnt = "15, %";
   String Date = "05/03/23";

void setup() {

//TURN ON SERIAL PRINTER AND PRINT 3 BLANK LINES
    Serial.begin(9600);
    Serial.println();
    Serial.println();
    Serial.println();

//REFRESHING CODE TO GIVE MICROCONTROLLER TIME TO STABILIZE - Zana
    for(uint8_t t = 4; t > 0; t--) {
    Serial.printf("[SETUP] WAIT %d...\n", t);
    Serial.flush();
    delay(1000);
    }

//INITIALLY CLEAR THE myStats VARIABLES
    myStats1.clear();
```

```
//PRINT HEADER
   delay(3000);
   Serial.println();
   Serial.print("Test ID:, "); Serial.println(Test_ID);
   Serial.print("Target Dry UW:, "); Serial.println(Dry_UW);
   Serial.print("Target Mst. Cont.:, "); Serial.println(Mst_Cnt);
   Serial.print("Date:, "); Serial.println(Date);
   Serial.println();
   Serial.print("Raw mV Outputs"); Serial.print(","); Serial.println("Ellapsed Time");
   delay(1000);

}

void loop() {

//BEGIN TAKING READINGS AND SUMMING THEM
   myStats1.add(analogRead(analogPin7));

//ONCE numReadings IS ACHIEVED, AVERAGE THE READINGS
   if (myStats1.count() == numReadings){
   T10_1= myStats1.average();

//PRINT MEASUREMENTS TO SERIAL MONITOR
    Serial.print(T10_1); Serial.print(",");

//PRINT ELAPSED TIME IN MILLISECONDS TO SERIAL MONITOR
    Serial.println(millis());

//CLEAR THE myStats VARIABLES
   myStats1.clear();

}
}
```

```
//CODE USED FOR INFILTRATION TESTING//

//LIBRARIES TO INCLUDE
  #include <Arduino.h>    //Base Arduino Library
  #include "Statistic.h"  //Stats Library

//DEFINE VARIABLES
  double analogPin7 = A7; //Assigning a variable name to physical microcontroller pins
  Statistic myStats1; //Identify variables needed for Stats Function
  const int numReadings= 5000; //Each reported output will be the average of this many measurements
  double T10_1; //Sensor 1 connected to pin A7

//HEADER INFO
   String Test_ID = "Inundation Test #1";
   String Date = "05/03/23";

void setup() {

//TURN ON SERIAL PRINTER AND PRINT 3 BLANK LINES
    Serial.begin(9600);
    Serial.println();
    Serial.println();
    Serial.println();

//REFRESHING CODE TO GIVE MICROCONTROLLER TIME TO STABILIZE - Zana
    for(uint8_t t = 4; t > 0; t--) {
    Serial.printf("[SETUP] WAIT %d...\n", t);
    Serial.flush();
    delay(1000);
    }

//INITIALLY CLEAR THE myStats VARIABLES
    myStats1.clear();
```

```
//PRINT HEADER
   delay(3000);
   Serial.println();
   Serial.print("Test ID:, "); Serial.println(Test_ID);
   Serial.print("Date:, "); Serial.println(Date);
   Serial.println();
   Serial.print("Raw mV Outputs"); Serial.print(","); Serial.println("Ellapsed Time");
   delay(1000);

}

void loop() {

//BEGIN TAKING READINGS AND SUMMING THEM
   myStats1.add(analogRead(analogPin7));

//ONCE numReadings IS ACHIEVED, AVERAGE THE READINGS
   if (myStats1.count() == numReadings){
   T10_1= myStats1.average();

//PRINT MEASUREMENTS TO SERIAL MONITOR
    Serial.print(T10_1); Serial.print(",");

//PRINT ELAPSED TIME IN MILLISECONDS TO SERIAL MONITOR
    Serial.println(millis());

//CLEAR THE myStats VARIABLES
   myStats1.clear();

//DELAY 4.5 Seconds
   delay(4500);
}
}
```

APPENDIX D

DATA PROCESSING

DETAILS FOR SMALL MOLD				
Characteristic	**Units**	**Mold 1**	**Mold 2**	**Mold 3**
Total Empty Mold Mass	g	503.75	503.23	504.00
Mold Diameter	mm	102.10	102.38	102.24
		102.27	102.17	102.03
		101.94	102.11	102.25
Average		**102.10**	**102.22**	**102.17**
Height of Controlled Volume	mm	96.73	101.12	98.18
		97.91	100.70	98.15
		97.91	100.14	98.15
Average		**97.52**	**100.65**	**98.16**
Total Mold Height	mm	152.63	153.10	152.61
		152.85	153.91	152.68
		152.52	153.28	152.47
Average		**152.67**	**153.43**	**152.59**
Approx. Cross Sectional Area	mm^2	8187.85	8206.57	8199.08
Approx. Cross Sectional Area	cm^2	81.88	82.07	81.99
Approx. Controlled Volume	mm^3	798451.55	826018.54	804821.47
Approx. Controlled Volume	cm^3	798.45	826.02	804.82

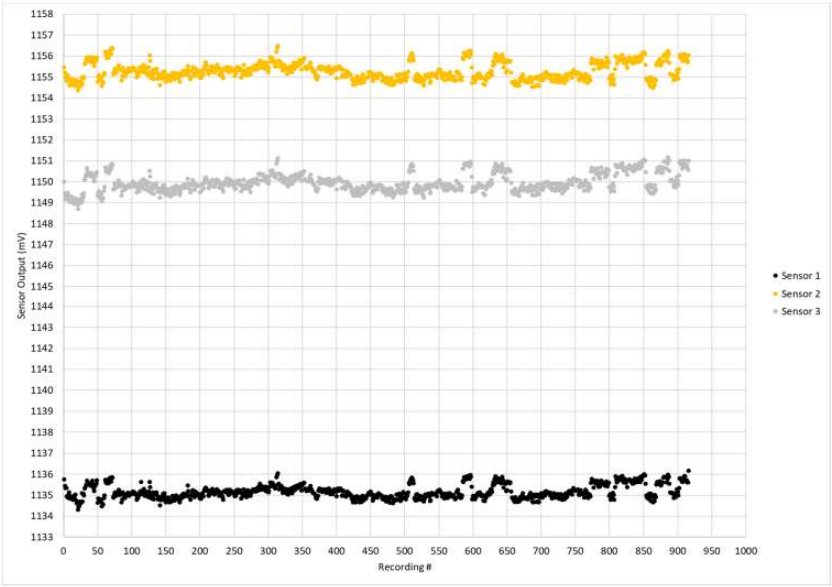
Calibration Test: M-01				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	8/3/2022	8/3/2022	8/3/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	90	90	90
	g/cm^3	1.44	1.44	1.44
Target Volumetric Moisture Content	%	0%	0%	0%
Target Gravimetric Moisture Content	%	0.0%	0.0%	0.0%
Details for Control Volume Prep				
Mass of Solids	g	1151.06	1190.80	1160.24
Mass of Water [a]	g	0.00	0.00	0.00
Details for Cover				
Mass of Solids [b]	g	432.48	432.48	432.48
Mass of Water [a, b]	g	0.00	0.00	0.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	8/4/2022	8/4/2022	8/4/2022
Mass of Mold	g	503.84	503.44	503.98
Mass of Mold + Specimen	g	1655.00	1694.33	1564.21
Depth to Top of Specimen	mm	53.97	52.99	63.11
	mm	55.89	53.13	63.14
	mm	53.57	52.68	61.81
	mm	54.97	52.20	63.20
Average	mm	54.60	52.75	62.82
Specimen Total Mass	g	1151.16	1190.89	1060.23
Specimen Total Volume	cm^3	802.95	826.24	736.04
Specimen Total Density	g/cm^3	1.43	1.44	1.44
	pcf	89.5	90.0	89.9
Specimen Dry Density	**g/cm^3**	**1.43**	**1.44**	**1.44**
	pcf	**89.2**	**89.7**	**89.6**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	154.15	358.83	152.74
Mass of Tare + Wet Tailings	g	1166.84	1472.33	1026.93
Mass of Tare + Dry Tailings	g	1162.93	1468.63	1024.18
Total Sample Mass	g	1012.69	1113.5	874.19
Mass of Solids	g	1008.78	1109.8	871.44
Mass of Water	g	3.91	3.7	2.75
Gravimetric Moisture Content	%	0.4%	0.3%	0.3%
Volumetric Moisture Content [a]	**%**	**0.6%**	**0.5%**	**0.5%**
Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	4.44	3.96	3.34
Mass of Solids (in molded specimen)	g	1146.72	1186.93	1056.89
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	421.59	436.37	388.56
Volume of Water [a]	cm^3	4.44	3.96	3.34
Volume of Voids	cm^3	381.37	389.87	347.48
Degree of Saturation	**%**	**1.2%**	**1.0%**	**1.0%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-01
Target Dry UW: 90 pcf
Target Vol. Mst. Con.: 0 %
Date: 08/04/22

Specimen A	Specimen B	Specimen C	
1135.75	1155.46	1150	1
1135.45	1155.22	1149.45	2
1135.34	1155.01	1149.16	3
1135.34	1154.98	1149.32	4
1134.94	1154.81	1149.27	5
1134.89	1155.08	1149.46	6
1135	1154.88	1149.2	7
1135.14	1154.91	1149.33	8
1134.84	1154.6	1149.03	9
1134.95	1154.77	1149.08	10
1134.89	1154.65	1149.03	11
1134.89	1154.9	1149.28	12
1134.79	1154.78	1149.19	13
1134.94	1154.74	1149.09	14
1134.83	1154.57	1148.95	15
1134.92	1154.74	1149.1	16
1135.04	1154.86	1149.2	17
1134.76	1154.64	1149.04	18
1134.62	1154.65	1148.94	19
1134.68	1154.8	1149.14	20
1134.31	1154.36	1148.71	21
1134.46	1154.54	1148.92	22
1134.49	1154.54	1148.97	23
1134.71	1154.79	1149.19	24
1134.64	1154.75	1149.13	25
1134.64	1154.61	1149	26
1135.1	1154.98	1149.4	27
1134.7	1154.7	1149.11	28
1135.07	1154.93	1149.29	29
1135	1155.01	1149.44	30
1135.32	1155.63	1150.1	31
1135.36	1155.68	1150.21	32
1135.49	1155.84	1150.33	33
1135.69	1155.94	1150.65	34
1135.56	1155.92	1150.49	35
1135.56	1155.93	1150.44	36
1135.5	1155.8	1150.32	37
1135.51	1155.87	1150.39	38
1135.46	1155.73	1150.28	39
1135.45	1155.75	1150.29	40
1135.62	1155.96	1150.42	41
1135.7	1155.77	1150.37	42
1135.44	1155.76	1150.25	43
1135.35	1155.65	1150.19	44
1135.2	1155.52	1150.02	45
1135.45	1155.89	1150.36	46
1135.53	1155.76	1150.3	47
1135.54	1155.79	1150.43	48
1135.72	1155.93	1150.46	49
	Cont.		

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	0.6%	0.5%	0.5%
Acutal DUW (g/cm^3)	1.43	1.44	1.44
Degree of Saturation	1.2%	1.0%	1.0%
Average Raw mV - Full	1135.17	1155.28	1149.96
Std. Dev. (mV) - Full	0.33	0.40	0.43
Average Raw mV > 500	1135.25	1155.29	1150.09
Std. Dev. (mV) > 500	0.37	0.46	0.48



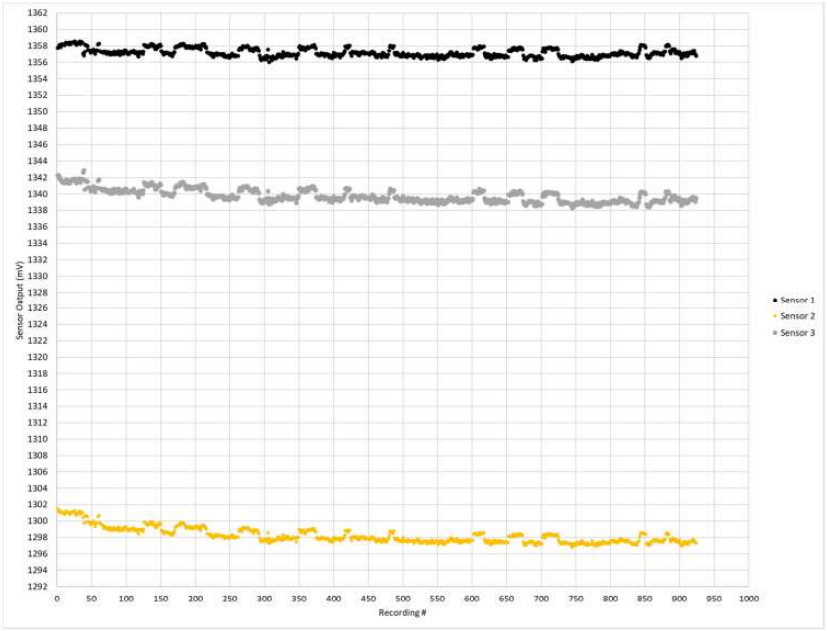
Calibration Test: M-02				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	8/4/2022	8/4/2022	8/4/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	90	90	90
	g/cm^3	1.44	1.44	1.44
Target Volumetric Moisture Content	%	5%	5%	5%
Target Gravimetric Moisture Content	%	3.5%	3.5%	3.5%
Details for Control Volume Prep				
Mass of Solids	g	1151.06	1190.80	1160.24
Mass of Water [a]	g	39.92	41.30	40.24
Details for Cover				
Mass of Solids [b]	g	432.48	432.48	432.48
Mass of Water [a, b]	g	15.00	15.00	15.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	8/6/2022	8/6/2022	8/6/2022
Mass of Mold	g	503.86	503.54	504.01
Mass of Mold + Specimen	g	1693.83	1734.82	1703.68
Depth to Top of Specimen	mm	67.94	54.16	55.72
	mm	65.70	52.56	56.97
	mm	63.88	51.72	56.86
	mm	66.27	53.02	55.96
Average	mm	65.95	52.87	56.38
Specimen Total Mass	g	1189.97	1231.28	1199.67
Specimen Total Volume	cm^3	710.04	825.29	788.83
Specimen Total Density	g/cm^3	1.68	1.49	1.52
	pcf	104.6	93.1	94.9
Specimen Dry Density	**g/cm^3**	**1.61**	**1.43**	**1.46**
	pcf	**100.3**	**89.4**	**91.2**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	154.09	358.78	152.6
Mass of Tare + Wet Tailings	g	1298.22	1485.88	1319.67
Mass of Tare + Dry Tailings	g	1250.82	1440.24	1273.04
Total Sample Mass	g	1144.13	1127.1	1167.07
Mass of Solids	g	1096.73	1081.46	1120.44
Mass of Water	g	47.4	45.64	46.63
Gravimetric Moisture Content	%	4.3%	4.2%	4.2%
Volumetric Moisture Content [a]	**%**	**6.9%**	**6.0%**	**6.1%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	49.30	49.86	47.93
Mass of Solids (in molded specimen)	g	1140.67	1181.42	1151.74
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	419.36	434.35	423.43
Volume of Water [a]	cm^3	49.30	49.86	47.93
Volume of Voids	cm^3	290.68	390.95	365.39
Degree of Saturation	**%**	**17.0%**	**12.8%**	**13.1%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-02
Target Dry UW: 90 pcf
Target Vol. Mst. Con.: 5 %
Date: 08/06/22

Specimen A	Specimen B	Specimen C	
1357.73	1301.49	1342.24	1
1357.84	1301.29	1342.32	2
1357.92	1301.18	1341.91	3
1358.1	1301.3	1342.06	4
1357.82	1301.02	1341.76	5
1358.14	1301.1	1341.6	6
1358.23	1301.13	1341.56	7
1358.1	1301.05	1341.41	8
1358.15	1300.99	1341.43	9
1358.11	1300.87	1341.34	10
1358.07	1300.8	1341.28	11
1358.32	1301.07	1341.59	12
1358.39	1301.25	1341.74	13
1358.37	1301.14	1341.68	14
1358.26	1301.09	1341.55	15
1358.24	1300.97	1341.29	16
1358.34	1301.06	1341.61	17
1358.39	1301.05	1341.62	18
1358.17	1300.81	1341.29	19
1358.32	1301	1341.54	20
1358.4	1301.1	1341.65	21
1358.43	1301.16	1341.74	22
1358.35	1301.04	1341.65	23
1358.45	1301.1	1341.71	24
1358.51	1301.17	1341.78	25
1358.54	1301.28	1341.85	26
1358.27	1300.87	1341.53	27
1358.12	1300.71	1341.31	28
1358.28	1300.9	1341.49	29
1358.28	1300.98	1341.59	30
1358.37	1300.99	1341.57	31
1358.5	1301.19	1341.85	32
1358.53	1301.16	1341.83	33
1358.2	1300.79	1341.41	34
1358.33	1300.94	1341.63	35
1358.48	1301.08	1341.79	36
1358.43	1301.04	1341.8	37
1357.08	1300.42	1342.61	38
1356.83	1299.78	1342.87	39
1357.25	1299.79	1340.55	40
1358.1	1300.73	1341.61	41
1358.11	1300.63	1341.61	42
1358	1300.59	1341.51	43
1357.98	1300.54	1341.5	44
1357.49	1299.94	1340.78	45
1357.45	1299.87	1340.76	46
1357.44	1299.9	1340.79	47
1357.42	1299.83	1340.72	48
1357.15	1299.57	1340.36	49
	Cont.		

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	6.9%	6.0%	6.1%
Acutal DUW (g/cm^3)	1.61	1.43	1.46
Degree of Saturation	17.0%	12.8%	13.1%
Average Raw mV - Full	1357.18	1298.23	1339.76
Std. Dev. (mV) - Full	0.52	0.95	0.82
Average Raw mV > 500	1356.98	1297.60	1339.23
Std. Dev. (mV) > 500	0.43	0.40	0.49



Calibration Test: M-03				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	8/6/2022	8/6/2022	8/6/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	90	90	90
	g/cm^3	1.44	1.44	1.44
Target Volumetric Moisture Content	%	10%	10%	10%
Target Gravimetric Moisture Content	%	6.9%	6.9%	6.9%
Details for Control Volume Prep				
Mass of Solids	g	1151.06	1190.80	1160.24
Mass of Water [a]	g	79.85	82.60	80.48
Details for Cover				
Mass of Solids [b]	g	432.48	432.48	432.48
Mass of Water [a, b]	g	30.00	30.00	30.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	8/7/2022	8/7/2022	8/7/2022
Mass of Mold	g	503.88	503.48	504.04
Mass of Mold + Specimen	g	1733.71	1776.04	1743.93
Depth to Top of Specimen	mm	56.09	54.00	56.01
	mm	56.48	54.08	56.81
	mm	55.91	54.21	56.81
	mm	56.53	53.78	55.52
Average	mm	56.25	54.02	56.29
Specimen Total Mass	g	1229.83	1272.56	1239.89
Specimen Total Volume	cm^3	789.42	815.84	789.56
Specimen Total Density	g/cm^3	1.56	1.56	1.57
	pcf	97.3	97.4	98.0
Specimen Dry Density	**g/cm^3**	**1.45**	**1.45**	**1.46**
	pcf	**90.6**	**90.7**	**91.2**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	155.53	289.57	279.12
Mass of Tare + Wet Tailings	g	1369.23	1245.96	1305.98
Mass of Tare + Dry Tailings	g	1285.64	1180.42	1234.23
Total Sample Mass	g	1213.7	956.39	1026.86
Mass of Solids	g	1130.11	890.85	955.11
Mass of Water	g	83.59	65.54	71.75
Gravimetric Moisture Content	%	7.4%	7.4%	7.5%
Volumetric Moisture Content [a]	**%**	**10.7%**	**10.7%**	**11.0%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	84.70	87.21	86.64
Mass of Solids (in molded specimen)	g	1145.13	1185.35	1153.25
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	421.00	435.79	423.99
Volume of Water [a]	cm^3	84.70	87.21	86.64
Volume of Voids	cm^3	368.42	380.04	365.57
Degree of Saturation	**%**	**23.0%**	**22.9%**	**23.7%**

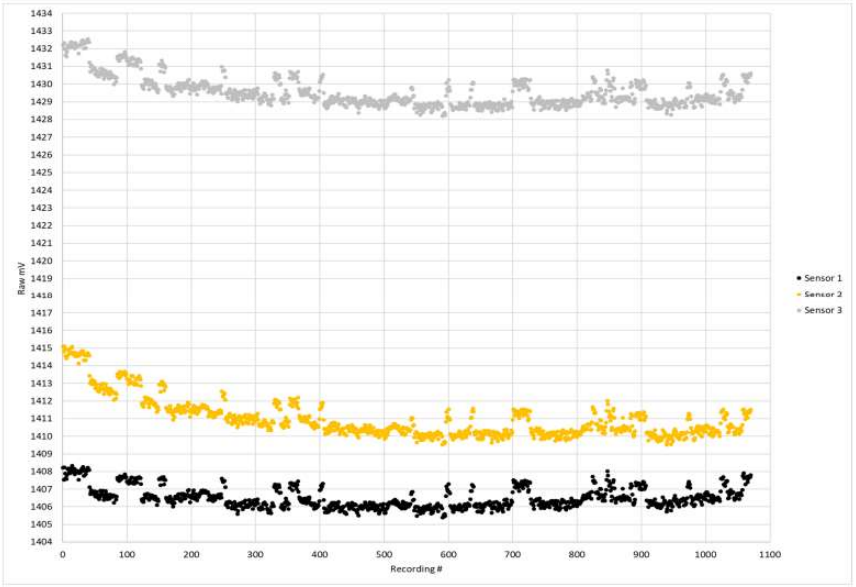
Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-03
Target Dry UW: 90 pcf
Target Vol. Mst. Con.: 10 %
Date: 08/07/22

Specimen A	Specimen B	Specimen C	
1408.22	1415.08	1432.22	1
1407.54	1414.79	1432	2
1408.23	1415.11	1432.32	3
1407.88	1414.93	1431.98	4
1407.63	1414.55	1431.64	5
1407.58	1414.42	1431.56	6
1407.8	1414.54	1431.81	7
1408.13	1414.93	1432.14	8
1408.18	1414.91	1432.19	9
1407.91	1414.67	1432.05	10
1407.98	1414.77	1432.07	11
1407.9	1414.72	1432.09	12
1408.17	1414.99	1432.36	13
1408.13	1415.01	1432.21	14
1408.32	1415.08	1432.34	15
1408	1414.67	1432.1	16
1408.07	1414.76	1432.19	17
1408.15	1414.76	1432.29	18
1407.84	1414.55	1432.01	19
1408.08	1414.7	1432.33	20
1408.05	1414.67	1432.17	21
1407.96	1414.54	1432.11	22
1407.98	1414.56	1432.17	23
1408.03	1414.71	1432.19	24
1407.53	1414.14	1431.73	25
1407.91	1414.58	1432.17	26
1408	1414.64	1432.18	27
1407.94	1414.65	1432.19	28
1408.1	1414.8	1432.29	29
1408.15	1414.85	1432.44	30
1408.05	1414.64	1432.28	31
1408.26	1414.83	1432.49	32
1407.76	1414.32	1432.02	33
1408.1	1414.64	1432.29	34
1408.05	1414.57	1432.33	35
1407.85	1414.31	1432.05	36
1408.01	1414.58	1432.37	37
1408.13	1414.59	1432.42	38
1408.21	1414.73	1432.54	39
1408.08	1414.62	1432.37	40
1408.09	1414.57	1432.36	41
1407.12	1413.43	1431.23	42
1406.71	1412.98	1430.7	43
1406.84	1413.11	1430.98	44
1406.93	1413.17	1431.07	45
1406.9	1413.2	1431	46
1406.73	1412.95	1430.78	47
1406.83	1413.09	1430.9	48
1406.76	1412.97	1430.83	49

Cont.

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	10.7%	10.7%	11.0%
Acutal DUW (g/cm^3)	1.45	1.45	1.46
Degree of Saturation	23.0%	22.9%	23.7%
Average Raw mV - Full	1406.51	1411.00	1429.55
Std. Dev. (mV) - Full	0.59	1.15	0.87
Average Raw mV > 500	1406.42	1410.39	1429.16
Std. Dev. (mV) > 500	0.51	0.49	0.52



Calibration Test: M-04				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	8/7/2022	8/7/2022	8/7/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	90	90	90
	g/cm^3	1.44	1.44	1.44
Target Volumetric Moisture Content	%	15%	15%	15%
Target Gravimetric Moisture Content	%	10.4%	10.4%	10.4%
Details for Control Volume Prep				
Mass of Solids	g	1151.06	1190.80	1160.24
Mass of Water [a]	g	119.77	123.90	120.72
Details for Cover				
Mass of Solids [b]	g	432.48	432.48	432.48
Mass of Water [a, b]	g	45.00	45.00	45.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	8/8/2022	8/8/2022	8/8/2022
Mass of Mold	g	503.88	503.45	504.05
Mass of Mold + Specimen	g	1774.22	1817.59	1784.44
Depth to Top of Specimen	mm	57.97	54.62	56.04
	mm	56.04	54.45	56.05
	mm	56.04	53.31	57.20
	mm	56.36	53.77	55.99
Average	mm	56.60	54.04	56.32
Specimen Total Mass	g	1270.34	1314.14	1280.39
Specimen Total Volume	cm^3	786.56	815.67	789.30
Specimen Total Density	g/cm^3	1.62	1.61	1.62
	pcf	100.8	100.6	101.3
Specimen Dry Density	**g/cm^3**	**1.45**	**1.45**	**1.46**
	pcf	**90.7**	**90.5**	**91.3**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	154.06	152.59	358.79
Mass of Tare + Wet Tailings	g	1350.45	1379.09	1601.36
Mass of Tare + Dry Tailings	g	1230.24	1256.74	1478.82
Total Sample Mass	g	1196.39	1226.5	1242.57
Mass of Solids	g	1076.18	1104.15	1120.03
Mass of Water	g	120.21	122.35	122.54
Gravimetric Moisture Content	%	11.2%	11.1%	10.9%
Volumetric Moisture Content [a]	**%**	**16.2%**	**16.1%**	**16.0%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	127.64	131.09	126.27
Mass of Solids (in molded specimen)	g	1142.70	1183.05	1154.12
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	420.11	434.94	424.31
Volume of Water [a]	cm^3	127.64	131.09	126.27
Volume of Voids	cm^3	366.45	380.73	364.99
Degree of Saturation	**%**	**34.8%**	**34.4%**	**34.6%**

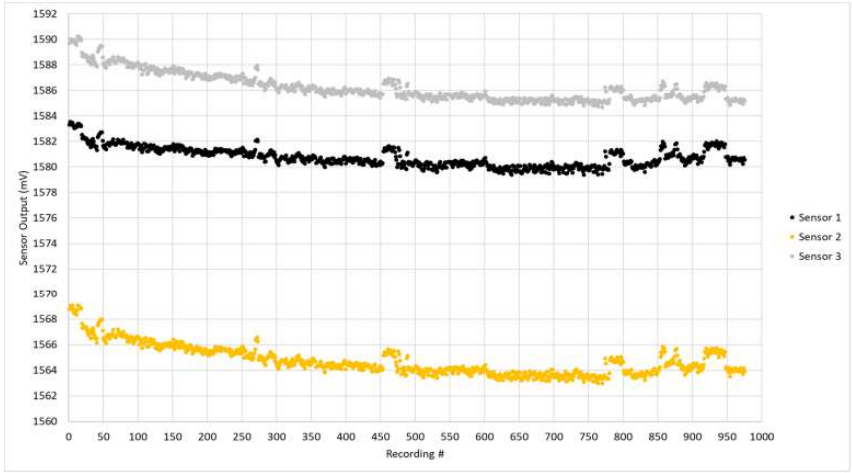
Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-04
Target Dry UW: 90 pcf
Target Vol. Mst. Con.: 15 %
Date: 08/08/22

Specimen A	Specimen B	Specimen C	
1583.32	1568.77	1589.68	1
1583.52	1569.02	1590	2
1583.32	1568.8	1589.83	3
1583.37	1568.99	1589.88	4
1583.48	1569.07	1589.99	5
1583.35	1568.85	1589.96	6
1583.17	1568.59	1589.81	7
1583.02	1568.44	1589.72	8
1583.17	1568.65	1589.95	9
1583.13	1568.39	1589.76	10
1583.11	1568.34	1589.55	11
1583.15	1568.7	1589.87	12
1583.36	1569.08	1590.22	13
1583.34	1568.96	1590.14	14
1583.38	1569	1590.19	15
1583.23	1568.86	1590.1	16
1583.28	1568.89	1590.07	17
1583.19	1568.8	1589.91	18
1582.53	1567.65	1588.97	19
1582.23	1567.3	1588.67	20
1582.22	1567.33	1588.65	21
1582.33	1567.4	1588.78	22
1582.28	1567.42	1588.79	23
1582.18	1567.31	1588.66	24
1582.18	1567.27	1588.64	25
1582.22	1567.36	1588.73	26
1581.93	1567	1588.46	27
1581.8	1566.76	1588.25	28
1582.05	1567.1	1588.55	29
1581.8	1566.88	1588.32	30
1582.05	1567.07	1588.58	31
1581.54	1566.49	1588.06	32
1581.59	1566.5	1588.01	33
1581.83	1566.88	1588.35	34
1582.2	1567.3	1588.74	35
1581.97	1567.04	1588.53	36
1581.63	1566.74	1588.22	37
1581.65	1566.65	1588.19	38
1581.52	1566.48	1587.98	39
1581.59	1566.46	1587.97	40
1581.32	1566.15	1587.84	41
1582.32	1567.51	1589.02	42
1582.45	1567.63	1589.18	43
1582.54	1567.76	1589.32	44
1582.61	1567.83	1589.35	45
1582.72	1567.96	1589.49	46
1582.72	1567.99	1589.47	47
1582.71	1567.96	1589.45	48
1582.05	1567.1	1588.57	49

Cont.

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	16.2%	16.1%	16.0%
Acutal DUW (g/cm^3)	1.45	1.45	1.46
Degree of Saturation	34.8%	34.4%	34.6%
Average Raw mV - Full	1580.75	1564.75	1586.23
Std. Dev. (mV) - Full	0.77	1.18	1.13
Average Raw mV > 500	1580.32	1563.99	1585.43
Std. Dev. (mV) > 500	0.59	0.60	0.39



Calibration Test: M-05				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	8/8/2022	8/8/2022	8/8/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	90	90	90
	g/cm^3	1.44	1.44	1.44
Target Volumetric Moisture Content	%	20%	20%	20%
Target Gravimetric Moisture Content	%	13.9%	13.9%	13.9%
Details for Control Volume Prep				
Mass of Solids	g	1151.06	1190.80	1160.24
Mass of Water [a]	g	159.69	165.20	160.96
Details for Cover				
Mass of Solids [b]	g	432.48	432.48	432.48
Mass of Water [a, b]	g	60.00	60.00	60.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	8/9/2022	8/9/2022	8/9/2022
Mass of Mold	g	503.87	503.45	504.04
Mass of Mold + Specimen	g	1813.87	1858.68	1824.47
Depth to Top of Specimen	mm	56.38	55.91	56.76
	mm	56.71	54.57	56.61
	mm	55.86	53.70	55.87
	mm	56.33	55.83	55.92
Average	mm	56.32	55.00	56.29
Specimen Total Mass	g	1310.00	1355.23	1320.43
Specimen Total Volume	cm^3	788.87	807.75	789.54
Specimen Total Density	g/cm^3	1.66	1.68	1.67
	pcf	103.7	104.7	104.4
Specimen Dry Density	**g/cm^3**	**1.46**	**1.47**	**1.47**
	pcf	**90.9**	**91.9**	**91.5**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	152.56	155.41	154.01
Mass of Tare + Wet Tailings	g	1411.02	1489.69	1432.03
Mass of Tare + Dry Tailings	g	1256.58	1326.34	1273.84
Total Sample Mass	g	1258.46	1334.28	1278.02
Mass of Solids	g	1104.02	1170.93	1119.83
Mass of Water	g	154.44	163.35	158.19
Gravimetric Moisture Content	%	14.0%	14.0%	14.1%
Volumetric Moisture Content [a]	**%**	**20.4%**	**20.5%**	**20.7%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	160.77	165.91	163.44
Mass of Solids (in molded specimen)	g	1149.23	1189.32	1156.99
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	422.51	437.25	425.36
Volume of Water [a]	cm^3	160.77	165.91	163.44
Volume of Voids	cm^3	366.36	370.50	364.18
Degree of Saturation	**%**	**43.9%**	**44.8%**	**44.9%**

Notes:

a) Value assumes density of water is 1 g/cm^3

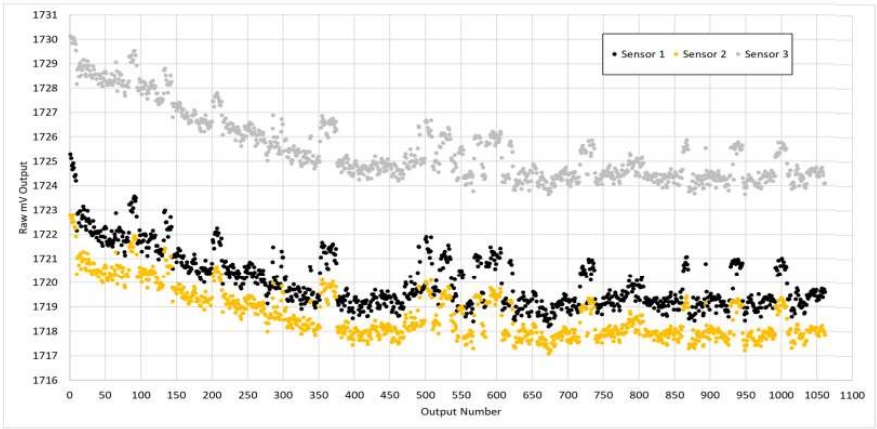
b) Value based on assumed total volume of 300 cm^3

Test ID: M-05
Target Dry UW: 90 pcf
Target Vol. Mst. Con.: 20 %
Date: 08/09/22

Specimen A	Specimen B	Specimen C	
1725.28	1722.78	1730.12	1
1725.13	1722.71	1730.06	2
1724.82	1722.65	1730.04	3
1724.66	1722.49	1729.84	4
1724.92	1722.8	1730.06	5
1724.73	1722.53	1730.05	6
1724.38	1722.31	1729.91	7
1724.44	1722.25	1729.81	8
1724.2	1721.91	1729.54	9
1722.15	1720.37	1728.17	10
1722.84	1721.02	1728.75	11
1722.88	1721.08	1728.8	12
1722.48	1720.73	1728.47	13
1722.96	1721.1	1728.91	14
1722.96	1721.21	1729.03	15
1722.33	1720.58	1728.51	16
1722.65	1720.89	1728.74	17
1722.78	1721	1728.86	18
1723.15	1721.28	1729.16	19
1723.02	1721.26	1729.15	20
1722.68	1720.97	1728.93	21
1722.33	1720.6	1728.57	22
1722.19	1720.53	1728.48	23
1722.55	1720.82	1728.78	24
1722.97	1721.22	1729.1	25
1722.63	1720.97	1728.91	26
1722.58	1720.88	1728.93	27
1722.46	1720.79	1728.73	28
1722.11	1720.49	1728.53	29
1722.11	1720.51	1728.54	30
1721.99	1720.38	1728.42	31
1721.96	1720.34	1728.42	32
1722.55	1720.83	1728.9	33
1722.3	1720.8	1728.75	34
1722.05	1720.53	1728.54	35
1722.11	1720.51	1728.57	36
1722.06	1720.45	1728.56	37
1721.87	1720.32	1728.37	38
1722.13	1720.55	1728.56	39
1722.06	1720.52	1728.55	40
1721.74	1720.22	1728.17	41
1722.13	1720.5	1728.53	42
1722.14	1720.5	1728.57	43
1721.92	1720.42	1728.4	44
1721.66	1720.07	1728.21	45
1721.54	1720	1728.06	46
1721.91	1720.37	1728.41	47
1722.23	1720.63	1728.63	48
1721.89	1720.39	1728.32	49

Cont.

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	20.4%	20.5%	20.7%
Acutal DUW (g/cm^3)	1.46	1.47	1.47
Degree of Saturation	43.9%	44.8%	44.9%
Average Raw mV - Full	1720.09	1718.71	1725.54
Std. Dev. (mV) - Full	1.20	1.06	1.45
Average Raw mV > 500	1719.56	1718.18	1724.69
Std. Dev. (mV) > 500	0.78	0.64	0.65



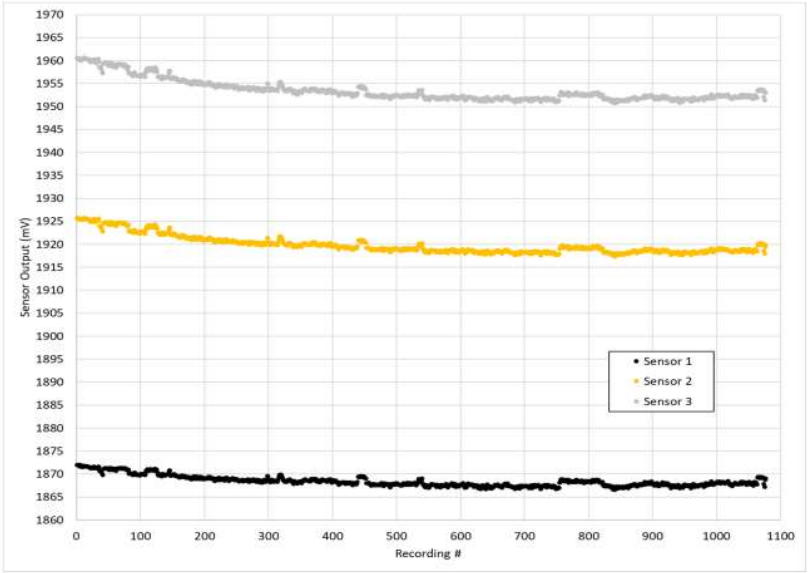
Calibration Test: M-06				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	8/9/2022	8/9/2022	8/9/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	90	90	90
	g/cm^3	1.44	1.44	1.44
Target Volumetric Moisture Content	%	25%	25%	25%
Target Gravimetric Moisture Content	%	17.3%	17.3%	17.3%
Details for Control Volume Prep				
Mass of Solids	g	1151.06	1190.80	1160.24
Mass of Water [a]	g	199.61	206.50	201.21
Details for Cover				
Mass of Solids [b]	g	432.48	432.48	432.48
Mass of Water [a, b]	g	75.00	75.00	75.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	8/10/2022	8/10/2022	8/10/2022
Mass of Mold	g	503.84	503.45	504.02
Mass of Mold + Specimen	g	1853.86	1900.05	1864.57
Depth to Top of Specimen	mm	56.25	54.14	56.06
	mm	55.90	54.22	56.72
	mm	56.74	54.86	56.14
	mm	56.37	54.04	56.09
Average	mm	56.32	54.32	56.25
Specimen Total Mass	g	1350.02	1396.60	1360.55
Specimen Total Volume	cm^3	788.91	813.39	789.85
Specimen Total Density	g/cm^3	1.71	1.72	1.72
	pcf	106.8	107.2	107.5
Specimen Dry Density	**g/cm^3**	**1.45**	**1.46**	**1.46**
	pcf	**90.8**	**91.2**	**91.4**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	154.02	152.5	155.32
Mass of Tare + Wet Tailings	g	1479.98	1520.59	1458.67
Mass of Tare + Dry Tailings	g	1281.42	1315.94	1263.28
Total Sample Mass	g	1325.96	1368.09	1303.35
Mass of Solids	g	1127.4	1163.44	1107.96
Mass of Water	g	198.56	204.65	195.39
Gravimetric Moisture Content	%	17.6%	17.6%	17.6%
Volumetric Moisture Content [a]	**%**	**25.6%**	**25.7%**	**25.8%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	202.16	208.91	203.97
Mass of Solids (in molded specimen)	g	1147.86	1187.69	1156.58
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	422.01	436.65	425.22
Volume of Water [a]	cm^3	202.16	208.91	203.97
Volume of Voids	cm^3	366.91	376.75	364.64
Degree of Saturation	**%**	**55.1%**	**55.5%**	**55.9%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-06
Target Dry UW: 90 pcf
Target Vol. Mst. Con.: 25 %
Date: 08/10/22

Specimen A	Specimen B	Specimen C	
1871.97	1925.76	1960.51	1
1871.89	1925.43	1960.25	2
1871.95	1925.69	1960.44	3
1871.93	1925.74	1960.42	4
1871.63	1925.3	1960.06	5
1872.02	1925.59	1960.27	6
1871.89	1925.38	1960.03	7
1871.69	1925.46	1960.25	8
1871.56	1925.37	1960.22	9
1871.54	1925.46	1960.37	10
1871.76	1925.74	1960.69	11
1871.81	1925.76	1960.64	12
1871.61	1925.45	1960.31	13
1871.58	1925.45	1960.39	14
1871.67	1925.59	1960.38	15
1871.63	1925.58	1960.41	16
1871.69	1925.62	1960.36	17
1871.6	1925.41	1960.21	18
1871.52	1925.35	1960.15	19
1871.55	1925.29	1960.14	20
1871.31	1925	1959.8	21
1871.2	1924.87	1959.62	22
1871.21	1924.91	1959.7	23
1871.41	1925.29	1960.07	24
1871.49	1925.35	1960.2	25
1871.46	1925.25	1960.12	26
1871.24	1924.88	1959.7	27
1871.65	1925.49	1960.32	28
1871.39	1925.07	1959.9	29
1871.23	1924.91	1959.59	30
1871.36	1925.01	1959.37	31
1871.37	1925.01	1959.76	32
1871.29	1925.03	1959.8	33
1871.65	1925.58	1960.4	34
1871.51	1925.2	1959.69	35
1870.65	1923.97	1958.55	36
1870.66	1923.95	1958.59	37
1870.55	1923.8	1958.42	38
1870.42	1923.6	1958.2	39
1870	1922.95	1957.51	40
1869.8	1922.78	1957.26	41
1871.07	1924.55	1959.26	42
1871.2	1924.71	1959.37	43
1871.17	1924.77	1959.42	44
1871.2	1924.8	1959.5	45
1871.31	1924.91	1959.59	46
1871.2	1924.68	1959.32	47
1871.12	1924.54	1959.21	48
1871.2	1924.69	1959.28	49
	Cont.		

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	25.6%	25.7%	25.8%
Acutal DUW (g/cm^3)	1.45	1.46	1.46
Degree of Saturation	55.1%	55.5%	55.9%
Average Raw mV - Full	1868.42	1919.84	1953.43
Std. Dev. (mV) - Full	1.17	1.95	2.31
Average Raw mV > 500	1867.70	1918.56	1951.94
Std. Dev. (mV) > 500	0.51	0.51	0.54



Calibration Test: M-07				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	8/10/2022	8/10/2022	8/10/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	90	100	100
	g/cm^3	1.44	1.60	1.60
Target Volumetric Moisture Content	%	5%	5%	5%
Target Gravimetric Moisture Content	%	3.5%	3.1%	3.1%
Details for Control Volume Prep				
Mass of Solids	g	1151.06	1323.11	1289.16
Mass of Water [a]	g	39.92	41.30	40.24
Details for Cover				
Mass of Solids [b]	g	432.48	480.54	480.54
Mass of Water [a, b]	g	15.00	15.00	15.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	8/11/2022	8/11/2022	8/11/2022
Mass of Mold	g	503.82	503.43	504.01
Mass of Mold + Specimen	g	1696.02	1866.90	1832.28
Depth to Top of Specimen	mm	56.87	55.16	57.16
	mm	56.16	54.84	56.16
	mm	56.31	55.56	56.28
	mm	56.47	55.23	57.50
Average	mm	56.45	55.20	56.78
Specimen Total Mass	g	1192.20	1363.47	1328.27
Specimen Total Volume	cm^3	787.79	806.15	785.57
Specimen Total Density	g/cm^3	1.51	1.69	1.69
	pcf	94.5	105.6	105.6
Specimen Dry Density	**g/cm^3**	**1.46**	**1.64**	**1.63**
	pcf	**91.1**	**102.2**	**102.0**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	154.04	152.47	155.3
Mass of Tare + Wet Tailings	g	1310.24	732.2	1406.69
Mass of Tare + Dry Tailings	g	1269.25	713.46	1364.95
Total Sample Mass	g	1156.2	579.73	1251.39
Mass of Solids	g	1115.21	560.99	1209.65
Mass of Water	g	40.99	18.74	41.74
Gravimetric Moisture Content	%	3.7%	3.3%	3.5%
Volumetric Moisture Content [a]	**%**	**5.4%**	**5.5%**	**5.6%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	42.27	44.07	44.30
Mass of Solids (in molded specimen)	g	1149.93	1319.40	1283.97
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	422.77	485.07	472.05
Volume of Water [a]	cm^3	42.27	44.07	44.30
Volume of Voids	cm^3	365.02	321.08	313.52
Degree of Saturation	**%**	**11.6%**	**13.7%**	**14.1%**

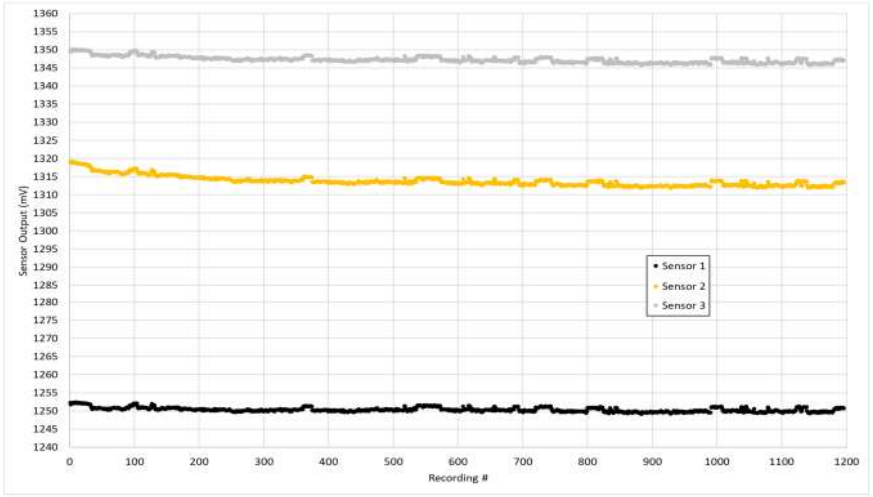
Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-07
Target Dry UW: 100 pcf
Target Vol. Mst. Con.: 5 %
Date: 08/11/22

Specimen A	Specimen B	Specimen C	
1252.26	1319.15	1349.96	1
1251.71	1318.69	1349.41	2
1252.05	1318.84	1349.63	3
1252.08	1318.94	1349.91	4
1252.24	1319.11	1350.01	5
1252.2	1318.82	1350.2	6
1252.07	1318.71	1349.73	7
1252.3	1318.92	1349.94	8
1252.45	1318.98	1350.07	9
1252.45	1318.93	1350.12	10
1252.27	1318.73	1349.94	11
1252.08	1318.51	1349.77	12
1252.04	1318.49	1349.72	13
1252.27	1318.69	1349.93	14
1252.24	1318.59	1349.93	15
1252.12	1318.47	1349.77	16
1252.09	1318.47	1349.81	17
1252.21	1318.62	1350	18
1252.18	1318.53	1350.03	19
1251.94	1318.35	1349.73	20
1252.06	1318.46	1349.85	21
1252.23	1318.54	1349.97	22
1252.12	1318.4	1349.87	23
1251.96	1318.24	1349.7	24
1252.1	1318.36	1349.86	25
1252.13	1318.37	1349.89	26
1251.94	1318.08	1349.72	27
1251.84	1317.99	1349.61	28
1252	1318.17	1349.69	29
1251.87	1318.02	1349.55	30
1251.88	1318.04	1349.77	31
1251.71	1317.84	1349.63	32
1251.33	1317.48	1349.17	33
1250.79	1316.86	1348.55	34
1250.46	1316.53	1348.25	35
1250.59	1316.64	1348.48	36
1250.71	1316.76	1348.61	37
1250.88	1316.95	1348.77	38
1250.72	1316.72	1348.56	39
1250.66	1316.62	1348.46	40
1250.66	1316.64	1348.51	41
1250.62	1316.6	1348.48	42
1250.84	1316.73	1348.67	43
1250.8	1316.71	1348.67	44
1250.86	1316.8	1348.71	45
1250.9	1316.76	1348.73	46
1250.67	1316.48	1348.42	47
1250.68	1316.51	1348.51	48
1250.73	1316.54	1348.55	49

Cont.

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	5.4%	5.5%	5.6%
Acutal DUW	1.46	1.64	1.63
Degree of Saturation	11.6%	13.7%	14.1%
Average Raw mV - Full	1250.33	1313.72	1347.24
Std. Dev. (mV) - Full	0.60	1.40	0.88
Average Raw mV > 500	1250.19	1312.96	1346.81
Std. Dev. (mV) > 500	0.57	0.69	0.63



Calibration Test: M-08				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	8/11/2022	8/11/2022	8/11/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	100	100	100
	g/cm^3	1.60	1.60	1.60
Target Volumetric Moisture Content	%	10%	10%	10%
Target Gravimetric Moisture Content	%	6.2%	6.2%	6.2%
Details for Control Volume Prep				
Mass of Solids	g	1278.95	1323.11	1289.16
Mass of Water [a]	g	79.85	82.60	80.48
Details for Cover				
Mass of Solids [b]	g	480.54	480.54	480.54
Mass of Water [a, b]	g	30.00	30.00	30.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	8/15/2022	8/15/2022	8/15/2022
Mass of Mold	g	503.85	503.41	504.05
Mass of Mold + Specimen	g	1861.83	1908.28	1872.85
Depth to Top of Specimen	mm	57.67	55.53	57.91
	mm	56.85	55.43	57.83
	mm	57.44	54.05	57.84
	mm	57.86	53.87	57.68
Average	mm	57.46	54.72	57.82
Specimen Total Mass	g	1357.98	1404.87	1368.80
Specimen Total Volume	cm^3	779.58	810.07	777.04
Specimen Total Density	g/cm^3	1.74	1.73	1.76
	pcf	108.7	108.3	110.0
Specimen Dry Density	**g/cm^3**	**1.63**	**1.63**	**1.65**
	pcf	**101.9**	**101.5**	**103.1**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	154.03	152.4	155.18
Mass of Tare + Wet Tailings	g	1428.02	1384.39	1403.07
Mass of Tare + Dry Tailings	g	1347.77	1307.19	1324.54
Total Sample Mass	g	1273.99	1231.99	1247.89
Mass of Solids	g	1193.74	1154.79	1169.36
Mass of Water	g	80.25	77.2	78.53
Gravimetric Moisture Content	%	6.7%	6.7%	6.7%
Volumetric Moisture Content [a]	**%**	**11.0%**	**10.9%**	**11.1%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	85.54	88.03	86.14
Mass of Solids (in molded specimen)	g	1272.44	1316.84	1282.66
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	467.81	484.13	471.57
Volume of Water [a]	cm^3	85.54	88.03	86.14
Volume of Voids	cm^3	311.77	325.94	305.47
Degree of Saturation	**%**	**27.4%**	**27.0%**	**28.2%**

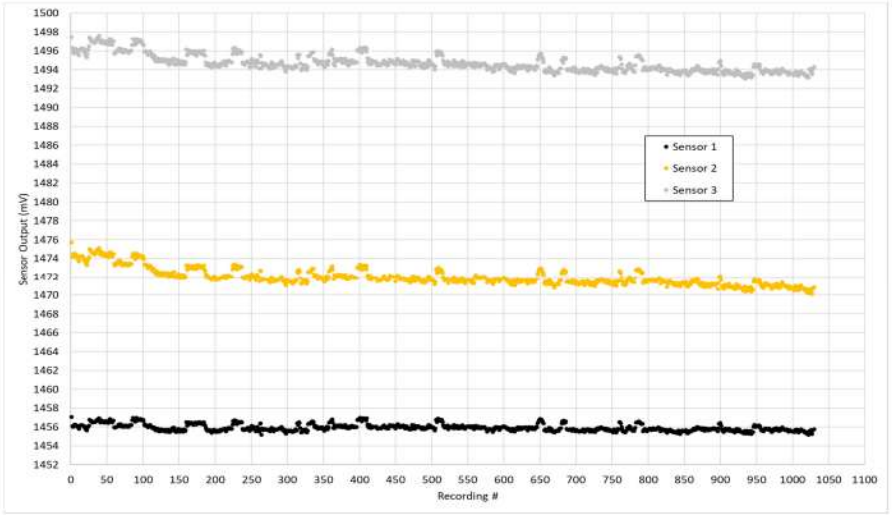
Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-08
Target Dry UW: 100 pcf
Target Vol. Mst. Con.: 10 %
Date: 08/15/22

Specimen A	Specimen B	Specimen C	
1457.07	1475.69	1497.47	1
1456.09	1474.41	1496.33	2
1456.02	1474.16	1495.94	3
1456.03	1474.23	1495.72	4
1456.27	1474.53	1496.25	5
1456.22	1474.41	1496.17	6
1456.23	1474.4	1496.2	7
1456.07	1474.21	1496.02	8
1456.03	1474.01	1495.75	9
1455.98	1473.93	1495.76	10
1455.8	1473.67	1495.51	11
1456.12	1474.22	1496.12	12
1456.11	1474.18	1496.08	13
1456.15	1474.22	1496.21	14
1456.2	1474.28	1496.29	15
1456.18	1474.22	1496.21	16
1456.14	1474.1	1496.26	17
1456.04	1473.89	1496	18
1455.91	1473.76	1495.83	19
1456.04	1473.95	1496.12	20
1455.72	1473.46	1495.49	21
1455.62	1473.29	1495.3	22
1455.91	1473.67	1495.71	23
1456.03	1473.95	1496.13	24
1456.13	1474.13	1496.49	25
1456.78	1475	1497.43	26
1456.72	1474.93	1497.27	27
1456.57	1474.74	1497.01	28
1456.62	1474.71	1497.14	29
1456.48	1474.56	1496.97	30
1456.51	1474.56	1496.95	31
1456.51	1474.56	1496.95	32
1456.52	1474.46	1496.84	33
1456.55	1474.55	1496.95	34
1456.65	1474.73	1497.19	35
1456.76	1474.91	1497.35	36
1456.75	1474.87	1497.3	37
1456.68	1474.8	1497.25	38
1456.92	1475.12	1497.6	39
1456.62	1474.59	1497.12	40
1456.47	1474.39	1496.88	41
1456.7	1474.75	1497.19	42
1456.67	1474.61	1497.04	43
1456.62	1474.55	1497.05	44
1456.61	1474.5	1496.98	45
1456.47	1474.26	1496.79	46
1456.46	1474.33	1496.79	47
1456.56	1474.52	1496.92	48
1456.62	1474.52	1497.06	49

Cont.

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	11.0%	10.9%	11.1%
Acutal DUW	1.63	1.63	1.65
Degree of Saturation	27.4%	27.0%	28.2%
Average Raw mV - Full	1455.91	1471.94	1494.67
Std. Dev. (mV) - Full	0.36	0.95	0.90
Average Raw mV > 500	1455.79	1471.40	1494.12
Std. Dev. (mV) > 500	0.29	0.51	0.52



Calibration Test: M-09				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	8/15/2022	8/15/2022	8/15/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	100	100	100
	g/cm^3	1.60	1.60	1.60
Target Volumetric Moisture Content	%	15%	15%	15%
Target Gravimetric Moisture Content	%	9.4%	9.4%	9.4%
Details for Control Volume Prep				
Mass of Solids	g	1278.95	1323.11	1289.16
Mass of Water [a]	g	119.77	123.90	120.72
Details for Cover				
Mass of Solids [b]	g	480.54	480.54	480.54
Mass of Water [a, b]	g	45.00	45.00	45.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	8/16/2022	8/16/2022	8/16/2022
Mass of Mold	g	503.83	503.44	504.01
Mass of Mold + Specimen	g	1902.03	1949.69	1913.26
Depth to Top of Specimen	mm	60.15	58.14	56.89
	mm	58.49	56.28	56.45
	mm	58.30	56.53	57.15
	mm	59.72	55.65	57.87
Average	mm	59.17	56.65	57.09
Specimen Total Mass	g	1398.20	1446.25	1409.25
Specimen Total Volume	cm^3	765.58	794.23	782.98
Specimen Total Density	g/cm^3	1.83	1.82	1.80
	pcf	114.0	113.7	112.4
Specimen Dry Density	**g/cm^3**	**1.66**	**1.66**	**1.64**
	pcf	**103.8**	**103.5**	**102.3**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	153.97	152.35	155.05
Mass of Tare + Wet Tailings	g	1492.37	1533.1	1491.32
Mass of Tare + Dry Tailings	g	1372.24	1409.99	1371.85
Total Sample Mass	g	1338.4	1380.75	1336.27
Mass of Solids	g	1218.27	1257.64	1216.8
Mass of Water	g	120.13	123.11	119.47
Gravimetric Moisture Content	%	9.9%	9.8%	9.8%
Volumetric Moisture Content [a]	**%**	**16.4%**	**16.2%**	**16.1%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	125.50	128.95	125.99
Mass of Solids (in molded specimen)	g	1272.70	1317.30	1283.26
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	467.91	484.30	471.78
Volume of Water [a]	cm^3	125.50	128.95	125.99
Volume of Voids	cm^3	297.67	309.93	311.20
Degree of Saturation	**%**	**42.2%**	**41.6%**	**40.5%**

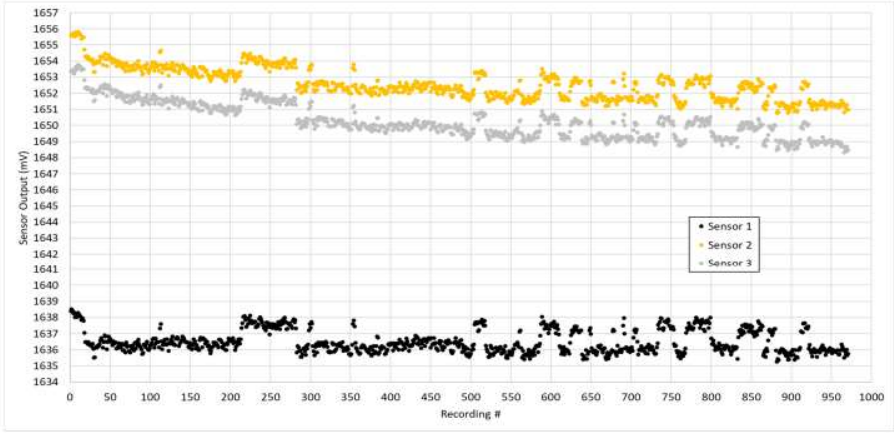
Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-09
Target Dry UW: 100 pcf
Target Vol. Mst. Con.: 15 %
Date: 08/16/22

Specimen A	Specimen B	Specimen C	
1638.39	1655.59	1653.36	1
1638.53	1655.6	1653.33	2
1638.44	1655.69	1653.44	3
1638.28	1655.74	1653.43	4
1638.31	1655.52	1653.22	5
1638.02	1655.54	1653.38	6
1638.24	1655.78	1653.65	7
1638.01	1655.62	1653.46	8
1638.07	1655.62	1653.56	9
1638.3	1655.81	1653.77	10
1638.23	1655.77	1653.75	11
1638.08	1655.69	1653.61	12
1638.08	1655.63	1653.64	13
1637.86	1655.39	1653.45	14
1637.86	1655.42	1653.51	15
1637.95	1655.49	1653.52	16
1637.79	1655.48	1653.49	17
1637.05	1654.72	1652.81	18
1636.47	1654.28	1652.32	19
1636.48	1654.23	1652.37	20
1636.49	1654.32	1652.38	21
1636.36	1654.15	1652.23	22
1636.47	1654.27	1652.32	23
1636.39	1654.15	1652.26	24
1636.29	1654.07	1652.23	25
1636.27	1654.01	1652.19	26
1636.21	1653.99	1652.06	27
1636.37	1654.12	1652.25	28
1636.06	1653.79	1651.99	29
1635.52	1653.31	1651.5	30
1635.54	1653.32	1651.58	31
1636.14	1653.9	1652.01	32
1636.2	1653.96	1652.14	33
1636.15	1653.89	1652.07	34
1636.29	1653.98	1652.1	35
1636.25	1653.92	1652.13	36
1636.36	1654.04	1652.22	37
1636.58	1654.29	1652.35	38
1636.72	1654.28	1652.44	39
1636.59	1654.23	1652.43	40
1636.12	1653.76	1652.01	41
1636.48	1654.18	1652.29	42
1636.9	1654.43	1652.57	43
1636.82	1654.45	1652.51	44
1636.5	1654.13	1652.3	45
1636.03	1653.69	1651.82	46
1636.49	1654.13	1652.27	47
1636.82	1654.39	1652.49	48
1636.64	1654.24	1652.39	49

Cont.

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	16.4%	16.2%	16.1%
Acutal DUW	1.66	1.66	1.64
Degree of Saturation	42.2%	41.6%	40.5%
Average Raw mV - Full	1636.50	1652.58	1650.27
Std. Dev. (mV) - Full	0.70	0.98	1.09
Average Raw mV > 500	1636.46	1651.96	1649.52
Std. Dev. (mV) > 500	0.75	0.65	0.59



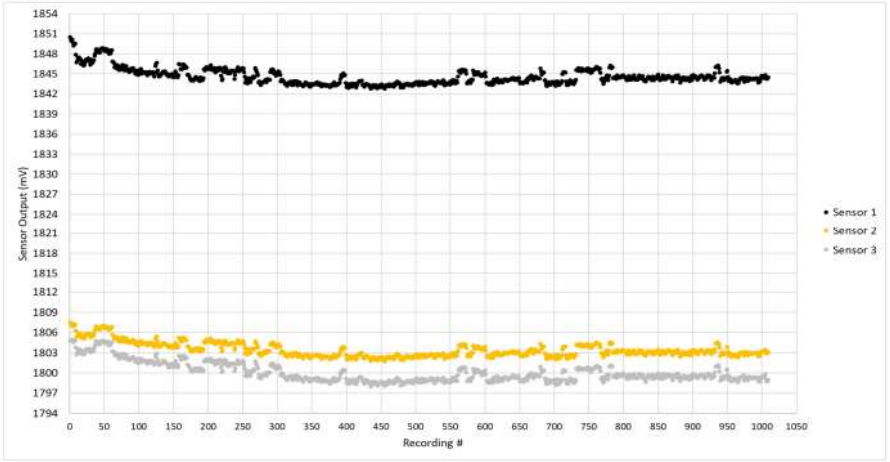
Calibration Test: M-10				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	8/16/2022	8/16/2022	8/16/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	100	100	100
	g/cm^3	1.60	1.60	1.60
Target Volumetric Moisture Content	%	20%	20%	20%
Target Gravimetric Moisture Content	%	12.5%	12.5%	12.5%
Details for Control Volume Prep				
Mass of Solids	g	1278.95	1323.11	1289.16
Mass of Water [a]	g	159.69	165.20	160.96
Details for Cover				
Mass of Solids [b]	g	480.54	480.54	480.54
Mass of Water [a, b]	g	60.00	60.00	60.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	8/17/2022	8/17/2022	8/17/2022
Mass of Mold	g	503.79	503.36	504.01
Mass of Mold + Specimen	g	1941.79	1990.39	1953.18
Depth to Top of Specimen	mm	57.74	55.55	55.48
	mm	56.52	55.57	56.06
	mm	57.34	54.32	56.68
	mm	57.61	54.59	56.99
Average	mm	57.30	55.01	56.30
Specimen Total Mass	g	1438.00	1487.03	1449.17
Specimen Total Volume	cm^3	780.83	807.71	789.44
Specimen Total Density	g/cm^3	1.84	1.84	1.84
	pcf	115.0	114.9	114.6
Specimen Dry Density	**g/cm^3**	**1.63**	**1.63**	**1.63**
	pcf	**101.8**	**101.8**	**101.5**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	153.93	152.32	155.04
Mass of Tare + Wet Tailings	g	1567.08	1463.57	1451.76
Mass of Tare + Dry Tailings	g	1404.99	1313.88	1303.14
Total Sample Mass	g	1413.15	1311.25	1296.72
Mass of Solids	g	1251.06	1161.56	1148.1
Mass of Water	g	162.09	149.69	148.62
Gravimetric Moisture Content	%	13.0%	12.9%	12.9%
Volumetric Moisture Content [a]	**%**	**21.1%**	**21.0%**	**21.0%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	164.94	169.76	166.09
Mass of Solids (in molded specimen)	g	1273.06	1317.27	1283.08
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	468.04	484.29	471.72
Volume of Water [a]	cm^3	164.94	169.76	166.09
Volume of Voids	cm^3	312.79	323.42	317.72
Degree of Saturation	**%**	**52.7%**	**52.5%**	**52.3%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-10
Target Dry UW: 100 pcf
Target Vol. Mst. Con.: 20 %
Date: 08/17/22

Specimen A	Specimen B	Specimen C	
1850.47	1807.46	1804.82	1
1850.02	1807.29	1804.81	2
1849.87	1807.01	1804.69	3
1850.11	1807.29	1804.94	4
1849.64	1807.27	1804.81	5
1849.19	1806.97	1804.57	6
1849.54	1807.18	1804.83	7
1849.5	1807.2	1804.84	8
1847.87	1806.25	1803.77	9
1846.71	1805.36	1802.78	10
1846.98	1805.51	1803.08	11
1847.45	1805.93	1803.48	12
1847.2	1805.68	1803.32	13
1847.44	1805.88	1803.51	14
1847.26	1805.83	1803.44	15
1846.5	1805.29	1802.88	16
1847.04	1805.65	1803.31	17
1846.87	1805.51	1803.18	18
1846.82	1805.52	1803.12	19
1846.26	1805.09	1802.73	20
1846.38	1805.13	1802.82	21
1846.73	1805.41	1803.06	22
1847.11	1805.77	1803.49	23
1847.14	1805.8	1803.45	24
1846.96	1805.7	1803.35	25
1847.07	1805.79	1803.46	26
1847.31	1805.91	1803.61	27
1846.96	1805.68	1803.44	28
1846.83	1805.54	1803.3	29
1846.38	1805.3	1803.03	30
1847.12	1805.79	1803.52	31
1846.65	1805.48	1803.15	32
1846.63	1805.4	1803.18	33
1847.03	1805.66	1803.4	34
1847.04	1805.69	1803.41	35
1847.72	1806.18	1803.85	36
1848.03	1806.41	1804.18	37
1848.64	1806.92	1804.76	38
1848.28	1806.66	1804.4	39
1848.64	1806.83	1804.66	40
1848.27	1806.6	1804.31	41
1848.19	1806.5	1804.29	42
1848.23	1806.6	1804.39	43
1848.19	1806.46	1804.28	44
1848.71	1806.85	1804.67	45
1848.8	1806.9	1804.73	46
1848.82	1806.89	1804.75	47
1848.84	1806.98	1804.84	48
1848.71	1806.89	1804.73	49
	Cont.		

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	21.1%	21.0%	21.0%
Acutal DUW	1.63	1.63	1.63
Degree of Saturation	52.7%	52.5%	52.3%
Average Raw mV - Full	1844.58	1803.42	1800.08
Std. Dev. (mV) - Full	1.22	1.09	1.48
Average Raw mV > 500	1844.34	1803.07	1799.46
Std. Dev. (mV) > 500	0.65	0.55	0.62



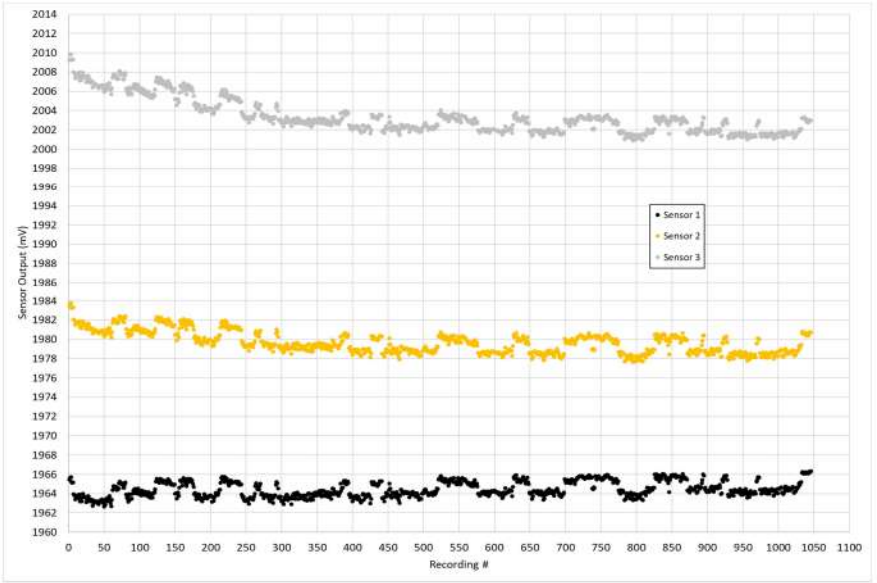
Calibration Test: M-11				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	8/17/2022	8/17/2022	8/17/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	100	100	100
	g/cm^3	1.60	1.60	1.60
Target Volumetric Moisture Content	%	25%	25%	25%
Target Gravimetric Moisture Content	%	15.6%	15.6%	15.6%
Details for Control Volume Prep				
Mass of Solids	g	1278.95	1323.11	1289.16
Mass of Water [a]	g	199.61	206.50	201.21
Details for Cover				
Mass of Solids [b]	g	480.54	480.54	480.54
Mass of Water [a, b]	g	75.00	75.00	75.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	8/18/2022	8/18/2022	8/18/2022
Mass of Mold	g	503.74	503.33	503.98
Mass of Mold + Specimen	g	1981.44	2032.02	1993.40
Depth to Top of Specimen	mm	56.45	54.36	56.68
	mm	56.48	53.75	56.09
	mm	56.38	54.09	56.60
	mm	56.06	54.14	56.79
Average	mm	56.34	54.09	56.54
Specimen Total Mass	g	1477.70	1528.69	1489.42
Specimen Total Volume	cm^3	788.69	815.28	787.49
Specimen Total Density	g/cm^3	1.87	1.88	1.89
	pcf	117.0	117.1	118.1
Specimen Dry Density	**g/cm^3**	**1.61**	**1.62**	**1.63**
	pcf	**100.7**	**100.9**	**101.8**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	153.9	152.28	155.01
Mass of Tare + Wet Tailings	g	1491.25	1624.25	1602.54
Mass of Tare + Dry Tailings	g	1305.62	1421.57	1403.23
Total Sample Mass	g	1337.35	1471.97	1447.53
Mass of Solids	g	1151.72	1269.29	1248.22
Mass of Water	g	185.63	202.68	199.31
Gravimetric Moisture Content	%	16.1%	16.0%	16.0%
Volumetric Moisture Content [c]	**%**	**26.0%**	**25.8%**	**26.0%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	205.11	210.49	205.08
Mass of Solids (in molded specimen)	g	1272.59	1318.20	1284.34
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	467.86	484.63	472.18
Volume of Water [a]	cm^3	205.11	210.49	205.08
Volume of Voids	cm^3	320.82	330.65	315.31
Degree of Saturation	**%**	**63.9%**	**63.7%**	**65.0%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-11
Target Dry UW: 100 pcf
Target Vol. Mst. Con.: 25 %
Date: 08/18/22

Specimen A	Specimen B	Specimen C	
1965.43	1983.51	2009.24	1
1965.68	1983.71	2009.83	2
1965.7	1983.77	2009.82	3
1965.19	1983.25	2009.25	4
1965.1	1983.3	2009.33	5
1965.16	1983.31	2009.3	6
1963.93	1982.06	2007.98	7
1963.81	1981.93	2007.86	8
1963.4	1981.49	2007.37	9
1963.68	1981.76	2007.76	10
1963.6	1981.63	2007.64	11
1963.71	1981.71	2007.68	12
1963.88	1981.81	2007.91	13
1963.53	1981.61	2007.5	14
1963.9	1981.88	2007.95	15
1963.2	1981.24	2007.1	16
1963.52	1981.5	2007.63	17
1963.21	1981.17	2007.19	18
1963.55	1981.39	2007.49	19
1963.98	1981.87	2007.94	20
1963.74	1981.63	2007.6	21
1963.65	1981.57	2007.58	22
1963.62	1981.59	2007.52	23
1963.54	1981.45	2007.4	24
1963.11	1981.06	2006.96	25
1963.21	1981.1	2007.1	26
1963.75	1981.59	2007.6	27
1963.72	1981.64	2007.57	28
1963.46	1981.3	2007.25	29
1963.19	1981.04	2006.91	30
1963.28	1981.09	2006.98	31
1963.37	1981.11	2007.11	32
1963.35	1981.15	2007.03	33
1962.73	1980.59	2006.42	34
1963.03	1980.84	2006.62	35
1963.06	1980.78	2006.65	36
1963.25	1981	2006.84	37
1963.14	1980.84	2006.66	38
1963.18	1980.92	2006.67	39
1963.12	1980.75	2006.6	40
1963	1980.68	2006.42	41
1962.88	1980.59	2006.32	42
1963.08	1980.69	2006.52	43
1963.26	1980.87	2006.58	44
1963.17	1980.75	2006.48	45
1963.16	1980.72	2006.55	46
1963.38	1980.95	2006.67	47
1963.2	1980.78	2006.47	48
1963.04	1980.6	2006.28	49
	Cont.		

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	26.0%	25.8%	26.0%
Acutal DUW	1.61	1.62	1.63
Degree of Saturation	63.9%	63.7%	65.0%
Average Raw mV - Full	1964.44	1979.66	2003.32
Std. Dev. (mV) - Full	0.80	1.13	1.80
Average Raw mV > 500	1964.74	1979.18	2002.28
Std. Dev. (mV) > 500	0.75	0.83	0.75



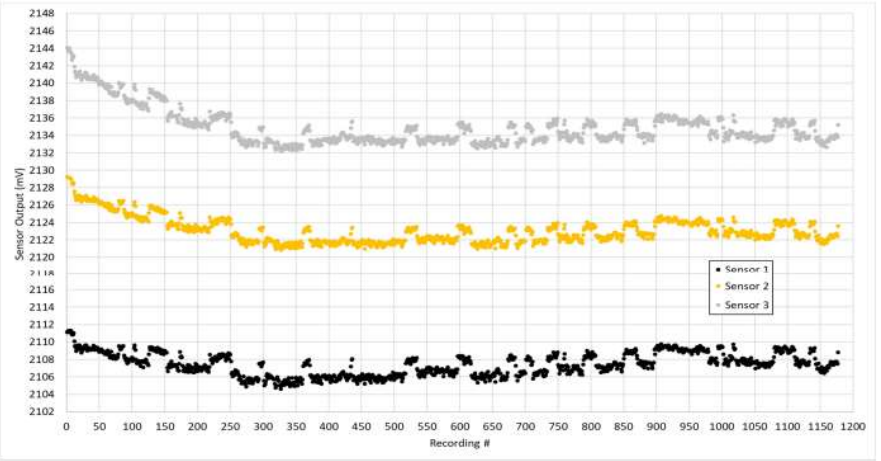
Calibration Test: M-12				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	8/18/2022	8/18/2022	8/18/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	100	100	100
	g/cm^3	1.60	1.60	1.60
Target Volumetric Moisture Content	%	30%	30%	30%
Target Gravimetric Moisture Content	%	18.7%	18.7%	18.7%
Details for Control Volume Prep				
Mass of Solids	g	1278.95	1323.11	1289.16
Mass of Water [a]	g	239.54	247.81	241.45
Details for Cover				
Mass of Solids [b]	g	480.54	480.54	480.54
Mass of Water [a, b]	g	90.00	90.00	90.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	8/22/2022	8/22/2022	8/22/2022
Mass of Mold	g	503.70	503.26	503.92
Mass of Mold + Specimen	g	2019.90	2072.63	2033.00
Depth to Top of Specimen	mm	57.74	54.51	56.98
	mm	57.33	54.25	56.19
	mm	56.39	54.20	56.67
	mm	56.82	54.45	56.92
Average	mm	57.07	54.35	56.69
Specimen Total Mass	g	1516.20	1569.37	1529.08
Specimen Total Volume	cm^3	782.73	813.09	786.26
Specimen Total Density	g/cm^3	1.94	1.93	1.94
	pcf	120.9	120.5	121.4
Specimen Dry Density	**g/cm^3**	**1.63**	**1.62**	**1.63**
	pcf	**101.5**	**101.2**	**102.0**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	153.97	152.23	154.97
Mass of Tare + Wet Tailings	g	1567.08	1588.72	1594.35
Mass of Tare + Dry Tailings	g	1339.99	1358.28	1363.79
Total Sample Mass	g	1413.11	1436.49	1439.38
Mass of Solids	g	1186.02	1206.05	1208.82
Mass of Water	g	227.09	230.44	230.56
Gravimetric Moisture Content	%	19.1%	19.1%	19.1%
Volumetric Moisture Content [a]	**%**	**31.1%**	**31.0%**	**31.2%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	243.66	251.76	244.93
Mass of Solids (in molded specimen)	g	1272.54	1317.61	1284.15
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	467.85	484.42	472.11
Volume of Water [a]	cm^3	243.66	251.76	244.93
Volume of Voids	cm^3	314.88	328.67	314.15
Degree of Saturation	**%**	**77.4%**	**76.6%**	**78.0%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-12
Target Dry UW: 100 pcf
Target Vol. Mst. Con.: 30 %
Date: 08/22/22

Specimen A	Specimen B	Specimen C	
2111.14	2129.23	2144.04	1
2111.27	2129.22	2143.88	2
2111.12	2129.15	2143.7	3
2111.29	2129.15	2144	4
2111.16	2129.11	2143.67	5
2111.28	2129.08	2143.63	6
2111.28	2128.96	2143.44	7
2110.86	2128.48	2142.68	8
2110.88	2128.47	2143	9
2110.83	2128.4	2142.97	10
2111.01	2128.58	2143.15	11
2110.08	2127.57	2141.91	12
2109.52	2127.14	2141.35	13
2109.36	2126.89	2141.07	14
2108.94	2126.53	2140.66	15
2109.34	2126.88	2141.07	16
2109.61	2127.04	2141.1	17
2109.2	2126.77	2140.9	18
2109.18	2126.66	2140.85	19
2109.63	2127.11	2141.34	20
2109.52	2127.03	2141.04	21
2109.07	2126.52	2140.67	22
2108.78	2126.36	2140.37	23
2109	2126.51	2140.59	24
2109.37	2126.88	2140.81	25
2109.3	2126.76	2140.89	26
2109.31	2126.72	2140.88	27
2109.22	2126.67	2140.7	28
2109.64	2127.04	2141.21	29
2109.62	2127.06	2141.23	30
2109.46	2126.88	2141	31
2108.98	2126.42	2140.44	32
2109.36	2126.74	2140.81	33
2109.14	2126.53	2140.55	34
2109.12	2126.49	2140.54	35
2109.19	2126.48	2140.51	36
2109.09	2126.42	2140.42	37
2109.23	2126.57	2140.63	38
2109.27	2126.56	2140.58	39
2109.11	2126.49	2140.48	40
2109.57	2126.85	2140.93	41
2109.54	2126.89	2140.9	42
2109.09	2126.39	2140.36	43
2109.3	2126.58	2140.57	44
2109.41	2126.65	2140.33	45
2109.32	2126.59	2140.59	46
2109.36	2126.65	2140.67	47
2109.14	2126.47	2140.39	48
2109.13	2126.37	2140.23	49
	Cont.		

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	31.1%	31.0%	31.2%
Acutal DUW	1.63	1.62	1.63
Degree of Saturation	77.4%	76.6%	78.0%
Average Raw mV - Full	2107.42	2123.06	2134.91
Std. Dev. (mV) - Full	1.30	1.49	2.12
Average Raw mV > 500	2107.63	2122.78	2134.30
Std. Dev. (mV) > 500	1.08	0.90	0.97



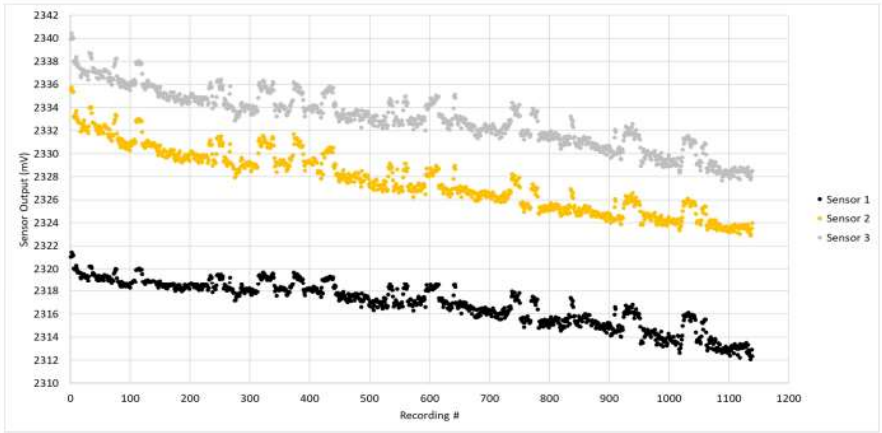
Calibration Test: M-15				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	9/21/2022	9/21/2022	9/21/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	66.04	66.04	66.04
	g/cm^3	1.06	1.06	1.06
Target Volumetric Moisture Content	%	60%	60%	60%
Target Gravimetric Moisture Content	%	56.7%	56.7%	56.7%
Details for Control Volume Prep				
Mass of Solids	g	844.62	873.78	851.36
Mass of Water [a]	g	479.07	495.61	482.89
Details for Cover				
Mass of Solids [b]	g	317.35	317.35	317.35
Mass of Water [a, b]	g	180.00	180.00	180.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	9/21/2022	9/21/2022	9/21/2022
Mass of Mold	g	503.65	503.23	503.85
Mass of Mold + Specimen	g	1846.58	1882.57	1806.78
Depth to Top of Specimen	mm	52.14	50.28	55.19
	mm	52.08	50.21	54.75
	mm	51.96	50.29	55.07
Average	mm	51.99	49.49	54.88
	mm	52.04	50.07	54.97
Specimen Total Mass	g	1342.93	1379.34	1302.93
Specimen Total Volume	cm^3	823.90	848.25	800.35
Specimen Total Density	g/cm^3	1.63	1.63	1.63
	pcf	101.8	101.5	101.6
Specimen Dry Density	**g/cm^3**	**1.06**	**1.05**	**1.05**
	pcf	**65.9**	**65.7**	**65.7**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	358.78	289.52	279.08
Mass of Tare + Wet Tailings	g	1542.39	1506.98	1476.67
Mass of Tare + Dry Tailings	g	1125.49	1077.27	1052.8
Total Sample Mass	g	1183.61	1217.46	1197.59
Mass of Solids	g	766.71	787.75	773.72
Mass of Water	g	416.9	429.71	423.87
Gravimetric Moisture Content	%	54.4%	54.5%	54.8%
Volumetric Moisture Content [a]	**%**	**57.4%**	**57.4%**	**57.6%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	473.02	486.85	461.15
Mass of Solids (in molded specimen)	g	869.91	892.49	841.78
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	319.82	328.12	309.48
Volume of Water [a]	cm^3	473.02	486.85	461.15
Volume of Voids	cm^3	504.07	520.13	490.87
Degree of Saturation	**%**	**93.8%**	**93.6%**	**93.9%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-15
Target Dry UW: 66 pcf
Target Vol. Mst. Con.: 60 %
Date: 09/21/22

Specimen A	Specimen B	Specimen C	
2321.06	2335.55	2339.97	1
2321.45	2335.73	2340.44	2
2321.41	2335.45	2340.12	3
2321.12	2335.36	2339.97	4
2321.19	2335.36	2340.01	5
2320.04	2333.23	2338.02	6
2320.01	2333.14	2337.98	7
2319.93	2333.1	2337.81	8
2320.02	2333.46	2338.15	9
2320.27	2333.69	2338.4	10
2320.03	2333.2	2338.04	11
2319.7	2332.8	2337.56	12
2319.8	2332.91	2337.73	13
2319.7	2332.75	2337.53	14
2319.66	2332.67	2337.49	15
2319.7	2332.64	2337.4	16
2319.29	2331.95	2336.76	17
2319.18	2331.9	2336.6	18
2319.61	2332.62	2337.29	19
2319.42	2332.27	2336.96	20
2319.39	2332.09	2336.92	21
2319.35	2332.55	2337.23	22
2319.55	2332.89	2337.28	23
2319.33	2332.31	2337.05	24
2319.24	2332.03	2336.99	25
2319.35	2332.08	2336.88	26
2319.26	2332.28	2336.97	27
2319.4	2332.31	2337.09	28
2319.16	2331.98	2336.75	29
2318.96	2331.78	2336.41	30
2319.36	2332.36	2337.12	31
2320.23	2333.98	2338.73	32
2320.23	2334	2338.65	33
2320.19	2333.93	2338.42	34
2320.21	2334.04	2338.67	35
2320.06	2333.51	2338.23	36
2319.5	2332.67	2337.11	37
2319.66	2332.72	2337.46	38
2319.6	2332.66	2337.39	39
2319.53	2332.6	2337.32	40
2319.49	2332.62	2337.28	41
2319.35	2332.33	2337.04	42
2319.33	2332.21	2336.99	43
2319.07	2331.97	2336.59	44
2319.32	2332.38	2337.07	45
2319.39	2332.29	2337.03	46
2318.94	2331.72	2336.48	47
2319.42	2332.42	2337.16	48
2319.28	2332.21	2336.97	49
	Cont.		

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	57.4%	57.4%	57.6%
Acutal DUW	1.06	1.05	1.05
Degree of Saturation	93.8%	93.6%	93.9%
Average Raw mV - Full	2316.90	2327.66	2333.03
Std. Dev. (mV) - Full	1.95	2.68	2.48
Average Raw mV > 500	2315.58	2325.69	2331.37
Std. Dev. (mV) > 500	1.53	1.44	1.75



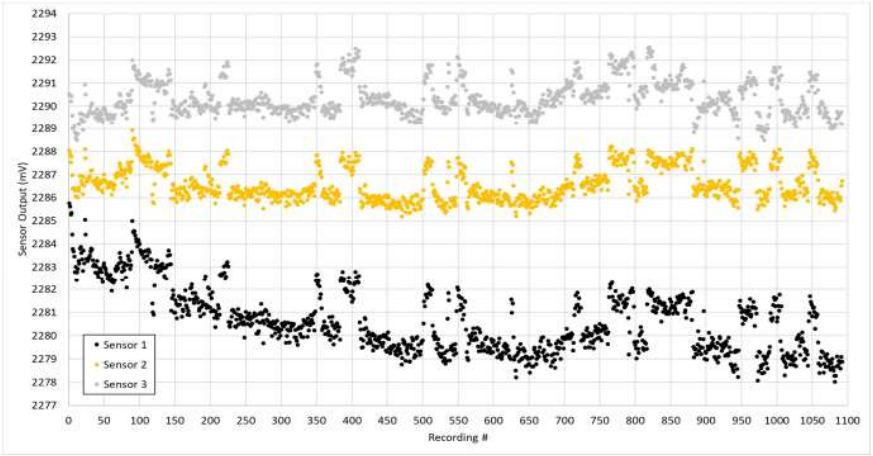
Calibration Test: M-17				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	9/28/2022	9/28/2022	9/28/2022
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	84.07	84.07	84.07
	g/cm^3	1.35	1.35	1.35
Target Volumetric Moisture Content	%	50%	50%	50%
Target Gravimetric Moisture Content	%	37.1%	37.1%	37.1%
Details for Control Volume Prep				
Mass of Solids	g	1075.22	1112.34	1083.80
Mass of Water [a]	g	399.23	413.01	402.41
Details for Cover				
Mass of Solids [b]	g	403.99	403.99	403.99
Mass of Water [a, b]	g	150.00	150.00	150.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	9/28/2022	9/28/2022	9/28/2022
Mass of Mold	g	503.68	503.32	503.90
Mass of Mold + Specimen	g	1941.85	2038.30	1948.78
Depth to Top of Specimen	mm	55.19	49.86	55.89
	mm	54.94	49.64	55.16
	mm	54.34	49.77	55.02
Average	mm	55.10	49.47	55.65
	mm	54.89	49.69	55.43
Specimen Total Mass	g	1438.17	1534.98	1444.88
Specimen Total Volume	cm^3	800.56	851.39	796.60
Specimen Total Density	g/cm^3	1.80	1.80	1.81
	pcf	112.2	112.6	113.2
Specimen Dry Density	**g/cm^3**	**1.31**	**1.31**	**1.32**
	pcf	**81.7**	**82.0**	**82.3**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	358.76	289.51	279.08
Mass of Tare + Wet Tailings	g	1700.93	1552.52	1463.32
Mass of Tare + Dry Tailings	g	1336.52	1209.71	1140.1
Total Sample Mass	g	1342.17	1263.01	1184.24
Mass of Solids	g	977.76	920.2	861.02
Mass of Water	g	364.41	342.81	323.22
Gravimetric Moisture Content	%	37.3%	37.3%	37.5%
Volumetric Moisture Content [a]	**%**	**48.8%**	**48.9%**	**49.5%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	390.47	416.63	394.36
Mass of Solids (in molded specimen)	g	1047.70	1118.35	1050.52
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	385.18	411.16	386.22
Volume of Water [a]	cm^3	390.47	416.63	394.36
Volume of Voids	cm^3	415.38	440.23	410.37
Degree of Saturation	**%**	**94.0%**	**94.6%**	**96.1%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-17
Target Dry UW: 84 pcf
Target Vol. Mst. Con.: 50 %
Date: 09/28/22

Specimen A	Specimen B	Specimen C	
2285.75	2288.03	2290.53	1
2285.61	2287.88	2290.47	2
2285.27	2287.53	2290.22	3
2285.34	2287.77	2290.43	4
2284.4	2286.96	2289.59	5
2283.78	2286.4	2289.01	6
2283.69	2286.39	2289.01	7
2283.46	2286.41	2289.14	8
2282.78	2286.31	2288.82	9
2283.01	2286.06	2288.58	10
2282.4	2286.32	2288.72	11
2282.77	2286.01	2288.48	12
2282.92	2286.02	2288.77	13
2283.26	2286.45	2289.23	14
2283.14	2286.3	2289.18	15
2283.81	2286.93	2289.67	16
2283.88	2286.95	2289.7	17
2283.62	2286.72	2289.44	18
2283.34	2286.58	2289.34	19
2282.83	2286.16	2288.94	20
2283.71	2286.89	2289.63	21
2283.17	2286.52	2289.35	22
2285.04	2288.11	2290.94	23
2284.41	2287.71	2290.5	24
2283.36	2286.69	2289.57	25
2283.33	2286.8	2289.56	26
2283.27	2286.71	2289.57	27
2283.37	2286.84	2289.68	28
2283.44	2286.87	2289.72	29
2283.51	2286.93	2289.82	30
2283.68	2287.15	2289.98	31
2283.8	2287.16	2290.04	32
2283.77	2287.19	2290.13	33
2283.31	2286.73	2289.68	34
2283.05	2286.67	2289.71	35
2283.11	2286.7	2289.71	36
2283.1	2286.74	2289.75	37
2282.76	2286.55	2289.49	38
2283.02	2286.64	2289.67	39
2283.26	2286.85	2289.89	40
2282.7	2286.47	2289.54	41
2282.56	2286.38	2289.38	42
2282.81	2286.56	2289.53	43
2282.94	2286.7	2289.7	44
2282.93	2286.71	2289.76	45
2282.79	2286.63	2289.64	46
2282.47	2286.32	2289.44	47
2282.32	2286.22	2289.33	48
2283.04	2286.77	2289.88	49
	Cont.		

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	48.8%	48.9%	49.5%
Acutal DUW	1.31	1.31	1.32
Degree of Saturation	94.0%	94.6%	96.1%
Average Raw mV - Full	2280.67	2286.58	2290.34
Std. Dev. (mV) - Full	1.43	0.72	0.76
Average Raw mV > 500	2280.04	2286.63	2290.43
Std. Dev. (mV) > 500	1.03	0.74	0.79



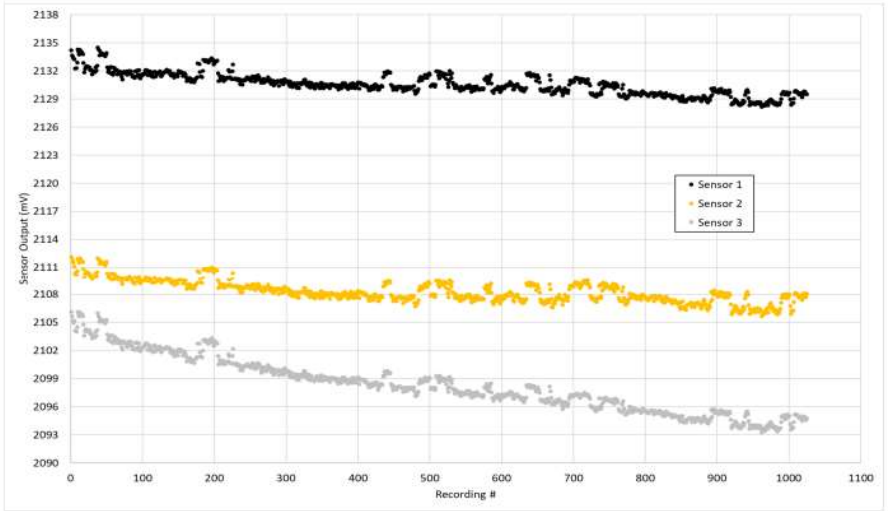
Calibration Test: M-18				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	1/25/2023	1/25/2023	1/25/2023
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	105	105	105
	g/cm^3	1.68	1.68	1.68
Target Volumetric Moisture Content	%	35%	35%	35%
Target Gravimetric Moisture Content	%	20.8%	20.8%	20.8%
Details for Control Volume Prep				
Mass of Solids	g	1342.90	1389.27	1353.62
Mass of Water [a]	g	279.46	289.11	281.69
Details for Cover				
Mass of Solids [b]	g	504.57	504.57	504.57
Mass of Water [a, b]	g	105.00	105.00	105.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	1/26/2023	1/26/2023	1/26/2023
Mass of Mold	g	503.39	502.99	503.54
Mass of Mold + Specimen	g	2116.16	2170.84	2128.56
Depth to Top of Specimen	mm	55.57	51.65	54.67
	mm	52.57	50.03	52.22
	mm	50.93	49.08	50.98
Average	mm	54.57	52.17	54.01
	mm	53.41	50.73	52.97
Specimen Total Mass	g	1612.77	1667.85	1625.02
Specimen Total Volume	cm^3	812.70	842.79	816.76
Specimen Total Density	g/cm^3	1.98	1.98	1.99
	pcf	123.9	123.5	124.2
Specimen Dry Density	**g/cm^3**	**1.64**	**1.63**	**1.64**
	pcf	**102.3**	**102.1**	**102.6**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	286.66	291.59	279.12
Mass of Tare + Wet Tailings	g	1620.83	1666.62	1679.39
Mass of Tare + Dry Tailings	g	1388.17	1427.4	1435.29
Total Sample Mass	g	1334.17	1375.03	1400.27
Mass of Solids	g	1101.51	1135.81	1156.17
Mass of Water	g	232.66	239.22	244.1
Gravimetric Moisture Content	%	21.1%	21.1%	21.1%
Volumetric Moisture Content [b]	**%**	**34.6%**	**34.4%**	**34.7%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	281.24	290.16	283.28
Mass of Solids (in molded specimen)	g	1331.53	1377.69	1341.74
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	489.53	506.50	493.29
Volume of Water [a]	cm^3	281.24	290.16	283.28
Volume of Voids	cm^3	323.17	336.29	323.48
Degree of Saturation	**%**	**87.0%**	**86.3%**	**87.6%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-18
Target Dry UW: 105 pcf
Target Vol. Mst. Con.: 35 %
Date: 01/26/23

Specimen A	Specimen B	Specimen C	
2134.23	2112.12	2106.13	1
2133.65	2111.87	2105.65	2
2133.51	2111.69	2105.19	3
2133.38	2111.51	2104.94	4
2133.24	2111.05	2105.17	5
2132.26	2110.4	2104.12	6
2132.28	2110.21	2104.12	7
2132.31	2110.23	2103.99	8
2132.88	2110.59	2104.53	9
2134.29	2111.9	2106.11	10
2134.03	2111.76	2105.9	11
2133.76	2111.51	2105.64	12
2134.24	2111.98	2106.09	13
2133.87	2111.66	2105.75	14
2134.09	2111.81	2105.96	15
2133.97	2111.66	2105.88	16
2133.78	2111.57	2105.67	17
2132.86	2110.83	2104.78	18
2131.83	2109.9	2103.6	19
2132.31	2110.39	2104.06	20
2132.38	2110.39	2104.27	21
2132.51	2110.53	2104.26	22
2132.46	2110.41	2104.16	23
2132.48	2110.46	2104	24
2132.43	2110.27	2104.13	25
2132.41	2110.36	2104.17	26
2132.15	2110.14	2103.88	27
2132.05	2109.98	2103.7	28
2132.1	2110.07	2103.75	29
2131.65	2109.69	2103.29	30
2131.98	2109.94	2103.52	31
2131.87	2109.88	2103.41	32
2131.94	2109.9	2103.44	33
2131.88	2109.91	2103.42	34
2132.4	2110.34	2104.01	35
2132.05	2110.06	2103.59	36
2132.58	2110.48	2104.16	37
2134.5	2112.01	2105.99	38
2134.29	2111.83	2105.65	39
2133.64	2111.35	2105.08	40
2134.12	2111.74	2105.42	41
2133.74	2111.45	2105.08	42
2133.83	2111.44	2105.23	43
2133.89	2111.57	2105.29	44
2133.71	2111.45	2105.12	45
2133.69	2111.38	2105.1	46
2133.69	2111.35	2105.06	47
2133.59	2111.19	2104.88	48
2133.73	2111.41	2105.12	49
	Cont.		

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	34.6%	34.4%	34.7%
Acutal DUW	1.64	1.63	1.64
Degree of Saturation	87.0%	86.3%	87.6%
Average Raw mV - Full	2130.56	2108.29	2098.33
Std. Dev. (mV) - Full	1.17	1.19	2.95
Average Raw mV > 500	2129.85	2107.65	2096.03
Std. Dev. (mV) > 500	0.86	0.87	1.42



Calibration Test: M-19

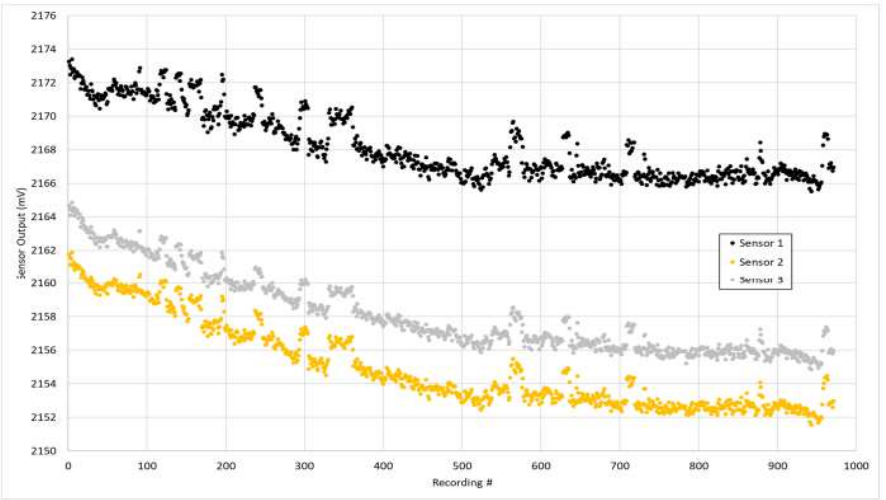
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	1/26/2023	1/26/2023	1/26/2023
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	110	110	110
	g/cm^3	1.76	1.76	1.76
Target Volumetric Moisture Content	%	40%	40%	40%
Target Gravimetric Moisture Content	%	22.7%	22.7%	22.7%
Details for Control Volume Prep				
Mass of Solids	g	1406.85	1455.42	1418.07
Mass of Water [a]	g	319.38	330.41	321.93
Details for Cover				
Mass of Solids [b]	g	528.59	528.59	528.59
Mass of Water [a, b]	g	120.00	120.00	120.00
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	1/27/2023	1/27/2023	1/27/2023
Mass of Mold	g	503.52	503.93	503.73
Mass of Mold + Specimen	g	2087.05	2148.69	2109.89
Depth to Top of Specimen	mm	54.34	51.84	54.82
	mm	54.86	51.77	52.64
	mm	53.63	49.03	51.91
Average	mm	53.27	49.65	51.35
	mm	54.03	50.57	52.68
Specimen Total Mass	g	1583.53	1644.76	1606.16
Specimen Total Volume	cm^3	807.66	844.11	819.14
Specimen Total Density	g/cm^3	1.96	1.95	1.96
	pcf	122.4	121.6	122.4
Specimen Dry Density	**g/cm^3**	**1.59**	**1.58**	**1.59**
	pcf	**99.5**	**98.8**	**99.4**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	286.64	291.62	279.11
Mass of Tare + Wet Tailings	g	1636.91	1758.88	1718.57
Mass of Tare + Dry Tailings	g	1383.85	1483.38	1448.42
Total Sample Mass	g	1350.27	1467.26	1439.46
Mass of Solids	g	1097.21	1191.76	1169.31
Mass of Water	g	253.06	275.5	270.15
Gravimetric Moisture Content	%	23.1%	23.1%	23.1%
Volumetric Moisture Content [a]	**%**	**36.7%**	**36.6%**	**36.8%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	296.78	308.83	301.44
Mass of Solids (in molded specimen)	g	1286.75	1335.93	1304.72
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	473.07	491.15	479.68
Volume of Water [a]	cm^3	296.78	308.83	301.44
Volume of Voids	cm^3	334.59	352.96	339.46
Degree of Saturation	**%**	**88.7%**	**87.5%**	**88.8%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: M-19
Target Dry UW: 110 pcf
Target Vol. Mst. Con.: 40 %
Date: 01/27/23

Specimen A	Specimen B	Specimen C	
2173.24	2161.75	2164.67	1
2173.01	2161.65	2164.45	2
2172.47	2161.15	2164.1	3
2172.85	2161.51	2164.54	4
2173.39	2161.88	2164.87	5
2172.64	2161.11	2164.34	6
2172.83	2161.3	2164.55	7
2172.26	2160.84	2164.06	8
2172.38	2160.91	2164.18	9
2172.64	2161.11	2164.43	10
2172.63	2161.16	2164.42	11
2172.55	2161.1	2164.26	12
2172.37	2160.92	2163.92	13
2172.42	2161.02	2164.17	14
2172.42	2160.96	2164.15	15
2171.62	2160.33	2163.41	16
2171.95	2160.57	2163.67	17
2172.32	2160.82	2163.94	18
2172.11	2160.7	2163.79	19
2171.94	2160.51	2163.51	20
2171.59	2160.23	2163.26	21
2171.65	2160.32	2163.37	22
2171.75	2160.3	2163.36	23
2171.27	2160.09	2163.07	24
2171.52	2160.21	2163.2	25
2171.51	2160.14	2163.22	26
2171.26	2159.96	2163.06	27
2171.04	2159.79	2162.77	28
2171.9	2160.39	2163.4	29
2171.53	2160.19	2163.12	30
2171.48	2160.06	2163.08	31
2170.99	2159.73	2162.69	32
2171.24	2159.93	2162.95	33
2170.76	2159.54	2162.5	34
2170.65	2159.33	2162.38	35
2171.12	2159.8	2162.74	36
2171.24	2159.86	2162.77	37
2171.33	2159.8	2162.78	38
2170.94	2159.6	2162.53	39
2170.46	2159.26	2162.18	40
2171.05	2159.62	2162.57	41
2171.26	2159.73	2162.74	42
2171.02	2159.64	2162.53	43
2171.03	2159.57	2162.52	44
2171.08	2159.54	2162.54	45
2171.23	2159.68	2162.66	46
2171.38	2159.86	2162.76	47
2171.28	2159.76	2162.66	48
2170.72	2159.38	2162.23	49
	Cont.		

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	36.7%	36.6%	36.8%
Acutal DUW	1.59	1.58	1.59
Degree of Saturation	88.7%	87.5%	88.8%
Average Raw mV - Full	2168.24	2155.02	2158.16
Std. Dev. (mV) - Full	2.02	2.60	2.42
Average Raw mV > 500	2166.75	2153.00	2156.25
Std. Dev. (mV) > 500	0.74	0.67	0.64



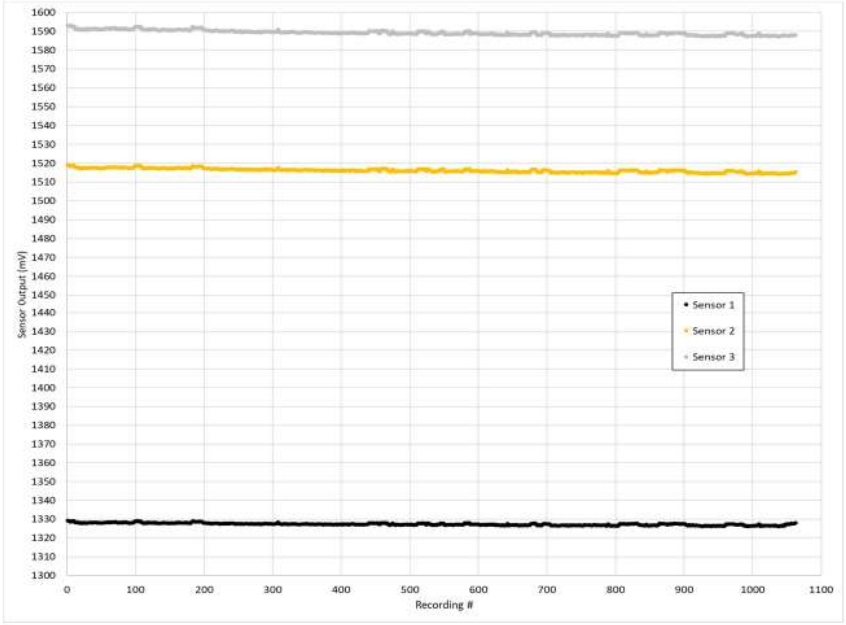
Accuracy Test Series 1				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	1/31/2023	1/31/2023	1/31/2023
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	95	95	95
	g/cm^3	1.52	1.52	1.52
Target Volumetric Moisture Content	%	7%	12%	17%
Target Gravimetric Moisture Content	%	4.6%	7.9%	11.2%
Details for Control Volume Prep				
Mass of Solids	g	1215.01	1256.96	1224.70
Mass of Water [a]	g	55.89	99.12	136.82
Details for Cover				
Mass of Solids [b]	g	456.51	456.51	456.51
Mass of Water [a, b]	g	21.00	36.00	51.00
Actual Mass Prepared for Controll Volume				
Mass of Solids	g	1300.00	1350.00	1300.00
Mass of Water [a]	g	59.80	106.46	145.23
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	2/2/2023	2/2/2023	2/2/2023
Mass of Mold	g	503.46	504.52	503.64
Mass of Mold + Specimen	g	1750.17	1868.31	1729.44
Depth to Top of Specimen	mm	54.22	54.72	58.20
	mm	53.03	55.98	57.32
	mm	54.72	53.23	56.47
	mm	56.28	53.66	56.93
Average	mm	54.56	54.40	57.23
Specimen Total Mass	g	1246.71	1363.79	1225.80
Specimen Total Volume	cm^3	803.26	812.72	781.84
Specimen Total Density	g/cm^3	1.55	1.68	1.57
	pcf	96.9	104.8	97.9
Specimen Dry Density	**g/cm^3**	**1.48**	**1.55**	**1.41**
	pcf	**92.5**	**97.0**	**87.9**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	286.64	291.6	279.09
Mass of Tare + Wet Tailings	g	1289.23	1245.58	1320.43
Mass of Tare + Dry Tailings	g	1244.07	1174.76	1214.6
Total Sample Mass	g	1002.59	953.98	1041.34
Mass of Solids	g	957.43	883.16	935.51
Mass of Water	g	45.16	70.82	105.83
Gravimetric Moisture Content	%	4.7%	8.0%	11.3%
Volumetric Moisture Content [a]	**%**	**7.0%**	**12.5%**	**15.9%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	56.16	101.24	124.58
Mass of Solids (in molded specimen)	g	1190.55	1262.55	1101.22
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	437.70	464.17	404.86
Volume of Water [a]	cm^3	56.16	101.24	124.58
Volume of Voids	cm^3	365.56	348.55	376.98
Degree of Saturation	**%**	**15.4%**	**29.0%**	**33.0%**
Estimated Void Ratio				
Void Ratio	--	0.84	0.75	0.93

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: Validation Series #1
Target Dry UW: Random
Target Vol. Mot. Con.: Random
Date: 02/02/23

Specimen A	Specimen B	Specimen C	
1329.12	1519.1	1593.08	1
1329.1	1519.1	1593.02	2
1328.97	1518.88	1592.86	3
1329.02	1518.74	1592.9	4
1328.65	1518.37	1592.45	5
1328.66	1518.41	1592.54	6
1328.83	1518.68	1592.69	7
1328.94	1518.81	1592.78	8
1328.99	1518.76	1592.63	9
1328.9	1518.72	1592.46	10
1328.89	1518.69	1592.48	11
1328.2	1517.79	1591.32	12
1328.17	1517.74	1591.14	13
1328.07	1517.59	1591.19	14
1328.2	1517.78	1591.41	15
1328.29	1517.88	1591.42	16
1328.09	1517.61	1591.19	17
1327.87	1517.32	1590.64	18
1327.74	1517.09	1590.69	19
1327.81	1517.26	1590.78	20
1328.1	1517.63	1591.29	21
1327.93	1517.4	1591.04	22
1327.89	1517.32	1590.92	23
1327.77	1517.17	1590.71	24
1327.93	1517.41	1591.05	25
1328.1	1517.62	1591.28	26
1327.97	1517.47	1591.19	27
1327.97	1517.47	1591.15	28
1327.74	1517.1	1590.67	29
1327.98	1517.42	1591.07	30
1328.02	1517.49	1591.17	31
1328.13	1517.62	1591.29	32
1328.19	1517.65	1591.4	33
1328.09	1517.58	1591.29	34
1328.08	1517.5	1591.2	35
1328.08	1517.5	1591.21	36
1328	1517.33	1591.08	37
1328.17	1517.57	1591.34	38
1328.19	1517.62	1591.4	39
1328.17	1517.56	1591.49	40
1328.1	1517.53	1591.32	41
1328.26	1517.67	1591.46	42
1328.12	1517.49	1591.33	43
1328.01	1517.32	1591.09	44
1328.13	1517.53	1591.39	45
1327.99	1517.32	1591.03	46
1327.98	1517.31	1590.93	47
1327.95	1517.2	1590.8	48
1327.88	1517.09	1590.9	49
1327.95	1517.22	1590.95	50
1327.93	1517.3	1591.09	51
1327.88	1517.16	1590.95	52
1328.01	1517.36	1591.09	53
1328.21	1517.61	1591.46	54
	Cont.		

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	7.0%	12.5%	15.9%
Acutal DUW	1.48	1.55	1.41
Degree of Saturation	15.4%	29.0%	33.0%
Average Raw mV - Full	1327.30	1516.11	1589.18
Std. Dev. (mV) - Full	0.60	1.02	1.27
Average Raw mV > 500	1326.94	1515.41	1588.28
Std. Dev. (mV) > 500	0.42	0.65	0.66



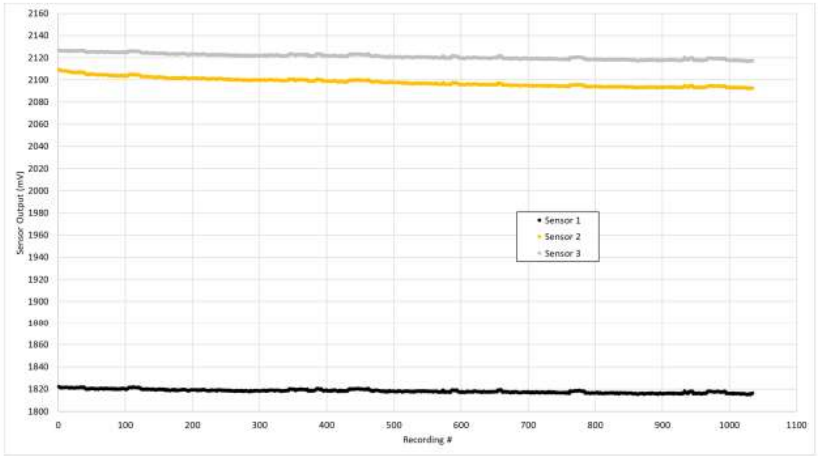
Accuracy Test Series 2				
Sample Preparation Details (For Moisture Conditioning)				
General Details	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Moisture Conditioning Date	--	1/31/2023	1/31/2023	1/31/2023
Mold #	--	1	2	3
Mold Approx. Control Volume	cm^3	798.45	826.02	804.82
Empty Mold Total Mass	g	503.75	503.23	504.00
Target Dry Density	pcf	95	95	95
	g/cm^3	1.52	1.52	1.52
Target Volumetric Moisture Content	%	22%	27%	30%
Target Gravimetric Moisture Content	%	14.5%	17.7%	19.7%
Details for Control Volume Prep				
Mass of Solids	g	1215.01	1256.96	1224.70
Mass of Water [a]	g	175.66	223.03	241.45
Details for Cover				
Mass of Solids [b]	g	456.51	456.51	456.51
Mass of Water [a,b]	g	66.00	81.00	90.00
Actual Mass Prepared for Controll Volume				
Mass of Solids	g	1300.00	1350.00	1300.00
Mass of Water [a]	g	187.95	239.53	256.29
Prepared Specimen (Prior to Sensor Insertion)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specimen Preparation Date	--	2/3/2023	2/3/2023	2/3/2023
Mass of Mold	g	503.43	504.41	503.62
Mass of Mold + Specimen	g	1885.36	2091.00	2056.55
Depth to Top of Specimen	mm	57.88	59.42	59.02
	mm	56.29	59.50	59.68
	mm	55.70	57.80	58.40
	mm	58.16	58.60	58.19
Average	mm	57.01	58.83	58.82
Specimen Total Mass	g	1381.93	1586.59	1552.93
Specimen Total Volume	cm^3	783.24	776.34	768.78
Specimen Total Density	g/cm^3	1.76	2.04	2.02
	pcf	110.1	127.6	126.1
Specimen Dry Density	**g/cm^3**	**1.54**	**1.74**	**1.69**
	pcf	**96.1**	**108.3**	**105.2**
Moisture Content (Post-Test)				
Measurement	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Mass of Tare	g	286.62	291.6	279.1
Mass of Tare + Wet Tailings	g	1403.04	1569.04	1550.96
Mass of Tare + Dry Tailings	g	1260.35	1376.21	1340.1
Total Sample Mass	g	1116.42	1277.44	1271.86
Mass of Solids	g	973.73	1084.61	1061
Mass of Water	g	142.69	192.83	210.86
Gravimetric Moisture Content	%	14.7%	17.8%	19.9%
Volumetric Moisture Content [a]	**%**	**22.6%**	**30.8%**	**33.5%**
Estimated Degree of Saturation				
Measurement/Value	**Units**	**Specimen A**	**Specimen B**	**Specimen C**
Specific Gravity	--	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	176.62	239.50	257.46
Mass of Solids (in molded specimen)	g	1205.31	1347.09	1295.47
Density of Solids [a]	g/cm^3	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	443.13	495.26	476.28
Volume of Water [a]	cm^3	176.62	239.50	257.46
Volume of Voids	cm^3	340.12	281.09	292.50
Degree of Saturation	**%**	**51.9%**	**85.2%**	**88.0%**
Estimated Void Ratio				
Void Ratio	--	0.77	0.57	0.61

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Test ID: Validation Series #2
Target Dry UW: Random
Target Vol. Mst. Con.: Random
Date: 02/03/23

Specimen A	Specimen B	Specimen C	
1822.17	2109.26	2126.92	1
1821.86	2109.01	2126.65	2
1821.38	2108.5	2126.19	3
1821.5	2108.66	2126.37	4
1821.28	2108.32	2126.17	5
1821.46	2108.47	2126.3	6
1821.25	2108.15	2126.09	7
1821.28	2108.2	2126.13	8
1821.54	2108.43	2126.4	9
1821.45	2108.26	2126.27	10
1821.45	2108.21	2126.29	11
1821.44	2107.99	2126.31	12
1821.48	2107.91	2126.29	13
1821.64	2107.94	2126.49	14
1821.17	2107.32	2125.89	15
1821.25	2107.37	2126.15	16
1821.43	2107.38	2126.29	17
1820.97	2106.8	2125.88	18
1821.33	2107.13	2126.25	19
1821.54	2107.27	2126.38	20
1821.35	2107.03	2126.26	21
1821.31	2106.93	2126.22	22
1821.1	2106.66	2126.06	23
1820.97	2106.48	2125.95	24
1821.02	2106.49	2126.01	25
1821.16	2106.6	2126.08	26
1821.64	2107.11	2126.5	27
1821.57	2106.98	2126.45	28
1821.35	2106.75	2126.27	29
1821.35	2106.75	2126.23	30
1821.29	2106.66	2126.22	31
1821.38	2106.81	2126.27	32
1821.98	2107.36	2126.77	33
1821.74	2107.15	2126.6	34
1821.57	2106.84	2126.49	35
1821.26	2106.55	2126.13	36
1821.44	2106.71	2126.34	37
1821.75	2106.96	2126.59	38
1821.55	2106.74	2126.4	39
1820.89	2106	2125.83	40
1820.22	2105.23	2125.26	41
1820.09	2105.02	2125.13	42
1819.93	2104.89	2124.84	43
1820.32	2105.25	2125.35	44
1820.26	2105.13	2125.25	45
1819.81	2104.68	2124.87	46
1820.56	2105.3	2125.46	47
1820.58	2105.35	2125.5	48
1820.7	2105.5	2125.6	49
1820.65	2105.29	2125.57	50
1820.5	2105.15	2125.43	51
1820.68	2105.34	2125.63	52
1820.58	2105.25	2125.55	53
1820.38	2104.97	2125.32	54
	Cont.		

	Sensor 1	Sensor 2	Sensor 3
Actual VMC	22.6%	30.8%	33.5%
Acutal DUW	1.54	1.74	1.69
Degree of Saturation	51.9%	85.2%	88.0%
Average Raw mV - Full	1818.24	2098.00	2121.13
Std. Dev. (mV) - Full	1.54	3.94	2.51
Average Raw mV > 500	1817.07	2094.77	2119.08
Std. Dev. (mV) > 500	0.89	1.37	1.11



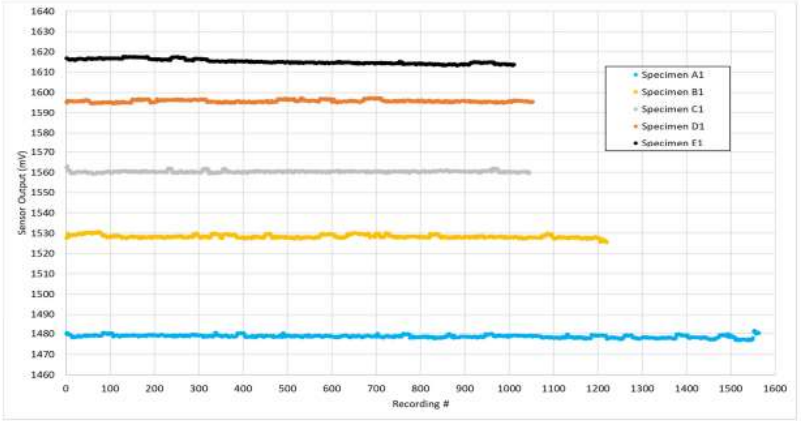
Characterization of Density Affects - Series 1 - VWC 15%						
Sample Preparation Details (For Moisture Conditioning)						
General Details	**Units**	**Spec. A1**	**Spec. B1**	**Spec. C1**	**Spec. D1**	**Spec. E1**
Moisture Conditioning Date	--	2/9/2023	2/7/2023	2/8/2023	2/8/2023	2/9/2023
Mold #	--	1	1	1	1	1
Mold Approx. Control Volume	cm^3	798.45	798.45	798.45	798.45	798.45
Empty Mold Total Mass	g	503.75	503.75	503.75	503.75	503.75
Target Dry Density	pcf	85	90	95	100	105
	g/cm^3	1.36	1.44	1.52	1.60	1.68
Target Volumetric Moisture Content	%	15%	15%	15%	15%	15%
Target Gravimetric Moisture Content	%	11.0%	10.4%	9.9%	9.4%	8.9%
Details for Control Volume Prep						
Mass of Solids	g	1087.11	1151.06	1215.01	1278.95	1342.90
Mass of Water [a]	g	119.77	119.77	119.77	119.77	119.77
Details for Cover						
Mass of Solids [b]	g	408.46	432.48	456.51	480.54	504.57
Mass of Water [a, b]	g	45.00	45.00	45.00	45.00	45.00
Prepared Specimen (Prior to Sensor Insertion)						
Measurement	**Units**	**Spec. A1**	**Spec. B1**	**Spec. C1**	**Spec. D1**	**Spec. E1**
Specimen Preparation Date	--	2/10/2023	2/8/2023	2/9/2023	2/9/2023	2/10/2023
Mass of Mold	g	503.27	503.36	503.33	503.32	503.29
Mass of Mold + Specimen	g	1709.15	1773.22	1837.14	1900.73	1964.60
Depth to Top of Specimen	mm	56.19	56.89	57.28	56.43	55.26
	mm	55.84	55.81	56.36	55.91	55.70
	mm	55.71	56.38	57.00	55.70	56.35
	mm	55.86	57.29	57.10	55.86	55.88
Average	mm	55.90	56.59	56.94	55.98	55.80
Specimen Total Mass	g	1205.88	1269.86	1333.81	1397.41	1461.31
Specimen Total Volume	cm^3	792.31	786.64	783.84	791.70	793.15
Specimen Total Density	g/cm^3	1.52	1.61	1.70	1.77	1.84
	pcf	95.0	100.8	106.2	110.2	115.0
Specimen Dry Density	**g/cm^3**	**1.37**	**1.46**	**1.55**	**1.61**	**1.69**
	pcf	**85.5**	**91.2**	**96.5**	**100.6**	**105.5**
Moisture Content (Post-Test)						
Measurement	**Units**	**Spec. A1**	**Spec. B1**	**Spec. C1**	**Spec. D1**	**Spec. E1**
Mass of Tare	g	279.1	279.1	291.59	286.63	286.62
Mass of Tare + Wet Tailings	g	1412.49	1381.48	1429.1	1370.73	1290.66
Mass of Tare + Dry Tailings	g	1298.51	1276.33	1324.91	1276.02	1207.32
Total Sample Mass	g	1133.39	1102.38	1137.51	1084.1	1004.04
Mass of Solids	g	1019.41	997.23	1033.32	989.39	920.7
Mass of Water	g	113.98	105.15	104.19	94.71	83.34
Gravimetric Moisture Content	%	11.2%	10.5%	10.1%	9.6%	9.1%
Volumetric Moisture Content [a]	**%**	**15.3%**	**15.4%**	**15.6%**	**15.4%**	**15.3%**
Estimated Degree of Saturation						
Measurement/Value	**Units**	**Spec. A1**	**Spec. B1**	**Spec. C1**	**Spec. D1**	**Spec. E1**
Specific Gravity	--	2.72	2.72	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	121.27	121.13	122.17	122.08	121.30
Mass of Solids (in molded specimen)	g	1084.61	1148.73	1211.64	1275.33	1340.01
Density of Solids [a]	g/cm^3	2.72	2.72	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	398.75	422.33	445.46	468.87	492.65
Volume of Water [a]	cm^3	121.27	121.13	122.17	122.08	121.30
Volume of Voids	cm^3	393.56	364.31	338.38	322.83	300.50
Degree of Saturation	**%**	**30.8%**	**33.2%**	**36.1%**	**37.8%**	**40.4%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Specimen A1	Specimen B1	Specimen C1	Specimen D1	Specimen E1	
1480.16	1527.67	1562.28	1595.31	1616.89	1
1479.68	1527.63	1562.35	1594.94	1616.86	2
1480.35	1528.56	1563.03	1595.23	1616.71	3
1480.22	1529.12	1561.28	1596.01	1616.58	4
1479.94	1529.79	1560.76	1595.83	1616.73	5
1479.88	1528.85	1560.79	1595.71	1616.24	6
1479.89	1528.65	1561.31	1595.66	1616.16	7
1479.69	1528.75	1560.94	1595.73	1616.07	8
1479.34	1528.52	1560.71	1595.58	1616.15	9
1479.42	1529.1	1560.73	1595.82	1615.95	10
1479.33	1529.23	1559.44	1595.77	1616.14	11
1479.19	1529.05	1559.3	1595.7	1616.13	12
1478.45	1529.24	1559.55	1595.72	1616.34	13
1478.19	1529.14	1559.62	1595.79	1616.43	14
1478.49	1529.44	1559.64	1595.7	1616.22	15
1478.15	1529.32	1559.6	1595.69	1616.3	16
1478.3	1529.25	1559.6	1595.56	1616.32	17
1478.38	1529.39	1559.77	1595.52	1616.17	18
1478.69	1529.17	1559.46	1595.6	1616.32	19
1478.41	1528.94	1559.84	1595.37	1616.22	20
1478.38	1529.09	1559.9	1595.59	1615.82	21
1478.32	1529.03	1559.7	1595.49	1616.08	22
1478.46	1529.1	1560.04	1595.69	1616.14	23
1478.46	1529.08	1560.3	1595.64	1616.43	24
1478.57	1529.35	1560.27	1595.59	1616.43	25
1478.54	1529.67	1560.18	1595.76	1616.4	26
1478.97	1529.82	1560.29	1595.85	1616.54	27
1479.06	1529.72	1560.27	1595.92	1616.46	28
1478.97	1529.98	1560.33	1595.58	1616.61	29
1478.79	1529.81	1560.3	1595.57	1616.66	30
1478.57	1529.99	1560.32	1595.66	1616.53	31
1478.51	1529.69	1560.42	1595.72	1616.52	32
1478.42	1529.83	1560.15	1595.63	1616.48	33
1478.65	1529.8	1559.93	1595.66	1616.64	34
1478.53	1529.33	1559.9	1596.01	1616.64	35
1478.44	1529.3	1560.06	1595.56	1616.56	36
1478.65	1529.6	1560.13	1595.48	1616.58	37
1478.91	1529.57	1560.19	1595.47	1616.5	38
1478.98	1530.24	1560.2	1595.71	1616.57	39
1479	1530.23	1560.4	1595.58	1616.33	40
1479.21	1529.91	1560.29	1595.81	1616.2	41
1478.96	1529.85	1560.45	1596.03	1616.26	42
1478.81	1529.71	1560.33	1595.95	1616.35	43
1479.13	1529.9	1560.47	1596.34	1616.19	44
1479.28	1530.22	1560.23	1596.31	1616.21	45
1479.02	1530.38	1560.39	1596.19	1616.18	46
1478.71	1530.41	1559.87	1596.01	1616.6	47
1479.12	1530.16	1559.61	1595.88	1616.62	48
1478.94	1530.24	1559.52	1595.73	1616.85	49

Cont.

	Specimen A1	Specimen B1	Specimen C1	Specimen D1	Specimen E1
Actual VMC	15.3%	15.4%	15.6%	15.4%	15.3%
Acutal DUW (g/cm^3)	1.37	1.46	1.55	1.61	1.69
Degree of Saturation	30.8%	33.2%	36.1%	37.8%	40.4%
Average Raw mV - Full	1478.69	1528.39	1560.34	1595.74	1615.23
Std. Dev. (mV) - Full	0.66	0.79	0.44	0.58	1.11
Average Raw mV > 500	1478.51	1528.26	1560.41	1595.82	1614.34
Std. Dev. (mV) > 500	0.66	0.76	0.35	0.54	0.43



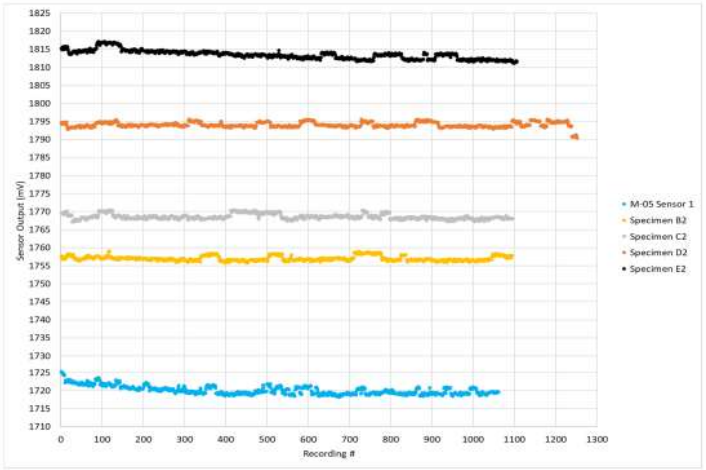
Characterization of Density Affects - Series 2 - VWC 20%						
Sample Preparation Details (For Moisture Conditioning)						
General Details	**Units**	**Spec. A2=M-05 Sensor 1**	**Spec. B2**	**Spec. C2**	**Spec. D2**	**Spec. E2**
Moisture Conditioning Date	--	8/8/2022	2/13/2023	2/13/2023	2/14/2023	2/14/2023
Mold #	--	1	1	1	1	1
Mold Approx. Control Volume	cm^3	798.45	798.45	798.45	798.45	798.45
Empty Mold Total Mass	g	503.75	503.75	503.75	503.75	503.75
Target Dry Density	pcf	90	95	100	105	110
	g/cm^3	1.44	1.52	1.60	1.68	1.76
Target Volumetric Moisture Content	%	20%	20%	20%	20%	20%
Target Gravimetric Moisture Content	%	13.9%	13.1%	12.5%	11.9%	11.4%
Details for Control Volume Prep						
Mass of Solids	g	1151.06	1215.01	1278.95	1342.90	1406.85
Mass of Water [a]	g	159.69	159.69	159.69	159.69	159.69
Details for Cover						
Mass of Solids [a]	g	432.48	456.51	480.54	504.57	528.59
Mass of Water [a, b]	g	60.00	60.00	60.00	60.00	60.00
Prepared Specimen (Prior to Sensor Insertion)						
Measurement	**Units**	**Spec. A2=M-05 Sensor 1**	**Spec. B2**	**Spec. C2**	**Spec. D2**	**Spec. E2**
Specimen Preparation Date	--	8/9/2022	2/14/2023	2/14/2023	2/15/2023	2/15/2023
Mass of Mold	g	503.87	503.24	503.21	503.18	503.19
Mass of Mold + Specimen	g	1813.87	1877.08	1940.48	2004.64	2068.45
Depth to Top of Specimen	mm	56.38	55.24	57.34	56.01	56.02
	mm	56.71	55.54	55.92	56.45	55.15
	mm	55.86	56.13	57.51	55.53	56.00
	mm	56.33	55.23	57.99	55.94	55.75
Average	mm	56.32	55.54	57.19	55.98	55.73
Specimen Total Mass	g	1310.00	1373.84	1437.27	1501.46	1565.26
Specimen Total Volume	cm^3	788.87	795.30	781.75	791.64	793.70
Specimen Total Density	g/cm^3	1.66	1.73	1.84	1.90	1.97
	pcf	103.7	107.8	114.8	118.4	123.1
Specimen Dry Density	**g/cm^3**	**1.46**	**1.53**	**1.63**	**1.69**	**1.77**
	pcf	**90.9**	**95.2**	**102.0**	**105.7**	**110.5**
Moisture Content (Post-Test)						
Measurement	**Units**	**Spec. A2=M-05 Sensor 1**	**Spec. B2**	**Spec. C2**	**Spec. D2**	**Spec. E2**
Mass of Tare	g	152.56	286.62	279.09	291.59	279.08
Mass of Tare + Wet Tailings	g	1411.02	1521.5	1462.82	1365.16	1276.97
Mass of Tare + Dry Tailings	g	1256.58	1376.9	1330.58	1249.5	1174.3
Total Sample Mass	g	1258.46	1234.88	1183.73	1073.57	997.89
Mass of Solids	g	1104.02	1090.28	1051.49	957.91	895.22
Mass of Water	g	154.44	144.6	132.24	115.66	102.67
Gravimetric Moisture Content	%	14.0%	13.3%	12.6%	12.1%	11.5%
Volumetric Moisture Content [a]	**%**	**20.4%**	**20.2%**	**20.5%**	**20.4%**	**20.3%**
Estimated Degree of Saturation						
Measurement/Value	**Units**	**Spec. A2=M-05 Sensor 1**	**Spec. B2**	**Spec. C2**	**Spec. D2**	**Spec. E2**
Specific Gravity	--	2.72	2.72	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	160.77	160.87	160.56	161.76	161.05
Mass of Solids (in molded specimen)	g	1149.23	1212.97	1276.71	1339.70	1404.21
Density of Solids [a]	g/cm^3	2.72	2.72	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	422.51	445.94	469.38	492.54	516.26
Volume of Water [a]	cm^3	160.77	160.87	160.56	161.76	161.05
Volume of Voids	cm^3	366.36	349.36	312.37	299.10	277.45
Degree of Saturation	**%**	**43.9%**	**46.0%**	**51.4%**	**54.1%**	**58.0%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

M-05 Sensor 1	Specimen B2	Specimen C2	Specimen D2	Specimen E2	
1725.28	1757.71	1769.5	1794.68	1815.23	1
1725.13	1757.16	1769.55	1794.19	1814.99	2
1724.82	1756.96	1769.48	1794.46	1814.88	3
1724.66	1756.83	1769.51	1794.36	1815.47	4
1724.92	1757.11	1769.61	1794.38	1815.68	5
1724.73	1757.56	1769.3	1794.74	1815.72	6
1724.38	1757.15	1769.23	1794.69	1815.7	7
1724.44	1756.82	1769.82	1794.54	1814.85	8
1724.2	1757.03	1769.98	1794.59	1815.14	9
1722.15	1756.91	1769.73	1794.18	1815.32	10
1722.84	1757.33	1769.3	1794.52	1815.8	11
1722.88	1757.14	1769.26	1794.82	1815.19	12
1722.48	1757.3	1769.3	1794.76	1815.48	13
1722.96	1757.5	1769.72	1794.52	1815.18	14
1722.96	1757.9	1770.12	1793.65	1815.39	15
1722.33	1758.08	1768.94	1792.95	1815.7	16
1722.05	1758.28	1769.19	1792.77	1815.28	17
1722.78	1758.27	1768.73	1793.08	1814.72	18
1723.15	1758.17	1768.89	1792.92	1813.9	19
1723.02	1757.76	1768.87	1792.94	1813.7	20
1722.68	1758.05	1768.84	1793.36	1813.72	21
1722.33	1757.98	1769.07	1793.44	1813.54	22
1722.19	1758.12	1768.74	1793.32	1813.63	23
1722.55	1758.1	1768.82	1793.2	1813.57	24
1722.97	1757.54	1768.94	1793.4	1813.98	25
1722.63	1757.57	1769.12	1793.24	1813.88	26
1722.58	1757.79	1768.83	1793.42	1813.8	27
1722.46	1757.91	1767.15	1793.26	1814.22	28
1722.11	1758.1	1767.22	1793.45	1814.27	29
1722.11	1758.11	1767.48	1793.35	1814.43	30
1721.99	1757.45	1767.6	1793.47	1814.17	31
1721.96	1756.97	1767.68	1793.25	1814.52	32
1722.55	1756.89	1767.54	1793.36	1814.3	33
1722.3	1756.95	1767.26	1793.41	1814.23	34
1722.05	1756.87	1767.84	1793.19	1814.27	35
1722.11	1756.63	1767.49	1793.37	1814.52	36
1722.06	1756.79	1767.52	1793.6	1814.5	37
1721.87	1757.05	1767.59	1793.58	1813.76	38
1722.13	1756.83	1767.38	1793.69	1813.79	39
1722.06	1756.97	1767.83	1793.5	1814.03	40
1721.74	1756.96	1767.63	1793.61	1814.06	41
1722.13	1756.4	1767.52	1793.48	1814.09	42
1722.14	1756.36	1767.46	1793.52	1814.19	43
1721.92	1756.48	1767.42	1793.65	1814.83	44
1721.68	1756.42	1767.67	1793.88	1814.58	45
1721.54	1756.49	1767.4	1793.57	1814.35	46
1721.91	1756.45	1767.72	1793.2	1814.19	47
1722.23	1756.61	1767.9	1793.34	1814.14	48
1721.88	1756.91	1768.33	1793.74	1814.27	49

Cont.

	M-05 Sensor 1	Specimen B2	Specimen C2	Specimen D2	Specimen E2
Actual VMC	20.4%	20.2%	20.5%	20.4%	20.3%
Acutal DUW (g/cm^3)	1.46	1.53	1.63	1.69	1.77
Degree of Saturation	43.9%	46.0%	51.4%	54.1%	58.0%
Average Raw mV - Full	1720.09	1756.99	1768.57	1794.03	1813.45
Std. Dev. (mV) - Full	1.20	0.69	0.72	0.70	1.23
Average Raw mV > 500	1719.56	1757.02	1768.41	1794.01	1812.65
Std. Dev. (mV) > 500	0.78	0.76	0.61	0.80	0.74



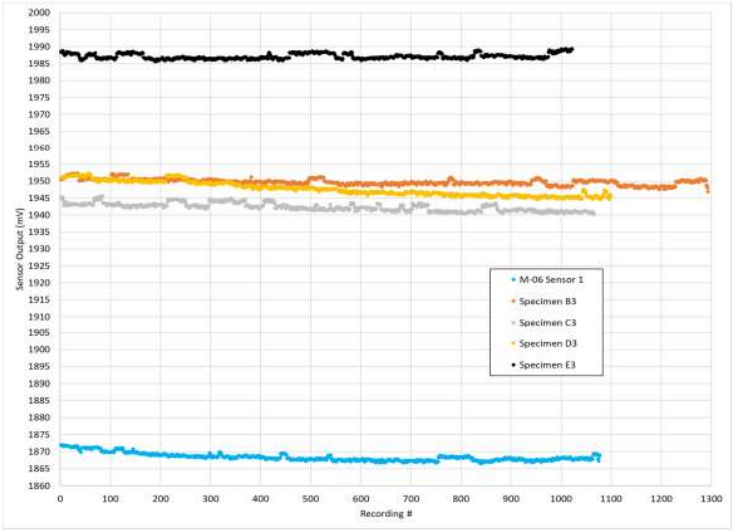
Characterization of Density Affects - Series 3 - VWC 25%						
Sample Preparation Details (For Moisture Conditioning)						
General Details	**Units**	**Spec. A3=M-06 Sensor 1**	**Spec. B3**	**Spec. C3**	**Spec. D3**	**Spec. E3**
Moisture Conditioning Date	--	8/9/2022	2/15/2023	2/16/2023	2/16/2023	2/17/2023
Mold #	--	1	1	1	1	1
Mold Approx. Control Volume	cm^3	798.45	798.45	798.45	798.45	798.45
Empty Mold Total Mass	g	503.75	503.75	503.75	503.75	503.75
Target Dry Density	pcf	90	95	100	105	110
	g/cm^3	1.44	1.52	1.60	1.68	1.76
Target Volumetric Moisture Content	%	25%	25%	25%	25%	25%
Target Gravimetric Moisture Content	%	17.3%	16.4%	15.6%	14.9%	14.2%
Details for Control Volume Prep						
Mass of Solids	g	1151.06	1215.01	1278.95	1342.90	1406.85
Mass of Water [a]	g	199.61	199.61	199.61	199.61	199.61
Details for Cover						
Mass of Solids [b]	g	432.48	456.51	480.54	504.57	528.59
Mass of Water [a, b]	g	75.00	75.00	75.00	75.00	75.00
Prepared Specimen (Prior to Sensor Insertion)						
Measurement	**Units**	**Spec. A3=M-06 Sensor 1**	**Spec. B3**	**Spec. C3**	**Spec. D3**	**Spec. E3**
Specimen Preparation Date	--	8/10/2022	2/16/2023	2/17/2023	2/17/2023	2/18/2023
Mass of Mold	g	503.84	503.15	503.11	503.11	503.10
Mass of Mold + Specimen	g	1853.86	1915.62	1980.47	2044.16	2108.27
Depth to Top of Specimen	mm	56.25	57.43	56.91	55.92	56.96
	mm	55.90	56.94	56.66	55.39	56.64
	mm	56.74	56.14	55.82	55.72	56.29
	mm	56.37	57.50	56.28	55.29	57.11
Average	mm	56.32	57.00	56.42	55.58	56.75
Specimen Total Mass	g	1350.02	1412.47	1477.36	1541.05	1605.17
Specimen Total Volume	cm^3	788.91	783.28	788.07	794.93	785.35
Specimen Total Density	g/cm^3	1.71	1.80	1.87	1.94	2.04
	pcf	106.8	112.6	117.0	121.0	127.6
Specimen Dry Density	**g/cm^3**	**1.45**	**1.55**	**1.62**	**1.68**	**1.79**
	pcf	**90.8**	**96.6**	**101.1**	**105.1**	**111.6**
Moisture Content (Post-Test)						
Measurement	**Units**	**Spec. A3=M-06 Sensor 1**	**Spec. B3**	**Spec. C3**	**Spec. D3**	**Spec. E3**
Mass of Tare	g	154.02	358.8	279.1	286.64	358.75
Mass of Tare + Wet Tailings	g	1479.98	1715.83	1486.18	1345.57	1847.35
Mass of Tare + Dry Tailings	g	1281.42	1522.87	1321.48	1206.53	1660.41
Total Sample Mass	g	1325.96	1357.03	1207.08	1058.93	1488.6
Mass of Solids	g	1127.4	1164.07	1042.38	919.89	1301.66
Mass of Water	g	198.56	192.96	164.7	139.04	186.94
Gravimetric Moisture Content	%	17.6%	16.6%	15.8%	15.1%	14.4%
Volumetric Moisture Content [a]	**%**	**25.6%**	**25.6%**	**25.6%**	**25.5%**	**25.7%**
Estimated Degree of Saturation						
Measurement/Value	**Units**	**Spec. A3=M-06 Sensor 1**	**Spec. B3**	**Spec. C3**	**Spec. D3**	**Spec. E3**
Specific Gravity	--	2.72	2.72	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	202.16	200.84	201.58	202.34	201.58
Mass of Solids (in molded specimen)	g	1147.86	1211.63	1275.78	1338.71	1403.59
Density of Solids [a]	g/cm^3	2.72	2.72	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	422.01	445.45	469.04	492.17	516.03
Volume of Water [a]	cm^3	202.16	200.84	201.58	202.34	201.58
Volume of Voids	cm^3	366.91	337.83	319.04	302.76	269.32
Degree of Saturation	**%**	**55.1%**	**59.5%**	**63.2%**	**66.8%**	**74.8%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

M-06 Sensor 1	Specimen B3	Specimen C3	Specimen D3	Specimen E3	
1871.97	1950.36	1944.97	1950.85	1988.61	1
1871.89	1950.34	1945.35	1950.96	1988.26	2
1871.95	1951.24	1945.16	1950.96	1988.48	3
1871.93	1950.67	1945	1951.03	1988.8	4
1871.63	1951.14	1945.16	1951.1	1988.33	5
1872.02	1951.17	1944.27	1951.14	1988.63	6
1871.89	1950.7	1942.92	1950.94	1987.97	7
1871.69	1950.91	1942.73	1950.77	1987.66	8
1871.56	1950.94	1943.41	1951.18	1987.48	9
1871.54	1951.16	1943.44	1951.38	1987.78	10
1871.76	1951.53	1943.39	1951.47	1987.59	11
1871.81	1951.75	1943.82	1951.54	1987.7	12
1871.61	1951.73	1943.62	1951.56	1988.42	13
1871.58	1951.86	1942.94	1951.54	1988.34	14
1871.67	1951.89	1942.77	1951.5	1988.46	15
1871.63	1951.8	1943.26	1951.36	1988.24	16
1871.69	1951.54	1942.79	1951.42	1988.18	17
1871.6	1951.74	1942.85	1951.49	1988.3	18
1871.52	1951.9	1942.99	1951.42	1988.23	19
1871.55	1951.94	1943.07	1951.56	1988.17	20
1871.31	1952.15	1943.4	1951.48	1987.69	21
1871.2	1951.99	1943.16	1951.68	1987.7	22
1871.21	1952.15	1943.11	1951.51	1987.98	23
1871.41	1951.9	1942.98	1951.46	1987.74	24
1871.49	1951.56	1943.24	1951.45	1987.97	25
1871.46	1951.8	1943.23	1951.58	1988.07	26
1871.24	1952.2	1943.47	1951.72	1988.02	27
1871.65	1952.04	1943.11	1951.88	1988.09	28
1871.39	1952.12	1943.26	1951.49	1987.9	29
1871.23	1952.12	1943.2	1951.59	1988.09	30
1871.36	1952.26	1943.1	1951.81	1987.86	31
1871.37	1952.2	1943.18	1951.83	1987.94	32
1871.29	1951.98	1943.13	1951.71	1987.77	33
1871.65	1952.15	1942.98	1951.82	1987.77	34
1871.51	1952.31	1943.13	1951.62	1987.91	35
1870.65	1951.72	1942.93	1951.45	1987.75	36
1870.66	1951.4	1943.06	1951.92	1987.64	37
1870.55	1950.06	1942.96	1951.38	1986.98	38
1870.42	1950.12	1942.91	1951.33	1986.54	39
1870	1950.61	1942.85	1951.56	1985.94	40
1869.8	1950.44	1942.96	1951.34	1985.94	41
1871.07	1950.68	1942.91	1951.65	1985.99	42
1871.2	1950.18	1943.22	1951.9	1985.89	43
1871.17	1950.42	1943.41	1951.57	1985.94	44
1871.2	1950.19	1942.77	1951.29	1986.11	45
1871.31	1950.25	1942.69	1951.42	1986.53	46
1871.2	1950.31	1942.81	1951.81	1986.49	47
1871.12	1950.57	1942.8	1951.59	1986.53	48
1871.2	1950.68	1943.4	1950.64	1986.6	49

Cont.

	M-06 Sensor 1	Specimen B3	Specimen C3	Specimen D3	Specimen E3
Actual VMC	25.6%	25.6%	25.6%	25.5%	25.7%
Acutal DUW (g/cm^3)	1.45	1.55	1.62	1.68	1.79
Degree of Saturation	55.1%	59.5%	63.2%	66.8%	74.8%
Average Raw mV - Full	1868.42	1949.72	1942.31	1947.71	1987.12
Std. Dev. (mV) - Full	1.17	0.88	1.17	2.05	0.79
Average Raw mV > 500	1867.70	1949.34	1941.53	1946.09	1987.25
Std. Dev. (mV) > 500	0.51	0.73	0.77	0.80	0.79



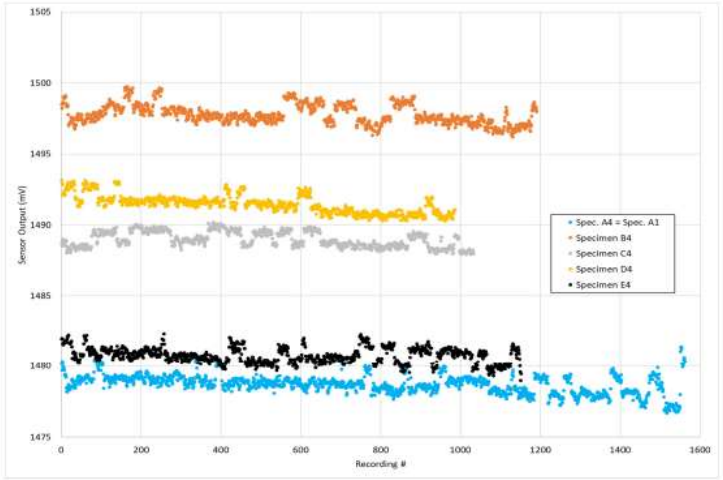
Characterization of Density Affects - Series 4 - Saturation 30%						
Sample Preparation Details (For Moisture Conditioning)						
General Details	**Units**	**Spec. A4 = Spec. A1**	**Spec. B4**	**Spec. C4**	**Spec. D4**	**Spec. E4**
Moisture Conditioning Date	--	2/9/2023	2/18/2023	2/18/2023	2/20/2023	3/5/2023
Mold #	--	1	1	1	1	1
Mold Approx. Control Volume	cm^3	798.45	798.45	798.45	798.45	798.45
Empty Mold Total Mass	g	503.75	503.75	503.75	503.75	503.75
Target Dry Density	pcf	85	90	95	100	105
	g/cm^3	1.36	1.44	1.52	1.60	1.68
Target Degree of Saturation	%	30.0%	30.0%	30.0%	30.0%	30.0%
Specific Gravity	--	2.72	2.72	2.72	2.72	2.72
Volume of Solids	cm^3	399.67	423.18	446.69	470.20	493.71
Volume of Water	cm^3	119.63	112.58	105.53	98.47	91.42
Target Volumetric Moisture Content	%	15.0%	14.1%	13.2%	12.3%	11.4%
Target Gravimetric Moisture Content	%	11.0%	9.8%	8.7%	7.7%	6.8%
Details for Control Volume Prep						
Mass of Solids	g	1087.11	1151.06	1215.01	1278.95	1342.90
Mass of Water [a]	g	119.63	112.58	105.53	98.47	91.42
Details for Cover						
Mass of Solids [b]	g	408.46	432.48	456.51	480.54	504.57
Mass of Water [a,b]	g	44.95	42.30	39.65	37.00	34.35
Prepared Specimen (Prior to Sensor Insertion)						
Measurement	**Units**	**Spec. A4 = Spec. A1**	**Spec. B3**	**Spec. C3**	**Spec. D3**	**Spec. E3**
Specimen Preparation Date	--	2/10/2023	2/20/2023	2/20/2023	2/21/2023	3/6/2023
Mass of Mold	g	503.27	503.08	503.08	503.05	502.86
Mass of Mold + Specimen	g	1709.15	1765.64	1822.42	1879.60	1935.57
Depth to Top of Specimen	mm	56.19	56.93	56.89	55.72	56.50
	mm	55.84	56.10	54.48	55.76	55.21
	mm	55.71	55.77	54.50	55.91	55.70
	mm	55.86	56.11	56.55	56.32	57.26
Average	mm	55.90	56.23	55.61	55.98	56.17
Specimen Total Mass	g	1205.88	1262.56	1319.34	1376.55	1432.71
Specimen Total Volume	cm^3	792.31	789.63	794.73	791.68	790.12
Specimen Total Density	g/cm^3	1.52	1.60	1.66	1.74	1.81
	pcf	95.0	99.8	103.6	108.6	113.2
Specimen Dry Density	**g/cm^3**	**1.37**	**1.45**	**1.52**	**1.61**	**1.69**
	pcf	**85.5**	**90.7**	**95.2**	**100.5**	**105.8**
Moisture Content (Post-Test)						
Measurement	**Units**	**Spec. A4 = Spec. A1**	**Spec. B3**	**Spec. C3**	**Spec. D3**	**Spec. E3**
Mass of Tare	g	279.1	291.59	279.09	358.75	279.08
Mass of Tare + Wet Tailings	g	1412.49	1425.88	1359.13	1679.37	1169.96
Mass of Tare + Dry Tailings	g	1298.51	1322.7	1270.91	1582.01	1111.5
Total Sample Mass	g	1133.39	1134.29	1080.04	1320.62	890.88
Mass of Solids	g	1019.41	1031.11	991.82	1223.26	832.42
Mass of Water	g	113.98	103.18	88.22	97.36	58.46
Gravimetric Moisture Content	%	11.2%	10.0%	8.9%	8.0%	7.0%
Volumetric Moisture Content [a]	**%**	**15.3%**	**14.5%**	**13.6%**	**12.8%**	**11.9%**
Estimated Degree of Saturation						
Measurement/Value	**Units**	**Spec. A4 = Spec. A1**	**Spec. B3**	**Spec. C3**	**Spec. D3**	**Spec. E3**
Mass of Water (in molded specimen)	g	121.27	114.85	107.77	101.48	94.02
Mass of Solids (in molded specimen)	g	1084.61	1147.71	1211.57	1275.07	1338.69
Density of Solids [a]	g/cm^3	2.72	2.72	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	398.75	421.95	445.43	468.77	492.17
Volume of Water [a]	cm^3	121.27	114.85	107.77	101.48	94.02
Volume of Voids	cm^3	393.56	367.68	349.29	322.90	297.95
Degree of Saturation	**%**	**30.8%**	**31.2%**	**30.9%**	**31.4%**	**31.6%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Spec. A4 = Spec. A1	Specimen B4	Specimen C4	Specimen D4	Specimen E4	
1480.16	1498.48	1488.72	1492.16	1481.94	1
1479.08	1498.22	1488.52	1492.03	1481.99	2
1480.35	1498.49	1488.79	1492.85	1481.97	3
1480.22	1498.59	1488.98	1492.17	1481.64	4
1479.94	1498.65	1488.95	1492.17	1481.54	5
1479.88	1499.01	1488.95	1492.08	1481.6	6
1479.89	1498.92	1488.83	1492.26	1481.67	7
1479.69	1498.89	1488.54	1492.36	1481.7	8
1479.34	1499.01	1488.84	1492.18	1481.82	9
1479.42	1499.1	1488.84	1492.11	1481.82	10
1479.33	1498.99	1488.52	1492.55	1481.82	11
1479.19	1498.55	1488.85	1492.46	1481.72	12
1478.45	1498.33	1488.91	1492.68	1481.84	13
1478.19	1498.38	1488.02	1492.64	1481.86	14
1478.49	1498.45	1488.18	1492.73	1481.95	15
1478.15	1498.31	1488.33	1492.89	1482.13	16
1478.3	1498.43	1488.24	1492.46	1482.11	17
1478.38	1497.76	1488.26	1492.03	1482.17	18
1478.69	1497	1488.45	1492.98	1482.23	19
1478.41	1497.13	1488.22	1492.92	1481.66	20
1478.38	1497.17	1488.3	1492.88	1481.69	21
1478.32	1497.15	1488.06	1492.98	1481.62	22
1478.46	1497.19	1488.04	1492.62	1481.72	23
1478.46	1497.32	1488.22	1492.6	1481.7	24
1478.57	1497.57	1488.22	1492.72	1481.72	25
1478.54	1497.5	1488.53	1492.74	1481.82	26
1478.97	1497.32	1488.64	1492.98	1481.42	27
1479.06	1497.4	1488.59	1492.72	1480.59	28
1478.97	1497.17	1488.61	1492.71	1480.99	29
1478.79	1497.44	1488.71	1493.08	1480.94	30
1478.57	1497.54	1488.38	1492.96	1481.05	31
1478.51	1496.99	1488.55	1493.03	1480.99	32
1478.62	1496.91	1488.35	1492.86	1480.52	33
1478.65	1496.75	1488.48	1492.62	1480.65	34
1478.53	1496.93	1488.51	1492.98	1480.74	35
1478.44	1497.08	1488.26	1491.79	1480.97	36
1478.65	1497.39	1488.16	1491.76	1480.76	37
1478.91	1497.04	1488.41	1491.87	1480.62	38
1478.98	1497.62	1488.47	1491.83	1480.52	39
1479	1497.6	1488.42	1491.78	1480.44	40
1479.21	1497.76	1488.33	1491.33	1480.39	41
1478.96	1497.83	1488.29	1491.3	1480.23	42
1478.81	1497.45	1488.29	1491.76	1480.21	43
1479.13	1497.36	1488.61	1491.49	1480.45	44
1479.28	1497.55	1488.34	1491.26	1480.33	45
1479.02	1497.43	1488.56	1491.41	1480.21	46
1478.71	1497.51	1488.49	1491.42	1480.48	47
1479.12	1497.45	1488.5	1491.71	1480.88	48
1478.94	1497.63	1488.61	1491.49	1480.74	49
1479.19	1497.79	1488.84	1491.61	1480.83	50
1479.01	1497.49	1488.54	1491.8	1480.86	51
1478.88	1497.75	1488.42	1491.72	1480.73	52

Cont.

	Spec. A4 = Spec. A1	Specimen B4	Specimen C4	Specimen D4	Specimen E4
Actual VMC	15.3%	14.5%	13.6%	12.8%	11.9%
Acutal DUW (g/cm^3)	1.37	1.45	1.52	1.61	1.69
Degree of Saturation	30.8%	31.2%	30.9%	31.4%	31.6%
Average Raw mV - Full	1478.69	1497.79	1488.98	1491.45	1480.76
Std. Dev. (mV) - Full	0.66	0.69	0.56	0.65	0.56
Average Raw mV > 500	1478.51	1497.67	1488.77	1491.02	1480.68
Std. Dev. (mV) > 500	0.66	0.73	0.51	0.49	0.60



Characterization of Density Affects - Series 5 - Saturation 45%

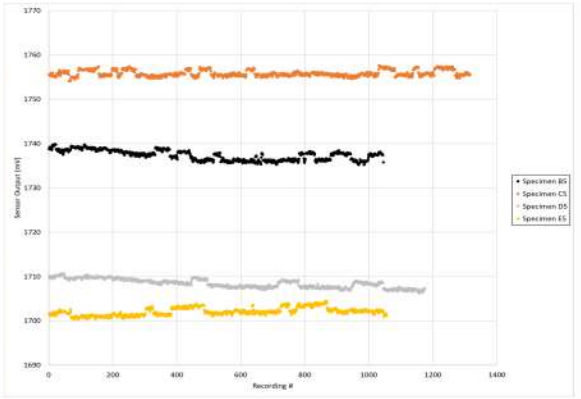
Sample Preparation Details (For Moisture Conditioning)

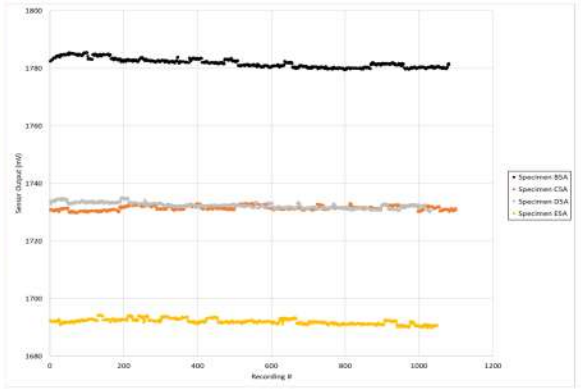
General Details	Units	Spec. BS	Spec. CS	Spec. DS	Spec. ES	Spec. BSA	Spec. CSA	Spec. DSA	Spec. ESA
Moisture Conditioning Date	--	2/20/2023	2/21/2023	2/21/2023	2/22/2023	3/4/2023	3/5/2023	3/8/2023	3/8/2023
Mold #	--	1	1	1	1	1	1	1	1
Mold Approx. Control Volume	cm^3	798.45	798.45	798.45	798.45	798.45	798.45	798.45	798.45
Target Dry Density	g	503.75	503.75	503.75	503.75	503.75	503.75	503.75	503.75
	pcf	90	95	100	105	90	95	100	105
	g/cm^3	1.44	1.52	1.60	1.68	1.44	1.52	1.60	1.68
Target Degree of Saturation	%	45.0%	45.0%	45.0%	45.0%	45.0%	45.0%	45.0%	45.0%
Specific Gravity	--	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
Volume of Solids	cm^3	423.18	446.69	470.20	493.71	423.18	446.69	470.20	493.71
Volume of Water	cm^3	168.87	158.29	147.71	137.13	168.87	158.29	147.71	137.13
Target Volumetric Moisture Content	%	21.1%	19.8%	18.5%	17.2%	21.1%	19.8%	18.5%	17.2%
Target Gravimetric Moisture Content	%	14.7%	13.0%	11.5%	10.2%	14.7%	13.0%	11.5%	10.2%
Details for Control Volume Prep									
Mass of Solids	g	1151.06	1215.01	1278.95	1342.90	1151.06	1215.01	1278.95	1342.90
Mass of Water *	g	168.87	158.29	147.71	137.13	168.87	158.29	147.71	137.13
Details for Cover									
Mass of Solids *	g	432.48	456.51	480.54	504.57	432.48	456.51	480.54	504.57
Mass of Water *,^	g	63.45	59.47	55.50	51.52	63.45	59.47	55.50	51.52
Prepared Specimen (Prior to Sensor Insertion)									
Measurement	**Units**	**Spec. BS**	**Spec. CS**	**Spec. DS**	**Spec. ES**	**Spec. BSA**	**Spec. CSA**	**Spec. DSA**	**Spec. ESA**
Specimen Preparation Date	--	2/21/2023	2/22/2023	2/22/2023	2/23/2023	3/5/2023	3/6/2023	3/9/2023	3/9/2023
Mass of Mold	g	503.10	503.03	503.03	502.99	502.80	502.90	502.88	502.84
Mass of Mold + Specimen	g	1822.07	1875.13	1928.64	1981.42	1821.52	1874.95	1928.63	1981.63
Depth to Top of Specimen	mm	54.99	56.62	55.73	55.15	56.94	55.81	56.38	56.05
	mm	55.42	56.38	55.34	54.30	56.24	56.69	56.16	55.92
	mm	55.16	55.91	54.16	54.74	56.28	55.68	56.67	56.20
	mm	54.98	55.10	54.18	55.75	56.48	55.12	55.96	56.16
Average	mm	55.19	56.00	54.85	55.04	56.49	55.83	56.29	56.08
Specimen Total Mass	g	1318.97	1372.10	1425.61	1478.43	1318.63	1372.05	1425.75	1478.79
Specimen Total Volume	cm^3	798.14	791.47	800.89	799.39	787.52	792.92	789.14	790.82
Specimen Total Density	g/cm^3	1.65	1.73	1.78	1.85	1.67	1.73	1.81	1.87
	pcf	103.2	108.2	111.1	115.5	104.5	108.0	112.8	116.7
Specimen Dry Density	**g/cm^3**	**1.44**	**1.53**	**1.59**	**1.67**	**1.46**	**1.53**	**1.62**	**1.69**
	pcf	**89.9**	**95.5**	**99.4**	**104.5**	**91.0**	**95.4**	**100.9**	**105.7**
Moisture Content (Post-Test)									
Measurement	**Units**	**Spec. BS**	**Spec. CS**	**Spec. DS**	**Spec. ES**	**Spec. BSA**	**Spec. CSA**	**Spec. DSA**	**Spec. ESA**
Mass of Tare	g	291.59	279.09	358.74	291.6	358.73	286.62	358.74	291.59
Mass of Tare + Wet Tailings	g	1539.80	1435.3	1741.15	1351.4	1626.65	1368.28	1760.56	1124.18
Mass of Tare + Dry Tailings	g	1379.00	1299.84	1505.15	1251.13	1462.71	1241.89	1612.25	1045.21
Total Sample Mass	g	1248.21	1156.21	1382.41	1059.8	1267.92	1081.66	1401.82	832.59
Mass of Solids	g	1087.41	1020.75	1236.41	959.53	1103.98	955.27	1253.51	753.62
Mass of Water	g	160.8	135.46	146	100.27	163.94	126.39	148.31	78.97
Gravimetric Moisture Content	%	14.8%	13.3%	11.8%	10.4%	14.8%	13.2%	11.8%	10.5%
Volumetric Moisture Content *	**%**	**21.3%**	**20.3%**	**18.8%**	**17.5%**	**21.6%**	**20.2%**	**19.1%**	**17.7%**
Estimated Degree of Saturation									
Measurement/Value	**Units**	**Spec. BS**	**Spec. CS**	**Spec. DS**	**Spec. ES**	**Spec. BSA**	**Spec. CSA**	**Spec. DSA**	**Spec. ESA**
Mass of Water (in molded specimen)	g	168.92	160.75	150.56	139.88	170.50	160.32	150.84	140.26
Mass of Solids (in molded specimen)	g	1149.05	1211.05	1275.05	1338.55	1148.13	1211.73	1274.91	1338.53
Density of Solids *	g/cm^3	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	422.45	445.35	468.77	492.11	422.11	445.49	468.72	492.11
Volume of Water *	cm^3	169.92	160.75	150.56	139.88	170.50	160.32	150.84	140.26
Volume of Voids	cm^3	375.70	346.12	312.12	307.28	365.41	347.44	320.42	298.71
Degree of Saturation	**%**	**45.2%**	**46.4%**	**45.3%**	**45.5%**	**46.7%**	**46.1%**	**47.1%**	**47.0%**

Notes:
a) Value assumes density of water is 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Specimen BS	Specimen CS	Specimen DS	Specimen ES	Specimen BSA	Specimen CSA	Specimen DSA	Specimen ESA	
1736.72	1755.56	1708.87	1701.66	1782.42	1730.61	1733.68	1692.49	1
1736.98	1755.63	1710.1	1701.65	1782.71	1731.05	1732.74	1692.13	2
1739.18	1756.69	1709.85	1701.4	1782.7	1731.06	1732.96	1692.26	3
1739.26	1755.98	1709.82	1701.16	1782.84	1731	1733.69	1692.15	4
1738.85	1755.91	1709.49	1701.41	1782.75	1730.79	1734.04	1692.13	5
1739.01	1755.23	1708.89	1701.67	1783.01	1730.63	1733.99	1692.26	6
1738.15	1755.55	1709.95	1701.48	1783.05	1730.82	1734.12	1691.88	7
1738.98	1755.88	1710.05	1701.22	1783.13	1730.87	1734.24	1691.87	8
1738.55	1756.02	1710.08	1701.46	1783.46	1730.76	1733.96	1691.98	9
1738.8	1755.23	1709.98	1701.77	1783.61	1730.46	1733.64	1692.07	10
1739.61	1755.6	1710.06	1701.23	1783.7	1730.37	1733.86	1692.42	11
1739.71	1755.83	1709.85	1701.39	1783.77	1730.27	1733.85	1692.11	12
1739.71	1755.51	1710.09	1701.17	1783.63	1730.53	1734	1692.1	13
1739.66	1755.08	1709.69	1701.55	1783.56	1730.73	1733.59	1691.99	14
1739.6	1755.37	1709.6	1701.71	1783.6	1730.54	1734.26	1691.99	15
1739.7	1755.17	1709.6	1701.97	1783.8	1731.09	1734.5	1692.12	16
1739.6	1755.12	1709.75	1701.97	1783.94	1730.68	1734.49	1692.07	17
1739.75	1755.25	1709.69	1701.76	1784.12	1731.09	1734.49	1692.07	18
1739.9	1755.59	1709.77	1701.68	1784.68	1731.03	1734.46	1692.18	19
1739.77	1755.35	1710.17	1701.59	1784.21	1730.96	1734.69	1692.15	20
1739.72	1755.13	1710.32	1701.11	1784.32	1731.05	1734.21	1692.45	21
1739.74	1754.89	1710.25	1701.1	1784.41	1730.72	1734.64	1692.23	22
1738.76	1755.29	1710.3	1701.23	1784.3	1730.68	1734.58	1692.53	23
1738.6	1755.22	1710.34	1701.22	1784.32	1730.53	1734.82	1692.85	24
1738.64	1755.77	1710.16	1701.95	1784.83	1730.3	1734.74	1692.62	25
1738.68	1755.87	1710.22	1701.76	1784.06	1730.54	1734.62	1692.46	26
1738.43	1755.71	1710.15	1701.99	1784.85	1730.71	1734.34	1691.72	27
1738.52	1755.42	1710.1	1702.08	1784.58	1731.26	1734.3	1692.78	28
1738.83	1755.85	1709.87	1701.81	1784.92	1731.17	1734.16	1692.98	29
1738.63	1755.81	1710.18	1701.89	1784.62	1731.43	1734.78	1691.48	30
1738.58	1755.92	1710.24	1701.7	1784.42	1731.31	1734.13	1691.89	31
1738.66	1756.14	1710.44	1701.94	1784.56	1731.36	1734.12	1691.6	32
1738.72	1756.56	1710.27	1701.94	1784.52	1731.27	1734.16	1691.43	33
1738.05	1756.02	1710.49	1702.12	1784.82	1731.09	1734.42	1691.79	34
1737.94	1755.99	1710.48	1702.46	1784.59	1730.91	1734.07	1691.85	35
1737.93	1755.26	1710.36	1702.38	1784.81	1731.39	1734.71	1691.9	36
1738.47	1755.62	1710.12	1702.34	1784.56	1731.42	1734.64	1691.88	37
1738.08	1756.1	1710.3	1702.13	1784.71	1731.34	1734.78	1691.86	38
1738.08	1756.29	1710.27	1702.8	1784.94	1731.51	1734.55	1691.37	39
1737.96	1756.27	1710.61	1702.11	1784.71	1731.4	1734.27	1691.92	40
1738.42	1756	1710.75	1702.19	1784.78	1731.53	1734.25	1691.99	41
1738.67	1755.96	1710.63	1702.05	1784.54	1731.32	1734	1692.06	42
1738.58	1755.89	1710.56	1702.18	1784.5	1731.37	1734.36	1692.06	43
1737.86	1756.14	1710.57	1702.18	1784.75	1731.28	1734.34	1691.64	44
1737.68	1756.39	1710.81	1702.38	1784.69	1731.05	1734.73	1691.79	45
1737.8	1756.38	1710.45	1702.28	1784.77	1731.05	1734.4	1691.85	46
1738.1	1756.28	1710.32	1702.13	1785.11	1731.43	1733.87	1691.57	47
1738.44	1756.26	1710.61	1702.02	1784.91	1731.42	1733.22	1691.65	48
1738.68	1756.5	1710.01	1702.15	1785.05	1731.51	1733.25	1691.59	49
1738.63	1756.04	1709.14	1702.18	1784.69	1731.45	1732.77	1691.98	50
1738.39	1755.79	1709.52	1702.08	1784.65	1730.52	1732.74	1691.62	51
1738.75	1755.93	1709.54	1702.12	1785.48	1729.95	1733.25	1691.86	52
1738.69	1756.29	1709.6	1702.08	1785.45	1729.87	1732.89	1691.8	53
1738.73	1756.25	1709.58	1701.96	1785.13	1730.01	1732.68	1691.61	54
1738.65	1756.4	1709.51	1701.88	1785.29	1730.18	1732.92	1691.58	55
1738.71	1756.18	1709.64	1701.84	1785.26	1729.85	1732.84	1692.16	56
1738.87	1755.91	1709.53	1701.73	1785.3	1730.16	1733.15	1692.1	57
1738.68	1755.81	1709.57	1701.62	1784.96	1730.45	1732.69	1692.15	58
1738.79	1755.93	1709.53	1701.51	1785.22	1730.42	1733.38	1692.23	59
1738.38	1756.22	1709.56	1701.52	1785.05	1730.33	1733.38	1692.14	60
1738.35	1756.62	1709.45	1701.55	1785.16	1729.95	1733.05	1692.2	61
1738.07	1756.27	1709.7	1701.52	1785.27	1730.08	1732.92	1691.73	62
1738.22	1755.57	1709.23	1701.54	1785.14	1730.52	1733.28	1692.18	63
1738.43	1754.23	1709.84	1701.79	1785.04	1730.19	1733.24	1691.96	64
1738.46	1754.08	1709.49	1701.58	1785.01	1730.4	1733.1	1691.69	65
1738.4	1754.09	1709.48	1701.83	1784.87	1730.08	1733.01	1691.55	66
1738.51	1754.26	1709.62	1702.16	1785.06	1730.55	1733.13	1691.89	67
1738.75	1754.14	1709.67	1702.44	1784.78 Cont.	1729.77	1733.66	1692.26	68

	Specimen BS	Specimen CS	Specimen DS	Specimen ES	Specimen BSA	Specimen CSA	Specimen DSA	Specimen ESA
Actual VMC	21.3%	20.3%	18.8%	17.5%	21.6%	20.2%	19.1%	17.7%
Acutal DUW (g/cm^3)	1.44	1.53	1.59	1.67	1.46	1.53	1.62	1.69
Degree of Saturation	45.2%	46.4%	45.3%	45.5%	46.7%	46.1%	47.1%	47.0%
Average Raw mV - Full	1737.33	1755.84	1708.43	1702.09	1781.85	1731.56	1732.37	1692.04
Std. Dev. (mV) - Full	1.14	0.69	0.99	0.87	1.55	0.78	0.97	0.92
Average Raw mV > 500	1736.63	1755.81	1707.75	1702.38	1780.66	1731.74	1731.74	1691.52
Std. Dev. (mV) > 500	0.80	0.66	0.62	0.74	0.67	0.68	0.64	0.73





Characterization of Density Affects - Series 6 - Saturation 60%

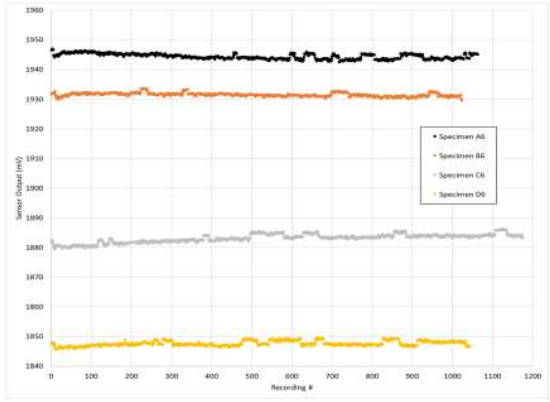
Sample Preparation Details (For Moisture Conditioning)									
General Details	**Units**	**Spec. B6**	**Spec. C6**	**Spec. D6**	**Spec. E6**	**Spec. B6A**	**Spec. C6A**	**Spec. D6A**	**Spec. E6A**
Moisture Conditioning Date	--	2/3/2023	2/22/2023	2/23/2023	2/23/2023	3/4/2023	3/2/2023	3/2/2023	3/3/2023
Mold #	--	1	1	1	1	1	1	1	1
Mold Approx. Control Volume	cm^3	798.45	798.45	798.45	798.45	798.45	798.45	798.45	798.45
Empty Mold Total Mass	g	503.75	503.75	503.75	503.75	503.75	503.75	503.75	503.75
Target Dry Density	pcf	95	100	105	110	95	100	105	110
	g/cm^3	1.52	1.60	1.68	1.76	1.52	1.60	1.68	1.76
Target Degree of Saturation	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
Specific Gravity	--	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
Volume of Solids	cm^3	448.69	470.20	493.71	517.22	448.69	470.20	493.71	517.22
Volume of Water	cm^3	211.05	196.95	182.84	168.74	211.05	196.95	182.84	168.74
Target Volumetric Moisture Content	%	26.4%	24.7%	22.9%	21.1%	26.4%	24.7%	22.9%	21.1%
Target Gravimetric Moisture Content	%	17.4%	15.4%	13.6%	12.0%	17.4%	15.4%	13.6%	12.0%
Details for Control Volume Prep									
Mass of Solids	g	1215.01	1278.95	1342.90	1406.85	1215.01	1278.95	1342.90	1406.85
Mass of Water [a]	g	211.05	196.95	182.84	168.74	211.05	196.95	182.84	168.74
Details for Cover									
Mass of Solids [b]	g	456.51	480.54	504.57	528.59	456.51	480.54	504.57	528.59
Mass of Water [a,b]	g	79.30	74.00	68.70	63.40	79.30	74.00	68.70	63.40
Prepared Specimen (Prior to Sensor Insertion)									
Measurement	**Units**	**Spec. B6**	**Spec. C6**	**Spec. D6**	**Spec. E6**	**Spec. B6A**	**Spec. C6A**	**Spec. D6A**	**Spec. E6A**
Specimen Preparation Date	--	2/4/2023	2/23/2023	2/24/2023	2/24/2023	3/5/2023	3/3/2023	3/3/2023	3/4/2023
Mass of Mold	g	502.88	502.88	502.98	502.91	502.92	502.87	502.91	502.88
Mass of Mold + Specimen	g	1927.09	1981.42	2027.27	2077.13	1927.29	1977.26	2027.51	2077.01
Depth to Top of Specimen	mm	55.15	55.15	56.21	55.27	56.02	55.47	54.94	55.63
	mm	55.97	54.50	55.66	55.24	55.49	56.15	55.70	55.00
	mm	55.57	54.74	55.63	56.18	54.97	55.89	56.25	54.48
	mm	55.87	55.75	55.78	56.03	55.71	55.26	55.89	54.58
Average	mm	55.64	55.04	55.82	55.68	55.55	55.64	55.70	54.92
Specimen Total Mass	g	1424.20	1478.43	1524.29	1574.22	1424.37	1474.39	1524.60	1574.13
Specimen Total Volume	cm^3	794.44	799.39	792.97	794.11	795.20	794.42	793.99	800.31
Specimen Total Density	g/cm^3	1.79	1.85	1.92	1.98	1.79	1.86	1.92	1.97
	pcf	111.9	115.5	120.0	123.8	111.8	115.9	119.9	122.8
Specimen Dry Density	**g/cm^3**	**1.52**	**1.60**	**1.69**	**1.77**	**1.52**	**1.61**	**1.69**	**1.75**
	pcf	**95.2**	**99.9**	**105.4**	**110.3**	**95.1**	**100.4**	**105.5**	**109.4**
Moisture Content (Post-Test)									
Measurement	**Units**	**Spec. B6**	**Spec. C6**	**Spec. D6**	**Spec. E6**	**Spec. B6A**	**Spec. C6A**	**Spec. D6A**	**Spec. E6A**
Mass of Tare	g	286.63	286.62	958.74	279.09	291.58	279.08	291.6	358.75
Mass of Tare + Wet Tailings	g	1148.87	1464.96	1587.73	952.73	1436.89	1058.91	1211.63	1378.76
Mass of Tare + Dry Tailings	g	1020.08	1306.4	1438.5	878.54	1265.73	954.73	1101.09	1267.5
Total Sample Mass	g	862.24	1178.34	1228.99	673.64	1145.31	775.83	920.03	1020.01
Mass of Solids	g	733.45	1019.78	1079.76	600.45	974.15	675.65	809.49	938.75
Mass of Water	g	128.79	158.56	149.23	73.19	171.16	104.18	110.54	111.26
Gravimetric Moisture Content	%	17.6%	15.5%	13.8%	12.2%	17.6%	15.4%	13.7%	12.2%
Volumetric Moisture Content [a]	**%**	**26.8%**	**24.9%**	**23.3%**	**21.5%**	**26.8%**	**24.8%**	**23.1%**	**21.5%**
Estimated Degree of Saturation									
Measurement/Value	**Units**	**Spec. B6**	**Spec. C6**	**Spec. D6**	**Spec. E6**	**Spec. B6A**	**Spec. C6A**	**Spec. D6A**	**Spec. E6A**
Mass of Water (in molded specimen)	g	212.73	198.94	185.09	171.04	212.86	196.97	183.18	171.70
Mass of Solids (in molded specimen)	g	1211.47	1279.49	1339.20	1403.18	1211.51	1277.42	1341.42	1402.43
Density of Solids [b]	g/cm^3	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	445.39	470.40	492.35	515.88	445.41	469.64	493.17	515.90
Volume of Water [a]	cm^3	212.73	198.94	185.09	171.04	212.86	196.97	183.18	171.70
Volume of Voids	cm^3	349.05	328.99	300.61	278.24	349.75	324.78	300.82	284.72
Degree of Saturation	**%**	**60.9%**	**60.5%**	**61.6%**	**61.5%**	**60.9%**	**60.6%**	**60.9%**	**60.3%**

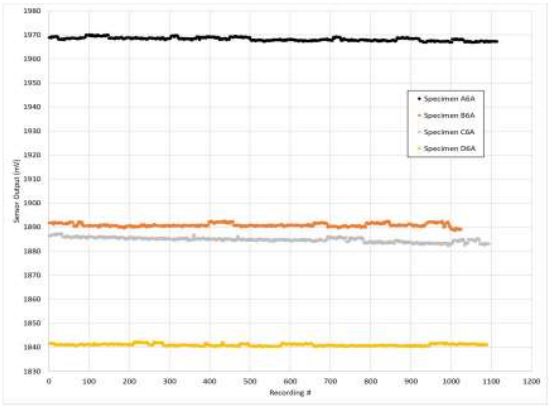
Notes:
a) Value assumes density of water = 1 g/cm^3
b) Value based on assumed total volume of 300 cm^3

Specimen A6	Specimen B6	Specimen C6	Specimen D6	Specimen A6A	Specimen B6A	Specimen C6A	Specimen D6A	
1946.66	1931.66	1881.9	1847.81	1968.94	1891.79	1886.31	1841.56	1
1946.64	1932.06	1881.78	1847.77	1968.92	1891.81	1886.31	1841.69	2
1947.03	1931.97	1881.88	1847.86	1969.02	1891.81	1886.65	1841.63	3
1946.86	1932.09	1882.23	1848.01	1969.02	1891.83	1886.92	1841.53	4
1946.63	1932.16	1881.16	1847.83	1968.72	1891.62	1886.77	1841.54	5
1946.87	1931.97	1880.33	1847.08	1968.81	1890.79	1886.01	1841.54	6
1946.59	1932.08	1880.06	1847.17	1969.21	1891.67	1886.63	1841.59	7
1946.13	1932.12	1879.5	1847.67	1969.19	1891.7	1886.65	1841.55	8
1946.74	1932.01	1879.83	1846.63	1969.36	1891.71	1886.77	1841.71	9
1946.83	1932.73	1879.82	1845.65	1969.17	1891.66	1886.67	1841.53	10
1946.68	1931.93	1880.2	1845.66	1969.13	1891.97	1886.96	1841.64	11
1946.83	1933.09	1880.71	1845.77	1969.27	1892.11	1887.07	1841.62	12
1946.74	1932.29	1880.66	1845.6	1969.02	1892.82	1886.9	1841.66	13
1946.56	1932.09	1880.5	1845.76	1969.15	1892.85	1887.07	1841.54	14
1945.36	1930.85	1880.55	1845.9	1969.24	1892.85	1887.15	1841.05	15
1945.85	1930.97	1880.7	1845.9	1969.35	1892.89	1886.73	1841.03	16
1946.69	1930.86	1880.75	1845.87	1969.35	1891.9	1886.64	1841.07	17
1946.39	1930.51	1880.9	1846.15	1969.26	1892.73	1886.65	1841.17	18
1945.86	1929.92	1880.87	1846.45	1969.33	1892.71	1887.07	1841	19
1945.31	1930.39	1880.58	1846.84	1969.28	1892.54	1887.19	1841.07	20
1946.89	1930.63	1880.53	1846.66	1969.33	1892.8	1887.13	1840.9	21
1946.92	1930.84	1880.54	1846.73	1969.27	1892.62	1886.96	1840.96	22
1945.9	1930.9	1880.84	1846.6	1968.96	1892.8	1887.13	1840.99	23
1945.57	1930.8	1880.59	1846.29	1968.09	1892.87	1887.06	1842.06	24
1945.47	1930.91	1880.33	1846.31	1968.24	1892.56	1887.13	1841.12	25
1945.27	1931.13	1880.01	1846.2	1968.17	1892.83	1887.33	1841.01	26
1945.64	1931.12	1879.63	1846.52	1968.07	1892.87	1887.28	1841.27	27
1946	1930.85	1879.76	1846.42	1968.08	1892.94	1887.16	1841.33	28
1946.06	1931.12	1880.48	1846.84	1968.24	1892.84	1886.92	1841.21	29
1945.72	1930.92	1880.31	1846.85	1968.1	1892.73	1887.05	1841.07	30
1945.87	1930.78	1880.35	1846.18	1968.01	1892.79	1886.98	1841.07	31
1945.89	1930.77	1880.18	1846.22	1968.05	1892.8	1887.1	1840.92	32
1946.29	1931.06	1880.29	1846.22	1968.04	1892.73	1887.26	1842.94	33
1945.83	1931.21	1880.34	1846.34	1968.16	1892.83	1886	1840.99	34
1945.86	1931.16	1880.09	1846.28	1968.16	1892.1	1885.95	1840.97	35
1945.89	1931.17	1880.22	1846.16	1968.16	1892.85	1885.96	1840.97	36
1945.63	1931.12	1880.31	1846.65	1968.18	1892.32	1885.84	1841.09	37
1945.62	1931.26	1880.15	1846.63	1967.88	1892.39	1885.76	1841.02	38
1945.3	1931.14	1879.93	1846.42	1968.05	1891.93	1885.84	1840.99	39
1945.77	1931.27	1879.83	1846.54	1968.1	1892.06	1885.94	1841.01	40
1945.84	1930.85	1879.83	1846.38	1968.11	1892.85	1885.59	1841.06	41
1945.74	1931.23	1879.68	1846.37	1968.1	1892.3	1886.14	1840.89	42
1946.62	1930.96	1879.68	1845.85	1968.53	1891.77	1886.22	1841	43
1945.85	1931.05	1879.72	1846.1	1968.64	1893.65	1886.13	1841.23	44
1945.52	1931.42	1880.17	1846.43	1968.56	1893.7	1885.95	1841.17	45
1945.33	1931.42	1880.5	1846.65	1968.66	1891.72	1886.35	1841.26	46
1945.65	1931.7	1880.07	1846.84	1968.6	1892.28	1886.02	1840.97	47
1945.87	1931.97	1880.18	1846.74	1968.61	1892.56	1886.06	1840.89	48
1945.8	1931.97	1880.19	1846.84	1968.58	1893.67	1886.04	1841.06	49
1945.91	1931.97	1880.01	1846.52	1968.29	1892.41	1885.82	1841.2	50
1945.88	1931.97	1879.88	1846.58	1968.56	1892.86	1885.66	1841.19	51
1945.53	1932.06	1880.16	1846.53	1968.41	1892.22	1885.75	1841.07	52
1945.78	1932.23	1880.56	1846.39	1968.32	1892.16	1885.97	1841.08	53
1945.77	1932.08	1880.81	1846.65	1968.44	1892.19	1885.99	1840.96	54
1945.85	1931.78	1880.94	1846.89	1968.68	1892.12	1885.89	1840.88	55
1945.89	1932.01	1880.91	1846.63	1968.6	1891.89	1885.7	1841.04	56
1945.51	1931.87	1880.9	1846.87	1968.68	1892.39	1885.56	1840.78	57
1946.11	1932.17	1880.81	1846.19	1968.67	1892.28	1885.97	1840.8	58
1945.76	1932.14	1880.59	1846.98	1968.78	1892.26	1885.7	1841.07	59
1946.25	1931.95	1880.85	1845.88	1968.77	1892.74	1885.65	1841.19	60
1946.31	1932.02	1880.96	1846.59	1968.7	1892.58	1885.73	1841.07	61
1946.08	1931.86	1880.28	1846.68	1968.57	1892.51	1885.88	1841.03	62
1946.29	1931.88	1880.29	1846.67	1968.53	1892.99	1885.93	1841.02	63
1945.83	1931.76	1880.18	1846.29	1968.57	1892.23	1886.15	1840.82	64
1946.02	1931.82	1880.49	1846.46	1968.64	1892.61	1886.23	1840.72	65
1945.54	1932.23	1880.43	1846.13	1968.51	1892.67	1886.17	1840.67	66
1945.59	1932.02	1880.21	1846.71	1968.62	1892.77	1885.78	1840.7	67
1945.7	1932	1880.71	1846.7	1968.66	1892.82	1885.73	1840.81	68
1945.75	1931.95	1880.87	1846.75	1968.54	1892.99	1885.97	1841.09	69
1946.1	1931.69	1880.84	1846.59	1968.35	1892.91	1885.92	1840.77	70
1946.09	1931.87	1880.48	1846.64	1968.5	1892.77	1885.67	1840.92	71
1946.25	1931.86	1880.6	1846.5	1968.48	1892.86	1886.06	1840.97	72
1946.34	1931.75	1880.42	1846.34	1968.57	1892.55	1885.91	1840.98	73
1946.25	1932.01	1880.37	1846.48	1968.59	1892.33	1885.92	1841.06	74
1945.76	1931.79	1880.8	1846.43	1968.52	1892.77	1885.96	1841.14	75
1945.53	1931.98	1880.68	1846.35	1968.38	1892.85	1885.95	1841.11	76
1945.64	1932.16	1880.78	1846.82	1968.81	1892.37	1886.04	1841.14	77
1945.85	1932.16	1880.25	1846.87	1968.92	1892.18	1885.81	1841.25	78
1945.68	1931.71	1880.14	1846.19	1968.58	1892.99	1885.78	1841.23	79
1946.18	1931.88	1880.8	1846.45	1968.81	1892.73	1885.55	1841.14	80
1946.13	1932.28	1880.85	1846.27	1968.74	1892.29	1885.83	1841.26	81
1946.52	1932.16	1880.85	1846.57	1968.86	1892.79	1885.98	1841.15	82
1946.67	1931.89	1880.1	1846.84	1968.71	1892.86	1886.07	1841.86	83
1946.09	1931.77	1880.14	1846.81	1968.71	1892.89	1886.15	1841.18	84
1945.98	1932.15	1879.85	1846.18	1968.67	1892.67	1886.02	1841.05	85
1946.2	1932.26	1879.86	1846.3	1968.68	1893.58	1885.95	1840.86	86

Cont.

	Specimen A6	Specimen B6	Specimen C6	Specimen D6	Specimen A6A	Specimen B6A	Specimen C6A	Specimen D6A
Actual VMC	26.8%	24.9%	23.3%	21.5%	26.8%	24.8%	23.1%	21.5%
Acutal DUW [g/cm^3]	1.52	1.60	1.69	1.77	1.52	1.61	1.69	1.75
Degree of Saturation	60.9%	60.5%	61.6%	61.5%	60.9%	60.6%	60.9%	60.3%
Average Raw mV - Full	1944.42	1931.51	1881.14	1847.63	1968.22	1890.86	1884.78	1841.00
Std. Dev. (mV) - Full	0.91	0.61	1.40	0.83	0.72	0.72	0.95	0.44
Average Raw mV > 500	1944.01	1931.23	1884.07	1847.93	1967.75	1890.83	1884.23	1840.90
Std. Dev. (mV) > 500	0.82	0.54	0.74	0.80	0.48	0.75	0.83	0.42





Sensor Temporal Response to Variations in Volumetric Water Content										
Sample Preparation Details (For Moisture Conditioning)										
General Details	**Units**	**Spec. T1**	**Spec. T2**	**Spec. T3**	**Spec. T4**	**Spec. T5**	**Spec. T6**	**Spec. T7**	**Spec. T8**	**Spec. T9**
Moisture Conditioning Date	--	4/10/2023	4/10/2023	4/10/2023	4/10/2023	4/10/2023	4/10/2023	4/12/2023	4/12/2023	4/12/2023
Mold #	--	1	1	1	1	1	1	1	1	1
Mold Approx. Control Volume	cm^3	798.45	798.45	798.45	798.45	798.45	798.45	798.45	798.45	798.45
Empty Mold Total Mass	g	503.75	503.75	503.75	503.75	503.75	503.75	503.75	503.75	503.75
Target Dry Density	pcf	90	95	95	95	100	105	95	100	105
	g/cm^3	1.44	1.52	1.52	1.52	1.60	1.68	1.52	1.60	1.68
Target Volumetric Moisture Content	%	5%	10%	15%	20%	25%	30%	20%	25%	30%
Target Gravimetric Moisture Content	%	3.5%	6.6%	9.9%	13.1%	15.6%	17.8%	13.1%	15.6%	17.8%
Details for Control Volume Prep										
Mass of Solids	g	1151.06	1215.01	1215.01	1215.01	1278.95	1342.90	1215.01	1278.95	1342.90
Mass of Water [a]	g	39.92	79.85	119.77	159.69	199.61	239.54	159.69	199.61	239.54
Prepared Specimen (Prior to Sensor Insertion)										
Measurement	**Units**	**Spec. T1**	**Spec. T2**	**Spec. T3**	**Spec. T4**	**Spec. T5**	**Spec. T6**	**Spec. T7**	**Spec. T8**	**Spec. T9**
Specimen Preparation Date	--	4/11/2023	4/11/2023	4/11/2023	4/11/2023	4/11/2023	4/11/2023	4/13/2023	4/13/2023	4/13/2023
Mass of Mold	g	502.79	502.82	502.80	502.79	502.76	502.76	502.42	502.44	502.41
Mass of Mold + Specimen	g	1689.63	1793.63	1833.22	1873.47	1975.21	2076.25	1875.10	1978.37	2080.81
Depth to Top of Specimen	mm	57.42	56.20	56.68	55.90	56.70	59.58	56.32	56.90	57.74
	mm	55.37	56.33	56.82	56.47	57.52	59.28	56.67	56.91	57.15
	mm	56.97	57.00	56.25	56.05	58.03	59.00	57.82	56.90	56.56
	mm	57.54	56.85	55.28	55.29	57.19	60.06	57.61	57.65	56.63
Average	mm	56.83	56.60	56.26	55.93	57.36	59.48	57.11	57.09	57.02
Specimen Total Mass	g	1186.84	1290.81	1330.42	1370.68	1472.45	1573.49	1372.68	1475.93	1578.40
Specimen Total Volume	cm^3	784.74	786.62	789.38	792.09	780.36	763.00	782.44	782.57	783.14
Specimen Total Density	g/cm^3	1.51	1.64	1.69	1.73	1.89	2.06	1.75	1.89	2.02
	pcf	94.4	102.4	105.2	108.0	117.8	128.7	109.5	117.7	125.8
Specimen Dry Density	**g/cm^3**	**1.46**	**1.54**	**1.53**	**1.53**	**1.63**	**1.75**	**1.55**	**1.63**	**1.71**
	pcf	**91.0**	**95.9**	**95.5**	**95.2**	**101.6**	**109.0**	**96.5**	**101.6**	**106.5**
Moisture Content (Post-Test)										
Measurement	**Units**	**Spec. T1**	**Spec. T2**	**Spec. T3**	**Spec. T4**	**Spec. T5**	**Spec. T6**	**Spec. T7**	**Spec. T8**	**Spec. T9**
Mass of Tare	g	155.7	154.28	274.21	289.52	286.61	358.74	358.48	274.02	289.34
Mass of Tare + Wet Tailings	g	1341.96	1442.11	1162.34	1051.85	980.1	1276.43	1730.41	1099.66	1102.45
Mass of Tare + Dry Tailings	g	1299.06	1359.3	1080.46	961.5	884.93	1135.68	1567.74	986.3	977.62
Total Sample Mass	g	1186.26	1287.83	888.13	762.33	693.49	917.69	1371.93	825.64	813.11
Mass of Solids	g	1143.36	1205.02	806.25	671.98	598.32	776.94	1209.26	712.28	688.28
Mass of Water	g	42.9	82.81	81.88	90.35	95.17	140.75	162.67	113.36	124.83
Gravimetric Moisture Content	%	3.8%	6.9%	10.2%	13.4%	15.9%	18.1%	13.5%	15.9%	18.1%
Volumetric Moisture Content [a]	**%**	**5.5%**	**10.6%**	**15.5%**	**20.5%**	**25.9%**	**31.6%**	**20.8%**	**25.9%**	**30.9%**
Estimated Degree of Saturation										
Measurement/Value	**Units**	**Spec. T1**	**Spec. T2**	**Spec. T3**	**Spec. T4**	**Spec. T5**	**Spec. T6**	**Spec. T7**	**Spec. T8**	**Spec. T9**
Specific Gravity	--	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
Mass of Water (in molded specimen)	g	42.92	83.00	122.66	162.45	202.07	241.33	162.76	202.64	242.32
Mass of Solids (in molded specimen)	g	1143.92	1207.81	1207.76	1208.23	1270.38	1332.16	1209.92	1273.29	1336.08
Density of Solids [a]	g/cm^3	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
Volume of Solids (in molded specimen)	cm^3	420.56	444.05	444.03	444.20	467.05	489.76	444.82	468.12	491.21
Volume of Water [a]	cm^3	42.92	83.00	122.66	162.45	202.07	241.33	162.76	202.64	242.32
Volume of Voids	cm^3	364.18	342.57	345.35	347.88	313.30	273.23	337.62	314.45	291.93
Degree of Saturation	**%**	**11.8%**	**24.2%**	**35.5%**	**46.7%**	**64.5%**	**88.3%**	**48.2%**	**64.4%**	**83.0%**

Notes:

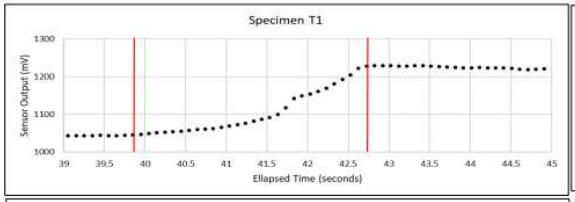
a) Value assumes density of water is 1 g/cm^3

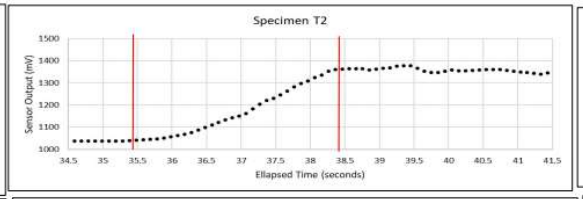
b) Value based on assumed total volume of 300 cm^3

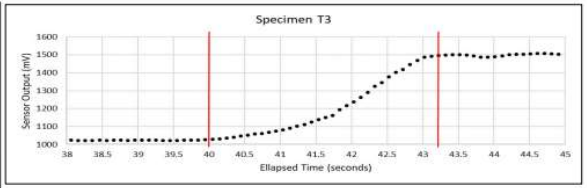
Sensor Data from Temporal Response Testing

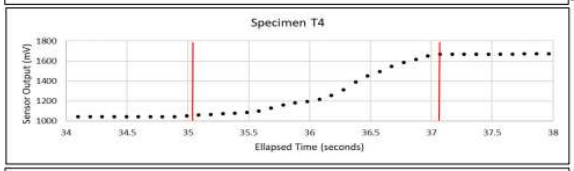
Specimen T1			Specimen T2			Specimen T3			Specimen T4			Specimen T5			Specimen T6			Specimen T7			Specimen T8			Specimen T9		
mV	Time (ms)	Time (s)	mV	Time (ms)	Time (s)	mV	Time (ms)	Time (s)	mV	Time (ms)	Time (s)	mV	Time (ms)	Time (s)	mV	Time (ms)	Time (s)	mV	Time (ms)	Time (s)	mV	Time (ms)	Time (s)	mV	Time (ms)	Time (s)
1018.52	8214	8.214	1027.3	8213	8.213	1037.69	8213	8.213	1034.21	8213	8.213	1034.9	8213	8.213	1035.13	8213	8.213	1034.02	8213	8.213	1036.27	8213	8.213	1037.67	8213	8.213
1029.01	8314	8.314	1026.94	8313	8.313	1036.29	8313	8.313	1035.23	8313	8.313	1034.22	8313	8.313	1035.06	8313	8.313	1034.02	8313	8.313	1036.33	8313	8.313	1036.91	8313	8.313
1033.26	8413	8.413	1027.84	8412	8.412	1025.4	8412	8.412	1034.98	8412	8.412	1034.49	8412	8.412	1035.15	8412	8.412	1033.89	8412	8.412	1036.86	8412	8.412	1037	8412	8.412
1033.7	8512	8.512	1026.47	8511	8.511	1022.21	8511	8.511	1034.96	8511	8.511	1034.78	8511	8.511	1034.28	8511	8.511	1034.14	8511	8.511	1036.89	8511	8.511	1036.68	8511	8.511
1034.42	8611	8.611	1027.49	8610	8.61	1021.54	8610	8.61	1034.67	8610	8.61	1035.15	8610	8.61	1032.92	8610	8.61	1034.35	8610	8.61	1036.73	8610	8.61	1035.64	8610	8.61
1034.39	8710	8.71	1027.79	8709	8.709	1021.36	8709	8.709	1034.33	8709	8.709	1034.8	8709	8.709	1032.69	8709	8.709	1033.53	8709	8.709	1036.21	8709	8.709	1035.54	8709	8.709
1034.49	8809	8.809	1027.77	8808	8.808	1020.9	8808	8.808	1034.45	8808	8.808	1035	8808	8.808	1033.04	8808	8.808	1034.44	8808	8.808	1035.44	8808	8.808	1035.85	8808	8.808
1035.24	8909	8.909	1027.73	8908	8.908	1020.4	8908	8.908	1034.32	8908	8.908	1034.88	8908	8.908	1032.67	8908	8.908	1033.79	8907	8.907	1034.69	8907	8.907	1035.31	8908	8.908
1034.73	9008	9.008	1027.26	9007	9.007	1020.59	9007	9.007	1034.94	9007	9.007	1034.28	9007	9.007	1032.7	9007	9.007	1033.18	9007	9.007	1034.63	9007	9.007	1035.55	9007	9.007
1034.95	9107	9.107	1027.54	9106	9.106	1020.65	9106	9.106	1034.07	9106	9.106	1034.61	9106	9.106	1032.46	9106	9.106	1033.52	9106	9.106	1033.27	9106	9.106	1035.01	9106	9.106
1034.85	9206	9.206	1027.94	9205	9.205	1020.42	9205	9.205	1034.42	9205	9.205	1034.38	9205	9.205	1033.01	9205	9.205	1033.11	9205	9.205	1032.67	9205	9.205	1034.85	9205	9.205
1034.78	9305	9.305	1027.4	9304	9.304	1021.07	9304	9.304	1034.51	9304	9.304	1034.46	9304	9.304	1033.54	9304	9.304	1033.23	9304	9.304	1031.79	9304	9.304	1035.35	9304	9.304
1034.98	9404	9.404	1027.39	9403	9.403	1020.81	9403	9.403	1034.4	9403	9.403	1034.46	9403	9.403	1034.12	9403	9.403	1031.52	9403	9.403	1030.97	9403	9.403	1035.82	9403	9.403
1034.97	9504	9.504	1028.92	9503	9.503	1020.03	9503	9.503	1034.25	9503	9.503	1035.09	9503	9.503	1034.27	9503	9.503	1030.9	9502	9.502	1030.81	9503	9.503	1036.15	9503	9.503
1035.16	9603	9.603	1029.27	9602	9.602	1020.39	9602	9.602	1034.15	9602	9.602	1034.98	9602	9.602	1033.94	9602	9.602	1030.1	9601	9.601	1031.79	9602	9.602	1036	9602	9.602
1035.02	9702	9.702	1029.53	9701	9.701	1021.29	9701	9.701	1033.93	9701	9.701	1035.41	9701	9.701	1033.83	9701	9.701	1029.71	9701	9.701	1030.69	9701	9.701	1035.71	9701	9.701
1034.86	9801	9.801	1029.65	9800	9.8	1021.07	9800	9.8	1033.33	9800	9.8	1035.09	9800	9.8	1033.85	9800	9.8	1029.23	9800	9.8	1029.07	9800	9.8	1034.89	9800	9.8
1034.98	9900	9.9	1030.08	9899	9.899	1020.98	9899	9.899	1033.48	9899	9.899	1035.16	9899	9.899	1033.76	9899	9.899	1029.82	9899	9.899	1028.15	9899	9.899	1033.8	9899	9.899
1035.37	9999	9.999	1029.44	9998	9.998	1020.14	9998	9.998	1033.4	9999	9.999	1034.79	9998	9.998	1033.93	9999	9.999	1029.67	9998	9.998	1027.9	9998	9.998	1034.23	9998	9.998
1035.15	10099	10.099	1030.43	10098	10.098	1019.02	10098	10.098	1034.04	10098	10.098	1034.88	10098	10.098	1033.09	10098	10.098	1029.62	10097	10.097	1026.5	10097	10.097	1034.63	10098	10.098
1034.94	10198	10.198	1030.18	10197	10.197	1018.03	10197	10.197	1033.85	10197	10.197	1034.37	10197	10.197	1032.39	10197	10.197	1028.81	10196	10.196	1024.87	10197	10.197	1035.14	10197	10.197
1035.13	10297	10.297	1030.48	10296	10.296	1018.57	10296	10.296	1033.92	10296	10.296	1032.42	10296	10.296	1031.49	10296	10.296	1028.27	10295	10.295	1025.3	10296	10.296	1034.76	10296	10.296
1035.13	10396	10.396	1030.35	10395	10.395	1018.37	10395	10.395	1034.1	10395	10.395	1032.04	10395	10.395	1032.39	10395	10.395	1026.28	10395	10.395	1024.88	10395	10.395	1034.67	10395	10.395
1035.28	10495	10.495	1030.57	10494	10.494	1019.51	10494	10.494	1033.01	10494	10.494	1030.96	10494	10.494	1032.12	10494	10.494	1024.91	10494	10.494	1025.15	10494	10.494	1034.08	10494	10.494
1035.01	10594	10.594	1030.36	10593	10.593	1020.6	10593	10.593	1032.94	10594	10.594	1030.88	10593	10.593	1032.15	10594	10.594	1024.92	10593	10.593	1025.1	10593	10.593	1033.25	10593	10.593
1035.34	10694	10.694	1029.39	10693	10.693	1021.53	10693	10.693	1032.35	10693	10.693	1030.39	10693	10.693	1032.38	10693	10.693	1024.97	10692	10.692	1025.06	10692	10.692	1034.11	10693	10.693
1035.18	10793	10.793	1029.69	10792	10.792	1022.12	10792	10.792	1031.49	10792	10.792	1030.68	10792	10.792	1032.54	10792	10.792	1025.53	10791	10.791	1025.73	10792	10.792	1034.66	10792	10.792
1035.21	10892	10.892	1029.03	10891	10.891	1021.85	10891	10.891	1031.27	10891	10.891	1030.67	10891	10.891	1032.43	10891	10.891	1026.3	10890	10.89	1025.87	10891	10.891	1034.39	10891	10.891
1035.42	10991	10.991	1028.98	10990	10.99	1021.97	10990	10.99	1031	10990	10.99	1030.45	10990	10.99	1033.05	10990	10.99	1027.08	10989	10.989	1026.11	10990	10.99	1032.88	10990	10.99
1035.48	11090	11.09	1028.72	11089	11.089	1022.04	11089	11.089	1030.68	11089	11.089	1029.92	11089	11.089	1034.49	11089	11.089	1027.47	11089	11.089	1025.91	11089	11.089	1034.54	11089	11.089
1035.09	11189	11.189	1028.64	11188	11.188	1021.71	11189	11.189	1031.03	11189	11.189	1030.13	11188	11.188	1034.79	11189	11.189	1027.98	11188	11.188	1025.54	11188	11.188	1033.6	11188	11.188
1035.61	11289	11.289	1028.14	11288	11.288	1021.44	11288	11.288	1031.26	11288	11.288	1030.08	11288	11.288	1034.83	11288	11.288	1028.4	11287	11.287	1026.52	11287	11.287	1030.85	11288	11.288
1035.36	11388	11.388	1028.46	11387	11.387	1022.56	11387	11.387	1031.05	11387	11.387	1030.21	11387	11.387	1034.75	11387	11.387	1028.77	11386	11.386	1026.16	11386	11.386	1031.14	11387	11.387
1035.35	11487	11.487	1028.51	11486	11.486	1022.09	11486	11.486	1031.06	11486	11.486	1029.77	11486	11.486	1034.71	11486	11.486	1028.48	11485	11.485	1026.14	11486	11.486	1032.5	11486	11.486
1035.36	11586	11.586	1028.48	11585	11.585	1022.42	11585	11.585	1031.19	11585	11.585	1030.47	11585	11.585	1034.86	11585	11.585	1028.74	11584	11.584	1026.9	11585	11.585	1032.37	11585	11.585
1034.79	11685	11.685	1028.64	11684	11.684	1021.76	11684	11.684	1030.8	11684	11.684	1030.46	11684	11.684	1035.03	11684	11.684	1029	11683	11.683	1026.55	11684	11.684	1032.06	11684	11.684
1035	11784	11.784	1028.96	11783	11.783	1021.84	11784	11.784	1031.33	11784	11.784	1030.75	11784	11.784	1035.2	11784	11.784	1029.08	11783	11.783	1027.15	11783	11.783	1031.84	11783	11.783
1035.48	11884	11.884	1028.8	11883	11.883	1023.07	11883	11.883	1031.26	11883	11.883	1031.03	11883	11.883	1034.13	11883	11.883	1029.28	11882	11.882	1027.2	11882	11.882	1029.87	11883	11.883
1035.42	11983	11.983	1027.45	11982	11.982	1029.84	11982	11.982	1031.37	11982	11.982	1030.74	11982	11.982	1032.01	11982	11.982	1029.16	11981	11.981	1026.58	11981	11.981	1028.79	11982	11.982
1035.34	12082	12.082	1028.21	12081	12.081	1038.88	12081	12.081	1031.33	12081	12.081	1030.6	12081	12.081	1031.71	12081	12.081	1030.31	12080	12.08	1027.77	12080	12.08	1029.52	12081	12.081
1034.65	12181	12.181	1028.69	12180	12.18	1039.85	12180	12.18	1031.89	12180	12.18	1031.25	12180	12.18	1033.14	12180	12.18	1031.04	12179	12.179	1026.98	12180	12.18	1030.12	12180	12.18
1035.06	12280	12.28	1028.36	12279	12.279	1038.36	12279	12.279	1031.89	12279	12.279	1030.96	12279	12.279	1033.41	12279	12.279	1031.17	12278	12.278	1027.16	12279	12.279	1029.97	12279	12.279
1033.77	12379	12.379	1028.35	12379	12.379	1037.66	12379	12.379	1031.99	12379	12.379	1031	12379	12.379	1033.61	12379	12.379	1031.77	12378	12.378	1027.32	12378	12.378	1030.14	12378	12.378
1034.3	12479	12.479	1028.55	12478	12.478	1037.11	12478	12.478	1031.74	12478	12.478	1031.36	12478	12.478	1033.83	12478	12.478	1031.51	12477	12.477	1027.6	12477	12.477	1030.74	12478	12.478
1034.29	12578	12.578	1028.66	12577	12.577	1037.19	12577	12.577	1031.83	12577	12.577	1031.15	12577	12.577	1033.48	12577	12.577	1031.96	12576	12.576	1027.38	12576	12.576	1030.19	12577	12.577
1034.22	12677	12.677	1028.43	12676	12.676	1036.99	12676	12.676	1031.77	12676	12.676	1031.51	12676	12.676	1033.1	12676	12.676	1032.26	12675	12.675	1027.76	12675	12.675	1030.31	12676	12.676
1033.73	12776	12.776	1028.28	12775	12.775	1036.94	12775	12.775	1031.67	12775	12.775	1031.79	12775	12.775	1032.84	12775	12.775	1032.38	12774	12.774	1027.38	12775	12.775	1030.5	12775	12.775
1034.05	12875	12.875	1029.12	12874	12.874	1035.54	12874	12.874	1031.81	12874	12.874	1031.96	12874	12.874	1032.35	12875	12.875	1032.45	12873	12.873	1028	12874	12.874	1030.68	12874	12.874
1034.99	12975	12.975	1028.94	12974	12.974	1035.05	12974	12.974	1032.31	12974	12.974	1032.32	12974	12.974	1032.65	12974	12.974	1032.72	12972	12.972	1027.9	12973	12.973	1030.61	12973	12.973
1034.67	13074	13.074	1029.1	13073	13.073	1034.5	13073	13.073	1032.17	13073	13.073	1032.28	13073	13.073	1032.34	13073	13.073	1032.91	13071	13.071	1028.27	13072	13.072	1030.64	13073	13.073
1033.4	13173	13.173	1028.96	13172	13.172	1033.85	13172	13.172	1031.69	13172	13.172	1032.2	13172	13.172	1032.5	13172	13.172	1032.37	13171	13.171	1028.17	13171	13.171	1030.94	13172	13.172
Cont.			Cont.			Cont.			Cont.			Cont.			Cont.			Cont.			Cont.			Cont.		

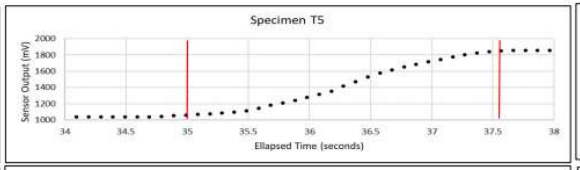
Evaluation of Sensor Response Time									
	Specimen T1	Specimen T2	Specimen T3	Specimen T4	Specimen T5	Specimen T6	Specimen T7	Specimen T8	Specimen T9
Actual VMC	5.5%	10.6%	15.5%	20.5%	25.9%	31.6%	20.8%	25.9%	30.9%
Acutal DUW (g/cm^3)	1.46	1.54	1.53	1.53	1.63	1.75	1.55	1.63	1.71
Degree of Saturation	11.8%	24.2%	35.5%	46.7%	64.5%	88.3%	48.2%	64.4%	83.0%
Recorded Insertion Time (sec.)	3	4	4	2	3	3	2.1	1.6	1.6
Approx. Response Time (sec.)	2.9	3	3.2	2.1	2.6	2.7	1.8	1.4	1.3

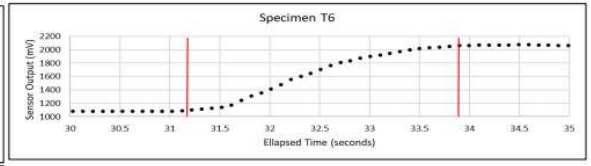


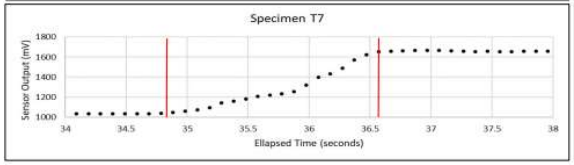


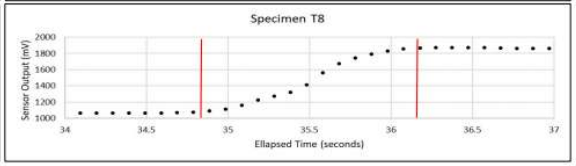


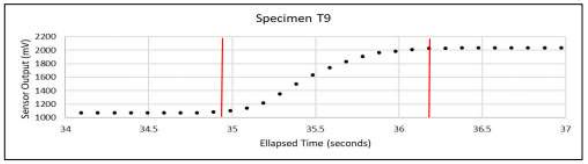












DETAILS FOR LARGE MOLD			
Mold Characteristic	**Units**	**Test 1**	**Test 2**
Total Empty Mold Mass	g	503.75	503.75
Mold Diameter	mm	301.96	301.96
		300.20	300.20
		302.29	302.29
Average		**302.43**	**302.43**
Height of Primary Zone	mm	108.92	108.92
Height of Secondary Zone	mm	32.55	32.55
Height of Buffer Zone	mm	45.00	45.00
Targeted Specimen Total Height	mm	186.47	186.47
Total Mold Height	mm	364	364
		363	363
		363	363
		362	362
Average		**363**	**363**
Approx. Cross Sectional Area	mm^2	71835.58	71835.58
Approx. Cross Sectional Area	cm^2	718.36	718.36
Approx. Primary Zone Volume	mm^3	7824331.69	7824331.69
Approx. Primary Zone Volume	cm^3	7824.33	7824.33
Approx. Secondary Zone Volume	mm^3	2338248.224	2338248.224
Approx. Secondary Zone Volume	cm^3	2338.25	2338.25
Approx. Buffer Zone Volume	mm^3	3232601.232	3232601.232
Approx. Buffer Zone Volume	cm^3	3232.60	3232.60
Approx. Total Test Volume	mm^3	13395181.15	13395181.15
Approx. Total Test Volume	cm^3	13395.18	13395.18
Approx. Sensor Volume	mm^3	67711.76	68098.23
Approx. Sensor Volume	cm^3	67.71	68.10
Approx. Total Volume of Conditioned Tailings	mm^3	13327469.39	13327082.91
Approx. Total Volume of Conditioned Tailings	cm^3	13327.47	13327.08
Load Platten Characteristic	**Units**	**Test #1**	**Test #2**
Thickness	mm	12.35	12.35
		12.57	12.57
		12.47	12.47
		12.35	12.35
Average		**12.44**	**12.44**
Diameter	mm	298.52	298.52
		298.5	298.5
		298.51	298.51
		298.55	298.55
Average		**298.52**	**298.52**
Approx. Cross Sectional Area	mm^2	69990.12147	69990.12147
	cm^2	699.9012147	699.9012147

SENSOR VOLUME DETAILS			
Item	**Unit**	**Test 1**	**Test 2**
Sensor Body			
Height	mm	20.15	20.15
Width	mm	23.71	23.71
Length	mm	51.11	51.11
Total Volume	mm^3	24418.13	24418.13
Sensor Needles			
Total Length	mm	53.47	53.47
Diameter	mm	3.12	3.12
Tip Length	mm	10.9	10.9
Rod Length	mm	42.57	42.57
Rod Volume	mm^3	325.4638	325.4638
Tip Volume	mm^3	27.77821	27.77821
Total Volume (2 Needles)	mm^3	706.4841	706.4841
Cord between Sensor Body and Ferrite Core			
Length	mm	89.62	89.62
Diameter	mm	4.05	4.05
Total Volume	mm^3	1154.529	1154.529
Ferrite Core			
Min. Diameter	mm	29.83	29.83
Max. Diameter	mm	32.55	32.55
Body Length	mm	49.67	49.67
Body Volume	mm^3	34753.44	34753.44
Nipple Length	mm	5.79	5.79
Nipple Diameter	mm	11.81	11.81
Nipple Volume	mm^3	1268.523	1268.523
Total Volume	mm^3	36021.96	36021.96
Cord from Ferrite Core to Mold Wall			
Length	mm	420	450
Diameter	mm	4.05	4.05
Total Volume	mm^3	5410.647	5797.122
Total Sensor Volume	**mm^3**	**67711.76**	**68098.23**
Total Sensor Volume	**cm^3**	**67.71176**	**68.09823**

Sensor Response to Specimen Compression - Test 1

Sample Preparation Details (For Moisture Conditioning)

General Details	Units	Value
Moisture Conditioning Date	--	4/22/2023
# of Sensors	--	1
Target Dry Density	pcf	85
	g/cm^3	1.36
Target Volumetric Moisture Content	%	15%
Target Gravimetric Moisture Content	%	11.0%
Details for Primary Zone Prep		
Number of Lifts	--	7
Target Compacted Lift Height	mm	15.56
Total Volume per Lift	mm^3	1117761.67
	cm^3	1117.76
Mass of Solids	g	1521.86
Mass of Water [a]	g	167.66
Details for Secondary Zone Prep		
Number of Lifts	--	3
Target Total Zone Height	mm	32.55
Total Zone Volume	mm^3	2338248.22
	cm^3	2338.25
Approximate Sensor Volume	mm^3	67711.76
	cm^3	67.71
Approximate Total Volume of Conditioned Tailings Required	mm^3	2270536.47
	cm^3	2270.54
Approximate Total Volume of Conditioned Tailings Per Lift	mm^3	756845.49
	cm^3	756.85
Mass of Solids	g	1030.46
Mass of Water [a]	g	113.53
Details for Buffer Zone Prep		
Number of Lifts	--	3
Target Compacted Lift Height	mm	15.00
Total Volume per Lift	mm^3	1077533.74
	cm^3	1077.53
Mass of Solids	g	1467.09
Mass of Water [a]	g	161.63

Initially Prepared Specimen

Measurement	Units	Value
Specimen Preparation Date	--	4/24/2023
Mass of Mold + Sensor	g	9468
Mass of Mold + Sensor + Wet Soil	g	29673
Depth to Top of Specimen	mm	180.81
	mm	178.78
	mm	177.95
	mm	177.17
	mm	181.74
	mm	179.09
	mm	178.34
	mm	182.84
Average	mm	179.59
Specimen Ht. Prior to Load Plattens	mm	183.41
Depth to Top of Load Platten	mm	167.74
	mm	167.68
	mm	165.84
	mm	165.68
	mm	164.64
	mm	165.43
	mm	165.94
	mm	167.24
Average	mm	166.27
Thickness of Plastic Load Platten	mm	12.44
Specimen Ht. Immediately Prior to Compression	mm	184.29
Specimen Total Mass	g	20205.00
Specimen Total Volume (+ Sensor Vol.)	cm^3	13238.67
Specimen Total Volume (- Sensor Vol.)	cm^3	13170.96
Specimen Total Density	g/cm^3	1.53
	pcf	95.8
Specimen Initial Dry Density	**g/cm^3**	**1.38**
	pcf	**86.1**

Gravimetric Moisture Content (Post-Test)

Measurement	Units	Value
Mass of Tare #1	g	289.32
Mass of Tare + Wet Soil	g	1064.02
Mass of Tare + Dry Soil	g	985.21
Total Sample Mass	g	774.7
Mass of Solids	g	695.89
Mass of Water	g	78.81
Gravimetric Moisture Content	%	11.3%
Volumetric Moisture Content [a]	%	15.6%
Mass of Tare #2	g	286.43
Mass of Tare + Wet Soil	g	976.36
Mass of Tare + Dry Soil	g	906.65
Total Sample Mass	g	689.93
Mass of Solids	g	620.22
Mass of Water	g	69.71
Gravimetric Moisture Content	%	11.2%
Volumetric Moisture Content [a]	%	15.5%
Mass of Tare #3	g	274.03
Mass of Tare + Wet Soil	g	1027.61
Mass of Tare + Dry Soil	g	951.33
Total Sample Mass	g	753.58
Mass of Solids	g	677.3
Mass of Water	g	76.28
Gravimetric Moisture Content	%	11.3%
Volumetric Moisture Content [a]	%	15.5%
Mass of Tare #4	g	358.51
Mass of Tare + Wet Soil	g	1848.15
Mass of Tare + Dry Soil	g	1696.84
Total Sample Mass	g	1489.64
Mass of Solids	g	1338.33
Mass of Water	g	151.31
Gravimetric Moisture Content	%	11.3%
Volumetric Moisture Content [a]	%	15.6%
Mass of Tare #5	g	155.31
Mass of Tare + Wet Soil	g	1347.05
Mass of Tare + Dry Soil	g	1226.04
Total Sample Mass	g	1191.74
Mass of Solids	g	1070.73
Mass of Water	g	121.01
Gravimetric Moisture Content	%	11.3%
Volumetric Moisture Content [a]	%	15.6%
Average Gravimetric Water Content	**%**	**11.3%**
Initial Average Volumetric Water Content [a]	**%**	**15.6%**

Initial Degree of Saturation

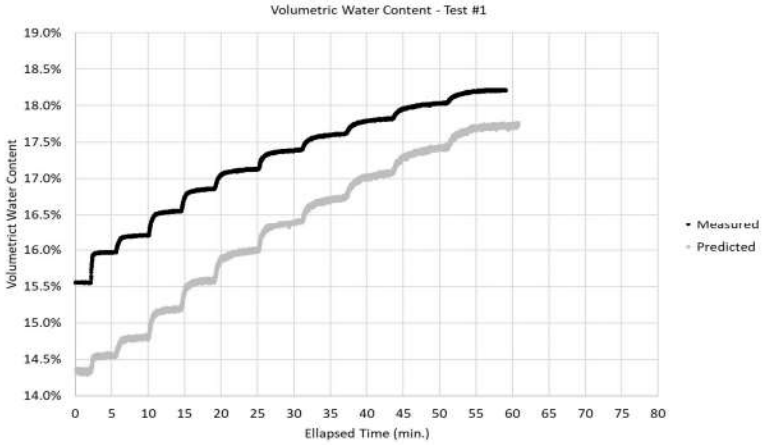
Measurement/Value	Units	Value
Specific Gravity	--	2.72
Mass of Water (in molded specimen)	g	2049.22
Mass of Solids (in molded specimen)	g	18155.78
Density of Solids [a]	g/cm^3	2.72
Volume of Solids (in molded specimen)	cm^3	6674.92
Volume of Water [a]	cm^3	2049.22
Volume of Voids	cm^3	6496.04
Degree of Saturation	**%**	**31.5%**

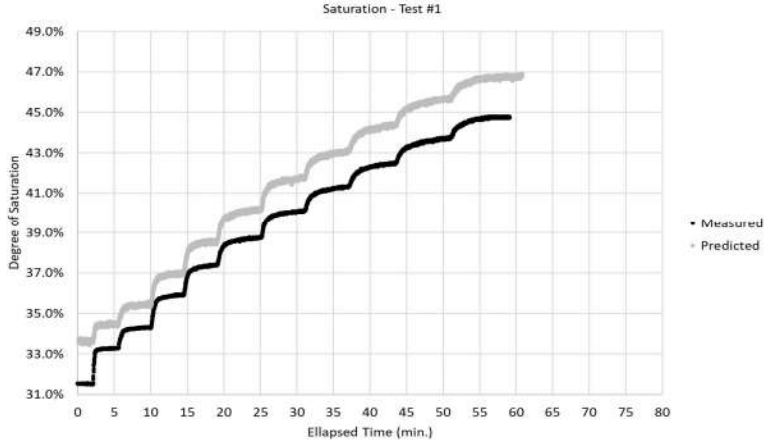
Notes:

a) Value assumes density of water is 1 g/cm^3

Compression Test 1 - Compression and Sensor Data Processing

Raw Compression Data														Measured Properties		Raw Sensor Data			Predicted Properties	
Time	Applied Force (lbs.)	LVDT Position (mm)	Ellapsed Time from Teros 10 Sensor Activation (days)	Ellapsed Time from Teros 10 Sensor Activation (min.)	Applied Force (kN)	Applied Load (kPa)	Axial Deformation (mm)	Specimen Ht. (mm)	Specimen Total Volume (cm^3) Excluding Sensor Volume	Change in Volume of Voids (cm^3)	Volume of Voids (cm^3)	Void Ratio	Specimen Dry Density (g/cm^3)	Volumetric Water Content	Degree of Saturation	Sensor mV Output	Ellapsed Time (ms)	Ellapsed Time (min.)	Volumetric Water Content	Degree of Saturation
4/24/2023 13:58	-46.769814	21.935246	0	0	-0.208032133	-2.972307067	0	184.29125	13170.95761	0	6496.04	0.97	1.38	15.6%	31.5%	1560.84	8206	0.14	14.3%	33.7%
4/24/2023 13:58	58.532322	21.854469	1.15741E-05	0.016666671	0.260351768	3.719835925	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1560.03	8304	0.14	14.3%	33.6%
4/24/2023 13:58	58.532322	21.90832	2.31481E-05	0.033333331	0.260351768	3.719835925	-0.026926	184.318176	13172.89186	-1.934244906	6497.97	0.97	1.38	15.6%	31.5%	1561.97	8403	0.14	14.4%	33.7%
4/24/2023 13:58	42.331993	21.854469	3.47222E-05	0.050000001	0.188292705	2.69027544	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1561.35	8501	0.14	14.4%	33.7%
4/24/2023 13:58	90.932979	21.854469	4.62963E-05	0.066666672	0.404469891	5.778956831	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1560.47	8600	0.14	14.3%	33.6%
4/24/2023 13:58	58.532322	21.90832	5.78704E-05	0.083333332	0.260351768	3.719835925	-0.026926	184.318176	13172.89186	-1.934244906	6497.97	0.97	1.38	15.6%	31.5%	1560.99	8699	0.14	14.3%	33.7%
4/24/2023 13:58	42.331993	21.854469	6.94444E-05	0.100000002	0.188292705	2.69027544	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1561.06	8797	0.15	14.3%	33.7%
4/24/2023 13:58	58.532322	21.854469	8.10185E-05	0.116666673	0.260351768	3.719835925	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1560.98	8896	0.15	14.3%	33.7%
4/24/2023 13:58	26.131665	21.90832	9.25926E-05	0.133333333	0.116233646	1.660715019	-0.026926	184.318176	13172.89186	-1.934244906	6497.97	0.97	1.38	15.6%	31.5%	1561.94	8994	0.15	14.4%	33.7%
4/24/2023 13:58	90.932979	21.827543	0.000104167	0.150000004	0.404469891	5.778956831	-0.107703	184.398953	13178.69452	-7.736907788	6503.78	0.97	1.38	15.5%	31.5%	1561.47	9093	0.15	14.4%	33.7%
4/24/2023 13:58	82.832815	21.854469	0.000115741	0.166666664	0.368440361	5.26417662	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1561.65	9191	0.15	14.4%	33.7%
4/24/2023 13:58	99.033144	21.854469	0.000127315	0.183333334	0.440499425	6.293737105	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1561.02	9290	0.15	14.3%	33.7%
4/24/2023 13:58	50.432158	21.881395	0.000138889	0.200000005	0.224322239	3.205055714	-0.053851	184.345101	13174.82603	-3.868417976	6499.91	0.97	1.38	15.6%	31.5%	1561.38	9388	0.16	14.4%	33.7%
4/24/2023 13:58	90.932979	21.881395	0.000150463	0.216666665	0.404469891	5.778956831	-0.053851	184.345101	13174.82603	-3.868417976	6499.91	0.97	1.38	15.6%	31.5%	1560.35	9487	0.16	14.3%	33.6%
4/24/2023 13:58	26.131665	21.854469	0.000162037	0.233333335	0.116233646	1.660715019	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1560.66	9585	0.16	14.3%	33.6%
4/24/2023 13:58	107.133308	21.881395	0.000173611	0.250000006	0.476528954	6.808517316	-0.053851	184.345101	13174.82603	-3.868417976	6499.91	0.97	1.38	15.6%	31.5%	1560.18	9684	0.16	14.3%	33.6%
4/24/2023 13:58	66.632486	21.800617	0.000185185	0.266666666	0.296381298	4.234616136	-0.134629	184.425879	13180.62877	-9.671152694	6505.71	0.97	1.38	15.5%	31.5%	1560.42	9782	0.16	14.3%	33.6%
4/24/2023 13:58	50.432158	21.800617	0.000196759	0.283333337	0.224322239	3.205055714	-0.134629	184.425879	13180.62877	-9.671152694	6505.71	0.97	1.38	15.5%	31.5%	1561.3	9881	0.16	14.4%	33.7%
4/24/2023 13:58	74.732651	21.854469	0.000208333	0.299999997	0.332410832	4.74939641	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1560.19	9980	0.17	14.3%	33.6%
4/24/2023 13:58	-22.469321	21.90832	0.000219907	0.316666667	-0.09994354	-1.427966372	-0.026926	184.318176	13172.89186	-1.934244906	6497.97	0.97	1.38	15.6%	31.5%	1560.38	10078	0.17	14.3%	33.6%
4/24/2023 13:58	74.732651	21.935246	0.000231481	0.333333338	0.332410832	4.74939641	0	184.29125	13170.95761	0	6496.04	0.97	1.38	15.6%	31.5%	1560.11	10177	0.17	14.3%	33.6%
4/24/2023 13:58	66.632486	21.881395	0.000243056	0.349999998	0.296381298	4.234616136	-0.053851	184.345101	13174.82603	-3.868417976	6499.91	0.97	1.38	15.6%	31.5%	1560.74	10275	0.17	14.3%	33.6%
4/24/2023 13:58	66.632486	21.854469	0.00025463	0.366666669	0.296381298	4.234616136	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1560.68	10374	0.17	14.3%	33.6%
4/24/2023 13:58	74.732651	21.935246	0.000266204	0.383333339	0.332410832	4.74939641	0	184.29125	13170.95761	0	6496.04	0.97	1.38	15.6%	31.5%	1560.46	10472	0.17	14.3%	33.6%
4/24/2023 13:58	99.033144	21.827543	0.000289352	0.41666667	0.440499425	6.293737105	-0.107703	184.398953	13178.69452	-7.736907788	6503.78	0.97	1.38	15.5%	31.5%	1560.97	10571	0.18	14.3%	33.7%
4/24/2023 13:58	1.831172	21.854469	0.000300926	0.43333333	0.008145053	0.116374324	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1561.73	10669	0.18	14.4%	33.7%
4/24/2023 13:58	74.732651	21.881395	0.0003125	0.45	0.332410832	4.74939641	-0.053851	184.345101	13174.82603	-3.868417976	6499.91	0.97	1.38	15.6%	31.5%	1560.91	10768	0.18	14.3%	33.7%
4/24/2023 13:58	99.033144	21.854469	0.000324074	0.466666671	0.440499425	6.293737105	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1561.31	10867	0.18	14.4%	33.7%
4/24/2023 13:58	58.532322	21.935246	0.000335648	0.483333331	0.260351768	3.719835925	0	184.29125	13170.95761	0	6496.04	0.97	1.38	15.6%	31.5%	1561.02	10965	0.18	14.3%	33.7%
4/24/2023 13:59	99.033144	21.854469	0.000347222	0.500000002	0.440499425	6.293737105	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1559.69	11064	0.18	14.3%	33.6%
4/24/2023 13:59	58.532322	21.800617	0.000358796	0.516666672	0.260351768	3.719835925	-0.134629	184.425879	13180.62877	-9.671152694	6505.71	0.97	1.38	15.5%	31.5%	1560.99	11162	0.19	14.3%	33.7%
4/24/2023 13:59	66.632486	21.827543	0.00037037	0.533333332	0.296381298	4.234616136	-0.107703	184.398953	13178.69452	-7.736907788	6503.78	0.97	1.38	15.5%	31.5%	1560.44	11261	0.19	14.3%	33.6%
4/24/2023 13:59	74.732651	21.935246	0.000381944	0.550000003	0.332410832	4.74939641	0	184.29125	13170.95761	0	6496.04	0.97	1.38	15.6%	31.5%	1560.85	11359	0.19	14.3%	33.7%
4/24/2023 13:59	74.732651	21.854469	0.000393519	0.566666663	0.332410832	4.74939641	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1560.71	11458	0.19	14.3%	33.6%
4/24/2023 13:59	123.333637	21.854469	0.000405093	0.583333333	0.548588017	7.838077801	-0.080777	184.372027	13176.76028	-5.802662882	6501.84	0.97	1.38	15.6%	31.5%	1561.12	11557	0.19	14.3%	33.7%
4/24/2023 13:59	74.732651	21.800617	0.000416667	0.600000004	0.332410832	4.74939641	-0.134629	184.425879	13180.62877	-9.671152694	6505.71	0.97	1.38	15.5%	31.5%	1560.89	11655	0.19	14.3%	33.7%
4/24/2023 13:59	58.532322	21.881395	0.000428241	0.616666664	0.260351768	3.719835925	-0.053851	184.345101	13174.82603	-3.868417976	6499.91	0.97	1.38	15.6%	31.5%	1560.28	11754	0.20	14.3%	33.6%
									CONT.											





Sensor Response to Specimen Compression - Test 2

Sample Preparation Details (For Moisture Conditioning)		
General Details	**Units**	**Value**
Moisture Conditioning Date	--	5/1/2023
# of Sensors	--	1
Target Dry Density	pcf	85
	g/cm^3	1.36
Target Volumetric Moisture Content	%	15.4%
Target Gravimetric Moisture Content	%	11.3%
Details for Primary Zone Prep		
Number of Lifts	--	7
Target Compacted Lift Height	mm	15.56
Total Volume per Lift	mm^3	1117761.67
	cm^3	1117.76
Mass of Solids	g	1521.86
Mass of Water [a]	g	172.14
Details for Secondary Zone Prep		
Number of Lifts	--	3
Target Total Zone Height	mm	32.55
Total Zone Volume	mm^3	2338248.22
	cm^3	2338.25
Approximate Sensor Volume	mm^3	68098.23
	cm^3	68.10
Approximate Total Volume of Conditioned Tailings Required	mm^3	2270149.99
	cm^3	2270.15
Approximate Total Volume of Conditioned Tailings Per Lift	mm^3	756716.66
	cm^3	756.72
Mass of Solids	g	1030.29
Mass of Water [a]	g	116.53
Details for Buffer Zone Prep		
Number of Lifts	--	3
Target Compacted Lift Height	mm	15.00
Total Volume per Lift	mm^3	1077533.74
	cm^3	1077.53
Mass of Solids	g	1467.09
Mass of Water [a]	g	165.94

Initially Prepared Specimen		
Measurement	**Units**	**Value**
Specimen Preparation Date	--	5/3/2023
Mass of Mold + Sensor	g	9472
Mass of Mold + Sensor + Wet Soil	g	29683
Depth to Top of Specimen	mm	182.56
	mm	182.30
	mm	183.80
	mm	181.84
	mm	180.85
	mm	179.01
	mm	178.62
	mm	183.55
Average	mm	181.57
Specimen Ht. Prior to Load Plattens	mm	181.43375
Depth to Top of Load Platten	mm	168.93
	mm	167.95
	mm	166.97
	mm	165.33
	mm	165.57
	mm	167.76
	mm	168.59
	mm	169.11
Average	mm	167.53
Thickness of Plastic Load Platten	mm	12.44
Specimen Ht. Immediately Prior to Compression	mm	183.03875
Specimen Total Mass	g	20211.00
Specimen Total Volume (+ Sensor Vol.)	cm^3	13148.70
Specimen Total Volume (- Sensor Vol.)	cm^3	13080.60
Specimen Total Density	g/cm^3	1.55
	pcf	96.5
Specimen Initial Dry Density	**g/cm^3**	**1.39**
	pcf	**86.7**
Initial Volumetric Water Content [a]	**%**	**15.7%**

Gravimetric Moisture Content (Post-Test)
Target Gravimetric Water Content from Sample Preparation used to determine Initial Dry Density, Volumetric Water Content, and Degree of Saturation

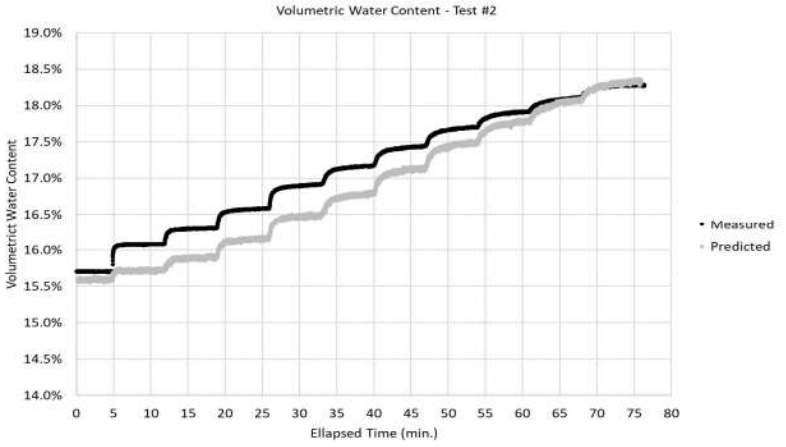
Initial Degree of Saturation		
Measurement/Value	**Units**	**Value**
Specific Gravity	--	2.72
Mass of Water (in molded specimen)	g	2053.74
Mass of Solids (in molded specimen)	g	18157.26
Density of Solids [a]	g/cm^3	2.72
Volume of Solids (in molded specimen)	cm^3	6675.46
Volume of Water [a]	cm^3	2053.74
Volume of Voids	cm^3	6405.13
Degree of Saturation	**%**	**32.1%**

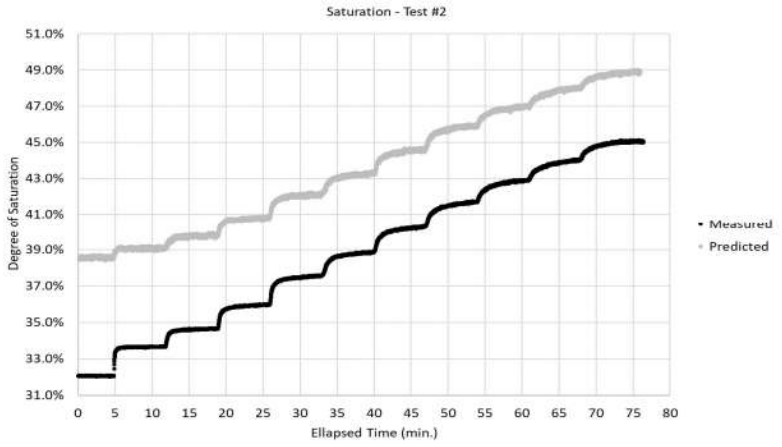
Notes:
a) Value assumes density of water is 1 g/cm^3

Compression Test 2 - Compression and Sensor Data Processing

Raw Compression Data														Measured Properties		Raw Sensor Data			Predicted Properties	
Time	Applied Force (lbs.)	LVDT Position (mm)	Ellapsed Time from Teros 10 Sensor Activation (days)	Ellapsed Time from Teros 10 Sensor Activation (min.)	Applied Force (kN)	Applied Load (kPa)	Axial Deformation (mm)	Specimen Ht. (mm)	Specimen Total Volume (cm^3) Excluding Sensor Volume	Change in Volume of Voids (cm^3)	Volume of Voids (cm^3)	Void Ratio	Specimen Dry Density (g/cm^3)	Volumetric Water Content	Degree of Saturation	Sensor mV Output	Ellapsed Time (ms)	Ellapsed Time (min.)	Volumetric Water Content	Degree of Saturation
5/3/2023 6:29	74.732651	8.229963	0	0	0.332410832	4.74939641	0	183.03875	13080.98355	0	6405.13	0.96	1.39	15.7%	32.1%	1620.51	8328	0.14	15.6%	38.5%
5/3/2023 6:29	90.932979	8.203037	1.15741E-05	0.01666666	0.404469891	5.778956831	-0.026926	183.065676	13082.91779	-1.934244906	6407.07	0.96	1.39	15.7%	32.1%	1620.03	8426	0.14	15.6%	38.5%
5/3/2023 6:29	66.632486	8.203037	2.31481E-05	0.03333331	0.296381298	4.234616136	-0.026926	183.065676	13082.91779	-1.934244906	6407.07	0.96	1.39	15.7%	32.1%	1620.18	8525	0.14	15.6%	38.5%
5/3/2023 6:29	74.732651	8.203037	3.47222E-05	0.050000001	0.332410832	4.74939641	-0.026926	183.065676	13082.91779	-1.934244906	6407.07	0.96	1.39	15.7%	32.1%	1620.19	8623	0.14	15.6%	38.5%
5/3/2023 6:29	82.832815	8.176111	4.62963E-05	0.066666661	0.368440361	5.26417662	-0.053852	183.092602	13084.85204	-3.868489812	6409.00	0.96	1.39	15.7%	32.0%	1619.42	8722	0.15	15.6%	38.5%
5/3/2023 6:29	58.532322	8.229963	5.78704E-05	0.083333332	0.260351768	3.719835925	0	183.03875	13080.98355	0	6405.13	0.96	1.39	15.7%	32.1%	1620.46	8820	0.15	15.6%	38.5%
5/3/2023 6:29	-14.369157	8.203037	6.94444E-05	0.100000002	-0.06391401	-0.913186161	-0.026926	183.065676	13082.91779	-1.934244906	6407.07	0.96	1.39	15.7%	32.1%	1620.91	8919	0.15	15.6%	38.6%
5/3/2023 6:29	58.532322	8.31074	8.10185E-05	0.116666663	0.260351768	3.719835925	0.080777	182.957973	13075.18088	5.802662882	6399.33	0.96	1.39	15.7%	32.1%	1620.42	9018	0.15	15.6%	38.5%
5/3/2023 6:29	34.231829	8.203037	9.25926E-05	0.133333333	0.152263175	2.17549523	-0.026926	183.065676	13082.91779	-1.934244906	6407.07	0.96	1.39	15.7%	32.1%	1621.18	9116	0.15	15.6%	38.6%
5/3/2023 6:29	123.333637	8.229963	0.000104167	0.149999993	0.548588017	7.838077801	0	183.03875	13080.98355	0	6405.13	0.96	1.39	15.7%	32.1%	1620.62	9215	0.15	15.6%	38.6%
5/3/2023 6:29	82.832815	8.149185	0.000115741	0.166666664	0.368440361	5.26417662	-0.080778	183.119528	13086.78628	-5.802734718	6410.94	0.96	1.39	15.7%	32.0%	1620.09	9313	0.16	15.6%	38.5%
5/3/2023 6:29	82.832815	8.283815	0.000127315	0.183333334	0.368440361	5.26417662	0.053852	182.984898	13077.11506	3.868489812	6401.27	0.96	1.39	15.7%	32.1%	1619.88	9412	0.16	15.6%	38.6%
5/3/2023 6:29	99.083144	8.283815	0.000138889	0.199999994	0.440499425	6.293737105	0.053852	182.984898	13077.11506	3.868489812	6401.27	0.96	1.39	15.7%	32.1%	1620.87	9510	0.16	15.6%	38.6%
5/3/2023 6:29	90.932979	8.176111	0.000150463	0.216666665	0.404469891	5.778956831	-0.053852	183.092602	13084.85204	-3.868489812	6409.00	0.96	1.39	15.7%	32.0%	1621.16	9609	0.16	15.6%	38.6%
5/3/2023 6:29	-6.268993	8.203037	0.000162037	0.233333335	-0.027884481	-0.39840595	-0.026926	183.065676	13082.91779	-1.934244906	6407.07	0.96	1.39	15.7%	32.1%	1620.39	9707	0.16	15.6%	38.5%
5/3/2023 6:29	66.632486	8.229963	0.000173611	0.249999996	0.296381298	4.234616136	0	183.03875	13080.98355	0	6405.13	0.96	1.39	15.7%	32.1%	1621.44	9806	0.16	15.6%	38.6%
5/3/2023 6:29	66.632486	8.203037	0.000185185	0.266666666	0.296381298	4.234616136	-0.026926	183.065676	13082.91779	-1.934244906	6407.07	0.96	1.39	15.7%	32.1%	1620.74	9904	0.17	15.6%	38.6%
5/3/2023 6:29	50.452158	8.256889	0.000196759	0.283333326	0.224322299	3.205055714	0.026926	183.011824	13079.0493	1.934244906	6403.20	0.96	1.39	15.7%	32.1%	1620.56	10003	0.17	15.6%	38.5%
5/3/2023 6:29	66.632486	8.203037	0.000208333	0.299999997	0.296381298	4.234616136	-0.026926	183.065676	13082.91779	-1.934244906	6407.07	0.96	1.39	15.7%	32.1%	1620.09	10102	0.17	15.6%	38.5%
5/3/2023 6:29	1.831172	8.31074	0.000219907	0.316666667	0.008145053	0.116374324	0.080777	182.957973	13075.18088	5.802662882	6399.33	0.96	1.39	15.7%	32.1%	1619.9	10200	0.17	15.6%	38.5%
5/3/2023 6:29	34.231829	8.149185	0.000231481	0.333333327	0.152263175	2.17549523	-0.080778	183.119528	13086.78628	-5.802734718	6410.94	0.96	1.39	15.7%	32.0%	1619.59	10299	0.17	15.6%	38.5%
5/3/2023 6:29	90.932979	8.283815	0.000243056	0.349999998	0.404469891	5.778956831	0.053852	182.984898	13077.11506	3.868489812	6401.27	0.96	1.39	15.7%	32.1%	1620.61	10397	0.17	15.6%	38.6%
5/3/2023 6:29	90.932979	8.283815	0.00025463	0.366666669	0.404469891	5.778956831	0.053852	182.984898	13077.11506	3.868489812	6401.27	0.96	1.39	15.7%	32.1%	1620.17	10496	0.17	15.6%	38.6%
5/3/2023 6:29	-6.268993	8.203037	0.000266204	0.383333329	-0.027884481	-0.39840595	-0.026926	183.065676	13082.91779	-1.934244906	6407.07	0.96	1.39	15.7%	32.1%	1621.12	10594	0.18	15.6%	38.6%
5/3/2023 6:29	66.632486	8.256889	0.000277778	0.399999999	0.296381298	4.234616136	0.026926	183.011824	13079.0493	1.934244906	6403.20	0.96	1.39	15.7%	32.1%	1620.41	10693	0.18	15.6%	38.5%
5/3/2023 6:29	58.532322	8.256889	0.000289352	0.416666659	0.260351768	3.719835925	0.026926	183.011824	13079.0493	1.934244906	6403.20	0.96	1.39	15.7%	32.1%	1620.78	10791	0.18	15.6%	38.6%
5/3/2023 6:29	42.331993	8.229963	0.000300926	0.43333333	0.188292705	2.69027544	0	183.03875	13080.98355	0	6405.13	0.96	1.39	15.7%	32.1%	1619.93	10890	0.18	15.6%	38.5%
5/3/2023 6:29	26.131665	8.176111	0.0003125	0.45	0.116233646	1.660715019	-0.053852	183.092602	13084.85204	-3.868489812	6409.00	0.96	1.39	15.7%	32.0%	1620.09	10988	0.18	15.6%	38.5%
5/3/2023 6:29	82.832815	8.203037	0.000324074	0.466666661	0.368440361	5.26417662	-0.026926	183.065676	13082.91779	-1.934244906	6407.07	0.96	1.39	15.7%	32.1%	1620.22	11087	0.18	15.6%	38.5%
5/3/2023 6:29	34.231829	8.283815	0.000335648	0.483333331	0.152263175	2.17549523	0.053852	182.984898	13077.11506	3.868489812	6401.27	0.96	1.39	15.7%	32.1%	1620.33	11186	0.19	15.6%	38.5%
5/3/2023 6:29	74.732651	8.149185	0.000347222	0.500000002	0.332410832	4.74939641	-0.080778	183.119528	13086.78628	-5.802734718	6410.94	0.96	1.39	15.7%	32.0%	1620.2	11284	0.19	15.6%	38.5%
5/3/2023 6:29	74.732651	8.229963	0.000358796	0.516666662	0.332410832	4.74939641	0	183.03875	13080.98355	0	6405.13	0.96	1.39	15.7%	32.1%	1620.66	11383	0.19	15.6%	38.6%
5/3/2023 6:29	66.632486	8.176111	0.00037037	0.533333332	0.296381298	4.234616136	-0.053852	183.092602	13084.85204	-3.868489812	6409.00	0.96	1.39	15.7%	32.0%	1621.21	11481	0.19	15.6%	38.6%
5/3/2023 6:29	42.331993	8.176111	0.000381944	0.550000003	0.188292705	2.69027544	-0.053852	183.092602	13084.85204	-3.868489812	6409.00	0.96	1.39	15.7%	32.0%	1620.92	11580	0.19	15.6%	38.6%
5/3/2023 6:29	42.331993	8.203037	0.000393519	0.566666663	0.188292705	2.69027544	-0.026926	183.065676	13082.91779	-1.934244906	6407.07	0.96	1.39	15.7%	32.1%	1621.04	11678	0.19	15.6%	38.6%
5/3/2023 6:29	42.331993	8.203037	0.000405093	0.583333333	0.188292705	2.69027544	-0.026926	183.065676	13082.91779	-1.934244906	6407.07	0.96	1.39	15.7%	32.1%	1620.59	11777	0.20	15.6%	38.6%
5/3/2023 6:29	82.832815	8.256889	0.000416667	0.599999994	0.368440361	5.26417662	0.026926	183.011824	13079.0493	1.934244906	6403.20	0.96	1.39	15.7%	32.1%	1620.53	11875	0.20	15.6%	38.5%

Cont.





Infiltration Testing

Immediately Prior to Infiltration

Specimen Details

Measurement	Units	Value
Specimen Preparation Date	--	5/3/2023
Depth to Top of Load Platten	mm	192.83
	mm	192.83
	mm	191.98
	mm	191.64
	mm	191.43
	mm	192.06
	mm	192.40
	mm	192.63
Average	mm	192.23
Thickness of Plastic Load Platten	mm	12.44
Specimen Ht. Immediately Prior to Inundation	mm	158.34
Specimen Total Mass (Prior to Compression) [b]	g	20211.00
Specimen Total Volume (+ Sensor Vol.)	cm^3	11374.45
Specimen Total Volume (- Sensor Vol.)	cm^3	11306.35
Specimen Total Density	g/cm^3	1.79
	pcf	111.6
Specimen Dry Density	**g/cm^3**	**1.61**
	pcf	**100.3**
Gravimetric Water Content (From Sample Prep.) [c]	%	11.3%
Volumetrict Water Content [a]	**%**	**18.2%**

Gravimetric Moisture Content

See Notes Below

Degree of Saturation

Measurement/Value	Units	Value
Specific Gravity	--	2.72
Mass of Water (in molded specimen) [c]	g	2053.74
Mass of Solids (in molded specimen)	g	18157.26
Density of Solids [a]	g/cm^3	2.72
Volume of Solids (in molded specimen)	cm^3	6675.46
Volume of Water [a]	cm^3	2053.74
Volume of Voids	cm^3	4630.88
Degree of Saturation	**%**	**44.3%**

Notes:

a) Assumes density of water is 1 g/cm^3

b) Specimen Total Mass immediately prior to inundation assumed to be same as specimen total mass measured prior to Compression Test 2.

c) Target Gravimetric Water from Sample Preparation for Compression Test 2 used to determine Dry Density, Volumetric Water Content, and Degree of Saturation of specimen prior to inundation.

After Infiltration

Specimen Details

Measurement	Units	Value
Total Mass of Specimen + Mold + Sensor	g	30630.79
Specimen Total Mass [b]	g	21158.79
Specimen Height at End of Test	mm	145.52
Specimen Total Volume (+ Sensor Vol.)	cm^3	10453.75
Specimen Total Volume (- Sensor Vol.)	cm^3	10385.65
Specimen Total Density	g/cm^3	2.04
	pcf	127.2
Specimen Dry Density	**g/cm^3**	**1.76**
	pcf	**110.0**

Notes:

a) Assumes density of water is 1 g/cm^3

1. Specimen Total Mass calculated based on mass of Mold + Sensor measured prior to Compression Test 2.

Gravimetric Moisture Content

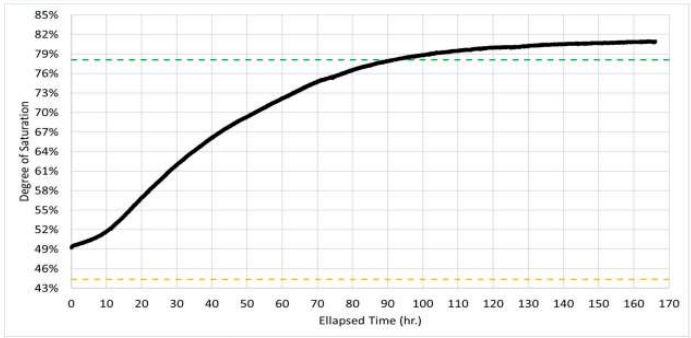
Measurement	Units	Value
Mass of Tare #1	g	274.02
Mass of Tare + Wet Soil	g	1118.25
Mass of Tare + Dry Soil	g	1002.34
Total Sample Mass	g	844.23
Mass of Solids	g	728.32
Mass of Water	g	115.91
Gravimetric Moisture Content	%	15.9%
Volumetric Moisture Content [a]	%	28.0%
Mass of Tare #2	g	286.43
Mass of Tare + Wet Soil	g	1035.89
Mass of Tare + Dry Soil	g	935.85
Total Sample Mass	g	749.46
Mass of Solids	g	649.42
Mass of Water	g	100.04
Gravimetric Moisture Content	%	15.4%
Volumetric Moisture Content [a]	%	27.2%
Mass of Tare #3	g	289.33
Mass of Tare + Wet Soil	g	983.05
Mass of Tare + Dry Soil	g	889.95
Total Sample Mass	g	693.72
Mass of Solids	g	600.62
Mass of Water	g	93.1
Gravimetric Moisture Content	%	15.5%
Volumetric Moisture Content [a]	%	27.3%
Mass of Tare #4	g	155.38
Mass of Tare + Wet Soil	g	1236.53
Mass of Tare + Dry Soil	g	1090.83
Total Sample Mass	g	1081.15
Mass of Solids	g	935.45
Mass of Water	g	145.7
Gravimetric Moisture Content	%	15.6%
Volumetric Moisture Content [a]	%	27.5%
Mass of Tare #5	g	358.52
Mass of Tare + Wet Soil	g	1912.4
Mass of Tare + Dry Soil	g	1702.82
Total Sample Mass	g	1553.88
Mass of Solids	g	1344.3
Mass of Water	g	209.58
Gravimetric Moisture Content	%	15.6%
Volumetric Moisture Content [a]	%	27.5%
Average Gravimetric Water Content	%	15.6%
Average Volumetrict Water Content [a]	**%**	**27.5%**

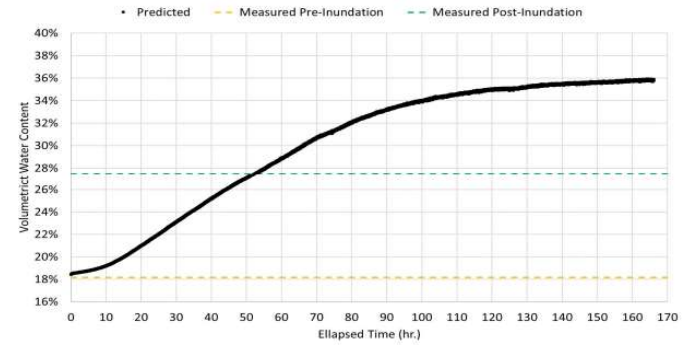
Degree of Saturation

Measurement/Value	Units	Value
Specific Gravity	--	2.72
Mass of Water (in molded specimen)	g	2854.88
Mass of Solids (in molded specimen)	g	18303.91
Density of Solids [a]	g/cm^3	2.72
Volume of Solids (in molded specimen)	cm^3	6729.38
Volume of Water [a]	cm^3	2854.88
Volume of Voids	cm^3	3656.27
Degree of Saturation	**%**	**78.1%**

Infiltration Test - Data Processing

Phase	Raw Compression Data: Time	Applied Force (lbs.)	LVDT Position (mm)	Ellapsed Time from Teros 10 Sensor Activation (days)	Ellapsed Time from Teros 10 Sensor Activation (hr.)	Ellapsed Time from Teros 10 Sensor Activation (mn.)	Ellapsed Time from Teros 10 Sensor Activation (sec.)	Applied Force (kN)	Applied Load (kPa)	Axial Deformation (mm)	Specimen Ht. (mm)	Specimen Total Volume (cm^3) Excluding Sensor Volume	Change in Volume of Voids (cm^3)	Volume of Voids (cm^3)	Void Ratio	Specimen Dry Density (g/cm^3)
Prior to Infiltration	5/3/2023 8:04	10799.35023	34.671197	0	0	0	0	48.03550981	686.3184231	0	158.34	11306.34797	0	4630.88	0.69	1.61
After Infiltration	5/10/2023 6:57	10783.1499	47.487926	6.953402778	166.8816667	10012.9	600774	47.96345074	685.2888627	12.816729	145.523271	10385.65077	920.6971989	3710.19	0.56	1.75





Raw Sensor Data: Sensor mV Output	Raw Sensor Data: Ellapsed Time (ms)	Ellapsed Time (sec.)	Ellapsed Time (min.)	Ellapsed Time (hr.)	Estimated Properties: Volumetric Water Content	Estimated Properties: Degree of Saturation
1751.22	8599	8.60	0.14	0.002	18.4%	49.3%
1751.45	13591	13.59	0.23	0.004	18.4%	49.3%
1751.18	18583	18.58	0.31	0.005	18.4%	49.3%
1750.73	23575	23.58	0.39	0.007	18.4%	49.2%
1750.86	28567	28.57	0.48	0.008	18.4%	49.2%
1750.24	33559	33.56	0.56	0.009	18.4%	49.2%
1750.69	38551	38.55	0.64	0.011	18.4%	49.2%
1750.46	43543	43.54	0.73	0.012	18.4%	49.2%
1750.48	48535	48.54	0.81	0.013	18.4%	49.2%
1750.94	53527	53.53	0.89	0.015	18.4%	49.2%
1751.02	58519	58.52	0.98	0.016	18.4%	49.2%
1751.31	63511	63.51	1.06	0.018	18.4%	49.3%
1751.18	68503	68.50	1.14	0.019	18.4%	49.3%
1751.51	73495	73.50	1.22	0.020	18.4%	49.3%
1751.35	78487	78.49	1.31	0.022	18.4%	49.3%
1751.22	83479	83.48	1.39	0.023	18.4%	49.3%
1751.58	88471	88.47	1.47	0.025	18.4%	49.3%
1751.38	93463	93.46	1.56	0.026	18.4%	49.3%
1751.3	98455	98.46	1.64	0.027	18.4%	49.3%
1750.78	103447	103.45	1.72	0.029	18.4%	49.2%
1751.48	108439	108.44	1.81	0.030	18.4%	49.3%
1751.03	113431	113.43	1.89	0.032	18.4%	49.2%
1751.58	118423	118.42	1.97	0.033	18.4%	49.3%
1751.15	123415	123.42	2.06	0.034	18.4%	49.2%
1750.61	128407	128.41	2.14	0.036	18.4%	49.2%
1751.29	133399	133.40	2.22	0.037	18.4%	49.3%
1751.36	138391	138.39	2.31	0.038	18.4%	49.3%
1750.88	143383	143.38	2.39	0.040	18.4%	49.2%
1751.35	148375	148.38	2.47	0.041	18.4%	49.3%
1751.32	153367	153.37	2.56	0.043	18.4%	49.3%
1750.99	158359	158.36	2.64	0.044	18.4%	49.2%
1751.28	163351	163.35	2.72	0.045	18.4%	49.3%
1750.15	168343	168.34	2.81	0.047	18.4%	49.2%
1750.51	173335	173.34	2.89	0.048	18.4%	49.2%
1751.2	178327	178.33	2.97	0.050	18.4%	49.3%
1751.57	183319	183.32	3.06	0.051	18.4%	49.3%
1751.15	188311	188.31	3.14	0.052	18.4%	49.2%
1751.08	193303	193.30	3.22	0.054	18.4%	49.2%
1751.12	198295	198.30	3.30	0.055	18.4%	49.2%
1751.38	203287	203.29	3.39	0.056	18.4%	49.3%
1751.07	208279	208.28	3.47	0.058	18.4%	49.2%
1751.01	213271	213.27	3.55	0.059	18.4%	49.2%

CONT.

Zero-Effective Stress Void Ratio Test

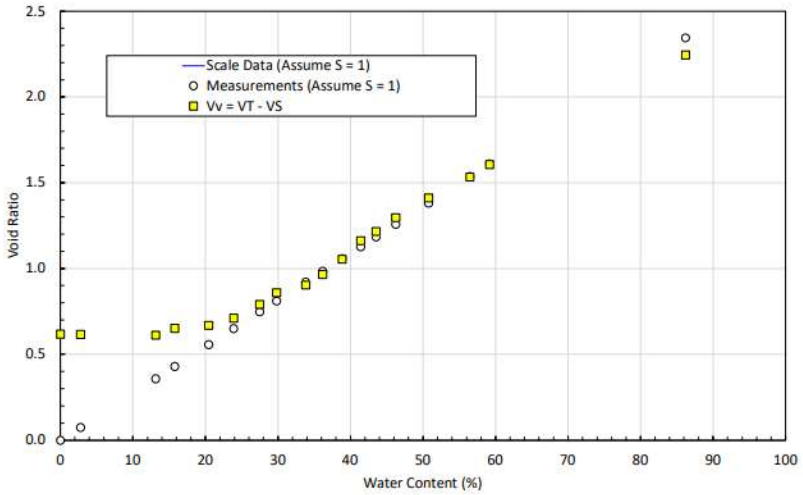
	Specimen A	Specimen B	Specimen C	
Particle Sedimentation Observation				
Date/Time	Approximate Beaker Reading (mL)	Approximate Beaker Reading (mL)	Approximate Beaker Reading (mL)	
8/29/22 @ 1700	~540	~600	~600	
8/30/22 @ 0800	~305	~340	~340	
8/30/22 @ 1615	~305	~340	~340	
8/31/22 @ 0830	~305	~340	~340	* Particle Settlement judged to be complete
Determining Weight of Water and Solids				
Wt. of Beaker - Pre Test (g)	404.14	405.35	393.85	
Wt. of Beaker + Sat. Sample (g)	929.04	934.24	913.54	*Remnants of solids remained on beaker glass after air drying. The purpose of obtaining these measurments is to perform a check on actual mass of Sat. Sample in tare to judge potential for sample loss (solids and/or water) during transfer from beaker to tare.
Wt. of Air Dry Beaker (g)	404.48	405.78	394.14	
Total Wt. of Sat. Sample (g)	524.90	528.89	519.69	
Wt. of Sat. Sample Removed From Beaker (g)	524.56	528.46	519.4	*Does not account for water that evaporated from remant soil on beaker
Tare ID	R-41	R-44	R-45	
Tare Wt. (g)	358.77	289.52	279.09	
Tare + Sat. Sample (g)	882.28	817.20	797.83	
Tare + Oven-Dry Sample (g)	654.66	584.94	573.17	
Total Wt. of Sat. Sample (g)	523.51	527.68	518.74	
Wt. of Solids (g)	295.89	295.42	294.08	
Wt. of Water (g)	227.62	232.26	224.66	
Gravimetric Water Content (%)	76.9%	78.6%	76.4%	
Solids Content (%)	56.5%	56.0%	56.7%	
Determining Void Ratio				
Assumed Unit Weight of Water (g/cm^3)	1.0	1.0	1.0	
Volume of Water (cm^3)	227.62	232.26	224.66	*Sample assumed to be 100% Saturated. Therefore Vol. of Water = Volume of Voids
Specific Gravity of Solids	2.72	2.72	2.72	
Volume of Solids (cm^3)	108.7830882	108.6102941	108.1176471	*Vs = Ws/(SG x UW of Water)
Approximate Void Ratio	**2.09**	**2.14**	**2.08**	

Shrinkage Curves

Specimen	Start Date & Time	Full Tare Mass (g)	Initial Total Specimen Mass (g)	Initial Specimen Thickness (cm)	Initial Specimen Diameter (cm)	Total Specimen Volume (cm^3)	Initial Solids Content (%)	Initial Solids Mass (g)	Specific Gravity	Final Oven-Dried Solids (g)	Solid Volume (cm^3)
Specimen A	8/31/2022 12:12	25.61	25.49	1.225	4.121	16.33	53.71	13.69	2.72	13.69	5.03

Physical Measurements of Volume Change

Date & Time	Elapsed Time (d)	M_T (g)	ΔH (cm)	ΔD (cm)	H (cm)	D (cm)	V_T (cm^3)	ΔV_T (cm^3)	M_S (g)	M_W (g)	V_S (cm^3)	V_W (cm^3)	Void Ratio (assume S = 1)	V_V (cm^3)	Void Ratio	Gravimetric Water Content (%)	Solids Content (%)	Volumetric Water Content (%)	Dry Density (g/cm^3)	Dry Density (pcf)	Degree of Saturation (%)
8/31/2022 12:12	0	25.49	0	0	1.225	4.121	16.3	0.0	13.69	11.80	5.03	11.80	2.344	11.30	2.245	86.2	53.7	0.723	0.84	52.3	104.4
9/1/2022 7:30	0.804	21.79	0.2413	0.000	0.984	4.121	13.1	3.2	13.69	8.10	5.03	8.10	1.609	8.08	1.606	59.2	62.8	0.618	1.04	65.2	100.2
9/1/2022 9:30	0.888	21.42	0.2685	0.000	0.956	4.121	12.8	3.6	13.69	7.73	5.03	7.73	1.536	7.72	1.534	56.5	63.9	0.606	1.07	67.0	100.2
9/1/2022 14:00	1.075	20.64	0.3145	0.000	0.910	4.121	12.1	4.2	13.69	6.95	5.03	6.95	1.381	7.11	1.412	50.8	66.3	0.573	1.13	70.4	97.8
9/2/2022 7:30	1.804	20.02	0.3580	0.000	0.867	4.121	11.6	4.8	13.69	6.33	5.03	6.33	1.258	6.52	1.296	46.2	68.4	0.548	1.18	73.9	97.0
9/2/2022 9:45	1.898	19.65	0.3885	0.000	0.836	4.121	11.2	5.2	13.69	5.96	5.03	5.96	1.184	6.12	1.216	43.5	69.7	0.534	1.23	76.6	97.4
9/2/2022 11:30	1.971	19.36	0.4088	0.000	0.816	4.121	10.9	5.5	13.69	5.67	5.03	5.67	1.127	5.85	1.162	41.4	70.7	0.521	1.26	78.5	97.0
9/2/2022 13:30	2.054	19.01	0.4078	0.106	0.817	4.015	10.3	6.0	13.69	5.32	5.03	5.32	1.057	5.31	1.055	38.9	72.0	0.514	1.32	82.6	100.2
9/2/2022 15:40	2.144	18.64	0.4235	0.156	0.801	3.965	9.9	6.4	13.69	4.95	5.03	4.95	0.983	4.86	0.965	36.2	73.4	0.500	1.38	86.4	101.9
9/6/2022 7:25	5.801	18.32	0.4245	0.216	0.800	3.905	9.6	6.7	13.69	4.63	5.03	4.63	0.920	4.55	0.904	33.8	74.7	0.483	1.43	89.2	101.8
9/6/2022 11:30	5.971	17.77	0.4170	0.281	0.808	3.840	9.4	7.0	13.69	4.08	5.03	4.08	0.811	4.32	0.858	29.8	77.0	0.436	1.46	91.4	94.4
9/7/2022 9:20	6.881	17.45	0.4305	0.319	0.794	3.801	9.0	7.3	13.69	3.76	5.03	3.76	0.747	3.98	0.791	27.5	78.5	0.417	1.52	94.8	94.5
9/7/2022 11:30	6.971	16.96	0.4385	0.387	0.786	3.734	8.6	7.7	13.69	3.27	5.03	3.27	0.650	3.58	0.710	23.9	80.7	0.380	1.59	99.3	91.5
9/7/2022 13:40	7.061	16.49	0.4478	0.411	0.777	3.709	8.4	7.9	13.69	2.80	5.03	2.80	0.556	3.36	0.668	20.5	83.0	0.333	1.63	101.8	83.2
9/7/2022 16:35	7.183	15.85	0.4475	0.431	0.777	3.689	8.3	8.0	13.69	2.16	5.03	2.16	0.429	3.28	0.651	15.8	86.4	0.260	1.65	102.9	65.9
9/12/2022 8:05	11.828	15.49	0.4640	0.437	0.761	3.683	8.1	8.2	13.69	1.80	5.03	1.80	0.358	3.07	0.611	13.1	88.4	0.222	1.69	105.4	58.6
9/12/2022 16:25	12.176	14.07	0.4630	0.434	0.762	3.687	8.1	8.2	13.69	0.38	5.03	0.38	0.076	3.10	0.616	2.8	97.3	0.047	1.68	105.1	12.3
9/13/2022 9:45	12.898	13.69	0.4623	0.434	0.763	3.687	8.1	8.2	13.69	0.00	5.03	0.00	0.000	3.11	0.617	0.0	100.0	0.000	1.68	105.0	0.0

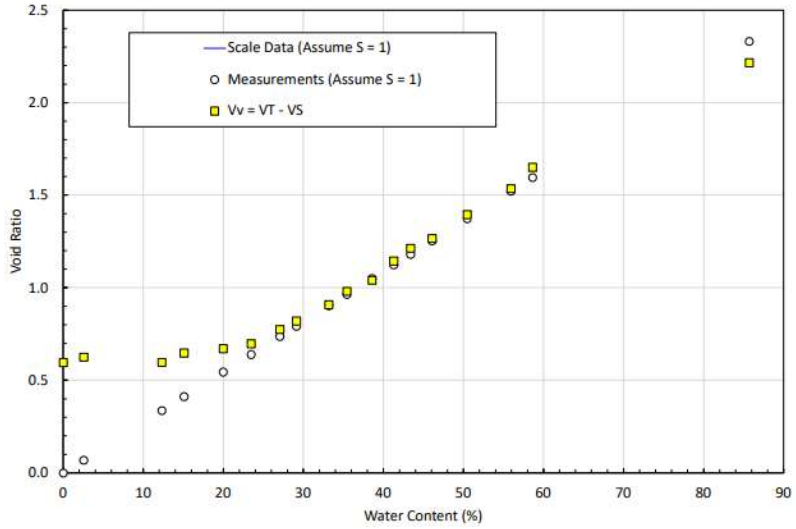


Shrinkage Curves

Specimen	Start Date & Time	Full Tare Mass (g)	Initial Total Specimen Mass (g)	Initial Specimen Thickness (cm)	Initial Specimen Diameter (cm)	Total Specimen Volume (cm^3)	Initial Solids Content (%)	Initial Solids Mass (g)	Specific Gravity	Final Oven-Dried Solids (g)	Solid Volume (cm^3)
Specimen B	8/31/2022 12:16	25.45	25.46	1.218	4.116	16.21	53.85	13.71	2.72	13.71	5.04

Physical Measurements of Volume Change

Date & Time	Elapsed Time (d)	M_T (g)	ΔH (cm)	ΔD (cm)	H (cm)	D (cm)	V_T (cm^3)	ΔV_T (cm^3)	M_S (g)	M_W (g)	V_S (cm^3)	V_W (cm^3)	Void Ratio (assume S = 1)	V_V (cm^3)	Void Ratio	Gravimetric Water Content (%)	Solids Content (%)	Volumetric Water Content (%)	Dry Density (g/cm^3)	Dry Density (pcf)	Degree of Saturation (%)
8/31/2022 12:16	0	25.46	0	0	1.218	4.116	16.2	0.0	13.71	11.75	5.04	11.75	2.331	11.17	2.215	85.7	53.8	0.725	0.85	52.8	105.2
9/1/2022 7:30	0.801	21.75	0.2138	0.000	1.004	4.116	13.4	2.8	13.71	8.04	5.04	8.04	1.595	8.32	1.651	58.6	63.0	0.602	1.03	64.1	96.6
9/1/2022 9:30	0.885	21.38	0.2575	0.000	0.961	4.116	12.8	3.4	13.71	7.67	5.04	7.67	1.522	7.74	1.536	55.9	64.1	0.600	1.07	67.0	99.1
9/1/2022 14:00	1.072	20.63	0.3108	0.000	0.907	4.116	12.1	4.1	13.71	6.92	5.04	6.92	1.373	7.03	1.395	50.5	66.5	0.573	1.14	70.9	98.4
9/2/2022 7:30	1.801	20.03	0.3598	0.000	0.858	4.116	11.4	4.8	13.71	6.32	5.04	6.32	1.254	6.38	1.266	46.1	68.4	0.553	1.20	75.0	99.1
9/2/2022 9:45	1.895	19.66	0.3798	0.000	0.838	4.116	11.2	5.1	13.71	5.95	5.04	5.95	1.180	6.11	1.213	43.4	69.7	0.533	1.23	76.7	97.3
9/2/2022 11:30	1.968	19.37	0.4060	0.000	0.812	4.116	10.8	5.4	13.71	5.66	5.04	5.66	1.123	5.76	1.144	41.3	70.8	0.524	1.27	79.2	98.2
9/2/2022 13:30	2.051	19.00	0.4033	0.108	0.815	4.008	10.3	5.9	13.71	5.29	5.04	5.29	1.050	5.24	1.039	38.6	72.2	0.515	1.33	83.3	101.0
9/2/2022 15:40	2.142	18.57	0.3980	0.179	0.820	3.937	10.0	6.2	13.71	4.86	5.04	4.86	0.964	4.94	0.980	35.4	73.8	0.487	1.37	85.7	98.3
9/6/2022 7:25	5.798	18.26	0.4110	0.220	0.807	3.896	9.6	6.6	13.71	4.55	5.04	4.55	0.903	4.58	0.908	33.2	75.1	0.473	1.43	89.0	99.4
9/6/2022 11:30	5.968	17.70	0.4220	0.286	0.796	3.830	9.2	7.0	13.71	3.99	5.04	3.99	0.792	4.13	0.819	29.1	77.4	0.435	1.49	93.3	96.7
9/7/2022 9:20	6.878	17.42	0.4268	0.323	0.791	3.793	8.9	7.3	13.71	3.71	5.04	3.71	0.736	3.90	0.774	27.1	78.7	0.415	1.53	95.7	95.1
9/7/2022 11:30	6.968	16.93	0.4340	0.389	0.784	3.727	8.6	7.7	13.71	3.22	5.04	3.22	0.639	3.51	0.697	23.5	81.0	0.376	1.60	100.1	91.7
9/7/2022 13:40	7.058	16.45	0.4398	0.405	0.778	3.711	8.4	7.8	13.71	2.74	5.04	2.74	0.544	3.38	0.670	20.0	83.3	0.325	1.63	101.7	81.1
9/7/2022 16:40	7.183	15.78	0.4393	0.432	0.779	3.684	8.3	7.9	13.71	2.07	5.04	2.07	0.411	3.26	0.647	15.1	86.9	0.249	1.65	103.1	63.5
9/12/2022 8:10	11.829	15.40	0.4600	0.439	0.758	3.677	8.0	8.2	13.71	1.69	5.04	1.69	0.335	3.01	0.597	12.3	89.0	0.210	1.70	106.4	56.2
9/12/2022 16:30	12.176	14.06	0.4483	0.436	0.770	3.680	8.2	8.0	13.71	0.35	5.04	0.35	0.069	3.15	0.625	2.6	97.5	0.043	1.67	104.5	11.1
9/13/2022 9:45	12.895	13.71	0.4620	0.435	0.756	3.681	8.0	8.2	13.71	0.00	5.04	0.00	0.000	3.00	0.596	0.0	100.0	0.000	1.70	106.4	0.0

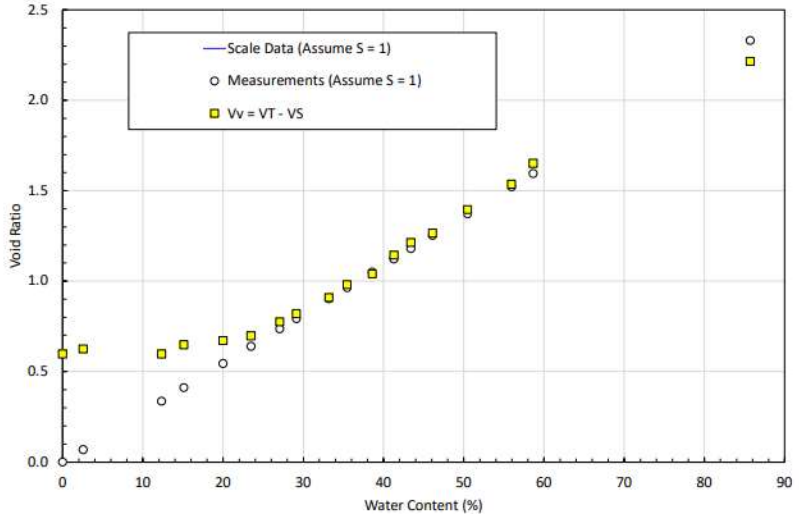


Shrinkage Curves

Specimen	Start Date & Time	Full Tare Mass (g)	Initial Total Specimen Mass (g)	Initial Specimen Thickness (cm)	Initial Specimen Diameter (cm)	Total Specimen Volume (cm^3)	Initial Solids Content (%)	Initial Solids Mass (g)	Specific Gravity	Final Oven-Dried Solids (g)	Solid Volume (cm^3)
Specimen C	8/31/2022 12:18	26.18	26.68	1.261	4.119	16.80	53.75	14.34	2.72	14.34	5.27

Physical Measurements of Volume Change

Date & Time	Elapsed Time (d)	M_T (g)	ΔH (cm)	ΔD (cm)	H (cm)	D (cm)	V_T (cm^3)	ΔV_T (cm^3)	M_S (g)	M_W (g)	V_S (cm^3)	V_W (cm^3)	Void Ratio (assume S = 1)	V_V (cm^3)	Void Ratio	Gravimetric Water Content (%)	Solids Content (%)	Volumetric Water Content (%)	Dry Density (g/cm^3)	Dry Density (pcf)	Degree of Saturation (%)
8/31/2022 12:18	0	26.68	0	0	1.261	4.119	16.8	0.0	14.34	12.34	5.27	12.34	2.341	11.53	2.187	86.1	53.7	0.735	0.85	53.3	107.0
9/1/2022 7:30	0.800	22.75	0.2093	0.000	1.052	4.119	14.0	2.8	14.34	8.41	5.27	8.41	1.595	8.74	1.658	58.6	63.0	0.600	1.02	63.9	96.2
9/1/2022 9:30	0.883	22.37	0.2565	0.000	1.004	4.119	13.4	3.4	14.34	8.03	5.27	8.03	1.523	8.11	1.538	56.0	64.1	0.600	1.07	66.9	99.0
9/1/2022 14:00	1.071	21.57	0.3008	0.000	0.960	4.119	12.8	4.0	14.34	7.23	5.27	7.23	1.371	7.52	1.426	50.4	66.5	0.565	1.12	70.0	96.1
9/2/2022 7:30	1.800	20.93	0.3568	0.000	0.904	4.119	12.0	4.8	14.34	6.59	5.27	6.59	1.250	6.77	1.285	46.0	68.5	0.547	1.19	74.3	97.3
9/2/2022 9:45	1.894	20.55	0.3845	0.000	0.876	4.119	11.7	5.1	14.34	6.21	5.27	6.21	1.178	6.40	1.215	43.3	69.8	0.532	1.23	76.7	97.0
9/2/2022 11:30	1.967	20.24	0.3900	0.087	0.871	4.032	11.1	5.7	14.34	5.90	5.27	5.90	1.119	5.85	1.109	41.1	70.8	0.531	1.29	80.5	100.9
9/2/2022 13:30	2.050	19.88	0.3855	0.182	0.875	3.938	10.7	6.1	14.34	5.54	5.27	5.54	1.051	5.39	1.022	38.6	72.1	0.520	1.35	84.0	102.9
9/2/2022 15:40	2.140	19.43	0.3948	0.221	0.866	3.899	10.3	6.5	14.34	5.09	5.27	5.09	0.965	5.07	0.961	35.5	73.8	0.492	1.39	86.6	100.5
9/6/2022 7:25	5.797	19.12	0.4148	0.250	0.846	3.869	9.9	6.9	14.34	4.78	5.27	4.78	0.907	4.67	0.887	33.3	75.0	0.481	1.44	90.0	102.3
9/6/2022 11:30	5.967	18.55	0.4015	0.297	0.859	3.822	9.9	6.9	14.34	4.21	5.27	4.21	0.799	4.59	0.870	29.4	77.3	0.427	1.45	90.8	91.8
9/7/2022 9:20	6.876	18.26	0.4030	0.346	0.858	3.773	9.6	7.2	14.34	3.92	5.27	3.92	0.744	4.32	0.819	27.3	78.5	0.409	1.50	93.4	90.8
9/7/2022 11:30	6.967	17.76	0.4218	0.410	0.839	3.709	9.1	7.7	14.34	3.42	5.27	3.42	0.649	3.79	0.719	23.8	80.7	0.377	1.58	98.8	90.2
9/7/2022 13:40	7.057	17.26	0.4343	0.435	0.827	3.684	8.8	8.0	14.34	2.92	5.27	2.92	0.554	3.54	0.671	20.4	83.1	0.332	1.63	101.6	82.6
9/7/2022 16:45	7.185	16.58	0.4208	0.457	0.840	3.662	8.8	8.0	14.34	2.24	5.27	2.24	0.425	3.57	0.678	15.6	86.5	0.253	1.62	101.2	62.7
9/12/2022 8:15	11.831	16.23	0.4393	0.466	0.822	3.653	8.6	8.2	14.34	1.89	5.27	1.89	0.358	3.34	0.633	13.2	88.4	0.219	1.67	104.0	56.6
9/12/2022 16:35	12.178	14.76	0.4508	0.464	0.810	3.655	8.5	8.3	14.34	0.42	5.27	0.42	0.080	3.23	0.612	2.9	97.2	0.049	1.69	105.4	13.0
9/13/2022 9:45	12.894	14.34	0.4443	0.462	0.817	3.657	8.6	8.2	14.34	0.00	5.27	0.00	0.000	3.30	0.626	0.0	100.0	0.000	1.67	104.4	0.0



APPEDINX E

CHARACTERIZATION OF DENSITY AFFECTS HYPOTHETICAL EXERCISE

To better understand the sensor behavior resulting from changes in dry density for a given value of volumetric water content or degree of saturation, phase diagrams were created to represent several of the test specimens and are shown in Figure E1. The four series of diagrams represent specimens prepared at constant volumetric water contents of 15% and 25% and constant degrees of saturation of 30% and 60%. The percentage of the specimen by volume for each phase (e.g. solids, water, and air) is included in each diagram. By definition, specimens with the same volumetric water content will have the same volume of water for a given total specimen volume. Specimens with the same degree of saturation will have the same ratio of water to void space by volume within the specimen.

The dielectric permittivity of air is 1, the dielectric permittivity of granite is about 7 to 9, and the dielectric permittivity of water is 80 (Noborio, 2001). By assigning these values of dielectric permittivity to each of the three phases shown in the phase diagrams, an average dielectric permittivity was computed for the entire specimen weighted by volume (Table E1). The following relationship between sensor output in millivolts and apparent dielectric permittivity is provided by the METER Group in the user manual for the Teros 10 sensor.

$$\epsilon = 1.054 \times 10^{-1} \times e^{2.827 \times 10^{-3} \times mV}$$

By rearranging this equation, a predicted sensor output in millivolts can be determined based on the hypothetical average dielectric permittivity values presented in Table E1.

The relationships between specimen dry density and predicted sensor output for each volumetric water content and degree of saturation are shown in Figure E2 and Figure E3. Based on the plotted data, the relationship between dry density and predicted sensor output is linear for each series of hypothetical specimens. Little variation was noted between the slope of the lines for simulated specimens at volumetric water contents of 15% and 25% (Figure E2). As the degree of saturation increases from 30% to 60%, the relationship between specimen dry density and predicted sensor output becomes increasingly negative (Figure E3). In general, variations in the relationship between dry density and the predicted sensor output for the given volumetric water

content and degrees of saturation exhibit a similar trend as the test results presented in Figure 22 and Figure 23.

Differences in the slopes and predicted sensor output values for this hypothetical exercise are assumed to be due to several factors. First, the assumed dielectric permittivity for each of the three phases within the specimens likely vary from the actual properties of the material tested, particularly the solid and liquid phase. Second, the hypothetical specimens are idealized as homogenous; however, some amount of heterogeneity exists within the actual specimens created during testing. While this exercise explaining the sensor behavior is simplified to some degree, the content offers a general understanding of sensor function and how variations in dry density affect sensor output for given values of volumetric water content and degree of saturation.

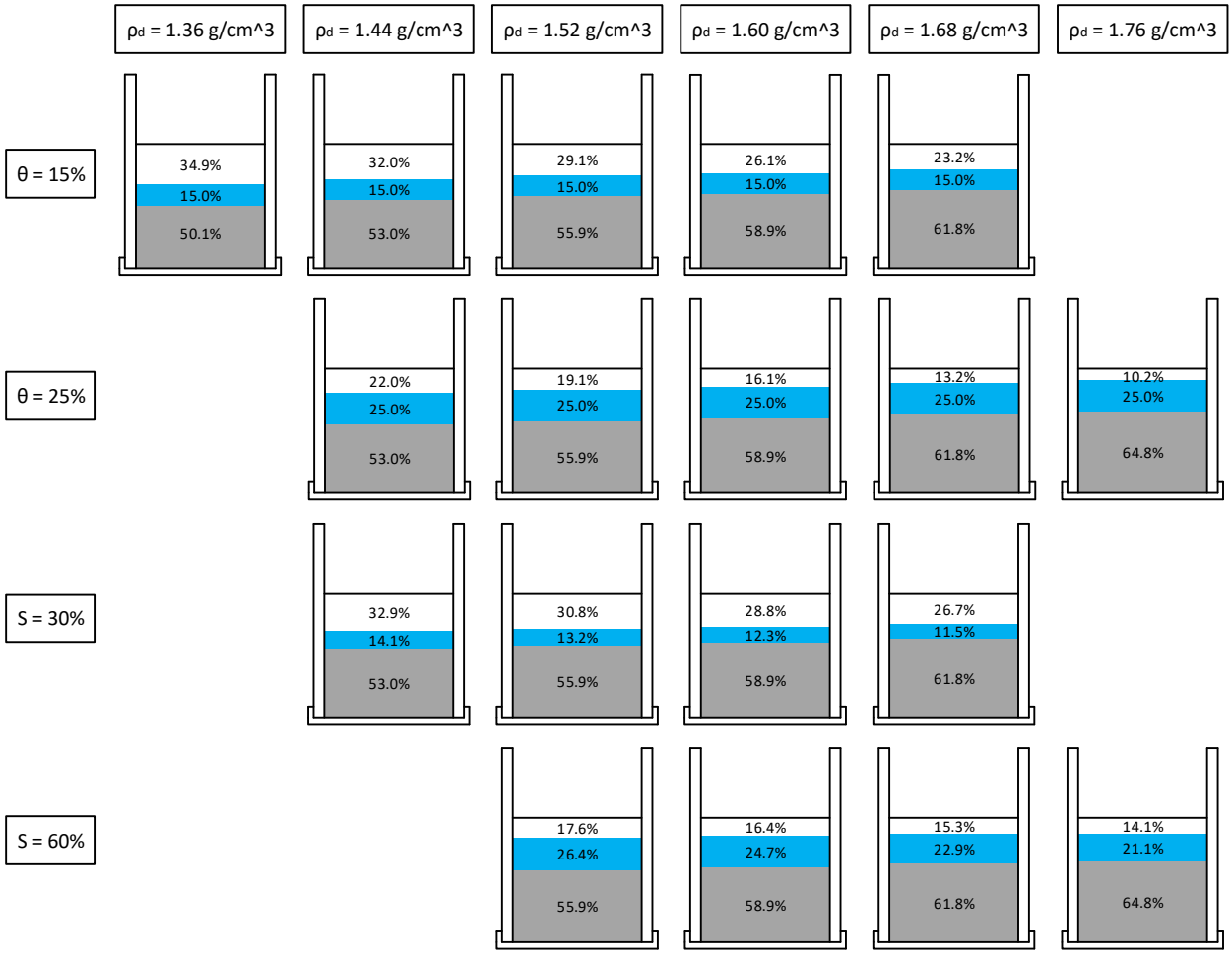


Figure E1. Sketches of phase diagrams representing test specimens prepared at constant values of volumetric water content or degree of saturation. a) Specimens prepared at volumetric water content of 15%. b) Specimens prepared at a volumetric water content of 20%. c) Specimens prepared at a saturation of 45%. d) Specimens prepared at a saturation of 60%.

Table E1. Hypothetical average dielectric permittivity of each specimen weighted by volume.

Volumetric Water Content or Degree of Saturation	Specimen Dry Density					
	1.36 g/cm^3	1.44 g/cm^3	1.52 g/cm^3	1.60 g/cm^3	1.68 g/cm^3	1.76 g/cm^3
Θ = 15%	16.35	16.56	16.77	16.97	17.18	--
Θ = 25%	--	24.46	24.67	24.87	25.08	25.28
S = 30%	--	15.85	15.36	14.87	14.37	--
S = 60%	--	--	25.80	24.61	23.42	22.23

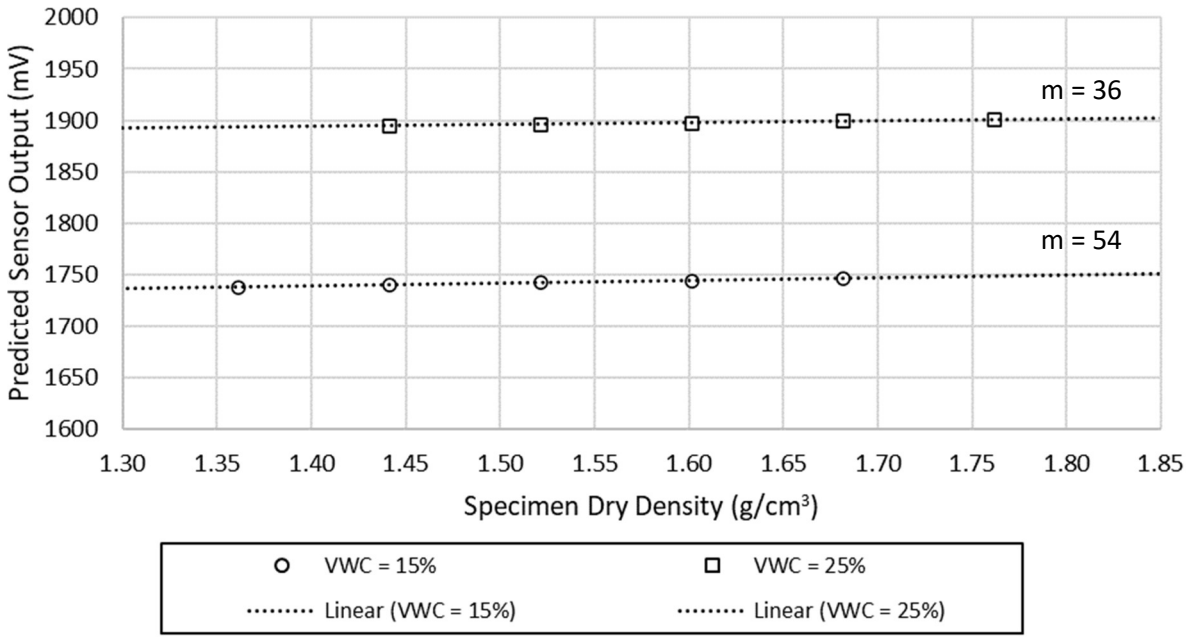


Figure E2. Relationship between specimen dry density and predicted sensor output for specimens prepared at volumetric water contents of 15% and 25%.

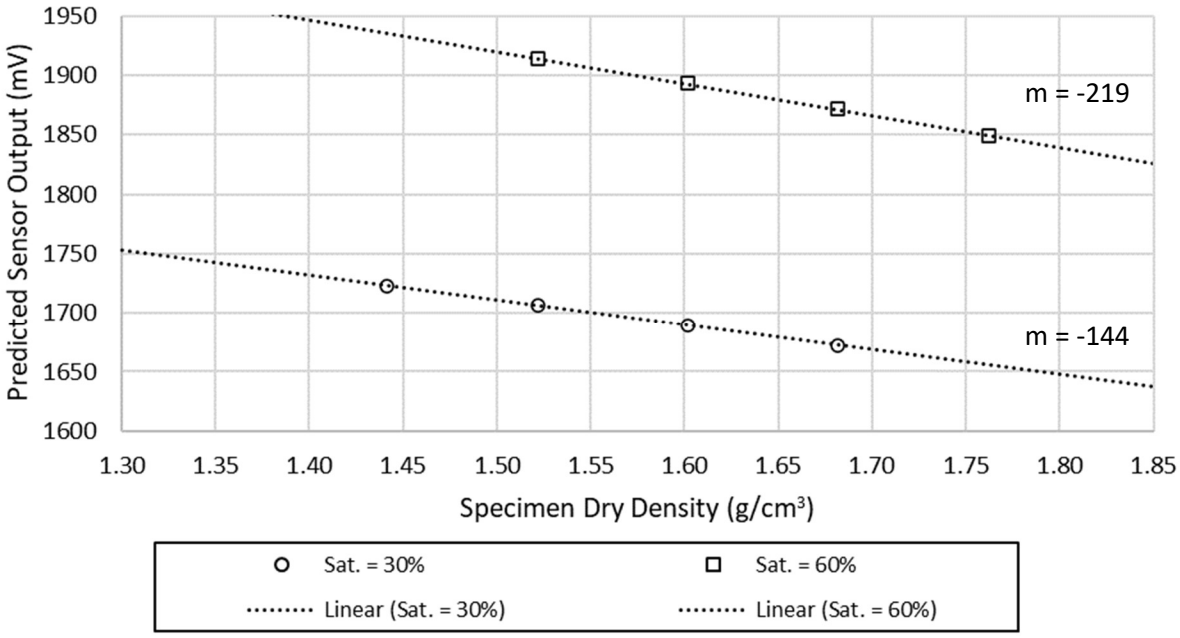


Figure E3. Relationship between specimen dry density and predicted sensor output for specimens prepared at 30% and 60% saturation.