Supplemental Design Investigation Sampling Plan - Revision 1

Northern Impoundment
San Jacinto River Waste Pits Superfund Site

International Paper Company and
McGinnes Industrial
Maintenance Corporation

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1. Introduction

GHD Services Inc. (GHD), on behalf of the International Paper Company and McGinnes Industrial Maintenance Corporation (collectively referred to as the Respondents), submits to the United States Environmental Protection Agency (EPA) this *Supplemental Design Investigation Sampling Plan - Revision 1* (Sampling Plan) for investigation activities at the Northern Impoundment of the San Jacinto River Waste Pits Superfund Site in Harris County, Texas. The Northern Impoundment is shown on Figure 1.

As the methods described herein for conducting the sampling are similar to those that were implemented during the 2019 Second Phase Pre-Design Investigation (PDI-2), this Sampling Plan is supported by the Quality Assurance Project Plan (QAPP), Health and Safety Plan (HASP), and Standard Operating Procedures (SOPs) prepared for the PDI-2 sampling event. The QAPP, HASP and SOPs were included as part of the *Final Second Phase Pre-Design Investigation Work Plan* (PDIWP-2), submitted to the EPA on June 3, 2019 (GHD, 2019) and approved by the EPA on August 8, 2019 (EPA, 2019).

On February 19, 2021, the *Supplemental Design Investigation Sampling Plan* (GHD, 2021a) was submitted to the EPA. A Technical Working Group (TWG) Meeting was held on March 10, 2021 to discuss preliminary comments on the Sampling Plan. Following this meeting, the EPA provided written comments in a letter dated March 29, 2021 (EPA, 2021a). Additionally, a TWG meeting was held on April 19, 2021 to review the Respondents' draft responses to EPA's comments. Following this TWG meeting, additional discussions were held and correspondence were received from the EPA to further review the comments and proposed responses[1],[2]. Respondents' responses to the comments (RTC) are summarized in Table 1 and the comments have been addressed throughout this Sampling Plan.

1.1 Background

During the February 19, 2020, TWG meeting, GHD reported that, based upon newly obtained PDI-2 data, material exceeding the Record of Decision (ROD) clean-up level for the Northern Impoundment of 30 nanograms per kilogram (ng/kg) toxicity equivalents for mammals ($TEQ_{DF,M}$) extended to depths that were significantly deeper than previously understood. GHD further explained that utilizing traditional excavation methodology in dry conditions (referred to as "Approach A" in the *Preliminary 30% Remedial Design - Northern Impoundment* [Northern Impoundment 30% RD], GHD, 2020b) would pose significant risk and technical challenges for the deeper areas within the Northern Impoundment, as excavating within the confines of an impermeable sheet pile barrier, herein referred to as the best management practice (BMP), to the required depth could undermine the structural integrity of the BMP. Therefore, when the Northern

[1] Email correspondence from the EPA dated May 5, 2021 and May 9, 2021.

[2] The schedule as outlined in the Request for Extension Letter approved by the EPA on March 29, 2021, was contingent upon final approval of the Supplemental Design Investigation Sampling Plan by April 30, 2021. The extended EPA review period and the expansion in the scope of the work mean that the information needed to complete the 90% Remedial Design will not be available in time to meet the current extended deadline for its submission, and that an additional extension of the schedule will be necessary, as will be detailed in a forthcoming extension request.

Impoundment 30% RD was submitted, it included an “Approach B” as an alternative for excavation in areas of deeper waste depths. This approach included installing the BMP and then removing material exceeding the clean-up level through a column of water using barge-mounted excavation equipment. As described in the Northern Impoundment 30% RD, this approach requires that prior to the end of an excavation season, the water within the BMP would be recirculated through a treatment system until it achieved the Texas Surface Water Quality Standard (as demonstrated through compliance with the Minimum Level [ML]). In order to evaluate the practicality and effectiveness of this conceptual approach, additional treatability testing was proposed. The proposed treatability testing was summarized in the *Additional Treatability Testing Notice*, submitted to the EPA on April 16, 2020 (GHD, 2020a). Comments were received from the EPA on May 5, 2020 (EPA, 2020a). These comments were addressed in the *Revised Additional Treatability Testing Notice* (Notice), submitted to the EPA on June 5, 2020 (GHD, 2020c), and approved by the EPA on June 11, 2020 (EPA, 2020b).

The additional treatability testing, as described in the Notice, included a bench-scale simulation of the recirculation process through a bench-scale filtration system. The recirculation testing was conducted by the GHD Treatability Laboratory in Niagara Falls, New York. Recirculation testing was initiated on November 7, 2020 (testing was delayed by material and supply chain issues associated with the COVID-19 Pandemic). Treatability data indicated that after 16 days of recirculation, the total suspended solids (TSS) reduction had plateaued at around 500 milligrams per liter (mg/L), meaning that the ML could not be achieved. Testing was suspended and modifications were made to the mixing methodology. The recirculation testing was then resumed for an additional 225 hours. Results from the additional testing were consistent with those obtained during the initial 16 days, with TSS never reaching levels below 500 mg/L.

As presented during the December 15, 2020, TWG meeting, Approach B water treatment is infeasible for full-scale application during the remedial action (RA) based on the results of the recirculation testing described above. Since the water treatment for Approach B is infeasible, Approach B excavation methodology is also infeasible. As a result, the Respondents are evaluating a significant modification to the RD to focus on performing all excavation work “in the dry”. As was discussed during the February 2020 TWG meeting when Approach B was proposed, there are significant challenges and risks associated with excavating the deeper areas in dry conditions. Additional data is required to evaluate the feasibility of excavating the deeper areas in the dry.

As discussed during the December 15, 2020, TWG meeting, an additional field investigation needs to be performed to better inform the modified RD and to fill data gaps in the delineation of the vertical extent of the material that must be excavated. Based on data collected during the first and second phases of the PDI, there are three locations where vertical delineation to concentrations below the clean-up standard of 30 ng/kg $TEQ_{DF,M}$ was not achieved. There are also data gaps in the spatial coverage of sampling locations along the perimeter and in the interior of the Northern Impoundment where, in the absence of additional sampling, target excavation elevations would have to be based on assumptions from surrounding datapoints. These data gaps were less of a concern when Approach B excavation methodology was thought to be feasible. The supplemental design investigation, described herein, will provide the Respondents with information that will aid in designing a structurally robust BMP, potentially capable of withstanding forces associated with excavation in the deeper areas of the Northern Impoundment. It will also allow the Respondents to develop a more robust estimate of the total volume of material for disposal, information that will aid in logistical planning, sequencing, and scheduling of the RA.

The current proposed BMP design includes a double wall system with shallower embedment depths than the single cantilever wall proposed in the Northern Impoundment 30% RD. The double wall is expected to be further offset from the area of excavation than had been previously described in the Northern Impoundment 30% RD in order to increase the structural stability of the BMP system. Prior investigations did not include collection of data regarding soil properties and stratigraphy in the areas of potential wall construction for the current conceptual BMP. Given the modified alignment and shallower embedment depths of the BMP resulting from the infeasibility of Approach B methodology, it is essential to collect additional geotechnical data to better understand the soil properties and thickness of the shallow stratigraphy in locations in and near the current conceptual BMP alignment. With the change in excavation methodology, an additional risk that needs to be evaluated is the potential for hydraulic heave during the RA in the deeper excavation areas. GHD proposes to install geotechnical borings as part of the supplemental design investigation to evaluate this risk, and to collect additional subsurface stratigraphy to better inform the current conceptual alignment of the BMP. The geotechnical evaluation will also include collection of hydraulic conductivity data for the material to be excavated to better estimate the amount of infiltration water that will require management during the RA.

1.2 Objectives

The objectives of the supplemental design investigation include the following:

- Further delineate the vertical extent of the material exceeding the ROD clean-up level around the perimeter of the excavation area to support the recently optimized conceptual BMP design, elements of the anticipated remediation methodology (such as the double wall cofferdam, Approach A only excavation, BMP alignment to allow a soil buttress for stability, etc.) and other aspects of the RD.
- Fill data gaps in the vertical and horizontal extent of material exceeding the ROD clean-up level across the area anticipated to be excavated to better refine the estimated excavation bottom and volume of material to be removed (due to the increased depths encountered during the PDI, and to provide information for post-excavation confirmation sampling).
- Collect additional geotechnical data along the current conceptual alignment of the BMP to inform the BMP design.
- Collect additional hydraulic conductivity data of the material to be excavated to better estimate the amount of seepage water that will require management during the RA.
- Collect additional hydraulic conductivity and pressure data to evaluate the risk of hydraulic heave during the RA.

Additional activities with separate objectives are being required by the EPA that were not a part of the original plan or the objectives listed above.

2. Sampling Plan

Data collection will be conducted in accordance with applicable EPA and Texas Commission on Environmental Quality (TCEQ) guidance and utilize best practices and lessons learned from the investigation activities conducted during the first and second phases of the PDI.

2.1 Sample Collection Objective and Location Rationale

2.1.1 Analytical Samples

Samples will be collected at the Northern Impoundment to further delineate the vertical and horizontal extent of material exceeding the ROD clean-up level. Northern Impoundment analytical sample locations were selected to supplement previously obtained horizontal and vertical $TEQ_{DF,M}$ delineation data. Sampling locations were chosen to fill data gaps from previous sampling events. Proposed sample locations are shown on Figure 2. These locations are approximate and are subject to change based upon field conditions, including (but not limited to) subsurface impediments and accessibility. If it is necessary to move a boring location, the EPA will be notified to discuss alternatives[3]. Figure 2 also includes the boring locations from the Remedial Investigation (RI), First Phase Pre-Design Investigation (PDI-1), and PDI-2.

A total of 420 discrete samples will be collected from 35 locations across the area of excavation. Discrete samples will be collected from 2-foot intervals, beginning at 0 to 2 feet below ground surface (ft bgs) to 22 to 24 ft bgs. The sample intervals from 0 to 18 ft bgs will be analyzed by an accredited laboratory, and the sample intervals from 18 to 24 ft bgs will be archived by the laboratory pending the results of the 16 to18 ft bgs sample interval. Analysis of the 16 to18 ft bgs interval from each location will be prioritized to expedite the determination as to whether the samples from the deeper intervals should be analyzed. If the 16 to 18 ft interval yields an analytical result with $TEQ_{D,F,M}$ levels > 30 ng/kg, the three deeper intervals from 18 to 24 ft will all be analyzed. If the 22-ft to 24-ft interval is greater than 30 ng/kg, the Respondents will discuss with the EPA whether it is technically practicable to sample at lower depths.

For the proposed collocated borings adjacent to historical borings with $TEQ_{D,F,M}$ levels > 30 ng/kg (SJGB010, SJGB012, SJSB036, SJSB046-C1, and SJSB071), with the exception of SJSB083 and SJSB101 which will be analyzed for waste characterization purposes, only samples in the collocated borings that are deeper than the terminal depth of each historical boring with $TEQ_{D,F,M}$ levels > 30 ng/kg will be analyzed. For example, at proposed boring location SJSB072, the first sample analyzed would be the interval from 8 to 10 ft bgs, because collocated historical boring SJGB012 had a $TEQ_{D,F,M}$ level > 30 ng/kg at its terminal depth of 8 ft bgs.

Determining the sequence in which the borings will be advanced will be heavily dependent on weather and tidal conditions. Tidal conditions contribute to the water level in the San Jacinto River along with the wind speed and direction. These weather and tidal conditions will largely determine what type of drilling method (tracked drilling rig versus airboat-mounted drilling rig) will need to be used to complete borings in locations with highly variable water depths.

[3] Any delay on the part of the EPA in responding to requests to adjust boring locations based upon field conditions could impact the schedule and time necessary to complete the investigation.

There are five proposed boring locations that are collocated with historical sample locations in which an interval below the clean-up standard was not observed at the bottom of the boring (i.e., SJSB072, SJSB075, SJSB077, SJSB083, and SJSB101). Three of the five locations are in upland areas (SJSB072, SJSB075, SJSB077). These three borings will be completed first by the land-based drill rig. The other two locations (SJSB083 and SJSB101) are in areas that are normally covered in water. These locations will be prioritized, but access may be affected by weather, tidal conditions, etc. In addition, boring locations in which subsurface data is more critical to the design of the BMP (i.e., around the perimeter) will be prioritized to the extent possible.

2.1.2 Geotechnical Samples

To delineate the subsurface stratigraphy along or in reasonable proximity to the current conceptual BMP alignment, eleven geotechnical borings will be installed to facilitate a Cone Penetrometer Test (CPT) investigation. CPT is a widely accepted in-situ geotechnical investigation method that involves pushing a cone penetrometer into the ground at a constant rate that records data in real-time during penetration. The cone penetrometer is equipped with electronic sensors that measure pore pressure, cone resistance at the tip and sleeve friction. As the cone takes continuous readings through the soil, the data can be correlated to data regarding the soil's strength, friction angle, pore water pressure, and soil behavior (soil classification and type).

Ten of these CPT borings will be installed along or in reasonable proximity to the current conceptual BMP alignment. No geotechnical samples will be collected for analysis at these locations. In order to correlate the newly-collected CPT data to existing geotechnical laboratory test data, a "calibration boring" is necessary. The calibration boring will collect both CPT data and geotechnical laboratory test data from ground surface to the Beaumont Sands. To that end, an eleventh CPT boring will be installed adjacent to planned piezometer location, SJMW-016 (described in Section 2.4) to provide the CPT data. To provide the corresponding laboratory test data for comparison, during the installation of piezometer SJMW-016, geotechnical samples will be collected for laboratory analysis. CPT data and physical samples will be collected along the entire length of this deep boring, including from the Beaumont Clay and Beaumont Sand layers (historical investigations have had limited data from these lower geological strata). Using the common set of information and well-defined relationships for various parameters available from the two tests, the CPT results obtained from the ten borings along the current conceptual BMP alignment can be calibrated using data from SJMW-016 and correlated to existing geotechnical laboratory test data from past investigations.

The locations of the proposed CPT borings and historical geotechnical borings are shown on Figure 3. These locations are approximate and are subject to change based upon field conditions encountered. Shear vane strength readings in accordance with ASTM Methods D2573 and STP 1014 will be taken in the top four to five feet of CPT borings SJCPT-002, SJCPT-003, and SJCPT-004 to provide more information about the shallow sediments in the northwest corner.

Consistent with the protocol followed during PDI-2 for all boring locations, a CPT boring location may be moved within 25 feet of its proposed location if necessary, to avoid refusal or surface impediments. If it is necessary to move a CPT boring location farther than 25 feet from the proposed location, the proposed new location will be discussed with the EPA at that time[4]. To supplement the geotechnical dataset for the RD, and to refine the assumptions regarding the grade of the excavation slope, three planned analytical boring locations on the southeast side of the Northern Impoundment will be extended beyond 24 ft bgs until the Beaumont clay formation is encountered. Subsurface stratigraphy will be logged but no samples will be collected below 24 ft bgs for analysis. These boring locations (SJSB084, SJSB085, and SJSB091) are shown on Figures 2 and 3.

2.1.3 Additional Waste Characterization Samples

As required by EPA, four additional waste characterization samples will be collected. The waste characterization samples will be collected from two planned analytical borings (SJSB083 and SJSB101), as shown on Figure 2. During installation of borings SJSB083 and SJSB101, duplicate samples will be collected from each planned 2-ft interval from 0 to 24 ft bgs. The samples for analytical characterization will be analyzed per the sampling program outlined in the proposed Sampling Plan and the waste characterization samples will be archived pending the results of the characterization samples. Upon receipt of the analytical results for the characterization samples, the two samples in each boring with the highest dioxins concentrations will be identified and the duplicate samples from those intervals will be analyzed for all four RCRA hazardous waste characteristics per EPA-required test methodology in 40 CFR Part 261. The list of parameters is provided in Table 3.

2.2 Drilling and Sampling Methods

Drilling methods suitable for sample collection at the Northern Impoundment during this Sampling Event were identified using ASTM D6286-12, Selection of Drilling Methods for Environmental Site Characterization. Drilling methods that may be used include sonic, large diameter, dual-tubed direct-push (e.g., Geoprobe®DT45), mud-rotary, or a hollow stem auger drilling rig. Typically, these types of drill rigs are mounted onto specialized tracked or self-propelled vehicles, trucks, or boats. Similar to the work performed during PDI-2, upland boring locations will likely be installed using track or truck-mounted drilling equipment and water borings will be installed using barge or airboat-mounted drilling equipment.

Sonic and direct push methods are widely accepted throughout the United States for soil sampling and are standardized by ASTM Methods D6914, D6282, and D5784. All sampling equipment, materials, consumables, tools, and other support equipment will be provided by the drilling subcontractor and will be stored on the drill rig.

Upon completion of sampling, soil borings will be plugged with cementitious grout, in accordance with 16 Texas Administrative Code (TAC) §76.104, Standards for Capping and Plugging of Wells. After each boring is filled with grout, any sample collected from a location within the Time Critical Removal Action (TCRA) cap will be restored, as described in Section 2.5.

[4] As noted in Section 2.1.1, a delay in the EPA's responses to requests to adjust boring locations based upon field conditions could impact the schedule and delay completion of the investigation

2.3 Supplemental Data Collection

In addition to the sampling described above, supplemental data will be collected to support the design of turbidity control measures for use during installation and removal of the BMP during the RA. These data collection activities will focus on thicknesses of surface materials, geotechnical characteristics of surficial sediment and velocity measurements in locations outside the proposed BMP alignment (Figure 4). Each of these data collection activities is described below.

2.3.1 Sediment and Rock Thickness

The extent and thickness of armor rock along the alignment of the proposed BMP will be investigated, together with the thickness of any sediment deposited on top of the armor rock. The information will be collected by diver assisted probing at specific intervals and will be further verified by examining past quarterly bathymetry surveys.

2.3.2 Surficial Sediments Geotechnical Properties

Six samples of river sediment that has deposited on top of the armor rock will be collected with diver assistance in Lexan® tubes that are hand driven into the sediment. The sediment within each tube will be composited to form a single sample for geotechnical analyses. Multiple cores may be collected adjacent to each other if necessary to collect sufficient sample for testing. If the sediment is too soft to stay within the tube, alternate sample collection techniques will be employed such as scooping sediment into a sample container. Sample locations are shown in orange on Figure 4. Divers will be required to clear surficial rock prior to installing each of the CPT borings. At the time of clearing the CPT boring locations, the nearby six surficial sediment samples will be collected at the six locations referenced above. In addition to surficial rock, geotextile also will be temporarily removed as necessary to facilitate sample collection and replaced following sample collection. Samples will be collected by the divers pushing a Lexan® tube into the sediment to collect a minimum 6-inch thick sample. Multiple cores may be collected adjacent to each other if necessary, to collect sufficient sample for testing. If the sediment is too soft to stay within the tube, alternate sample collection techniques will be employed. An additional four locations (shown in red on Figure 4) will be sampled in a similar manner though the removal of rock and/or geotextile at these locations should not be necessary. Both sets of samples will be shipped under chain-of-custody procedures to a geotechnical laboratory for testing. Each sample will be tested for water content (ASTM D2216), dry density (ASTM D2937), Atterberg Limits (ASTM D4318), specific gravity (ASTM D854), particle size distribution (ASTM D422) and organic carbon content (ASTM D2974). The samples will also be tested for consistency/stickiness using the Natural Resources Conservation Service method. Planned analytical tests are summarized in Table 2.

2.3.3 Water Velocity Measurements

Up to four velocity meters (e.g., acoustic doppler current profiler) will be deployed outside of the conceptual BMP alignment in the approximate locations shown on Figure 4. The exact locations will be determined in the field to avoid interfering with ongoing activities and other monitoring data collection devices. The meters will be deployed for a minimum of six months. The goal is to collect continuous velocity data via data loggers that can be transmitted automatically or retrieved through periodic downloads. These data will be used in the selection and design of turbidity controls to be utilized during the RA.

2.4 Piezometer Installation

Four piezometers will be installed during the supplemental design investigation to better understand the hydraulic conductivity and subsurface hydrostatic pressure of the groundwater bearing units below the Northern Impoundment. The locations of the proposed piezometers are shown on Figure 3.

A shallow piezometer will be installed at proposed boring SJMW-014 to get a better understanding of the hydraulic conductivity of the waste material itself. This information will aid in the design of water management and storage systems during the RA. Data from adjacent RI boring, SJGB012, indicate that the waste material extends to a depth of -8 ft mean sea level (msl), so a piezometer will be installed to a total depth of -8 ft msl and screened across the entire interval.

An intermediate piezometer will be installed at proposed boring SJMW-015 to obtain a better understanding of the hydraulic conductivity of the more permeable zone directly below the waste material. This information will be used to support the evaluation of water infiltration rates and volumes expected during the RA. A piezometer will be installed to a total depth of -25 ft msl and screened from approximately -20 to -25 ft msl.

With the change in planned excavation methodology, the design must now account for deep excavation areas that will be excavated in the dry. To account for the lack of weight and downward pressure from the water under the Approach B flooded condition, additional geotechnical data is needed to evaluate the potential for hydraulic heave during excavation in those locations. Deep piezometers will be installed at proposed borings SJMW-016 and SJMW-017. These piezometers will extend into the sand layer below the Beaumont Clay Formation, approximately -50 ft msl. Upon completion of the boreholes, piezometers will be installed and screened from approximately -50 to -60 ft msl, or the top ten feet of the lower sand layer.

During the installation of deep piezometer, SJMW-016, split spoon and Shelby Tube samples will be collected as explained in Section 2.1.2 and as summarized in Table 2. The samples will be shipped under chain-of-custody procedures to a geotechnical laboratory for testing. Each sample will be tested for Unconsolidated Undrained Compression Test (ASM D2850), Atterberg Limits (ASTM D4318), moisture content (ASTM D2216), grain size (ASTM D6913/D7928), and #200 wash (ASTM D1140).

The confined Beaumont Sand is expected to have a relatively gradual hydraulic gradient. The two measurement points obtained from SJMW-016 and SJMW-017 will be compared to each other and available historical well measurements to confirm the gradual hydraulic gradient. This low gradient will allow the water levels taken at SJMW-016 and SJMW-017 to be extrapolated to approximate water levels across the entire excavation area.

All four piezometers will be constructed of 2-inch diameter Schedule 40 polyvinyl chloride (PVC) threaded casing. After development, a transducer will be installed, and a slug test will be performed to evaluate the lateral hydraulic conductivity of the strata through which each piezometer is screened, in accordance with the Standard Operating Procedure (SOP), included as Appendix A. A slug test is a controlled field experiment in which the water level in a well/piezometer is caused to change suddenly (e.g. by purging a known amount of water) and the subsequent water-level response (displacement or change from static) is measured through time. Aquifer properties, such as hydraulic conductivity, are estimated by fitting mathematical models to displacement data using a procedure known as curve matching. Piezometer locations SJMW-14 and SJMW-15 were selected from adjacent boring log data to capture the highest representative conductivity values These values will inform choices on peak excavation seepage rates and water volumes. The hydraulic head in the lower sand will be measured after development of the deep piezometers to determine the confined hydrostatic pressure. Pressuremeter Tests will also be performed at multiple intervals in each of the deep piezometers to evaluate the at-rest horizontal pressures of the Beaumont Clay Formation and the sand layer below the Beaumont Clay Formation, in accordance with the SOP included as Appendix B.

2.5 Restoration of TCRA Cap

Collection of samples will require a temporary opening be made in the TCRA cap and removal of armor rock. After sample collection, any casing will be pushed to the sediment surface. In areas in which geotextile is present below the armor rock, new geotextile will be placed over the opened area with a minimum of three feet of overlap and the armor rock will be replaced. In areas in which geomembrane and geotextile are present below the armor rock, a geomembrane patch will be hot-welded onto the existing geomembrane, new geotextile will be placed over the opened area with a minimum of three feet of overlap, and the armor rock will be replaced.

3. Sample Analysis

All samples will be analyzed by an accredited laboratory using EPA approved methods. The sample media, number of samples, and associated analyses are listed in Table 2. All analytical chemistry samples will be analyzed for $TEQ_{D,F,M}$ using EPA Method 1613B, in accordance with the QAPP developed for the PDI-2 fieldwork. The four waste characterization samples will be analyzed for all four RCRA hazardous waste characteristics in accordance with RCRA Title 40 CFR 261.

In accordance with the QAPP, a chain-of-custody (COC) record will be completed during sample collection and will accompany each shipment identifying the contents of the shipment to the laboratory. The field personnel will be responsible for the custody of the samples until the samples are relinquished to the laboratory. Sample transfer will require that the individuals relinquishing and receiving the samples sign, date, and note the time of the sample transfer on the COC record.

Samples will be shipped or delivered in a timely fashion so that holding times and/or analysis times can be met and allow for any carrier delays.

Samples will be transported in containers (i.e., coolers) packed with ice. Samples will be transported via commercial transport or lab provided courier. Samples will be packaged and shipped to the accredited laboratory with a separate COC in each cooler. All samples will be placed in an upright position and limited to one layer of samples per each cooler. Additional bubble wrap or packaging material will be added to fill the cooler. Shipping containers will be secured with strapping and custody tape for shipment to the laboratory.

As previously stated, initially only the 2-ft interval samples collected from 0 to 18 ft bgs will be analyzed by the laboratory. All sample intervals will be analyzed on a standard TAT, though the 16 to 18 ft bgs samples will be prioritized. Samples from intervals 18 to 20, 20 to 22, and 22 to 24 ft bgs will be archived by the laboratory pending results from the 16 to 18 ft bgs interval sample. Upon evaluation of the results from the 16 to 18 ft bgs samples, samples collected from the deeper intervals may be analyzed, as described in Section 2.1.1.

Upon receipt of the preliminary analytical results from SJSB083 and SJSB101, the two 2-ft intervals from each boring that have the highest dioxins concentrations will be analyzed by the laboratory for waste characterization parameters as described in Section 2.1.3

4. Data Validation, Quality Control, and Reporting

The QAPP developed for PDI-2 will be followed for this sampling event. All laboratory analytical data will be reviewed and subsequently validated by a GHD project chemist. The validation of laboratory data will follow the guidance presented in the QAPP and will result in a completed data validation report that will be included in the *Pre-Final 90% Remedial Design - Northern Impoundment*. Analytical results from soil sampling efforts will be presented in a tabular format.

5. Investigation Derived Wastes (IDW)

Investigation derived waste (IDW) will be managed and tracked following the procedures developed for PDI-2 and outlined in the Investigation Derived Material Management SOP included in the PDIWP-2. Solid and liquid IDW from sampling and decontamination activities will be containerized and temporarily stored on-Site. Liquid waste (e.g., decontamination water) and dry waste (e.g., soil cuttings) will be segregated and transferred into United States Department of Transportation approved 55-gallon drums and temporarily stored on-Site prior to shipment to an authorized disposal facility.

All disposable materials used for sample collection and processing, such as paper towels and gloves, will be placed in heavyweight garbage bags or other appropriate containers. Disposable supplies that do not contain contaminated material will be removed from the work-site by sampling personnel and placed in a normal refuse container for disposal at a solid waste landfill.

IDW will be disposed of in accordance with applicable regulations and guidelines.

6. Health and Safety

GHD has developed task-specific Job Safety Analyses (JSAs) and a Site-specific HASP to protect the safety of on-Site workers. The HASP was submitted with the 2019 PDIWP-2. The HASP and JSAs will be present on-Site at all times during fieldwork activities, and they will be updated as needed.

7. References

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Paper Size ANSI B

0 30 60 90 120
Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane Texas South Central FIPS 4204 Feet

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SAN JACINTO RIVER WASTE PITS SITE
HARRIS COUNTY, TEXAS

NORTHERN IMPOUNDMENT

Project No. 11215702
Revision No. -
Date Feb 8, 2021

FIGURE 1

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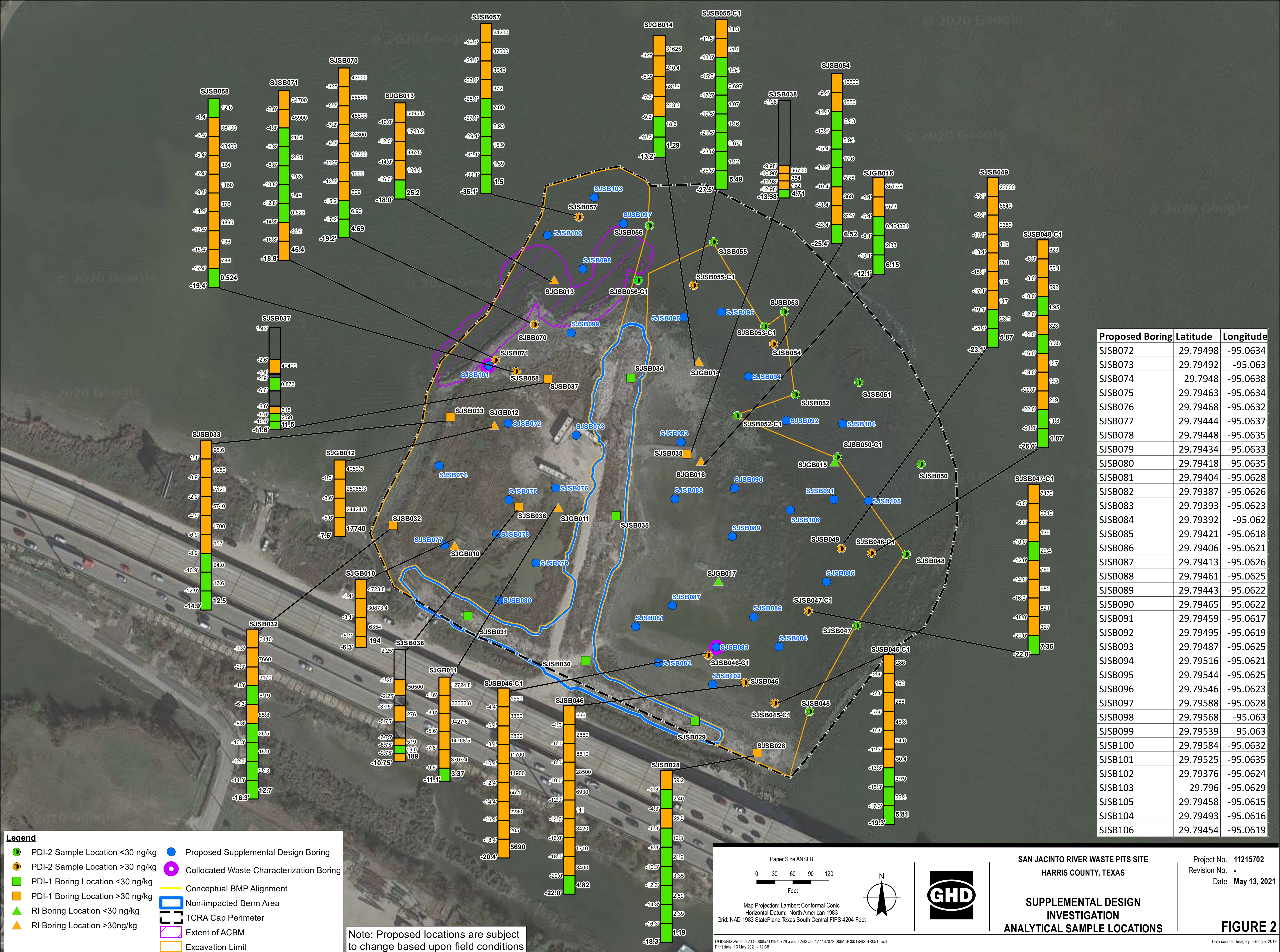
Data source: Imagery - Google, 2019.



Proposed Boring	Latitude	Longitude
SJSB072	29.79498	-95.0634
SJSB073	29.79492	-95.063
SJSB074	29.7948	-95.0638
SJSB075	29.79463	-95.0634
SJSB076	29.79468	-95.0632
SJSB077	29.79444	-95.0637
SJSB078	29.79448	-95.0635
SJSB079	29.79434	-95.0633
SJSB080	29.79418	-95.0635
SJSB081	29.79404	-95.0628
SJSB082	29.79387	-95.0626
SJSB083	29.79393	-95.0623
SJSB084	29.79392	-95.062
SJSB085	29.79421	-95.0618
SJSB086	29.79406	-95.0621
SJSB087	29.79413	-95.0626
SJSB088	29.79461	-95.0625
SJSB089	29.79443	-95.0622
SJSB090	29.79465	-95.0622
SJSB091	29.79459	-95.0617
SJSB092	29.79495	-95.0619
SJSB093	29.79487	-95.0625
SJSB094	29.79516	-95.0621
SJSB095	29.79544	-95.0625
SJSB096	29.79546	-95.0623
SJSB097	29.79588	-95.0628
SJSB098	29.79568	-95.063
SJSB099	29.79539	-95.063
SJSB100	29.79584	-95.0632
SJSB101	29.79525	-95.0635
SJSB102	29.79376	-95.0624
SJSB103	29.796	-95.0629
SJSB105	29.79458	-95.0615
SJSB104	29.79493	-95.0616
SJSB106	29.79454	-95.0619

Paper Size ANSI B

0 30 60 90 120

Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane Texas South Central FIPS 4204 Feet

GHD

SAN JACINTO RIVER WASTE PITS SITE
HARRIS COUNTY, TEXAS

SUPPLEMENTAL DESIGN INVESTIGATION
ANALYTICAL SAMPLE LOCATIONS

Project No. 11215702
Revision No. -
Date May 13, 2021

FIGURE 2

Data source: Imagery - Google, 2019.

SAN JACINTO RIVER WASTE PITS SITE
HARRIS COUNTY, TEXAS

SUPPLEMENTAL DESIGN INVESTIGATION GEOTECHNICAL EVALUATION

Project No. 11215702
Revision No. -
Date May 13, 2021

FIGURE 3

I:\GIS\GIS\Projects\11180000s\11187072\Layouts\MISC001\11187072-00(MISC001)GIS-BR052.mxd
Print date: 13 May 2021 - 12:43

Data source: Imagery - Google, 2019.


WVM-001
WVM-002
WVM-003
WVM-004
SJGC001
SJGC002
SJGC003
SJGC004
SJGC005
SJGC006
SJGC007
SJGC008
SJGC009
SJGC010
Legend
Proposed Geotechnical and Consistency Boring
Proposed Sediment and Rock Thickness, Geotechnical and Consistency Boring
Potential Water Velocity Meter Location
Conceptual BMP Alignment
Non-impacted Berm Area
TCRA Cap Perimeter
Extent of ACBM
Excavation Limit
Note: Proposed locations are subject to change based upon field conditions
Paper Size ANSI B
0 30 60 90 120
Feet
Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane Texas South Central FIPS 4204 Feet
N
SAN JACINTO RIVER WASTE PITS SITE
HARRIS COUNTY, TEXAS
SUPPLEMENTAL DESIGN INVESTIGATION ADDITIONAL DATA COLLECTION
Project No. 11215702
Revision No. -
Date May 7, 2021
FIGURE 4
I:\GIS\GIS\Projects\11180000s\11187072\Layouts\MISC001\11187072-00(MISC001)GIS-BR045.mxd
Print date: 07 May 2021 - 12:19
Data source: Imagery - Google, 2019.

Table 1

Response to Comments – Supplemental Design Investigation
Northern Impoundment
San Jacinto River Waste Pits Site
Harris County, Texas

Item No.	Reference	Comment	Response
General Comments from the EPA			
1	General	Additional waste characterization samples should be taken in locations of known contamination to supplement waste characterization sampling performed during previous PDI activities. Update the plan to include details regarding this additional effort.	During the Pre-Design Investigations (PDI), nine waste characterization samples were collected and analyzed for ignitability, corrosivity, reactivity, and toxicity to determine whether the waste in the Northern Impoundment would be considered Resource Conservation and Recovery Act (RCRA) hazardous waste. In addition to the analysis of these samples, a thorough evaluation of the history and nature of the waste material was also conducted as part of a waste characterization evaluation that was summarized in a letter submitted to the EPA on October 20, 2020. As detailed in the October submittal, the waste material in the Northern Impoundment is not listed hazardous waste under 40 CFR Part 261, Subpart D; nor is it characteristically hazardous, as defined in 40 CFR Part 261, Subpart C. The EPA agreed with this determination in an approval letter dated November 19, 2020. As such, collection of further waste characterization samples is not necessary. However, in response to EPA's request, the Respondents will collect the additional waste characterization samples described below during the supplemental sampling event in areas with known elevated concentrations of dioxins. As required by EPA, four additional waste characterization samples will be collected from two planned analytical borings (SJSB083 and SJSB0101), as shown in Figure 2. During installation of borings SJSB083 and SJSB0101, duplicate samples will be collected from each planned 2-ft interval from 0 - 24 feet below ground surface (ft bgs). The samples for analytical characterization will be analyzed per the sampling program outlined in the proposed Sampling Plan and the waste characterization samples will be archived pending the results of the characterization samples. Upon receipt of the analytical results for the characterization samples, the two samples in each boring with the highest dioxins concentrations will be identified and the duplicate samples from those intervals will be analyzed for all four RCRA hazardous waste characteristics per EPA-required test methodology in 40 CFR Part 261. An explanation of this procedure has been added as Section 2.1.3 of the Sampling Plan. Table 2 was updated to indicate which borings will be analyzed for waste characterization and the list of RCRA hazardous waste parameters is included as Table 3. Figure 2 has been updated to indicate the borings that will be sampled for waste characterization.
Analytical Samples Comments from the EPA			
1	Section 2.1.1	The plan proposes that if the 16-18 ft interval is above the clean-up level, the next interval sample will be analyzed, and so on until a clean interval is observed. To save time and thoroughly delineate the bottom of waste, all three of the archived samples below 18 ft bgs should be analyzed if the 16-18 ft bgs interval concentration is above the clean-up level.	The Respondents acknowledge that there are five historic sample locations (SJGB010, SJGB012, SJSB036, SJSB046-C1, SJSB071) where TEQ levels < 30 ng/kg were not observed at the terminal depth of the boring. Three of these five borings were shallow borings, only extending to terminal depths of 8 - 12 ft bgs. Further, it should be noted that historically, there are no locations at which TEQ levels > 30 ng/kg have been observed in an interval deeper than 18 ft bgs. That said, the Respondents propose to collect samples deeper than 18 ft bgs, as necessary, in an attempt to identify terminal depth TEQ levels < 30 ng/kg. Due to limitations of the drilling methodology, it may not be possible to extend the terminal depth of some borings below 24 ft bgs. The Respondents propose to prioritize the analysis of all 16-18 ft bgs sample intervals to expedite the receipt of results so a determination can be made as to whether to analyze the samples from deeper intervals. If the 16 to 18 ft interval yields an analytical result with a TEQ level > 30 ng/kg, the 18-24 ft intervals will be analyzed. If the 22-ft to 24-ft interval is greater than 30 ng/kg, the Respondents will discuss with the EPA whether it is technically practicable to sample at lower depths. Sections 2.1.1 and 3.0 and Table 2 of the Sampling Plan have been revised to reflect that analysis of the 16-18 ft bgs sample interval will be prioritized to expedite the determination of whether the deeper intervals (18 ft bgs +) need to be analyzed.

Table 1

Response to Comments – Supplemental Design Investigation
Northern Impoundment
San Jacinto River Waste Pits Site
Harris County, Texas

Item No.	Reference	Comment	Response
2	Section 2.1.1 and 3.0	Priority should be given to sample locations where TEQ levels > 30 ng/kg have been observed at depths of 18 ft bgs or more so that analytical results can be reviewed while fieldwork is ongoing and additional samples can be taken if needed. Update the plan to include a schedule/timeline that identifies prioritized sampling locations.	As stated above, the Respondents acknowledge that there are five historic sample locations (SJGB010, SJGB012, SJSB036, SJSB046-C1, and SJSB071) where TEQ levels < 30 ng/kg were not observed at the terminal depth of the boring. Proposed boring locations which are collocated with historic sample locations in which an interval below the clean-up standard was not observed at the bottom of the boring (i.e., SJSB072, SJSB075, SJSB077, SJSB083, SJSB101) will be prioritized to the extent practicable (taking into account weather, tidal conditions, etc.). Three of the five locations are located in upland areas (SJSB072, SJSB075, SJSB077). These three borings will be completed first by the land-based drill rig. The other two locations (SJSB083 and SJSB101) are located in areas that are normally covered in water. These locations will be prioritized, but access may be affected by weather, tidal conditions, etc. In addition, boring locations in which subsurface data is more critical to the design (i.e., around the perimeter) will be prioritized to the extent possible. The text in Section 2.1.1 of the Sampling Plan has been updated accordingly.
3	Section 2.0	One stated objective of the additional sampling is to "further delineate the vertical extent of the material exceeding the ROD clean-up level around the perimeter of the excavation area to support the recently optimized conceptual BMP design." The 30% Northern Impoundment Remedial Design states that "Once the BMP is designed and constructed, excavation to deeper elevations in an attempt to reach a clean-up level cannot exceed the design excavation elevations for the BMP, as doing so has the potential to put more hydraulic force on the BMP and presents a risk of a significant BMP failure." The depth of the dredge prism for BMP design would need to accommodate the uncertainty in the depth of contamination. Therefore, particularly in areas in proximity of the BMP that would impact BMP stability, review the spatial coverage of sample points to ensure there is sufficient density to reduce uncertainty in the dredge prism design. This information will aid in designing a structurally robust BMP that is capable of withstanding forces associated with excavation of all impacted materials in the deeper areas of the Northern Impoundment.	The supplemental investigation includes 14 proposed boring locations around the perimeter of the excavation area, in proximity to the conceptual alignment of the BMP. Analytical results from those borings will be used in conjunction with the existing subsurface data to inform the design of the BMP. The number and locations of the borings are based upon best engineering judgement.
4	Section 2.0, Figure 2	Conduct more extensive delineation at the deep northwestern corner of the removal area and surrounding the articulated concrete block mat (ACBM).	In the Sampling Plan, the spatial coverage of the proposed borings in the northwestern corner was the same as the spatial coverage in the rest of the Northern Impoundment (approximately one boring per 1/4 acre, when historic and proposed borings are combined). It should be noted, however, that due to significant water depths in this area, a different drilling method may be required that will be extremely challenging to utilize and poses logistical and safety-related risks. In response to this comment, the Respondents have added three boring locations (SJSB100, SJSB101, and SJSB103) in the northwestern corner in the vicinity of the ACBM to further delineate this area. The boring locations are shown on Figure 2.
5	Section 2.0, Figure 2	Conduct more extensive delineation in the southeast corner of the site in the vicinity of cores SJSB046, SJSB046-C1, and SJSB047-C1.	The proposed soil borings in the southeastern corner of the Northern Impoundment have been adjusted and an additional boring location (SJSB102) has been added between historic borings SJSB046 and SJSB045-C1 to further delineate this area. The boring locations are shown on Figure 2.

Table 1

Response to Comments – Supplemental Design Investigation
Northern Impoundment
San Jacinto River Waste Pits Site
Harris County, Texas

Item No.	Reference	Comment	Response
6	Section 2.0, Figure 2	Supplemental borings are required as part of this sampling event if previous borings did not reached TEQ levels < 30 ng/kg.	As stated in the response to Analytical Sampling Comment 1 above, there are five historic sample locations (SJGB010, SJGB012, SJSB036, SJSB046-C1, and SJSB071) where TEQ levels < 30 ng/kg were not observed at the terminal depth of the boring. The initial submittal of this Sampling Plan included proposed borings adjacent to each of these historic borings, with the exception of SJSB071. A proposed boring location (SJSB101) has been added adjacent to SJSB071 such that now there will be a collocated boring installed beside all five of these historic boring locations as part of the Supplemental Design Investigation. With the exception of borings SJSB083 and SJSB101 which will be analyzed for waste characterization purposes, the Respondents will only analyze the samples in the collocated borings that are deeper than the terminal depth of each historic boring with TEQ levels > 30 ng/kg (e.g. at proposed boring location SJSB072, the first sample analyzed would be the interval from 8 - 10 ft bgs, because collocated historic boring SJGB012 had a TEQ level > 30 ng/kg at its terminal depth of 8 ft bgs). The text in Section 2.1.1 of the Sampling Plan has been updated accordingly. The planned sample intervals are detailed in Table 2. The boring locations are shown on Figure 2.
7	Section 2.0, Figure 2	Some of proposed supplemental borings are close to a PDI-2 sample location showing contamination as opposed to equally spaced between two PDI-2 sample location showing contamination, such as SJSB085 and SJSB076, despite the adjacent core having reached clean. Review these sample locations.	The number and locations of the proposed borings have been adjusted in accordance with the boring placement specified by the EPA in email correspondence dated May 9, 20201.Borings moved or added at the EPA's direction appear to be investigative in nature and the Respondents do not regard the addition of these borings to be necessary or appropriate to inform the 90% RD. The adjusted boring locations are shown on Figure 2.
Geotechnical Samples Comments from the EPA			
1	Figure 3	Update Figure 3 to include locations of geotechnical samples that were taken during previous investigations.	Figure 3 has been updated to include previous geotechnical sample locations from the Remedial Investigation (RI), and first and second phases of the PDI.

Table 1

Response to Comments – Supplemental Design Investigation
Northern Impoundment
San Jacinto River Waste Pits Site
Harris County, Texas

Item No.	Reference	Comment	Response
2	Section 2.1.2	Based on the proposed CPT exploration plan along the alignment of the BMP, conduct at least one CPT adjacent to a previously completed SPT boring with laboratory shear strength and consolidation testing for data comparison and site specific correlation. Update plan to include discussion on how this correlation will be done.	In order to correlate the CPT data collected during this investigation to the abundant geotechnical laboratory test data collected during past geotechnical investigations, a "calibration boring" will be necessary. The calibration boring will have both CPT data and geotechnical laboratory test data from ground surface to the Beaumont Sands. To that end, an eleventh CPT boring will be installed adjacent to planned piezometer location, SJMW-016 to provide the CPT data. To provide the corresponding laboratory test data for comparison, during the installation of piezometer SJMW 016, geotechnical samples will be collected for laboratory analysis (including shear strength and consolidation testing). CPT data and physical samples will be collected along the entire length of this deep boring, including from the Beaumont Clay and Beaumont Sand layers. Using the common set of information and well defined relationships for various parameters available from the two tests, the CPT results obtained from the ten borings along the current conceptual BMP alignment can be calibrated using data from SJMW-016 and correlated to existing geotechnical laboratory test data from past investigations. The location of this boring and all other historic geotechnical borings have been added to Figure 3. Section 2.1.2 of the Sampling Plan has been updated to discuss the correlation of the CPT data.
3	Section 2.1.2	Per prior designs and documentation, a key concern with the site stratigraphy is potential long-term strengths of the clay layers. Testing was performed in the preliminary subsurface investigation to characterize the long-term strength. Based on the original and new findings, tabulate skin friction values for steel piling that could be referenced by a Contractor for developing the pile installation plan, and possible removal during the Remedial Action.	Acknowledged. The site stratigraphy, details of soil characterization and friction parameters, and calculated skin friction values will be included in the Northern Impoundment Remedial Design and will be available to the Remedial Contractor during the Remedial Action.
4	Section 2.1.2	Review the site history to evaluate the risk of potential early CPT refusal due to obstructions and/or stiff/dense soil conditions. The CPT operator should evaluate the existing conditions to confirm the equipment can penetrate to the required depths. Additionally, if CPT cannot be advanced, adjustments to the sampling locations may be made in the field. Add a description as to how these decisions will be made and what the adjustment will be.	Site stratigraphy information from the RI and PDIs was reviewed with the project team to determine the CPT locations and was incorporated into the Sampling Plan. Consistent with the protocol followed during PDI-2, a CPT boring location may be moved within 25 feet of its proposed location if necessary, to avoid refusal or surface impediments. If it is necessary to move a CPT boring location farther than 25 feet from the proposed location, it will be discussed with the EPA at that time. Section 2.1.2 of the Sampling Plan has been updated to provide information about the procedure that will be followed if there are problems advancing a boring due to subsurface refusal or some other field condition.
Piezometer Installation Comments from the EPA			

Table 1

Response to Comments – Supplemental Design Investigation
Northern Impoundment
San Jacinto River Waste Pits Site
Harris County, Texas

Item No.	Reference	Comment	Response
1	Section 2.3	As stated in the plan, "With the change in planned excavation methodology, the design must now account for deep excavation areas that will be excavated in the dry." During the March 2021 TWG meeting we discussed the concern that hydraulic heave may be more likely to occur in the deep excavation areas. There was also discussion regarding the placement of the piezometers and whether there was a need for installation of additional deep piezometer(s) in the northwest area and eastern area where deep excavations are planned in addition to the proposed locations. After consideration of this concern, update the plan to include additional deep piezometers, or add an explanation to support how the proposed location near boring SJMW-016 will be representative of the pressures at other deep excavation areas at the site.	With the change in planned excavation methodology, the design must now account for the need to excavate to deeper depths in the dry. To account for the lack of weight and downward pressure from what would have been a flooded condition under Approach B, additional geotechnical data are needed to evaluate the potential for hydraulic heave during the RA. In addition to the deep piezometer (SJMW-016) proposed in the initial submittal of this Sampling Plan, an additional deep piezometer has been added (SJMW-017) in the southeast corner. These piezometers will extend into the sand layer below the Beaumont Clay Formation, approximately 50 ft msl. Upon completion of the boreholes, temporary monitoring wells will be installed and screened from approximately 50 to 60 ft msl, or the top ten feet of the lower sand layer. The confined Beaumont Sand is expected to have a relatively gradual hydraulic gradient. The two measurement points obtained from SJMW-016 and SJMW-017 will be compared to each other and available historical well measurements to confirm this. This low gradient will allow the water levels taken at SJMW-016 and SJMW-017 to be extrapolated to approximate water levels across the entire excavation area. Section 2.3 of the Sampling Plan has been updated to provided further detail and Table 2 and Figure 3 have been updated to include the addition of SJMW-017.
2	Section 2.3, Page 5	The final paragraph of this section proposes that a slug test will be performed to evaluate the hydraulic conductivity of the strata through which each temporary monitoring well is screened. Aquifer tests were not part of the Pre-Design Investigation Phase 2 (PDI-2) scope of work so standard operating procedures (SOPs) for aquifer testing methodology were not included in PDI-2 Field Sampling Plan Appendix C-1. Please provide an SOP or similarly detailed description of the aquifer testing methodology proposed (slug test and Pressure meter test).	SOPs for Slug Testing and Pressuremeter Testing have been added as Attachments 1 and 2, respectively, and referenced in Section 2.3, paragraph 5 of the Sampling Plan.
3	Section 1.2, Objective, 4th Bullet	As discussed in the March 2021 TWG, lateral hydraulic conductivity of the waste materials may be needed for estimating drainage from the waste pile while excavating deeper areas. During the March 2021 TWG meeting, it was clarified that the slug test from the upper well screen will provide an estimate of the lateral drainage or seepage from the waste pile during drawdown activities. Update the report to clarify how the proposed method in the plan will measure lateral hydraulic conductivity.	A slug test is a controlled field experiment in which the water level in a well is caused to change suddenly (e.g. by purging a known amount of water) and the subsequent water-level response (displacement or change from static) is measured through time. Aquifer properties, such as hydraulic conductivity, are estimated by fitting mathematical models to displacement data using a procedure known as curve matching. The locations of piezometers SJMW014 and SJMW015 were selected from adjacent boring log data to capture the highest representative conductivity values testable from dry land. The observed conductivity values will inform choices on peak excavation seepage rates and water volumes. The text in paragraph 5 of Section 2.3 of the Sampling Plan has been updated to provide clarification regarding how the proposed method will measure lateral hydraulic conductivity. In addition, the fourth bullet in Section 1.2 of the proposed Sampling Plan has been updated to replace the word "infiltration" with the word "seepage".
Additional Scope Added Since February Submittal of the Supplemental Design Investigation Sampling Plan			
1	Section 2.1.1	Seven analytical borings have been added to the Sampling Plan (SJSB100 - SJSB106), as detailed in Section 2.1.1 and Table 2. At EPA's direction, the locations of many of the proposed borings have also been adjusted. The final proposed boring locations are shown in Figure 2.	
2	Section 2.3	Supplemental data will be collected to support the design of turbidity control measures for use during installation and removal of the BMP during the RA. Additional data collection will include verifying thicknesses of surface materials, geotechnical characteristics of surficial sediment, and velocity measurements in locations outside the proposed BMP alignment as detailed in Section 2.3, Figure 4, and Table 3.	
3	Section 2.4	An additional deep piezometer (SJMW-017) will be installed in the southeast corner of the Northern Impoundment, as detailed in Section 2.4, Figure 3, and Table 2.	

Table 1

Response to Comments – Supplemental Design Investigation
Northern Impoundment
San Jacinto River Waste Pits Site
Harris County, Texas

Item No.	Reference	Comment	Response
4	Sections 2.1.2 and 2.4	As detailed in Sections 2.1.2 and 2.4, an eleventh CPT boring (SJCPT-011) will be installed adjacent to deep piezometer SJMW-016 to serve as a "calibration boring". Geotechnical laboratory samples will also be collected during the installation of adjacent piezometer SJMW-016. Having a CPT boring that is collocated with a geotechnical boring with laboratory test data will serve to establish a correlation between the CPT investigation data and laboratory test data. This calibration data can then be used to correlate the CPT data collected from the borings around the perimeter to the laboratory test data collected during previous investigations to supplement limited existing data from the lower geological strata (Beaumont Clay and Beaumont Sands). Table 2 has been updated to include the additional data collection.	
5	Section 2.1.2	To further investigate shallow sediments in the northwest corner, shear vane strength readings will be taken in the top 4 to 5 feet of CPT borings SJCPT-002, SJCPT-003, and SJCPT-004. Details are provided in Section 2.1.2, Figure 3, and Table 2.	
6	Section 2.1.3	A total of four waste characterization samples will be collected from two boring locations (SJSB083 and SJSB101). Details are provided in Section 2.1.3, Figure 2, and Table 2.	

Table 2

Details of Planned Supplemental Design Investigation Borings
Supplemental Design Investigation Work Plan Revision 1
San Jacinto River Waste Pits Site
Harris County, Texas

Station ID	Location	Boring Type	Boring Details	Total Depth (feet bgs)	Analyses	Total Number of Samples Collected	Initial Sample Depth (feet bgs)	Coordinates[a]	
								X	Y
Soil Chemistry Borings									
SJSB072	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals from 8 f bgs to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	8	8	29.7950	-95.0634
SJSB073	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7949	-95.0630
SJSB074	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7948	-95.0638
SJSB075	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals from 10 ft bgs to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	6	12	29.7946	-95.0634
SJSB076	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7947	-95.0632
SJSB077	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals from 6 ft bgs to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	9	6	29.7944	-95.0637
SJSB078	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7945	-95.0635
SJSB079	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7943	-95.0633
SJSB080	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7942	-95.0635
SJSB081	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7940	-95.0628
SJSB082	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7939	-95.0626
SJSB083	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7939	-95.0623
		Waste Characterization	2-foot discrete intervals to depth of 24 feet. Upon receipt of the results analytical results for the soil chemistry borings, the two samples with the highest dioxins concentrations will be identified and the duplicate samples from those intervals will be analyzed.	24	RCRA Hazardous Waste Parameters	12	0		
SJSB084	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7939	-95.0620
		Deep Geotechnical Boring	SB-084 will be extended from 24 ft bgs into the Beaumont clay formation. Analytical samples will not be collected, only subsurface stratigraphy logged.	~40	NA	0	NA		

Table 2

Details of Planned Supplemental Design Investigation Borings
Supplemental Design Investigation Work Plan Revision 1
San Jacinto River Waste Pits Site
Harris County, Texas

Station ID	Location	Boring Type	Boring Details	Total Depth (feet bgs)	Analyses	Total Number of Samples Collected	Initial Sample Depth (feet bgs)	Coordinates[a]	
								X	Y
SJSB085	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7942	-95.0618
		Deep Geotechnical Boring	SB-085 will be extended from 24 ft bgs into the Beaumont clay formation. Analytical samples will not be collected, only subsurface stratigraphy logged.	~40	NA	0	NA		
SJSB086	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7941	-95.0621
SJSB087	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7941	-95.0626
SJSB088	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7946	-95.0625
SJSB089	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7944	-95.0622
SJSB090	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7947	-95.0622
SJSB091	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7946	-95.0617
		Deep Geotechnical Boring	SB-091 will be extended from 24 ft bgs into the Beaumont clay formation. Analytical samples will not be collected, only subsurface stratigraphy logged.	~40	NA	0	NA		
SJSB092	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7950	-95.0619
SJSB093	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7949	-95.0625
SJSB094	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7952	-95.0621
SJSB095	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7954	-95.0625
SJSB096	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7955	-95.0623
SJSB097	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7959	-95.0628
SJSB098	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7957	-95.0630
SJSB099	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7954	-95.0630
SJSB100	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7958	-95.0632

Table 2

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Harris County, Texas

Station ID	Location	Boring Type	Boring Details	Total Depth (feet bgs)	Analyses	Total Number of Samples Collected	Initial Sample Depth (feet bgs)	Coordinates[a]	
								X	Y
SJSB101	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals from 18 ft bgs to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7952	-95.0635
		Waste Characterization	2-foot discrete intervals to depth of 24 feet. Upon receipt of the results analytical results for the soil chemistry borings, the two samples with the highest dioxins concentrations will be identified and the duplicate samples from those intervals will be analyzed.	24	RCRA Hazardous Waste Parameters	12	0		
SJSB102	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7938	-95.0624
SJSB103	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7960	-95.0629
SJSB104	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7946	-95.0615
SJSB105	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7949	-95.0616
SJSB106	Northern Impoundment	Soil Chemistry Boring	2-foot discrete intervals to depth of 24 feet. Samples collected from 18-24 ft bgs will be held pending analysis of 16-18 ft bgs interval.	24	Dioxins and furans	12	0	29.7945	-95.0619
Cone Penetrometer Test (CPT) Geotechnical Borings[b]									
SJCPT001	Northern Impoundment	CPT Boring	CPT boring will be advanced into the top of the Beaumont sand formation. Analytical samples will not be collected but continuous in-situ data will be recorded.	~50-70	NA	0	NA	29.7950	-95.0641
SJCPT002	Northern Impoundment	CPT Boring	CPT boring will be advanced into the top of the Beaumont sand formation. Analytical samples will not be collected but continuous in-situ data will be recorded.	~50-70	NA	0	NA	29.7956	-95.0638
		Shallow Sediment	Real-time shear vane strength readings will be collected at 2 ft intervals down to approximately 4-5 feet below mudline of SJCPT-02. No analytical samples will be collected.	~4-5					
SJCPT003	Northern Impoundment	CPT Boring	CPT boring will be advanced into the top of the Beaumont sand formation. Analytical samples will not be collected but continuous in-situ data will be recorded.	~50-70	NA	0	NA	29.7960	-95.0635
		Shallow Sediment	Real-time shear vane strength readings will be collected at 2 ft intervals down to approximately 4-5 feet below mudline of SJCPT-03. No analytical samples will be collected.	~4-5					
SJCPT004	Northern Impoundment	CPT Boring	CPT boring will be advanced into the top of the Beaumont sand formation. Analytical samples will not be collected but continuous in-situ data will be recorded.	~50-70	NA	0	NA	29.7963	-95.0630
		Shallow Sediment	Real-time shear vane strength readings will be collected at 2 ft intervals down to approximately 4-5 feet below mudline of SJCPT-04. No analytical samples will be collected.	~4-5					
SJCPT005	Northern Impoundment	CPT Boring	CPT boring will be advanced into the top of the Beaumont sand formation. Analytical samples will not be collected but continuous in-situ data will be recorded.	~50-70	NA	0	NA	29.7962	-95.0624
SJCPT006	Northern Impoundment	CPT Boring	CPT boring will be advanced into the top of the Beaumont sand formation. Analytical samples will not be collected but continuous in-situ data will be recorded.	~50-70	NA	0	NA	29.7960	-95.0618
SJCPT007	Northern Impoundment	CPT Boring	CPT boring will be advanced into the top of the Beaumont sand formation. Analytical samples will not be collected but continuous in-situ data will be recorded.	~50-70	NA	0	NA	29.7953	-95.0613
SJCPT008	Northern Impoundment	CPT Boring	CPT boring will be advanced into the top of the Beaumont sand formation. Analytical samples will not be collected but continuous in-situ data will be recorded.	~50-70	NA	0	NA	29.7947	-95.0610
SJCPT009	Northern Impoundment	CPT Boring	CPT boring will be advanced into the top of the Beaumont sand formation. Analytical samples will not be collected but continuous in-situ data will be recorded.	~50-70	NA	0	NA	29.7940	-95.0610

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								X	Y
SJCPT010	Northern Impoundment	CPT Boring	CPT boring will be advanced into the top of the Beaumont sand formation. Analytical samples will not be collected but continuous in-situ data will be recorded.	~50-70	NA	0	NA	29.7935	-95.0616
SJCPT011	Northern Impoundment	CPT Boring	CPT boring will be advanced into the top of the Beaumont sand formation. Analytical samples will not be collected but continuous in-situ data will be recorded.	~50-70	NA	0	NA	29.7948	-95.0632
Surficial Sediment Geotechnical Properties									
SJGC001	Northern Impoundment	Surficial Sediment	0-6 inch surficial sediment interval analyzed for water content (ASTM D2216), dry density (ASTM D2937),Atterberg Limits (ASTM D4318), specific gravity (ASTM D854), particle size distribution (ASTM D422), organic carbon content (ASTM D2974), and consistency/stickiness using the Natural Resources Conservation Service method.	0.5	Geotechnical Properties	1	0	29.7950	-95.0641
SJGC002	Northern Impoundment	Surficial Sediment	0-6 inch surficial sediment interval analyzed for water content (ASTM D2216), dry density (ASTM D2937),Atterberg Limits (ASTM D4318), specific gravity (ASTM D854), particle size distribution (ASTM D422), organic carbon content (ASTM D2974), and consistency/stickiness using the Natural Resources Conservation Service method.	0.5	Geotechnical Properties	1	0	29.7956	-95.0638
SJGC003	Northern Impoundment	Surficial Sediment	0-6 inch surficial sediment interval analyzed for water content (ASTM D2216), dry density (ASTM D2937),Atterberg Limits (ASTM D4318), specific gravity (ASTM D854), particle size distribution (ASTM D422), organic carbon content (ASTM D2974), and consistency/stickiness using the Natural Resources Conservation Service method.	0.5	Geotechnical Properties	1	0	29.7960	-95.0635
SJGC004	Northern Impoundment	Surficial Sediment	0-6 inch surficial sediment interval analyzed for water content (ASTM D2216), dry density (ASTM D2937),Atterberg Limits (ASTM D4318), specific gravity (ASTM D854), particle size distribution (ASTM D422), organic carbon content (ASTM D2974), and consistency/stickiness using the Natural Resources Conservation Service method.	0.5	Geotechnical Properties	1	0	29.7963	-95.0630
SJGC005	Northern Impoundment	Surficial Sediment	0-6 inch surficial sediment interval analyzed for water content (ASTM D2216), dry density (ASTM D2937),Atterberg Limits (ASTM D4318), specific gravity (ASTM D854), particle size distribution (ASTM D422), organic carbon content (ASTM D2974), and consistency/stickiness using the Natural Resources Conservation Service method.	0.5	Geotechnical Properties, Sediment and Rock Thickness	1	0	29.7962	-95.0624
SJGC006	Northern Impoundment	Surficial Sediment	0-6 inch surficial sediment interval analyzed for water content (ASTM D2216), dry density (ASTM D2937),Atterberg Limits (ASTM D4318), specific gravity (ASTM D854), particle size distribution (ASTM D422), organic carbon content (ASTM D2974), and consistency/stickiness using the Natural Resources Conservation Service method.	0.5	Geotechnical Properties, Sediment and Rock Thickness	1	0	29.7959	-95.0619
SJGC007	Northern Impoundment	Surficial Sediment	0-6 inch surficial sediment interval analyzed for water content (ASTM D2216), dry density (ASTM D2937),Atterberg Limits (ASTM D4318), specific gravity (ASTM D854), particle size distribution (ASTM D422), organic carbon content (ASTM D2974), and consistency/stickiness using the Natural Resources Conservation Service method.	0.5	Geotechnical Properties, Sediment and Rock Thickness	1	0	29.7953	-95.0614
SJGC008	Northern Impoundment	Surficial Sediment	0-6 inch surficial sediment interval analyzed for water content (ASTM D2216), dry density (ASTM D2937),Atterberg Limits (ASTM D4318), specific gravity (ASTM D854), particle size distribution (ASTM D422), organic carbon content (ASTM D2974), and consistency/stickiness using the Natural Resources Conservation Service method.	0.5	Geotechnical Properties, Sediment and Rock Thickness	1	0	29.7946	-95.0611
SJGC009	Northern Impoundment	Surficial Sediment	0-6 inch surficial sediment interval analyzed for water content (ASTM D2216), dry density (ASTM D2937),Atterberg Limits (ASTM D4318), specific gravity (ASTM D854), particle size distribution (ASTM D422), organic carbon content (ASTM D2974), and consistency/stickiness using the Natural Resources Conservation Service method.	0.5	Geotechnical Properties, Sediment and Rock Thickness	1	0	29.7941	-95.0611
SJGC010	Northern Impoundment	Surficial Sediment	0-6 inch surficial sediment interval analyzed for water content (ASTM D2216), dry density (ASTM D2937),Atterberg Limits (ASTM D4318), specific gravity (ASTM D854), particle size distribution (ASTM D422), organic carbon content (ASTM D2974), and consistency/stickiness using the Natural Resources Conservation Service method.	0.5	Geotechnical Properties, Sediment and Rock Thickness	1	0	29.7935	-95.0616

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								X	Y
Piezometer Borings for Hydraulic Conductivity and Subsurface Hydrostatic Pressure									
SJMW-014	Northern Impoundment	Shallow Piezometer	Piezometer for waste material investigation, temporary well screened from 0-8 ft bgs.	~8	NA	0	NA	29.7950	-95.0633
SJMW-015	Northern Impoundment	Intermediate Piezometer	Piezometer to investigate permeable zone below waste material, temporary well screened at bottom five feet bgs.	~25	NA	0	NA	29.7949	-95.0633
SJMW-016	Northern Impoundment	Deep Piezometer	Piezometer advanced into the sand layer beneath the Beaumont Clay formation to evaluate the potential for hydraulic heave during RA, temporary well screened at the top ten feet of the lower sand layer.	~50-60	NA	0	NA	29.7949	-95.0633
		Geotechnical	Additional geotechnical data will be collected during SJMW-016 installation and between PMT tests to correlate to adjacent SJCPT-011. Shelby Tube samples will be collected at ~10 ft bgs intervals until boring termination. Geotechnical samples will be tested for tested for Unconsolidated Undrained Compression Test (ASM D2850), Atterberg Limits (ASTM D4318), moisture content (ASTM D2216), grain size (ASTM D6913/D7928), and #200 wash (ASTM D1140).		Geotechnical Properties	Up to 8	10		
SJMW-017	Northern Impoundment	Deep Piezometer	Piezometer advanced into the sand layer beneath the Beaumont Clay formation to evaluate the potential for hydraulic heave during RA, temporary well screened at the top ten feet of the lower sand layer.	~50-60	NA	0	NA	29.7935	-95.0623

Notes:
bgs = below ground surface
NA = Not applicable
[a] NAD 1983; State Plane Texas South Central FIPS 4204; US feet.
[b] In-situ geotechnical investigation method to record data in real-time at regular intervals during penetration.

Table 3

RCRA TCLP Regulatory Levels
Supplemental Design Investigation Sampling Plan
San Jacinto River Waste Pits Site
Harris County, Texas

Analysis	Units	EPA Regulatory Limtis
General Chemistry		
Flash Point	°C	>60
Percent solids	%	--
pH, lab	s.u.	>2 or <12
Reactive cyanide	mg/kg	--
Reactive sulfide	mg/kg	--
Sulfur	mg/kg	--
TCLP-Herbicides		
2,4,5-TP (Silvex)	mg/L	1.0
2,4-Dichlorophenoxyacetic acid (2,4-D)	mg/L	10.0
TCLP-Metals		
Arsenic	mg/L	5.0
Barium	mg/L	100.0
Cadmium	mg/L	1.0
Chromium	mg/L	5.0
Lead	mg/L	5.0
Mercury	mg/L	0.2
Selenium	mg/L	1.0
Silver	mg/L	5.0
TCLP-Pesticides		
Chlordane	mg/L	0.03
Endrin	mg/L	0.02
gamma-BHC (lindane)	mg/L	0.4
Heptachlor	mg/L	0.008
Heptachlor epoxide	mg/L	0.008
Methoxychlor	mg/L	10.0
Toxaphene	mg/L	0.5
TCLP-Semi-Volatile Organic Compounds (SVOCs)		
o-Cresol	mg/L	200.0
m-Cresol	mg/L	200.0
p-Cresol	mg/L	200.0
Total Cresol[1]	mg/L	200.0
2,4,5-Trichlorophenol	mg/L	400.0
2,4,6-Trichlorophenol	mg/L	2.0
2,4-Dinitrotoluene	mg/L	0.13
Hexachlorobenzene	mg/L	0.13
Hexachlorobutadiene	mg/L	0.5
Hexachloroethane	mg/L	3.0
Nitrobenzene	mg/L	2.0
Pentachlorophenol	mg/L	100.0
Pyridine	mg/L	5.0
TCLP-Volatile Organic Compounds (VOCs)		
1,1-Dichloroethylene	mg/L	0.7
1,2-Dichloroethane	mg/L	0.5
1,4-Dichlorobenzene	mg/L	7.5
2-Butanone (Methyl ethyl ketone) (MEK)	mg/L	200.0
Benzene	mg/L	0.5
Carbon tetrachloride	mg/L	0.5
Chlorobenzene	mg/L	100.0
Chloroform (Trichloromethane)	mg/L	6.0
Tetrachloroethylene	mg/L	0.7
Trichloroethylene	mg/L	0.5
Vinyl chloride	mg/L	0.2

Notes:
TCLP - Toxicity Characteristic Leaching Procedure
mg/L - milligrams per Liter
mg/kg - milligram per kilogram
Deg F - Degrees in Fahrenheit
s.u. - standard unit
1. If o, m, and p-Cresol concentrations cannot be differentiated, the total cresol concentration is used.

Appendices

Appendix A
GHD Groundwater Well Slug Testing Standard Operating Procedure

Appendix A

1. Introduction

This standard operating procedure (SOP) describes the approach to be taken to undertake slug or hydraulic conductivity tests on groundwater observation wells. The conventional form of slug test is carried out by the displacement of a 'slug' of water using a bailer or displacer and measuring the response of the recovering water level in the well through time. Slug tests are carried out on conventionally constructed, fully or partially penetrating wells.

A slug test is conducted by instantaneously removing or introducing a known volume (or slug) to a well that displaces (either decreases or increases) the water level in the well. The slug could comprise a known volume of water or a solid object of a known volume into a well. Slug tests are often classified as either rising-head tests or falling-head tests, depending on the direction of water level recovery being monitored.

The resulting recovery to equilibrium conditions (either rise or fall) of the water level in the well is then monitored, and the data analysed by one of several methods to determine the horizontal hydraulic conductivity.

1.1 Purpose of this document

This procedure describes the approach to be taken for conducting a slug test in a manner that is reliable, representative, and repeatable.

1.2 Scope of this document

This procedure applies to all projects where a rapid, simplistic estimation of hydraulic conductivity is required from a groundwater well. For a more accurate determination of aquifer properties, SOP 12 *Groundwater Well Pumping Test* should be consulted.

Slug tests are most commonly applied in situations where groundwater flow to the well is not sufficient to allow pumping or where well diameters are narrow (< 100 mm). In addition, this approach is useful when only an order of magnitude of aquifer transmissivity is desired.

They may not be appropriate in fractured rock or formations with a transmissivity greater than 250 m^2/day (Kruseman and de Ridder, 1990).

1.3 Planning

A number of factors must be considered during the field-planning phase. These include:

- Data required:
  - well diameter and depth (i.e. casing inside radius)
  - screen slot size and length
  - filter pack material (thickness, grain size and porosity)

- borehole diameter
- depth to top of screen from water table (unconfined aquifer) or overlying confining unit (confined aquifer);
- slug radius and length (solid slug);
- static (pre-test) depth to water in well;
- saturated thickness of aquifer

- Is your well fully or only partially penetrating the aquifer?
  - Analytical methods for slug test data require knowledge of the thickness of the tested water bearing zone (i.e. the aquifer). Correction factors (Cedegren, 1977) need to be applied when analysing the data from partially penetrating wells.
- Does the water table intersect the well screen? Rising versus falling head tests.
  - There is a need to consider problems encountered with wells in which the well screen crosses the water table.
  - For a rising head test, the slug test can be run as usual with a corrected value used for the casing radius in calculations.
  - For a falling head test however, introduction of a slug pushes water into both the saturated zone and unsaturated zone (i.e. above and below the surface of the water table). For equal screen lengths in the saturated and unsaturated zones, the flow into the unsaturated zone will generally be lower because unsaturated hydraulic conductivity is always lower than the saturated hydraulic conductivity, but the magnitude of the flow cannot be quantified with some calculation methods (e.g. Bouwer and Rice Method). <u>When the screen length in the unsaturated zone is a significant portion of the total screen length, either limit the water level rise (by using a smaller slug), or run a rising head test only.</u>

1.4 Health safety and environment

A site specific safety plan should be prepared prior to commencing all field work on site and should be regularly reviewed and updated throughout the project as changes in conditions or work methods occur.

Reference should be made to safety requirements and considerations described in specific sampling procedures and in SOP 19 *Safety Plan Preparation and PPE.*

The following provides a brief summary of some typical safety issues that should be considered when undertaking groundwater well slug tests.

- These tests are often undertaken on contaminated sites and therefore appropriate OH&S procedures should be followed. The procedure is similar to groundwater sampling and therefore exposure (both personal and equipment) to hazardous materials is possible;
- Suitable gloves (nitrile under leather) should be used when raising or lowering the slug as the weighted line can injure hands. A clean pair (double layer) of nitrile gloves should be worn when handling potentially contaminated groundwater. Care should be taken not to spread potentially contaminated material around the work area and / or cross-contaminate other materials;

- Slug tests cause rapid movements of water level in the well. They should not be carried out where the resultant rapid pressure changes could cause collapse of the well wall, or where serious particle rearrangement would be caused in a filter pack;
- The procedure involves the placement of tools and instruments within a groundwater well. Should water quality monitoring ever be undertaken in the well, instruments should be decontaminated both prior to and following removal from the well.
- At hazardous waste sites, the injection of water into a well will result in the well not being useful, for a period of time, for the collection of ground water samples. When potentially contaminated water is removed from a well it may require storage or treatment prior to disposal. (Refer to SOP 22 *Disposal of Waste Materials*).

1.4.1 Personal protective equipment

Personal protective equipment (PPE) required for groundwater sampling include as a minimum:

- Steel-cap lace-up boots.
- Long cotton drill pants (no jeans with elastin).
- Long-sleeved high-visibility shirt.
- Wide-brimmed hard hat (if in an area where something could fall on you); or wide-brimmed sun hat.
- Safety glasses.
- Manual handling gloves with a rubber (or similar) grip.
- Nitrile gloves.
- Sunscreen (broad spectrum SPF 30+).
- Insect repellent.
- Hearing protection (if using a generator).

2. Equipment specifications

2.1 Equipment

The following equipment is required:

- Dip meter or interface probe.
- Level logger, data transfer devise (ie optical reader), cable.
- Bailer/slug with cord / cable.
- Distilled water (if using a bailer rather than slug for the test).
- Decontamination equipment.
- Watch/timer.

- Notepad & pen, field record sheet (see Appendix A).
- Laptop computer with logger software installed.

3. Directions

3.1 Set-up

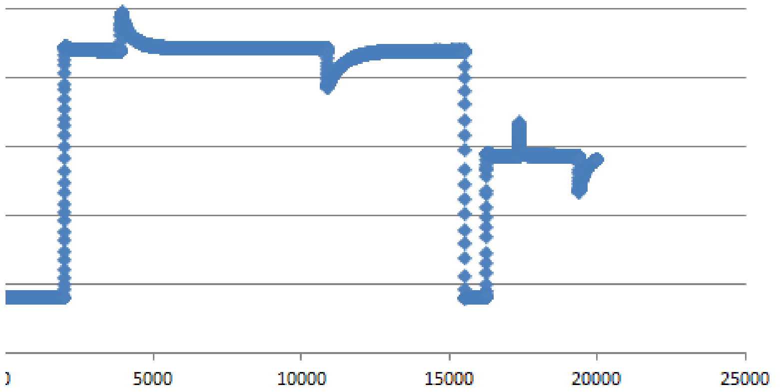
- Set up logger prior to use. You will need to specify the recording period (start & stop times) and the recording interval (time between measurements). Multiple tests can be done over a single recording period provided the test order and times are recorded. Ensure all units are appropriate (i.e. metres, cm, seconds etc.).
- Selection of appropriate logger recording time is important. Within permeable strata such as sands and gravels, a recording interval of 1 to 2 seconds is required. For clay, a 5-second interval will suffice, unless very long recovery times (hours/days) are anticipated, in which case a recording interval of 10 seconds may be adopted. Ensure that the selected interval and recording frequency will result in a total number of data points less than the capacity of the logger.
- On arrival at site, inspect the bore to be tested. Record signs of tampering or poor state of repair.
- Remove bore end cap & allow bore to equilibrate with the atmosphere.
- Decontaminate all items to be inserted into the bore (logger, slug & IP probe).
- Dip bore and record the standing water level (SWL) to the nearest mm. Record this value on the data sheet.
- Attach the logger securely to the loop of the marked cable using the D-shackle and pliers and/or shifter. **Ensure logger is securely attached prior to insertion into bore**.
- Insert logger so that it is a few metres below the groundwater surface in the bore - it will need to be a minimum of 2 metres below the base of the slug when it is inserted, however it must not be in any sediment at the base of the bore. Secure the logger so that it will not move. The logger may need to be weighted to keep it in place. **It is important that the pressure transducer is not disturbed over the life of the test.**

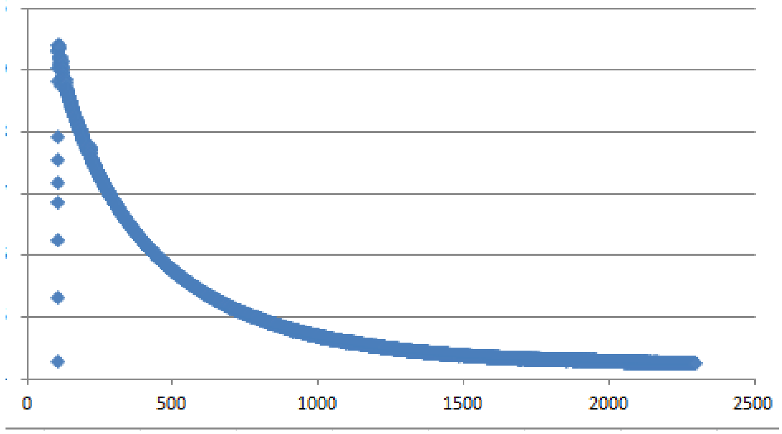
3.2 Falling head test

- Dip the bore. When the SWL has returned to the original level proceed to the next step.
- Lower the slug into the bore in a **single, fluid and rapid motion** so that it is completely submerged and secure firmly in place (only just submerged, **be very careful not to disturb the logger**). It is preferable to use a solid slug, however if a bailer is being used, fill the bailer with distilled water so that it will not fill with bore water (this water will need to be purged prior to sampling).
- Wait a short while
- Dip the bore again. If the water level has returned to the original level, proceed to the next step. If the water level has not returned to the original level, keep waiting. Dip the bore periodically. Proceed to the next step once water level has returned to the original level.

3.3 Rising head test

- Remove the bailer in a single fluid and rapid movement, being careful not to disturb the logger.
- Allow the bore to recover. Dip the bore periodically. When the SWL has returned to the original level (or very close to it) the test is complete. This may take in the order of a minute or two in higher permeability media (such as sand), to a few hours in clays.
- Ideally, the falling and rising head tests should be repeated again, using a slug of a different volume. For low permeability media, this will not always be practical.
- Download the data onto the laptop and check to ensure that the recovery curves look good. These are nice recovery curves:





- Decontaminate and dry equipment.
- ****TURN OFF LOGGER AFTER TESTS****** otherwise battery will go flat.

4. General notes

4.1 Field notes

Ensure that site notes are complete before removing equipment and moving to the next bore. Notes must include:

- Bore ID
- Date
- Original SWL
- SWL prior to insertion of slug/bailer
- SWL immediately prior to removal of bailer
- SWL immediately prior to removal of logger
- Final SWL
- Time when test was commenced and completed
- Volume of slug. This should be the gross volume of the bailer, not just the water volume within. If using the pre-fabricated screw together slug, note how many segments were used for the test.

4.2 General advice

- This method completes two tests per slug insertion - one when the slug is lowered into the well, and one when it is removed. The two data sets increase accuracy.
- In low permeability media, bores will respond slowly. It may be possible to complete the second phase of the test (ie removal of the slug/bailer) before the SWL has recovered completely. Ideally, the water level should have recovered 95% of the original displacement.
- Use of a bailer filled with distilled water is not ideal. A solid slug should be used whenever possible.
- Equipment must be cleaned and dried prior to leaving site / returned to the pelican case.
- Be sure to note the slug displacement dimensions. Refer to Lohman (1979) for additional detail regarding this method. The method is strictly applicable only to fully penetrating or fully screened wells in confined aquifers of rather low transmissivity - say less than 2,100 m^2/day.
  - For partially penetrating wells, the value of transmissivity obtained generally would apply only to that part of the aquifer in which the well is screened or open.
  - In addition, the estimated transmissivity is representative of the zone immediately adjacent to the well screen.
- When a well has been fitted with a screen with a limited open area per unit length, a slug test may provide little useful information about the aquifer characteristics, but can provide information on the degree of development of an observation well. An open area of at least 10% should be considered as the limiting value.
- An example log sheet from AS2368-1990 has been provided. For most applications time and drawdown measurements are recorded digitally and therefore only details regarding the well are required to be recorded on the form.

5. Edit history

Revision	Date	Title	Written by	Approved by
2	July 2014	SOP 13 Groundwater Well Slug Test	NA	Sherri Sibio
A	July 2016	GHD SOP (SQOC) - Groundwater Well Slug Testing	James Dowdeswell	James Dowdeswell

Appendix A - Example slug test record sheet

Slug Test - Field Record Sheet

Sheet: ....of................

GHD job number: ....

Field personnel: ....

Bore ID	Test Date	Time				Standing Water Level (m below TOC)				Slug vol (L) number of segments or dimensions	Comments
		Start	Slug in	Slug out	Finish	1	2	3	4		

SWL - 1: SWL prior to insertion of logger into bore, 2: SWL prior to insertion of slug/bailer, 3: SWL prior to removal of slug/bailer, 4: SWL prior to removal of logger
SWL should return to original levels (or >95% recovery for slow response bores) prior to proceeding to next phase of test
Repeat test where possible, using different volume slug

Appendix B
Braun Intertec Pressuremeter Testing Standard Operating Procedure

A. Purpose

The purpose of this Standard Operating Procedure (SOP) is to establish procedural guidelines to perform pressuremeter tests effectively and safely by utilizing the TEXAM pressuremeter for any Braun Intertec project.

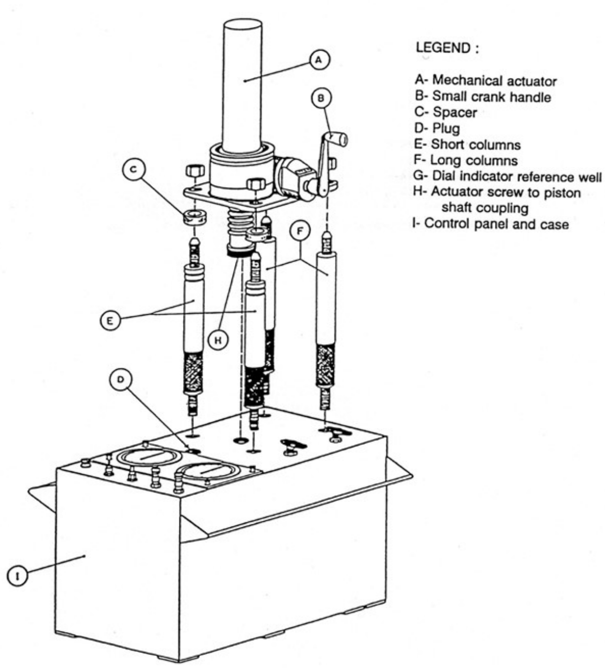
B. Health and Safety

Field work should be performed in accordance with the Braun Intertec Corporate Health and Safety Manual Standard Operating Procedures and the site-specific health and safety plan (HASP), if applicable.

C. Equipment and Supplies

TEXAM control unit
    Cylinder, piston, pressure gauges, and valves
Actuator
70mm TEXAM probe
Volume counter
Tecalan Tubing
Level D Personal protective equipment (PPE)

C.1. Equipment Assembly



1. Remove the cover from the control unit case.
2. Screw in the 4 actuator support columns (E and F). The two columns (E), which have the 2 parallel grooves at one of their extremities are screwed into the two holes located near the center of the control panel and to the right of the pressure gauges. The columns are equipped with a ring fixed by a set screw. These rings are removed to permit the installation of the dial gauge used for the creep test (optional). The knurled portion of the columns point downward and the columns are hand tightened.

3. Remove the threaded PVC protective caps from the piston shaft.
4. Install the mechanical actuator (A) on its support columns. Position it so that the crank shaft is to the right of the control unit and perpendicular to the case handles. Secure the actuator (A) to the support columns with the four ¾" nuts. Tighten the nuts with a wrench.
5. Place the smaller of the two crank handles (B) provided on the crank shaft of the actuator (A). Turn the handle counterclockwise to bring the actuator screw in contact with the piston shaft. Couple the actuator screw with the piston shaft by threading the knurled nut onto the male thread of the piston shaft. Hand tighten the knurled nut.
6. Apply 50 kPa of pressure by rotating the crank handle (B) clockwise.
7. Stop the injection and record the corresponding counter reading and pressure after 30 seconds.
8. Continue the pressurization to 500 kPa in 50 kPa increments recording both pressure and volume after 30 seconds for each step.
9. Install the large crank handle.
10. For a low-pressure test calibration, increase the pressure to 2500 kPa taking readings at every 500 kPa.
11. For a high-pressure test, repeat the same procedure used for a low pressure calibration. When the pressure gauge No. 6 reaches 2500 kPa, place valve No. 8 on "TEST" with gauge 7. Continue to increase the pressure to 10,000 kPa again taking readings every 500 kPa.
12. Return the piston to its lowermost position stopping when gauge No. 7 reaches 2500 ka. At this point, place valve No. 8 on "TEST" with gauge 6 and continue to decrease the pressure to 0. Pressure gauges 6 and 7, and the counter, will now read 0.

D. Equipment Saturation

D.1. Fitting and Saturating the Instrument

1. Connect the two lengths of white flexible tubing to quick connects No. 4 and No. 5.
2. Set valve No. 8 on "FILL" and set valve No. 9 on "TEST".
3. Turn the small crank handle (B) clockwise to bring the cylinder piston to its uppermost position corresponding to about 1732 cc on the counter.
4. Place the free ends of the tubing connected at 4 and 5 in a reservoir of clean water or antifreeze solution. (Water and ethylene 50-50 by volume). It is imperative that during the saturation, the ends of the tubing in the reservoir are and remain submerged. Otherwise, air will enter the cylinder.
5. Lower the piston by turning the crank handle counter-clockwise at a rate of approximately 45 revolutions per minute (rpm).
6. When the piston has traveled to its lowermost positions corresponding to 0000.00 cc on counter, stop the cranking operations and wat one minute for the suction to stop.
7. Incline about 15 degrees the control unit toward yourself when facing the control unit. Turn the crank 16 revolutions (0192.00 cc on the counter) clockwise to expel any air that may have accumulated at the top of the cylinder. During this operation, watch closely to see that all entrapped air is evacuated and only bubble-free water is flowing into the reservoir.
8. Return the instrument to the vertical and bring the piston to its lowermost position (0000.00 cc) by turning the crank handle counterclockwise. When fully lowered, wait 30 seconds.

D.2. Saturating the Pressure Gauges

1. Hook-up the male quick connect fitted with the short length of ¼" outside diameter black tubing port No. 1.

2. Place valve No. 8 on “TEST” with gauge 6. Raise the piston by rotating the crank handle 8 revolutions clockwise, 0096.00 cc on the counter. Make sure that the water flowing out of the black tubing does not contain any air bubbles.
3. Disconnect the quick connect from port No. 1.
4. Place valve No. 8 on “TEST” with gauge 6.
5. Raise the piston by turning 8 revolutions clockwise, the counter will indicate 0192.00 cc.
6. Place valve No. 8 on “TEST” with gauge 7 and valve No.9 on gauge 7 and raise the piston by turning revolutions clockwise, (0288.00 cc reading on the counter).
7. Place valve No. 9 on “TEST”.
8. Place valve No. 8 on “TEST” with gauge 3.
9. Hook up he short length of black tubing fitted with the female quick connect to No. 3 port and raise the piston by turning 8 revolutions clockwise, (0380.00 cc reading on counter).
10. Disconnect the quick connect from outlet No. 3.
11. Place valve No. 8 on “FILL”. Return the piston to its lowermost position (counter will indicate 0), and wait one minute.
12. Repeat steps D.1.7 and D.1.8.

D.3. Saturation Check Procedure

D.3.a. Verify Valve No. 8 is Not Leaking

Before checking saturation, you need verify that valve No. 8 is not leaking:

1. Disconnect the short length of tubing and place valve No. 8 on “TEST” with gauge 7 and valve No. 9 on “TEST”.
2. Install the large crank handle on the rear section of the actuator crankshaft opposite the small one (B).
3. Increase pressure up to 10,000 kPa and make sure that dial gauge 6 does not show any pressure increase. If so, valve No. 8 is leaking. To stop the leak, remove the valve handle using a 3/32” Allen wrench and tighten the packing nut using the chrome plated packing nut tool provided with the instrument. Usually 1/8” of a turn will suffice to stop the leak. If the leak persists, valve No. 8 must be replaced.

D.3.b. Saturation Check

Once it has been verified that valve No. 8 is not leaking, you may proceed with the saturation check.

1. Place valve No. 8 on “TEST” with gauge No. 6 and valve 9 on “Test”
2. Install the large crank handle on the rear section of the actuator crankshaft opposite the small one.
3. The counter should indicate zero. Apply 2500 kPa to pressure gauge No. 6 and No. 7 by rotating the large crank handle clockwise. Read the counter.

   If the counter reads more than 0018.00 cc, the instrument is not completely saturated. Set valve No. 8 on “Fill” and valve No. 9 on “Test” and repeat the saturation procedure described in steps D.1.7 to this current step (D.3.b).

   The instrument is completely saturated when the counter indicates less than 0018.00 cc at 2500 kPa. Having determined that the instrument is completely saturated, place valve No. 8 on 7 and rotate the large crank handle until the pressure reaches 10,000 kPa.

   The pressure should stabilize after 2 minutes between 9500 kPa and 10,000 kPa if there is no leak in the system.

Bring the pressure back to 2500 kPa and place valve No. 8 on gauge 6 and return the piston to the lowermost position.

D.4. Saturating the Tubing Probe Assembly

1. Connect the extremity of the Tecalan tubing fitted with the quick connect to outlet No. 1. Thread the other end of the tubing through the probe to rod adaptor and connect it to the probe. Tighten the nut firmly using two wrenches. Do not over-tighten.
2. Remove the tubing plug located at the lower extremity of the prove, Hold the probe bottom end up slightly inclined and with the saturation tubing in the 12 o' clock position.
3. Keep the prove in this position.
4. Inject water into the probe by rotating the crank handle clockwise until bubble-free water only is flowing out of the saturation tube. Valve No. 8 should be on "TEST" with gauge 6 and valve No. 9 should be on "TEST".
5. Stop turning the crank handle and hold the probe by its extremities and position it so that its center is at the same height as the pressure gauges and the saturation tube is in the 12 o'clock position, pointing upwards. Allow the excess water to flow out of the probe, until the probe reaches its original diameter. Replace saturation tubing plug and tighten.
6. Disconnect the Tecalan tubing from outlet No. 1. Refill the cylinder by placing valve No. 8 on "FILL" and returning the piston to its lowermost position.
7. Wait 1 minute.
8. Repeat steps D.3.b.1 through 3 as a final check on the saturation.
9. The instrument is ready to be calibrated. The instrument probe and tubing can be saturated before and transported to the site ready for testing.
10. Disconnect the two white tubing from ports No. 4 and No. 5.

E. Calibration Procedure

E.1. Saturating the Equipment

E.1.a. Saturating the Control Box Cylinder

Connect the short length of flexible tubing to the "Fill" quick connect Port 4. Push on the connector until you hear a 'click'.

Place the free ends of the saturation tubing in a small container – typically a 1-gallon plastic bottle - of clean water or antifreeze solution. It is imperative to maintain the ends of the tubing submerged during the saturation. Otherwise, air will enter the TEXAM. You may tape the tubing to the bottle for ensuring they stay submerged.

Set Valve 6 on "FILL".

Turn the small crank handle clockwise to bring the cylinder piston to its uppermost position corresponding to about 1732.00 cc on the counter. The uppermost position is reached when resistance is felt while cranking. Stop cranking then to not damage the equipment. While the piston is rising, the air in the cylinder is coming out from the tubing connected to the Port 4. Bubbles should be observed in the bottle.

Lower the piston by turning the crank handle counterclockwise at a rate of approximately 1 rotation per second, or slightly slower. While the piston is lowering, water is pumped inside the cylinder via the tubing connected to the Port 4.

When the piston has traveled to its lowermost position corresponding to 0 cc, stop the cranking operation and wait up to about a minute for the suction to stop, as indicated by a 0-kPa reading.

Set Valve 6 on "TEST".

Connect the short length of flexible tubing to the "Probe" quick connect Port 1.

Incline the control unit about 45 degrees toward yourself when facing the control unit. Turn the crank about 20 revolutions (240 cc) clockwise to expel any air that may have accumulated at the top of the cylinder. During this operation, watch closely to see that all entrapped air is evacuated and only bubble free water is flowing into the bottle by the tubing connected on the Port 1.

Return the instrument to the vertical and disconnect tubing from the Port 1.

Connect the hose to Port 3 and turn the crank until water comes out from the short tubing to expel the air trapped in the gauge line. Disconnect the hose from Port 3.

When using the optional digital gauge kit, proceed the same way, but make sure to open the valve mounted on the pressure gauge assembly before cranking and to close it after cranking. If the gage does not read zero when the valve is open, re-zero it. Never re-zero this one when the valve is closed.

Set Valve 6 on "FILL".

Bring the piston to 0 cc, by turning the crank handle counterclockwise. When fully lowered, wait about 30 seconds, and perform the saturation check.

E.1.b. Saturation and Leak Checks

Set Valve 6 on "TEST".

The volume and pressure should indicate around zero.

Install the large crank handle (a) on the rear side of the actuator and pressurize the unit up to 2500 kPa by rotating the large crank handle clockwise. Read the volume. If the volume indicated on the readout is more than 15 cc, the instrument is not completely saturated, and the saturation procedure described in steps 7 to 14. in section E.1.a. must be repeated.

Having determined that the instrument is completely saturated, verify that the unit is not leaking at high pressure by rotating the large crank handle until the pressure reaches 10,000 kPa. The pressure should stabilize after 2 minutes between 10,000 kPa and 9,500 kPa if there is no leak in the system. Bring the pressure back to 0 kPa by returning the piston to its lowermost position.

E.1.c. Saturating the Tubing Probe Assembly

Connect the extremity of the Tecalan tubing fitted with the quick connect to Port 1. Thread the other end of the tubing through the probe to rod adaptor and connect it to the probe. Tighten the nut using two wrenches. Do not over tighten: the brass nut is fragile and may crack. Lay down the probe next to the control box.

Remove the plug located at the lower extremity of the probe. Hold the probe bottom end up slightly inclined and with the saturation outlet in the 12 o'clock position.

With the Valve 6 on "TEST", inject water into the probe by rotating the crank handle clockwise until bubble free water only is flowing out of the saturation outlet of the probe. Stop turning the crank handle. Put the plug-in place and tighten.

Inject 100 cc of fluid in the probe.

Disconnect the Tecalan tubing from Port 1. Refill the cylinder by placing Valve 6 on "FILL" and returning the piston to its lowermost position. Wait 30 to 60 seconds.

Repeat steps 1-3 in section D.1.b. as a final check on the saturation of the unit.

Disconnect the tubing from Port 4.

The instrument is ready to be calibrated. The instrument, probe and tubing can be saturated in advance and transported to the site ready for testing.

F. Calibration

Calibration should be performed before any use of the pressuremeter, and after any rebuild of the probe that may be required on site.

F.1. Calibrations for Pressure Correction

1. The probe is placed at ground level and is unconfined.
2. Connect the Tecalan tubing to outlet No. 1.
3. Place valve No. 8 on "TEST" with gauge 6.
4. Place valve No. 9 on "TEST".
5. Rotate the small crank handle clockwise at a rate of 1 revolution every 2 seconds, until 80 cc have been injected.
6. Stop the injection, wait 30 seconds, and record the pressure which corresponds to the 80 or 40 cc of injection depending on the size of the probe used.
7. Continue this procedure until 1600 cc are injected.
8. Slowly rotate the crank handle counterclockwise to return the piston to its initial position (lowermost). The counter will indicate 0000.00
9. Plot the curve of injected volume versus pressure on the counter.

F.2. Calibration for Volume Correction

1. Connect the Tecalan tubing to outlet No. 1
2. Place valve No. 8 on "TEST" with gauge 6.
3. Place valve No. 9 on "TEST".
4. Place the probe inside a 0.5 inch thick drill casing reserved for this purpose.
5. Counter should be at 0 cc.
6. Apply 50 kPa of pressure by rotating the handle clockwise.
7. Stop the injection and record the corresponding counter reading and pressure after 30 seconds.
8. Continue the pressurization to 500 kPa in 50 kPa increments recording both pressure and volume after 30 seconds for each step.
9. Install the large crank handle.
10. For a low pressure test calibration, increase the pressure to 2500 kPa taking readings at every 500 kPa.
11. For a high pressure test calibration, repeat the same procedure used for a low pressure calibration.
12. For a high pressure test calibration, repeat the same procedure used for a low pressure calibration. When pressure gauge No. 6 reaches 2500 kPa, place valve No. 8 on "TEST with gauge 7". Continue to increase the pressure to 10,000 kPa and take readings every 500 kPa.

G. Correct Borehole Preparation

Two conditions are required to obtain a quality borehole:

1. The diameter of the borehole must be within certain tolerances.
2. The equipment and the method used to prepare the borehole should cause the least possible disturbance to the soil and the wall of the borehole. The diameter of the drilling tool is D_1, the diameter of the deflated probe is D_2, and the initial diameter of the borehole is D_3. The tolerances on the diameters are:

$$D_2 \leq D_1 \leq 1.03D_2$$
$$1.03D_2 \leq D_3 \leq 1.2D_2$$

Braun Intertec utilizes a 70mm diameter Texam Probe. Therefore, the above tolerances can be re-written as:

$$70mm \leq D_1 \leq 72.1mm$$
$$72.1mm \leq D_3 \leq 84mm$$
or
$$2.75in \leq D_1 \leq 2.84in$$
$$2.84in \leq D_3 \leq 3.3in$$

Use AW rods for a tricone roller drill bit (standard Braun Intertec bit for PM).

G.1. Drilling Requirements

Here are the requirements for proper borehole preparation once the correct tooling has been acquired. There are two methods used by Braun Intertec that depend on the soils at each site. These are the mud rotary method and the hollow stem auger method.

G.2. Mud Rotary Method

1. Mix drilling mud so that it is thick enough to keep hole open. If drilling in gravels, the mud should be very thick.
2. Drill rate should be very slow, 60 rpm. There should be no bubbles or big ripples on the return to the mud pit.
3. Do not move bit up and down while drilling. Only downward movement.
4. Dill approximately 3 feet past the test depth to allow cuttings to settle (not required, but best practice for high quality test), if difficult to achieve due to project requirements, this step may be ignored.

G.3. Hollow-Stem Auger Method

1. Advance auger approximately 3 feet above the test depth.
2. Push Thin-Wall samples, at least 2, to create an opening for the test probe.

A demonstration video produced by Roctest for a PM test and drilling can be viewed at the link below.

Borehole Preparation for a Pressuremeter Test

H. Inserting the Probe

Only rod weight should be used to lower probe. Do not use hydraulics on drill rig to lower probe. After double-checking that the borehole is filled with fluid, and the boring is drilled about 3 feet past the test depth, the probe is ready to be lowered in place.

1. Thread the probe tightly to the rods, using the adaptor for the tubing.
2. Keep the tubing taught as the probe is lowered. Secure the tubing to the rods every 10 feet with duct tape or electrical tape.
3. If a tight spot is encountered and it will not lower with the weight of the rods, two drillers can use two pipe wrenches to wiggle the probe up and down until the spot is cleared.
4. The test depth is the middle of the probe.

Vegetable oil can be placed on the outside membrane of the probe to prevent it from sticking to clayey soils.

I. Test Execution

I.1. Strain Controlled Test: Procedure B from ASTM D4719-20

1. Place valve No. 9 on "TEST".
2. Place valve No. 9 on:
    1. "Test with gauge 6" for tests to 2,500 kPa.
    2. For tests to 10,000 kPa, initially place valve No. 8 on "Test with gauge 6" until the pressure reaches 2,500 kPa. When gauge 6 reaches 2,500 kPa, place valve No. 8 on "Test with gauge 7".
3. Should an auxiliary gauge be used, connect it to outlet No. 3 and place valve No. 8 on "Test with gauge 3".
4. Lower the probe to test depth. See section H for proper insertion procedure.

    With the probe set at the test depth, the test can begin. The test is carried out in 40 steps of equal volume increments. The volume increments are 40 cc. Rotate the crank handle clockwise at a uniform rate of 12 rpm. to inject water, stopping to record the pressure 30 seconds after each step of volume. The maximum volume injected is 1600 cc.

    It is possible to carry on load/unload cycles between steps or increments of volume during a normal test, by injecting and delating the probe by a preselected volume.

5. When the maximum volume for the probe is injected, return the piston to its initial position at a rate not exceeding 20 rpm (3 seconds per revolution).

    For tests where the pressure has exceeded 2,500 kPa, place valve No. 8 on "Test with gauge 6" when pressure gauge No. 7 reaches 2,500 kPa and continue to depressurize the system.

    During the final stage of depressurization, the pressure gauge should remain near zero. Rapid rotation of the crank handle will introduce air into the system by deairing the water.

While Braun Intertec does not regularly perform unload-reload cycles as part of pressuremeter testing, the data may be of significant value to a particular project. When performing, the unload-reload cycle It is suggested to carry on an unload-reload cycle should be performed in the pseudo-elastic zone i.e., between Pf (creep pressure) and Po (in-situ horizontal earth pressure). This cycle, started typically at the end of the pseudo-elastic zone, can be performed different ways. The ASTM -D4719 standard suggests running this cycle in one step down to Pf / 2, and then back the same way up to Pf. Another method consists in reducing pressure in three equal-pressure steps down to a point slightly above Po, and then back the same way up to Pf. Roctest recommends using the latter method. During a test, the end of the pseudo-elastic zone may be found by keeping track of Δp, which will start decreasing when the soil starts to yield. When the unload-reload cycle is completed, the test is resumed in the plastic zone as a normal test.

6. When the test is over, you are ready to deflate the probe. Deflation of the probe must be done slowly at 4 seconds per revolution. Using drilling fluid in the borehole is filled with fluid for helping will help in deflating the probe. For test depths greater than 20 feet, pause deflation every 400 cc and wait about 30 to 40 seconds. It can take more time for the fluids to migrate when the probe is at a deeper depth, therefore pausing helps the fluid catch up to the revolutions performed.
    If the pressure drops to zero or close to zero, this means that the sheath is punctured. Do not bring volume back to 0 cc. Dirty water or mud would get into the unit.

7. Withdraw the probe. If this can't be done because the probe is sticks due to stiff plastic clay or because of caving problem, use the pipe wrench procedure described in Section H.
8. After retrieving the probe, clean the probe (outside and inside) using a nylon brush and a bucket filled with water. Be sure to swipe away from the fins on the probe to avoid water moving into the internal parts.

Stress-Controlled Test

This method is used during a creep test (see below). It can also be used for tests in very hard soils or in soft rock.

1. Lower the probe to the test depth.
2. For low pressure tests up to 2,500 kPa, place valve No. 8 on "TEST with gauge No. 6" For high pressure tests up to 10,000 kPa, place valve No. 8 on "TEST with gauge No. 6" until pressure gauge No. 6 reaches 2,500 kPa. At this point, place valve No. 8 on "TEST with gauge No. 7".
3. If an auxiliary gauge is used, connect it to outlet No. 3 and place valve No. 8 on position 3.
4. Using the large crank, set the pressure gauge reading to the first pressure step corresponding to 1/10 of the estimated pressure.
5. Maintain the pressure at this value and record the counter readings 30 to 60 seconds after the pressure step has been reached.
6. When the loading phase of the test is completed, return the piston to its initial position by turning the crank handle counterclockwise at a rate which will maintain the pressure greater than 2,500 kPa. Place valve No. 8 on "TEST with gauge 6" when gauge 7 reaches 2,500 kPa and continue to depressurize the system.

Additional comments for stress-controlled test:

1. Pressure step (ΔP) is generally 0.25, 0.5, 1 or 2 bars in soils, and 5 bars in rock. Pressure step can be estimated with the following relation: Pressure step (bar) = N (blow per foot) /20. Example if N = 17, start with a 0.5-bar pressure increment.
2. Calculate change in volume (ΔV) between the 30- and 60 second readings at each step to determine if you are in the pseudo-elastic zone or in the yielding zone. The pseudo-elastic zone is characterized by rather constant ΔV, while the yielding zone is characterized by increasing ΔV. If the test is still in the pseudo-elastic zone after 7 pressure steps, double the pressure increment. Adjust pressure steps to try to get 7-14 steps total in the test with at least 2 to 3 steps in the yielding zone.
3. An unload-reload cycle can be done. See instructions in Section H.1.
4. Warning: If the pressure drops to zero or close to zero, this means that the sheath is punctured. Do not bring volume back to 0 cc. Dirty water or mud would get into the unit.

J. Probe Disassembly and Assembly

J.1. Disassembly

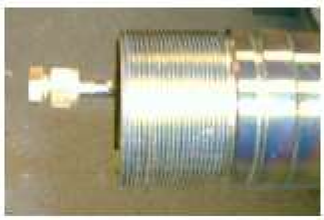
1. Screw the probe vise adaptor onto one end of the probe and clamp the adaptor in the jaws of a bench vice.
2. Use a strap wrench to unscrew the bronze knurled (2) nut from the free extremity of the probe.
3. To extract the metal tapered rings (3), use the strap wrench to rotate the ring in the direction of the lamination of the metal strips and simultaneously pull the ring outwards from the center of the probe.
4. To extract Vulcolan tapered rings (3), use the extractor provided with the instrument. Insert and screw in the extractor pins into the diametrically opposite holes located on the metal collar of

the Vulcolan ring. Rotate the extractor in the direction of lamination of the metal strips and simultaneously pull the extractor outwards.

5. In cases where removal of either type of tapered ring is difficult, the application of heat (using a propane torch or hot air gun with max temperature of 150°F) uniformly over the rings will facilitate their removal.
6. Clean all parts and probe's body and make sure O-rings are not damaged. For the probe body, see section I. For the interior parts, clean with dry or wet rags, using soap as needed. Clean at the end of every job. To clean the filter, flush it with water until any dirt has been washed away.

J.2. Assembly

1. Put an O-ring at the end close to the vice adaptor. Make sure probe's body is tightly fixed to the bench vice. Do not install the O-ring at the other end of the probe yet.



2. Do not grease the O-ring. Slide a metallic sheath on the probe's body. Make sure the electrical tape on each end of the sheath has been removed.
3. Place the second O-ring at the other end of the probe from the vice adaptor. Make sure the sheath is centered and that both O-rings are at their place.

4. Make sure that the metallic strips are not twisted.

5. Put hose clamps over the sheath. Pay attention to the direction of these clamps to prevent them from damaging the metallic strips during clamp tightening. The bottom portion of the clamp should move in the direction of overlapping of the metal strips (i.e., slide over the metal strips as opposed to sliding between/into the metal strips). Put a hose clamp at about 1 to 1.25 inches from the tip of the metallic strips.

6. Tightly put electrical tape at each ed of the sheath to squeeze the rubber and metallic strips.
7. Put MOLYKOTE 33 LIGHT grease (extreme-low-temperature grease) on the probe's threads, on the electrical tape, on the inner wall of yellow vulcolan rings, and on the flat inner side of the brass knurled nut.

8. Push, by hand, the yellow ring in place over the probe. Put the brass knurled nut in place and screw it. This will push the yellow ring inward. Continue screwing until three threads can be seen.
9. Free the probe from the vice and from the vice adaptor, then put the other end of the probe in the vice.

10. Make sure that the metallic strips are still straight. Following Steps X and X, put the yellow ring and knurled nut on this end of the probe.
11. Using a strap wrench, keep tightening the knurled nut until 5 to 6 threads can be seen.
12. Free the probe from the vice and reinstall it so the original end placed in the vice is back in the vice. Tighten the knurled nut until 5 to 6 threads can be seen.

13. Installation completed.

K. Transport

1. The instrument can be transported full of water and saturated as long as the piston is in its lowermost position. It is imperative to bleed water when unit will be exposed to freezing temperatures.
2. Unscrew the knurled nut on the screw actuator.
3. Dismount the screw jack and its support columns and disconnect the tubing.
4. Place Valve 6 on "TEST" and install the control unit cover.

Always keep the two TEXAM carrying cases upright. Never tilt them on their side.

L. Use in Cold Weather

L.1. Antifreeze

In order to use the TEXAM at temperature below freezing (32°F), water must be replaced by an antifreeze solution. Braun Intertec uses an ethylene-glycol solution.

At low temperatures, ethylene glycol will significantly increase viscosity of the liquid, which means that time required for inflating and deflating the probe will significantly increase too. A 50-50 solution of water - ethylene glycol by volume will allow using the equipment at about -15°F, a 70-30 solution can be used down to about 15°F. When using ethylene-glycol, flush the unit with clean water at the end of every job to protect it and avoid deposits. Ethylene-glycol is not environment-friendly.

L.1.a. Other Antifreezes

Methanol-based antifreezes (regularly used in windshield washer liquid) offer the best protection for pressuremeters at temperatures below -15°F. Note that methanol can be corrosive for the equipment and requires flushing the TEXAM with clean water at the end of every job to protect it. Methanol is not environment-friendly and is inflammable.

Ethanol-based antifreezes are sometimes used. Note that ethanol can be corrosive for the equipment, depending on the brand. RocTest research has shown that it will be too viscous to use at or below about 5°F . Ethanol is environment-friendly, but is inflammable.

Propylene-glycol-based antifreeze is normally too viscous for use with pressuremeters.

L.2. Valve leakage

When the pressuremeter is used at low temperature, valve No. 6 may leak. This is caused by the differential thermal contraction of the brass ball valve and its spherical Teflon seat. To stop the leak, remove the valve handle using a 3/32" Allen wrench and tighten the packing nut using the chrome plated packing nut tool provided with the instrument. Usually 1/8" of a turn will suffice to stop the leak.

M. Maintenance

1. Unscre the four screws of the mounting panel and lift panel.
2. The filter is mounted on the copper line connected to the Port No. 1.
3. Unscrew the brass nut on the copper tube of Port No.1 with a 9/16” open wrench.
4. Unscrew the 2 nuts on both sides of the filter and remove the filter from instrument.
5. Open filter housing by means of 2 ¾ “ wrenches and remove filter cartridge.
6. Clean all parts with clean water and re-install filter, following the opposite procedure of the removal.

N. Data and Records Management

Observations should be documented in accordance with SOP 101 – Field Notes and Documentation.

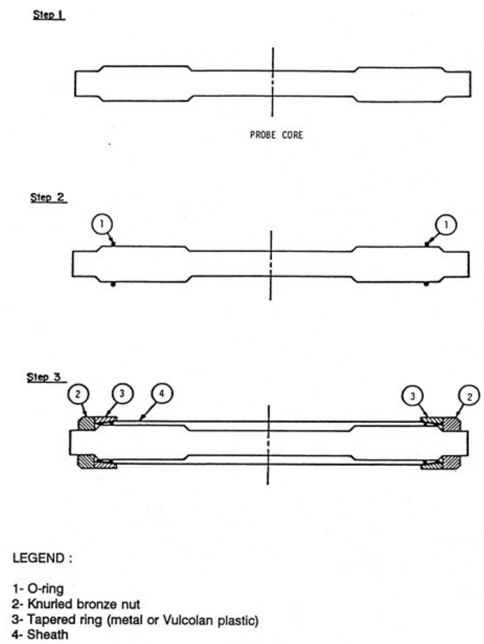
Use the TEXAM-Companion spreadsheet for data reduction. The spreadsheet is available through the Engineering Technical Practice Quality Site and contains instructions for use.

N.1. Quality Assurance/Quality Control

Quality assurance/quality control (QA/QC) procedures described in the work plan should be followed. See the Roctest TEXAM instruction manual for supplemental information and photographs that assist with operation.

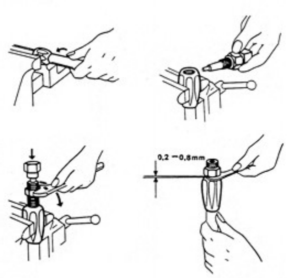
PAGE BREAK TO SEPARATE PHOTO PAGE

Photograph 1: Tricone drill bit (dense sands and gravels)



Photograph 2: Probe assembly and schematic drawing

1. Cut the tubing, at a right angle, cleanly.
2. Install a socket in a vice. Do not overtighten, do not misshape the socket
3. Screw the tubing into the socket thoroughly by rotating counterclockwise. Then, unscrew one quarter of a turn (**very important**)
4. Install the socket-fitted tubing vertically
5. Insert the coupling into the socket by pushing and screwing the coupling. Do not overtighten. Keep a 0.2 to 0.8 mm spacing between the socket and the coupling.



Photograph 3: Tecalan Tubing Splicing Method

	To Convert From	To	Multiply By
LENGTH	Microns Millimeters Meters	Inches Inches Feet	3.94E-05 0.0394 3.2808
AREA	Square millimeters Square meters	Square inches Square feet	0.0016 10.7643
VOLUME	Cubic centimeters Cubic meters Liters Liters	Cubic inches Cubic feet U.S. gallon Can–Br gallon	0.06101 35.3357 0.26420 0.21997
MASS	Kilograms Kilograms Kilograms	Pounds Short tons Long tons	2.20459 0.00110 0.00098
FORCE	Newtons Newtons Newtons	Pounds-force Kilograms-force Kips	0.22482 0.10197 0.00023
PRESSURE AND STRESS	Kilopascals Bars Inches head of water* Inches head of Hg Pascal Kilopascals Kilopascals Kilopascals	Psi Psi Psi PsI Newton / square meter Atmospheres Bars Meters head of water*	0.14503 14.4928 0.03606 0.49116 1 0.00987 0.01 0.10199
TEMPERATURE	Temp. in °F = (1.8 x Temp. in °C) + 32 Temp. in °C = (Temp. in °F – 32) / 1.8		

Photograph 4: Conversion Table

O. References

ASTM D4719-20 'Standard Test Methods for Prebored Pressuremeter Testing in Soils'

The Pressuremeter, Balkema, Briaud, J.-L., 1992

Attachments

Attachment A – ASTM D4719-20
Attachment B – Roctest TEXAM Pressuremeter Instruction Manual

Revision History

Revision No.	Date	Description
0	01/29/2021	Comments from M. Glisson
1	3/5/2021	Updated from comments, includes required follow up w/ Keith Alfonsi

about GHD

GHD is one of the world's leading professional services companies operating in the global markets of water, energy and resources, environment, property and buildings, and transportation. We provide engineering, environmental, and construction services to private and public sector clients.

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