Georgia Environmental Protection Division
Land Protection Branch
Response and Remediation Program
Response Development Units 1 – 3

2 Martin Luther King Jr. Dr. SE
Suite 1054 East Tower
Atlanta, Georgia 30334
Phone: 404-657-8600

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Name of Document:	Pre-Design Investigation Report & Final Design
Date of Document:	August 1, 2018
Site Name:	Cessna Aircraft Company GA1 Facility
Site ID Number:	VRP1460391735

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Signature:	
Name (printed): J. Thomas Duffey, PG	
Date: 8/1/2018	
Organization: CDM Smith	
Phone: 770-329-7143	
Email: DuffeyJT@CDMSmith.com	

REPORT

Pre-Design Investigation Report & Final Design

Cessna Aircraft Company GA1 Facility
VRP1460391735
Columbus, Muscogee County, Georgia

Cessna Aircraft Company

August 1, 2018

CDM Smith

Professional Certification

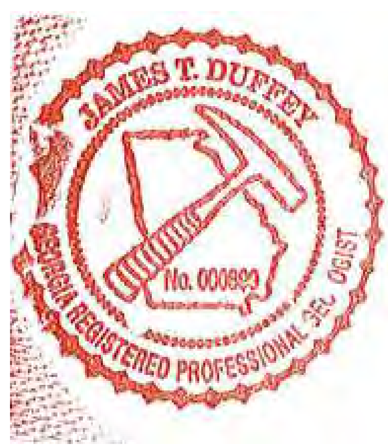
I certify under penalty of law that this report and all attachments were prepared by me or under my direct supervision in accordance with the Voluntary Remediation Program Act (O.C.G.A. Section 12-8-101, et seq.). I am a professional engineer / professional geologist who is registered with the Georgia State Board of Registration for Professional Engineers and Land Surveyors / Georgia State Board of Registration for Professional Geologists and I have the necessary experience and am in charge of the investigation and remediation of this release of regulated substances.

Furthermore, to document my direct oversight of the Voluntary Remediation Plan development, implementation of corrective action, and long term monitoring, I have attached a monthly summary of hours invoiced and description of services provided by me to the Voluntary Remediation Program participant since the previous submittal to the Georgia Environmental Protection Division.

The information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

J. Thomas Duffey, P.G.
Vice President
CDM Smith

Date: August 1, 2018



CDM Smith

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Acronyms / Abbreviations

bls	Below land surface
Cessna	Cessna Aircraft Company
CSM	Conceptual site model
DHC	dehalococcoides spp.
DCE	Dichloroethene
θ_e	Effective porosity
EPD	Environmental Protection Division
EVO	Emulsified vegetable oil
FOC	Fraction organic carbon
Ft/d	Feet/day
g	grams
g/cm^3	grams/cubic centimeter
GPM	Gallons per minute
Heatcraft	Worldwide Refrigeration
i	Hydraulic gradient
IDW	Investigation-derived waste
K	Hydraulic conductivity
Kemira	Kemira Chemicals, Inc.
mL	milliliters
MW	Molecular weight
NaCl	Sodium chloride
NS	Norfolk Southern Corporation
O&M	Operation and maintenance
POC	Point of compliance
PDI	Pre-design investigation
PRV	Pressure reducing valve
PVC	Polyvinyl chloride
RRS	Risk Reduction Standard
S	Storativity
SVE	Soil vapor extraction
S.U.	Standard unit
T	Transmissivity
TCE	Trichloroethene
TSI DC®	Terra Systems dechlorinating bioaugmentation culture
UIC	Underground injection control
VIRP	Voluntary Investigation and Remediation Plan
VOC	Volatile organic compound
VRP	Voluntary Remediation Program

Section 1 Introduction

This Pre-Design Investigation (PDI) Report has been prepared by CDM Smith for the Cessna Aircraft Company (Cessna) GA1 facility located in Columbus, GA. The Georgia Environmental Protection Division (EPD) accepted this site into the Voluntary Remediation Program (VRP) (EPD, September 27, 2016) and approved the VRP Application. The site is identified as VRP1460391735 and is not currently listed on the Hazardous Site Inventory.

A focused feasibility study was completed by CDM Smith in May 2017 that recommended a biobarrier in the Remediation Plan to treat groundwater (CDM Smith, May 24, 2017). EPD commented on the Remediation Plan (EPD, September 20, 2017) and CDM Smith submitted an Addendum (CDM Smith, November 16, 2017) to address EPD's comments. An initial task identified in the Remediation Plan was to conduct the PDI to provide data necessary to design, install, and operate an effective biobarrier. This PDI report describes the PDI methods, results, and conclusions and refines the biobarrier design details.

The design details presented in this PDI report are proposed to achieve the following objectives:

- ***Obtain EPD Response and Remediation Program approval to implement the biobarrier groundwater remedy;***
- ***Prepare an Underground Injection Control (UIC) Permit Application; and***
- ***Obtain a UIC permit from EPD's UIC Program.***

Details of the previous investigations are provided in the background documents identified above. Brief descriptions of the site, environmental conditions, and the groundwater remedy objectives are provided in the remainder of this report section below. Section 2 discusses the PDI methods and results. The design criteria for the biobarrier are presented in Section 3 and the final Biobarrier design is in Section 4. References are provided in Section 5.

1.1 Site Description

GA1 is a former Cessna facility that was used to fabricate and assemble aviation parts. The site is located at 4800 Cargo Drive in Columbus, Georgia (**Figure 1-1**). The facility is currently leased to Heatcraft Worldwide Refrigeration (Heatcraft) and used as a warehouse.

The site and surrounding properties are zoned for light industrial and manufacturing. The site is bordered by Cargo Drive to the west and a Norfolk Southern Corporation (NS) railroad to the immediate south. Beyond the NS railroad to the south is Kemira Chemicals, Inc. (Kemira). McCauley Propeller Systems is north of the site.

The former manufacturing building housed a vapor degreaser that is concluded to be the source of volatile organic compound (VOC) releases (**Figure 1-2**). The vapor degreaser used trichloroethene (TCE) and was decommissioned in 2010 and backfilled with concrete.

1.2 Hydrogeology

Three zones of hydrogeologic interest have been identified for the site, as summarized below.

Unit A - Unconsolidated Coastal Plain Sediments and Recent Alluvium. This unit is present beneath the building and extends off site to the south. The upper 20-25 feet consists of interbedded sand, silty sand, and silty clay. The lower portion of Unit A is permeable sand and permeable sand and gravel to a depth of approximately 30-35 feet below land surface (bls). The water table is at a depth of approximately 17-20 feet bls near the warehouse and from 5-7 feet bls downgradient and on the railroad property because the land surface elevation drops from approximately 312 feet down to 300 feet, as shown on Figure 2-1.

Unit B - Piedmont Saprolite. Unit B is below Unit A and encountered at depths ranging from approximately 30-35 feet bls and ranges from less than 1 foot up to 15 feet thick. Although water bearing, Unit B is primarily silt and has a lower permeability than Unit A. An upward hydraulic gradient exists from Unit B into Unit A.

Unit C - Piedmont Biotite Gneiss Bedrock. The bedrock depth ranges from approximately 30 feet to 45 feet bls. One monitoring well has been completed into bedrock, and the rock was dense biotite gneiss with few fractures.

1.3 Conceptual Site Model

Figure 1-3 provides the conceptual site model (CSM) previously developed for the site. The VOCs released from the former vapor degreaser entered the earthen fill underlying the building and the former vapor degreaser. The fill is silty sand. Soil beneath the fill is undisturbed stratified silty clayey sand to silty sandy clay with interbedded permeable sand lenses.

The liquid VOCs released from the former vapor degreaser to soil migrated downward and spread laterally. It is also possible that the VOCs migrated further as vapors resulting in a radial distribution. VOC migration in the vadose zone is currently controlled by a soil vapor extraction (SVE) system, and the vadose zone VOC mass is decreasing.

Because the former vapor degreaser pit is covered by the warehouse concrete floor, the soil has not been subjected to leaching from rainfall infiltration. Although leaching has not occurred, the VOCs have reached groundwater in Unit A and maintain a similar distribution in groundwater as in soil beneath the warehouse. Unit B contains lower VOC concentrations than Unit A. Unit C bedrock groundwater appears to be in poor communication with Unit A. TCE was detected in Unit C in February 2017 but has not been detected in following sampling events. Some natural TCE degradation could be occurring, but the natural TCE degradation potential appears to be low.

The highest potential for exposure exists for vapor intrusion in the warehouse. However, this exposure potential is currently controlled by the SVE system. Direct contact with soil beneath the warehouse is improbable, and beyond the footprint of the warehouse VOCs in soil are not encountered until a depth of 10-feet bls. Groundwater is not used on site or in the immediate site vicinity. CDM Smith postulates that low levels of TCE may discharge into the offsite tributary to Bull Creek on the Kemira property. However, this has not been verified because of the lack of access to Kemira property.

1.4 Biobarrier Objectives

As detailed in the Remediation Plan and Addendum, Risk Reduction Standards (RRSs) have been developed for groundwater (**Table 1-1**). VOCs may exceed the RRSs on the Kemira property. Because access to the Kemira property cannot be obtained, direct groundwater remediation on this property cannot be attempted. However, the VOCs on the Kemira property are expected to attenuate if an effective onsite groundwater remedy is implemented. The primary onsite groundwater remediation objective is to reduce VOC concentrations onsite to reduce the vapor intrusion potential and to mitigate offsite VOC migration in groundwater. This remediation is expected to result in groundwater onsite and offsite complying with the applicable RRSs.

1.5 Biobarrier Conceptual Design

The biobarrier will use *in-situ* biological treatment that involves injecting nutrients and microorganisms to promote microbial degradation of VOCs. Injection into injection wells will create a vertical "biobarrier" that treats groundwater as it passes through the barrier. Conventional small diameter wells are used for the injections. In addition to the vertical barrier, the treatment zone will extend downgradient to some extent as the dissolved bioremediation agent migrates with groundwater. The bioremediation agent will be injected into Unit A and Unit B, but it may also migrate into Unit C. However, the final design must ensure that the bioremediation agent does not migrate into the offsite tributary.

Section 2
Pre-Design Investigation

Data were collected during the PDI to support the biobarrier final design. The critical data requirements included aquifer hydraulic conductivity (K), transmissivity (T), effective porosity (θ_e), and dosing requirements for groundwater pH control. Groundwater tracer testing, groundwater sampling, formation sampling, and laboratory analyses were completed to fill the data gaps. An additional offsite well, MW-7A, was also installed to provide additional delineation data at EPD's request. The investigation locations are shown on **Figure 2-1**.

2.1 Well Installation

One groundwater monitoring well, two pilot test injection wells, and two pilot test monitor points were installed during the PDI. The two pilot test injection wells are intended to be incorporated into the future biobarrier. All wells were installed using hollow-stem augers and continuous soil core samples were collected. The boring logs and well construction data are included in **Appendix A**.

All wells were constructed using 2-inch diameter polyvinyl chloride (PVC) screen and casing and conventional annular backfill materials. Monitor well MW-7A was completed at a total depth of 16 feet bls and is screened exclusively in Unit A. The pilot test injection wells and monitor points were drilled to the depth of soil core refusal and the screen intervals were selected to intersect Unit A and Unit B with the injection well screens being approximately 2.5 feet below the water table surface.

All wells were developed following installation and were surveyed for location and elevation. Investigation-derived waste (IDW) consisting of soil cuttings and well development water was drummed and characterized for offsite disposal. The IDW was determined to be non-hazardous waste and was shipped offsite for disposal.

2.2 Groundwater Sampling

The pilot test injection wells and new well MW-7A were sampled and analyzed for VOCs following installation and development. The laboratory results for these analyses and the most recent results for the remainder of the monitor well network are summarized in **Table 2-1**. The laboratory reports and well purge records for samples collected during the PDI are in **Appendix B**.

EPD requested that CDM Smith consider potential mobilization of metals from soil during the groundwater remedy implementation. CDM Smith provided an evaluation in the Remediation Plan Addendum that recommended analyses and proposed RRSs for arsenic, barium, total chromium, lead, and manganese. During the PDI, monitor wells MW-3A, MW-3B, MW-4A, MW-4B, and MW-5A/B were sampled and analyzed for metals to provide the pre-remediation concentrations. These results are also summarized in Table 2-1 along with the associated field turbidity measurements. None of the metals exceeded the RRSs.

Groundwater samples were collected from MW-3A and MW-5A and analyzed for microorganisms and functional genes that are associated with chlorinated VOC biodegradation. This testing was completed to determine whether the necessary microorganisms for biodegradation were present in groundwater at the site or whether bioaugmentation would be necessary. All DHC results were below the laboratory detection limits and the laboratory report is provided in **Appendix C**.

2.3 Groundwater Tracer Tests

Two groundwater tracer tests were completed to provide data necessary to estimate design aquifer parameters (i.e., K, T, θ_e). The tracer tests consisted of injecting sodium chloride (NaCl) into the injection wells and injecting potable water to drive the NaCl tracer while water levels and groundwater specific conductivity were monitored. A UIC Program Pilot Test Notification form was submitted to EPD 30 days prior to the tracer tests (**Appendix D**).

The INJ-11 and INJ-13 tracer tests were performed on April 23rd and 24th, respectively. The tracer tests used 20 pounds of non-iodized, NaCl salt per well. The salt was introduced as a slug with gravity-driven potable water injection used to drive the NaCl tracer. Each tracer test was conducted separately. Water levels and specific conductance were recorded from the pilot test injection well, monitor wells, and temporary monitoring points using automated data loggers.

The tracer test injection system consisted of a water reservoir with a potable water supply controlled by a float valve. The float valve maintains the reservoir and injection well water level at a fixed elevation if the potable water supply rate is set higher than the rate at which the formation can accept the water under the pressure of gravity. In this case, the test is conducted as a constant-head test with a variable injection rate. The potable water flow rates were determined using a totalizing flow meter. The tracer test layout is shown on **Figure 2-2** along with the stratigraphy and the well screen intervals.

If the formation accepts the water a higher rate than furnished by the potable supply, then the test is conducted as a constant-injection rate test with a variable hydraulic head. Conventional methods are established to interpret the results from both the constant-head test and the constant-rate test.

2.3.1 INJ-11 Tracer Test

The INJ-11 test was initiated at 11:00 AM on April 23, 2018 and endured for 19 hours and 15 minutes. The average injection rate was 9.1 gallons per minute GPM and this test was completed as a constant-rate test. Hydrographs of the injection water levels and groundwater specific conductivity during the test are shown on **Figure 2-3**. The INJ-11 tracer test events are summarized below.

- 0 Minutes: Begin potable water injection
- 67 Minutes: Inject NaCl
- 360 Minutes: First NaCl arrival at MP-1
- 720 Minutes: Maximum peak at MP-1
- 1,155 Minutes: Stop injection

The INJ-11 potentiometric surface increased by approximately 20.3 feet and equilibrated at this level. The NaCl had migrated beyond INJ-11 within approximately 10 minutes of injection. The MP-1 potentiometric surface increased by approximately 3 feet and equilibrated. Useable conductivity data were not recorded by the MW-3A data logger because the conductivity sensor was inadvertently submerged in silt in the bottom of the well. The MW-3A water level increased by approximately 2.5 feet.

2.3.2 INJ-13 Tracer Test

The INJ-13 test was initiated at 7:15 AM on April 24, 2018 and endured for 26 hours and 15 minutes. The average injection rate was 4.6 GPM and test was completed as a constant-rate test. Hydrographs of the injection water levels and groundwater specific conductivity during the test are shown on **Figure 2-4**. The INJ-13 tracer test events are summarized below.

- 0 Minutes: Begin potable water injection
- 67 Minutes: Inject NaCl
- 170 Minutes: First NaCl arrival at MP-2
- 330 Minutes: Maximum peak at MP-2
- 915 Minutes: First NaCl arrival at MW-4A
- 1,575 Minutes: Stop injection
- 1,600 Minutes: Possible peak at MW-4A

The INJ-13 potentiometric surface increased by approximately 18 feet and equilibrated at this level. The tracer had migrated beyond INJ-13 within approximately 20 minutes of injection. The MP-2 potentiometric surface increased by 1.7 feet and equilibrated. The data show that the NaCl reached MW-4A and the conductivity breakthrough curve was depressed, indicating diffuse arrival at MW-4A. The MW-4A water level increased by approximately 1.7 feet.

2.3.3 Water Level Monitoring

Water levels were monitored during tracer testing to assess background potentiometric surface fluctuations and changes in response to injection. Rainfall data were also collected for the test period from the Columbus Airport located approximately 3 miles northwest of the site. These data are summarized in **Table 2-2**. Rainfall occurred prior to and during the tracer tests and it is probable that this resulted in some degree of recharge and increased groundwater levels. The amount of water level increase cannot be determined from the available data.

It is apparent that the injections affected the Unit A and Unit B water levels in all wells monitored out to 156 feet at MW-7A/B and MW-7A. This is a qualitative indication that Unit A and Unit B are under confined or semi-confined conditions, which likely minimized the effects of rainfall during the test relative to the effects of injection. **Figure 2-5** shows the potentiometric surface prior to injection and during the INJ-11 tracer test. **Figure 2-6** shows the potentiometric surface prior to injection and during the INJ-13 tracer test.

2.3.4 Tracer Test Solutions

The tracer test results were used to calculate T, K, and θ_e. Aquifer hydraulic parameter estimates were previously reported in the Remediation Plan and are summarized below.

Upper Unit A - Silty Sand

- Average Saturated Thickness = 9 feet
- K = 3 feet/day (ft/d)
- T = 27 ft^2/d

Lower Unit A - Sand and Gravel

- Average Saturated Thickness = 7 feet
- K = 25 ft/d
- T = 175 ft^2/d

Unit B - Saprolite

- Average Saturated Thickness = 6 feet
- K = 1 ft/d
- T = 6 ft^2/d

Unit A and B - Combined

- Average Saturated Thickness = 22 feet
- K = 9 ft/d
- T = 198 ft^2/d

Additional aquifer hydraulic parameters were estimated from the tracer test results and the Hydraulic analyses are shown in **Appendix E** on **Figure E-1** through **Figure E-4**. T and storativity (S) were estimated from the aquifer response to injection using the Theis solution (Theis, 1935) for MP-1, MP-2, MW-3A, and MW-4A and the results are listed below.

- MP-1: T = 209 ft^2/d, K = 10 ft/d, and S = 0.007
- MP-2: T = 282 ft^2/d, K = 15 ft/d, and S = 0.01
- MW-3A: T = 139 ft^2/d, K= 7 ft/d, and S = 0.01
- MW-4A: T = 211 ft^2/d, K = 12 ft/d, and S = 0.002
- Average: T = 210 ft^2/d, K = 11 ft/d, and S = 0.007

T was also estimated from the aquifer recovery data from the INJ-13 test using the Theis Recovery solution (Theis, 1935) for INJ-13, MP-2, and MW-4A. Recovery data were not collected following the INJ-11 test. These results are shown in Appendix E on **Figure E-5** through **Figure E-7**.

- INJ-13: T = 210 ft^2/d
- MP-2: T = 230 ft^2/d
- MW-4A: T = 130 ft^2/d
- Average: T = 190 ft^2/d

A good correlation exists between T and K from the Remediation Plan, the aquifer response to injection, and the recovery data. NaCl tracer data and the following formula were used to calculate θ_e from Darcy's Law.

$$\text{Velocity (V in ft/d)} = \frac{\text{K x hydraulic gradient } (i \text{ in ft/ft})}{\theta_e}$$

The calculations and results are shown in **Appendix F** for MP-1, MP-2, and MW-4A. The average values for T, S, and aquifer thickness for each pilot injection area were used for the calculations in Appendix F. The θ_e values calculated using the raw data were all too high to represent the actual aquifer conditions and this was because the observed water levels in the injection wells were artificially high because of well efficiency loss. The actual water levels in the aquifer adjacent to the borehole wall were lower than recorded in the well and therefore, the values of *i* used to calculate θ_e were too high. This is a common condition in this type of tracer test because well efficiency loss is nearly inevitable. It should be recognized that well efficiency does not affect the aquifer hydraulic solutions derived in Appendix E. These hydraulic solutions can be used to calculate representative water levels in response to injection for calculating the actual *i* in the aquifer.

The tables in Appendix F show the θ_e results determined using simulated water levels in the injection wells and the derived values were 0.32, 0.18, and 0.07. These values generally fall within the range for θ_e reported in literature of 0.1 to 0.35. It is apparent that the θ_e is highly variable at the site and this must be considered in selecting appropriate values for final design purposes.

2.4 pH Testing

Groundwater pH in the area proposed for the biobarrier has historically been too low to support *dehaloccoides spp.* (DHC) growth and pH control measures have been anticipated. MW-3A has had pH as low as approximately 4.5 standard units (S.U.) while the MW-3B pH was 6 S.U. The low pH problem appears to be associated with Unit A and not Unit B. As a result, pH testing of soil and groundwater with sodium bicarbonate was conducted to assess sodium bicarbonate dosing requirements for design purposes. A groundwater sample from MW-3A and two formation samples were collected. The formation samples were composite samples from INJ-11 and INJ-13. One sample was representative of the sandy clay/clayey sand zone in Unit A and one sample was representative of the sand and gravel zone in Unit A. The testing was completed by the CDM Smith Denver Treatability Laboratory. The test procedures are summarized below.

The soil samples were placed in stainless steel drying pans and allowed to air dry for 24-hours. The sandy clay sample was disaggregated using a disposable plastic knife to allow mixing and drying. Each soil sample was then mixed using a stainless-steel spoon and passed through a riffle splitter multiple times and 50-grams (g) were retained for testing. Gravel larger than ¼ inch was removed prior to splitting.

Sodium bicarbonate buffering of groundwater and groundwater mixed with soil was tested. Fisher, certified ACS crystalline sodium bicarbonate powder was used. Solution pH was measured using a calibrated Oakton 700 pH meter. All pH measurements were performed in a 250-milliliter (mL) flask. The solution was continuously mixed using a magnetic stir bar and plate. After each addition of sodium bicarbonate, the mixtures were allowed to equilibrate for a minimum of 5-minutes prior to measurement of pH. Testing of groundwater alone was performed on 100 mL. Testing of groundwater and soil mixtures used 100 mL of groundwater and 50 g of soil. One duplicate test was performed.

The pH testing results are in **Table 2-3**. The initial pH values prior to sodium bicarbonate addition were consistent with the historic groundwater pH measurements for MW-3A and the addition of soil to the groundwater further reduced the pH, meaning that the Unit A soil is likely the leading cause for the low pH groundwater. The highest sodium bicarbonate average demand was for the sandy clay soil at 331 mg sodium bicarbonate per S.U. pH. For all soil tests, the demand was the highest in raising the pH from approximately 6.1 S.U. to 6.3 S.U. and the demand was lower for further raising the pH up to 7 or more S.U. This indicates that the soil's acidification capacity may be neutralized by sodium bicarbonate at a pH greater than approximately 6.3 S.U.

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Section 3
Design Criteria

CDM Smith proposes using offsite wells MW-5A/B, MW-6, MW-7A/B, and MW-7A as points of compliance (POCs) and the compliance concentrations are the offsite RRSs. Maintaining the POCs below the offsite RRSs constitutes the success of the groundwater remedy. Onsite groundwater VOC concentrations will be reduced, but an extended time is anticipated to achieve the onsite RRSs. Future mass loading from the vadose zone soil is possible, but the SVE system is accomplishing VOC mass removal from the vadose zone. Back diffusion from the clayey soil layers beneath the water table could also contribute to VOC mass loading to groundwater.

3.1 Treatment Area

The estimated area having VOCs above the RRSs is shown on **Figure 3-1** and includes all locations that have historically reported VOCs above the RRSs. The most recent TCE results are posted on Figure 3-1. The biobarrier location will be selected to treat groundwater in Unit A and Unit B in the source area and immediately downgradient along the access road. The land slope is too steep to install injection wells further than the access road to the southeast. In addition, installation/operation of injection wells on NS property would present safety and logistical challenges because the railroad is an active and heavily used line. The previously determined biobarrier length of 145 feet remains an effective length and groundwater treatment should include the saturated thickness of Unit A and Unit B.

3.2 Aquifer Properties

Approximate average aquifer properties from the INJ-11 and the INJ-13 areas are recommended for the final design, as listed below.

- T = Rounded to one significant digit, 200 ft^2/d;
- S = Rounded to one significant digit, 0.007;
- Aquifer thickness = Unit A 14 feet and Unit B 11 feet;
- K = Unit A estimated 12 ft/d and Unit B estimated 3 ft/d;
- i = 0.01;
- θ_e = 0.1 to estimate injection radius in Unit A;
- θ_e = 0.2 to estimate aquifer volume and EVO requirements; and
- θ_e = 0.35 to estimate aquifer volume and sodium bicarbonate requirements.

3.3 VOC Concentrations and Degradation

The TCE concentrations in groundwater within the source area where the biobarrier will be installed reported from the site investigations were typically in mg/L range. However, nine wells have multiple sampling events over time and TCE appears to be decreasing (**Table 3-1**). Decreasing TCE in groundwater could be associated with the decommissioning of the vapor degreaser in 2010 and decreased VOC mass loading to groundwater from VOC mass removal by the SVE system beginning in February 2017. The TCE design criteria for the biobarrier is 3,000 µg/L, which is the average source area TCE groundwater from the current and historic data.

The proposed biological treatment is reductive dechlorination, an anaerobic process that utilizes DHC bacteria. This treatment sequentially degrades TCE into cis-1,2-dichloroethene (DCE), vinyl chloride, and ultimately ethene. Determination of the site-specific degradation rates was beyond the scope of the PDI. However, literature data and data from CDM Smith's experience on similar sites are sufficient for design purposes. The biodegradation rates for these compounds were researched and summarized by the Air Force Center for Environmental Excellence Technology for inclusion in the U.S. Environmental Protection Agency's BIOCHLOR model for evaluating natural attenuation (Air Force, 2002). These rates are summarized below as half-life values and as rate constants.

	Rate Constant (1/years)		Half-Life (years)	
	Average	75th Percentile	Average	75th Percentile
TCE	1.5	2.4	0.46	0.29
cis-1,2-DCE	3.5	2.2	0.2	0.32
Vinyl Chloride	3.6	4.9	0.19	0.14

The degradation rates listed above are from natural attenuation sites that had coincidental carbon sources as electron donor such as petroleum contamination. The biobarrier design will result in carbon source concentrations that will exceed the coincidental carbon source concentrations observed at the natural attenuation sites.

CDM Smith has current experience with degradation rates at a similar chlorinated VOC site. The source at this site was a former vapor degreaser that used TCE and the VOC source area was beneath a manufacturing building. The hydrogeology was similar with a surficial sandy clay/silt layer underlain by permeable sand and gravel. The groundwater depth was approximately 20 feet bls, the treatment depth was approximately 35 feet bls, and the treatment used emulsified vegetable oil (EVO). The average observed half-life value for TCE at this site is based on six source area wells and was approximately 0.3 years and the rate constant was 2.3/year.

Based on the range of literature values and CDM Smith's experience under similar site conditions, rate constants at the 75th percentile of the literature values are selected for use for the biobarrier design and these are considered conservative design criteria.

The molecular weight (MW) of TCE is 131.39, the cis-1,2-DCE MW is 96.94, and vinyl chloride is 62.5. The VOC breakdown concentrations and RRS comparisons are provided below.

- TCE at 3,000 µg/L → cis-1,2-DCE at 2,213 µg/L → Vinyl Chloride at 1,427 µg/L
- TCE at 95 µg/L → cis-1,2-DCE offsite RRS of 70 µg/L
- TCE at 4.2 µg/L → Vinyl Chloride offsite RRS of 2 µg/L
- cis-1,2-DCE at 3.1 µg/L → Vinyl Chloride offsite RRS of 2 µg/L

Based on these reactions and the VOC degradation rates, TCE will require approximately 3 years to achieve 4.2 µg/L and no longer produce vinyl chloride above the offsite RRS of 2 µg/L. cis-1,2-DCE will also require approximately 3 years to achieve 3.1 µg/L and no longer produce vinyl chloride above the offsite RRS of 2 µg/L. Vinyl chloride will require approximately 1 to 2 years to achieve the 2 µg/L RRS. Full breakdown is sequential, and the reactions do occur simultaneously. The overall lag time is expected to be less than one year.

Microorganism testing showed that DHC is not present in groundwater at the site at detectable concentrations. The bioaugmentation design criteria is recommended to add sufficient bacteria culture and promote growth to levels of 1E+06 cells/mL or more of DHC. The selected bioaugmentation product should supply a culture that has been demonstrated to efficiently degrade TCE down to ethene.

3.4 VOC Transport

The VOC migration rates in groundwater need to be considered to assess the treatment performance requirements to achieve the remediation objective of maintaining the offsite POCs below the offsite RRSs. A Domenico model (Domenico and Schwartz, 1990) was used to assess the VOC migration rates. It should be recognized by EPD that the use of this model is for design purposes only and it is not intended for compliance purposes. The currently planned compliance demonstration will be made through groundwater monitoring. As a result, CDM Smith is not requesting that EPD approve or disapprove of the model or the results.

The model is analytical and assumes a continuous source under steady-state conditions. The model incorporates the effects of advective transport, dispersion, adsorption, and first-order degradation using rate constants. Assuming a continuous source is a conservative assumption and allows an estimation of the long-term source area VOC concentrations that could result in RRS exceedances offsite. Additional model parameters are discussed below.

- Source Characteristics - A continuous source was assumed. The source area VOC concentrations used to calibrate the model are the maximum observed TCE concentrations. The source area VOC concentrations used to calculate the POC concentrations assume an average source area concentration of 3,000 µg/L TCE.
- Aquifer Properties - The aquifer properties used in the model are those recommended in Section 3.2 above.
- Degradation Rate Constants – The rate constants used for model calibration were the minimum values reported in the referenced literature. For future results under the biobarrier scenario, the 75th percentile of the literature values were used.
- Calibration Wells – Model calibration used the historic highest TCE concentrations starting with SB-4 as the source location at 16,600 µg/L leading down to SB-46 at 540 µg/L.
- Dispersivity – The dispersivity values are derived from well-recognized published sources that are referenced in model results.

- Soil-Water Partitioning Coefficients – EPA default values derived from the current Regional Screening Levels Users Guide were used.
- Fraction Organic Carbon (FOC) – FOC was initially set at the EPA default of 0.002 and adjusted during calibration to 0.02 to match the monitoring results to model results. While an FOC of 0.02 is on the high end of the range reported in literature, a high FOC provides a reasonable explanation as to why the soil/groundwater pH is low.

3.4.1 Model Calibration Results

The model calibration results are shown in **Table 3-2**. The calibration assumes a source concentration of 16,600 µg/L TCE with a width of 20 feet, which is approximately twice that of the former vapor degreaser and the approximate distance from SB-16 to the former vapor degreaser. The modeled TCE concentration at the POC, MW-5A/B, equals the observed maximum concentration of 1,900 µg/L. The model TCE concentrations upgradient of the POC from SB-15 to SB-30 are slightly higher than the observed concentrations by 10 percent and the model TCE concentration at SB-36 is higher by 3 percent. The overall model results are higher by seven percent and this is considered acceptable to remain conservative.

3.4.2 Biobarrier Model Results

The biobarrier model results are shown in **Table 3-3**. This model assumes an average source concentration of 3,000 µg/L TCE with the source width being the TCE plume width of 105 feet. The degradation rates were increased from the calibration model to the 75^{th} percentile of the literature values to account for the treatment effects of the biobarrier.

The modeled VOC concentrations at the nearest POC, MW-5A/B, are all below the offsite RRSs. However, the TCE and vinyl chloride biobarrier model results are only slightly below the offsite RRSs. The narrow gap between the model results and the offsite RRSs may not be overly problematic because the source TCE concentration of 3,000 µg/L would have to be maintained for over 20 years, but the design of the biobarrier needs to ensure that the degradation rates in the source area are maximized and the treatment area coverage is complete.

For the reason stated above, the final design for injection well locations, pH dosing, and carbon source dosing should be conservative to ensure that the degradation rates in the source area are maximized and the treatment area coverage is complete.

3.5 pH Dosing

To determine the pH dosing rate, the pH testing results were converted to the formation dry bulk density of 1.8 grams/cubic centimeter (g/cm^3) and the estimated water volume for a 35 percent porosity. These calculations are shown in **Table 3-4**. The design criteria recommended for the beginning aquifer pH prior to sodium bicarbonate addition is 4.3 S.U. CDM Smith recommends that the sodium bicarbonate dosing rate be the maximum observed from the titration test of 2.75 g of sodium bicarbonate per kg of groundwater to raise the groundwater pH by 1 S.U.

CDM Smith recommends that the pH dosing design criteria be selected to achieve a pH of 6.5 S.U. based on the pH testing results, which will carry the groundwater pH through the highest sodium bicarbonate demand range. This pH could potentially neutralize the aquifer's acidification capacity using sodium bicarbonate and could limit the need for future pH control. As a result, the design criteria for sodium bicarbonate dosing is recommended to be sufficient to raise the pH by 2.2 S.U.

Section 4
Biobarrier Design

The conceptual design presented in Remediation Plan and Addendum is updated in this section to incorporate the design criteria recommended in Section 3. Following EPD approval of this updated biobarrier design, the UIC permit application will be submitted to obtain a UIC permit and implement the groundwater remedy. The UIC permit application will include this report and will address all information required for a complete UIC permit application. The complete UIC permit application will be submitted to both the EPD Response and Remediation Program and the UIC Program offices. The completed draft UIC application is provided in **Appendix G**.

The overall conceptual design reported in the Remediation Plan remains sound and no insurmountable concerns were identified from the PDI. However, several of the PDI conclusions and the resulting recommended design criteria must be addressed. The PDI found the aquifer properties to be consistent with the conceptual design assumption but the PDI did indicate that the aquifer is inhomogeneous with regards to θ_e. The design criteria also concluded that injection well locations, pH dosing, and carbon source dosing should be conservative to ensure that the degradation rates in the source area are maximized and the treatment area coverage is complete. Because of the inhomogeneous aquifer conditions and the need to ensure optimum degradation rates, the number of proposed injection wells has been increased by three to increase the coverage of the groundwater treatment area and into the area of the highest historic groundwater TCE concentrations (**Figure 4-1**). The injection well locations on the interior of the warehouse may be adjusted slightly in the field to accommodate warehouse operations.

4.1 Design Overview

The biobarrier will consist of 16 wells as shown on Figure 4-1. The final locations for wells in the warehouse may be shifted to accommodate operations. Injection wells INJ-1, -2, and -3 are additions from the Remediation Plan and these additional wells are intended proactively reduce the VOC mass beneath the warehouse to reduce the VOC mass passing through the barrier formed by the remainder of the injection wells. Each injection well will fully penetrate Unit A and Unit B to a maximum anticipated depth of 45 feet bls. CDM Smith estimates that over 95% of the injected solutions will migrate through Unit A and the characteristics of Unit A are used for most design calculations for this reason. Some direct treatment will occur in Unit B, but VOC attenuation and migration into Unit A will be the primary mechanisms for VOC reduction in Unit B. The highest current TCE concentration in Unit B is approximately 25 µ/L in the source area at MW-3B. VOCs reported in MW-5A/B and MW-7A/B are believed to be present primarily from migration in Unit A.

As bioremediation is initiated, VOC concentrations may briefly increase as the biological activity can desorb VOCs from soil into groundwater where they can be treated. The production of cis-1,2-DCE is be the first indication that bioremediation is occurring. However, vinyl chloride production followed by ethene production is necessary to treat TCE to the desired end product.

4.2 Injection Well Installation

A typical well construction diagram is shown in Appendix G (**Figure 1**). Prior to injection well installation, continuous soil cores will be collecting using direct-push techniques for final well depth determination. The injection wells will be installed using conventional hollow-stem auger techniques. The screens and casings will be 2-inch diameter PVC. The injection wells will be installed to the depth of bedrock refusal, estimated to be from 35 to 45 feet bls, and completed with approximate 20-foot screens. Final injection well design will be determined in the field based on the boring logs and depth to water measurements from existing wells adjacent to the well location.

- Well screens will be supplied in 10-, 5-, and 2.5-foot lengths to allow for variable depths to bedrock and water table depths.
- Screen bottoms will be placed 1 foot above the bottom of the borehole.
- Screen tops will be a minimum of 3 feet below the estimated water table.
- Silica sand filter pack will be installed to a level of one to two feet above the screen slots.
- Two-foot thick bentonite seals will be placed on top of the sand pack and below the water table.

Sand pack will be installed throughout the screen interval to a depth corresponding to 1 to 2 feet above the screen. All wells will have a 2-foot thick bentonite seal emplaced on top of the sand pack. The bentonite seal shall be placed below the water table to ensure it remains hydrated. The boreholes will be grouted to land surface using neat cement.

The wells will be completed with flush-mount, bolt-down protective covers set in concrete pads. The top of the injection well casings will be fitted with PVC 2-inch diameter female NPT pipe threads attached using a solvent weld for future injection purposes. The well plug and casing shall terminate at a level that will allow the bolt-down cover to be removed and reinstalled without interference.

The injection wells will be developed after the grout has been allowed to set for a minimum of 24 hours. Development will consist of pumping approximately 1.5 gallons per linear foot of screen. Development will continue should the development water remain excessively turbid. A groundwater sample will be collected from each injection well following development and analyzed for VOCs.

A short-term injection test will be performed on each injection well. This test will consist of injecting potable water under the pressure of gravity for a period of approximately 30 minutes at a rate not to exceed 5 gpm to determine whether the well can support the design flow rates and pressures. If the flow rate is lower than the design rate, or the injection pressure exceeds the design pressure, it will need to be determined whether a contingency well(s) is required or whether revised injection volumes may be necessary based on injection performance.

Drums will be used for the collection of soil cuttings and the development water. The soil cuttings and development water will be characterized for disposal purposes and transported to an appropriate offsite disposal facility.

4.3 Injection System

The biobarrier injection system will consist of a potable water supply, a portable tank for sodium bicarbonate addition and mixing, an inline chemical feed pump, the electron donor tank, a well injection manifold, injection distribution hoses, and injection wellheads. The injection system will be constructed to be watertight with solvent welds for PVC fittings and thread sealant on all threaded connections.

Potable water will be supplied via a potable water line with water meter to be installed in the treatment area. Temporary piping and hoses will be used to transfer the potable water from the supply to a portable 21,000-gallon tank. The water in the tank will be mixed with sodium bicarbonate for pH control. Batch process mixing will be completed by recirculating the solution through the tank using a high-volume pump. A submersible pump will be placed into the tank to supply the sodium bicarbonate solution to the electron donor addition system.

The electron donor mixing system will be portable and staged at the center of the biobarrier. The electron donor mixing system will consist of a 275-gallon electron donor reservoir and a chemical feed pump. Pressure gauges will be located upstream and downstream of the chemical feed pump. The chemical feed pump will be set to deliver the electron donor at the predetermined volumetric target donor product percentages.

A pressure reducing valve (PRV) will be located between the chemical feed pump and the injection well manifold. The injection solution will enter the injection well manifold downstream of the PRV. A totalizing flow meter, flow control valve, and pressure gauge will be supplied for each injection well connection on the manifold.

The injection solution will be piped from the injection manifold to the injection wellheads using 5/8-inch diameter hose. During injection, the flow control valve will be used to adjust the individual well injection rates. Injection pressures will be monitored at the manifold and at the wellhead with the flow rates and the PRV adjusted to ensure that the design injection pressures are not exceeded at the injection wellheads.

The injection wellhead assembly will consist of a connection for the delivery hose, a pressure gauge for monitoring injection pressure, and an air vent valve. The vent valve is open as injection is initiated, and once the wellhead assembly is full of solution, the valve is closed. Air in the headspace of the wellhead assembly can stop the flow of fluids into the injection well.

4.4 Injection Design

The injection design described in this section is based on CDM Smith's experience with bioremediation, best professional judgement, and the design criteria from the PDI. The design is focused on preventing the downgradient migration of the injection solution to prevent discharge to offsite tributary. The sequence of events to initiate and maintain treatment within the biobarrier is listed below.

1. Initial full-scale EVO and sodium bicarbonate bioremediation injection.
2. Establish reducing conditions over 2 months.
3. Perform DHC analyses. If sufficient DHC is reported, proceed to step 6.
4. Inject sodium ascorbate solution and Terra Systems TSI DC® Bioaugmentation Culture.
5. Follow-up 50% of full-scale EVO and sodium bicarbonate injection.
6. Repeat full-scale EVO and sodium bicarbonate injections, typically at 2- to 5-year intervals, as required for O&M.

Product information sheets and safety data sheets for the proposed injection products are provided in **Appendix H**. The bioremediation solution formulations and injection design calculations are in **Table 4-1**. The final design volumes listed below are rounded from Table 4-1 to accommodate the packaging and shipping volumes of the various materials.

The initial injection in step 1 is intended to prime the groundwater geochemical conditions for bioaugmentation, if necessary. This injection will utilize Terra Systems 60% SRS®-FRL Large Droplet EVO and sodium bicarbonate will be injected to buffer pH along with potable water. The injection design is summarized below.

Full-Scale EVO Injection Design

- Total Volume: 4,160 gallons per well, 66,560 gallons total
- 60% SRS®-FRL: 198 gallons per well, 3,168 gallons total (12 IBC totes), 4.76 percent by volume
- Sodium Bicarbonate: 17,500 pounds total (7 pallets), ~3.3 percent by weight

All injections will be followed by a clean water flush for approximately five screen pack volumes to prevent well fouling. The water flush will consist of approximately 100 gallons of potable water per well.

After allowing reducing conditions to be established over a period of approximately two months, select wells will be tested for pH to determine if the pH is appropriate for DHC growth. If so, groundwater samples will be collected from MW-3A, INJ-5, and INJ-11 for DHC analyses. Based on the results of the DHC analyses, a determination will be made as to whether bioaugmentation is necessary.

Sodium ascorbate will be used to prepare the bioaugmentation flush solution. This flush solution is necessary to ensure that the water used to flush the bioaugmentation culture into the formation is not toxic to the culture. Terra Systems dechlorinating bioaugmentation culture (TSI DC®) will be used as the bioaugmentation culture. The bioaugmentation injection design is summarized below.

Bioaugmentation Injection Design

- TSI DC®: 3 liters per well containing over 1E+11 cells per liter
- Flush Solution: 25 gallons of water per well, 450 gallons total
- 60% SRS®-FRL: 5 gallons total
- Sodium Ascorbate: 500 grams total

Following bioaugmentation, a reduced-scale EVO injection will be completed that will utilize 50 percent of the full-scale EVO injection design. This first EVO injection will also require use of 110 pounds of sodium ascorbate solution to protect the bioaugmentation culture. This injection will utilize a slow release electron donor, 60% SRS®-FRL EVO formulation. Sodium bicarbonate will be injected to buffer pH along with the 60% SRS®-FRL and potable water.

CDM Smith estimates that injection pressure should remain well below 10 pounds per square inch (psi) to prevent soil rupturing. To be conservative, a limit of 7.5 psi at the injection well head will be used as the maximum injection pressure. All injections will be performed under direct supervision of the field staff and monitoring for injection surfacing near the well heads and along the slope leading down to the railroad tracks will be completed at 30-minute intervals. CDM Smith calculated that minimal pressure will develop at the planned injection flow rate of approximately 5 gpm per well, as shown in Table 4-1.

4.5 Injection Procedures

The water supply lines, the injection system, and injection wells will be monitored during the all injections for leaks. Appropriate corrective measures will be taken if leaks or injection solution surfacing are discovered. Data collection during the injections will be recorded regularly. The injection data that will be recorded to document the injections includes, but is not limited to, daily volume for the total system, daily volume for each individual well, volume and pressure at each individual well at approximate 1-hour intervals, volume of flush water following injection completion at each individual well, volume of electron donor reservoir at approximate 2-hour intervals, and pressure at the PRV and chemical feed pressure gauges.

4.6 O&M

Maintenance injections using EVO and sodium bicarbonate are expected to be required at approximately two- to five-year intervals. The design for the maintenance injections is summarized below.

O&M EVO Injection Design

- Total Volume: 4,160 gallons per well, 66,560 gallons total
- 60% SRS®-FRL: 198 gallons per well, 3,168 gallons total (12 IBC totes), 4.76 percent by volume
- Sodium Bicarbonate: 17,500 pounds total (7 pallets), ~3.3 percent by weight

Biofouling of the injection wells may also occur, and if sufficient injection rates cannot be sustained, maintenance will be required. Biofouling can typically be corrected by redeveloping the wells using surging and pumping. Under extreme circumstances, a bleach product may be required to loosen bacterial growth followed by development. Because the bleach will be removed by development and is routinely used in this manner for water wells, this product does not need to be included in the UIC permit.

4.7 Groundwater Monitoring and Reporting

Site-wide groundwater monitoring and reporting will be completed, as currently required under the VRP program. Additional monitoring will be completed to assess the biobarrier performance. This performance monitoring will use groundwater wells MW-3A, -3B, -4A, -4B, -5A/B, -7A, and -7A/B. Quarterly sampling will be completed during the first year of the biobarrier operation and semi-annually thereafter. During each sampling event, the following additional data collection and analyses will be completed for these seven wells.

In Situ Measurements	Hach Analyses	Laboratory Analyses
-Redox potential	-Nitrate	-Ethene, Ethane, Methane
-Dissolved oxygen	-Sulfate	-Chemical oxygen demand
-Turbidity	-Ferrous iron	-Volatile organic compounds
-Specific conductance	-Total iron	-Arsenic, Barium, Total Chromium, Lead, and Manganese
-pH	-Carbon dioxide	
-Temperature	-Alkalinity	

On the first sampling event following bioaugmentation, groundwater samples collected from select injection wells, MW-3A, and MW-3B will be analyzed for DHC bacteria. Additional DHC analyses will be completed on as as-needed basis.

4.8 Compliance Status Report

Two years after startup of the biobarrier treatment, a compliance status report (CSR) will be prepared that conforms to the EPD's requirements. The CSR will document the site investigations, update the horizontal and vertical extent of RRS exceedances, and determine the effectiveness of the remedial actions. The following list of EPD's checklist items will be attached to the CSR.

- Concise statement of report findings;
- Property owner verification;
- Qualified groundwater scientist statement;
- Source description;
- Extent of groundwater contamination;
- Description of potential environmental receptors;
- Identification of affected properties;
- Potentially responsible party contact information; and

- Description of remediation.

4.9 Schedule

Figure 4-2 includes the proposed schedule for the biobarrier construction at the Cessna GA1 site. Following EPD review and approval of this document, approximately six weeks are anticipated to receive the UIC permit. Remedial construction cannot begin until the UIC permit is issued. Remedial construction on the biobarrier and injections are anticipated to occur in early 2019. Sufficient data to assess the biobarrier effectiveness should be available in 2021, at which time a Compliance Status Report will be submitted. Biobarrier O&M will continue on an as-needed basis and semiannual progress reports will continue to be submitted.

Section 5
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Figures

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Figure 1-1: Site Location
Cessna GA1 Facility
Columbus, Muscogee County, Georgia

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Topographic Contour
310
Contour Interval = 2 Ft.

Stream
(Possibly Intermittent)

Site Boundary

Offsite Properties

Scale in Feet
0 100 200

Figure 1-2: Site Features

Cessna GA1 Facility

Columbus, Muscogee County, Georgia

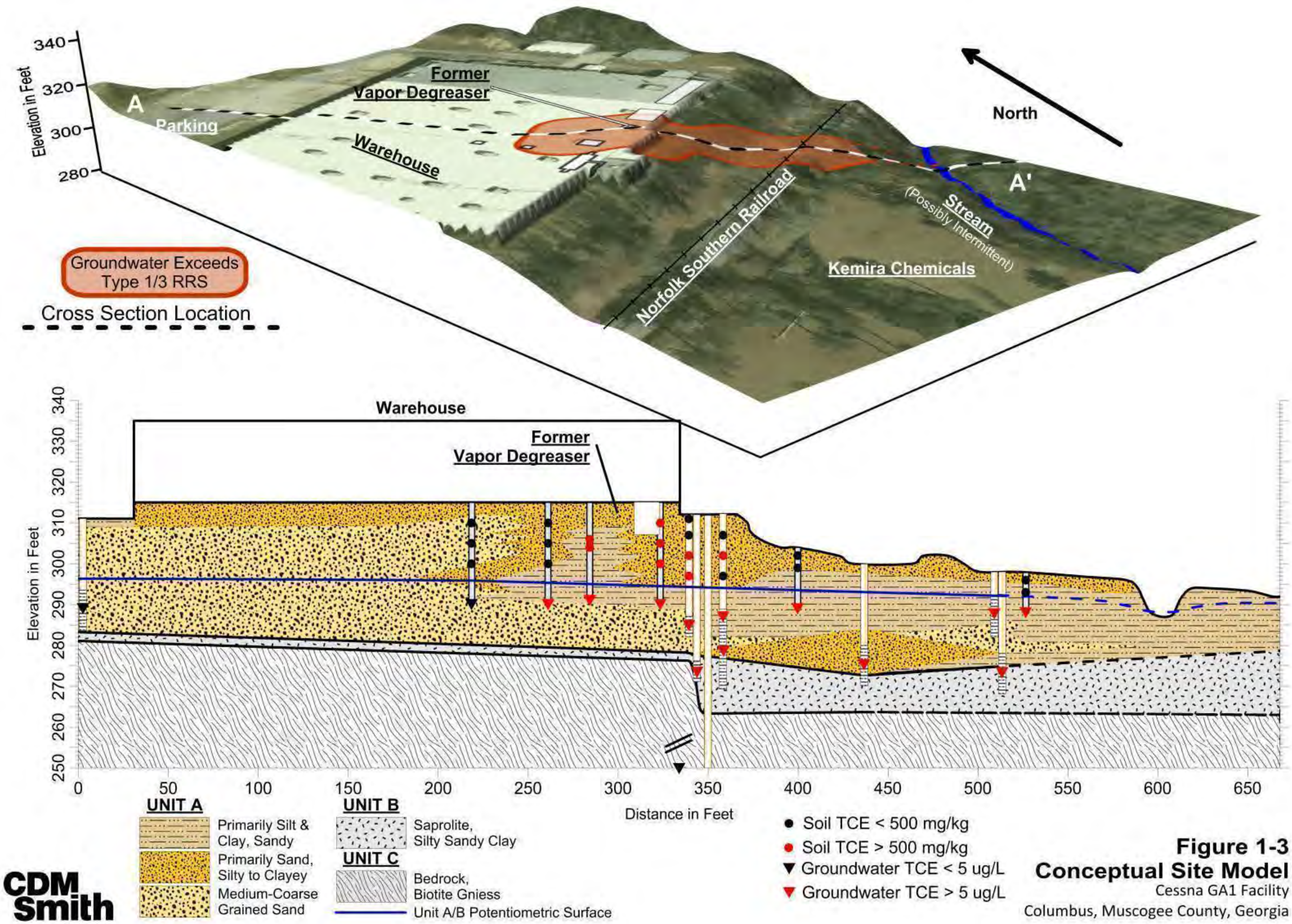

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Figure 1-3
Conceptual Site Model
Cessna GA1 Facility
Columbus, Muscogee County, Georgia

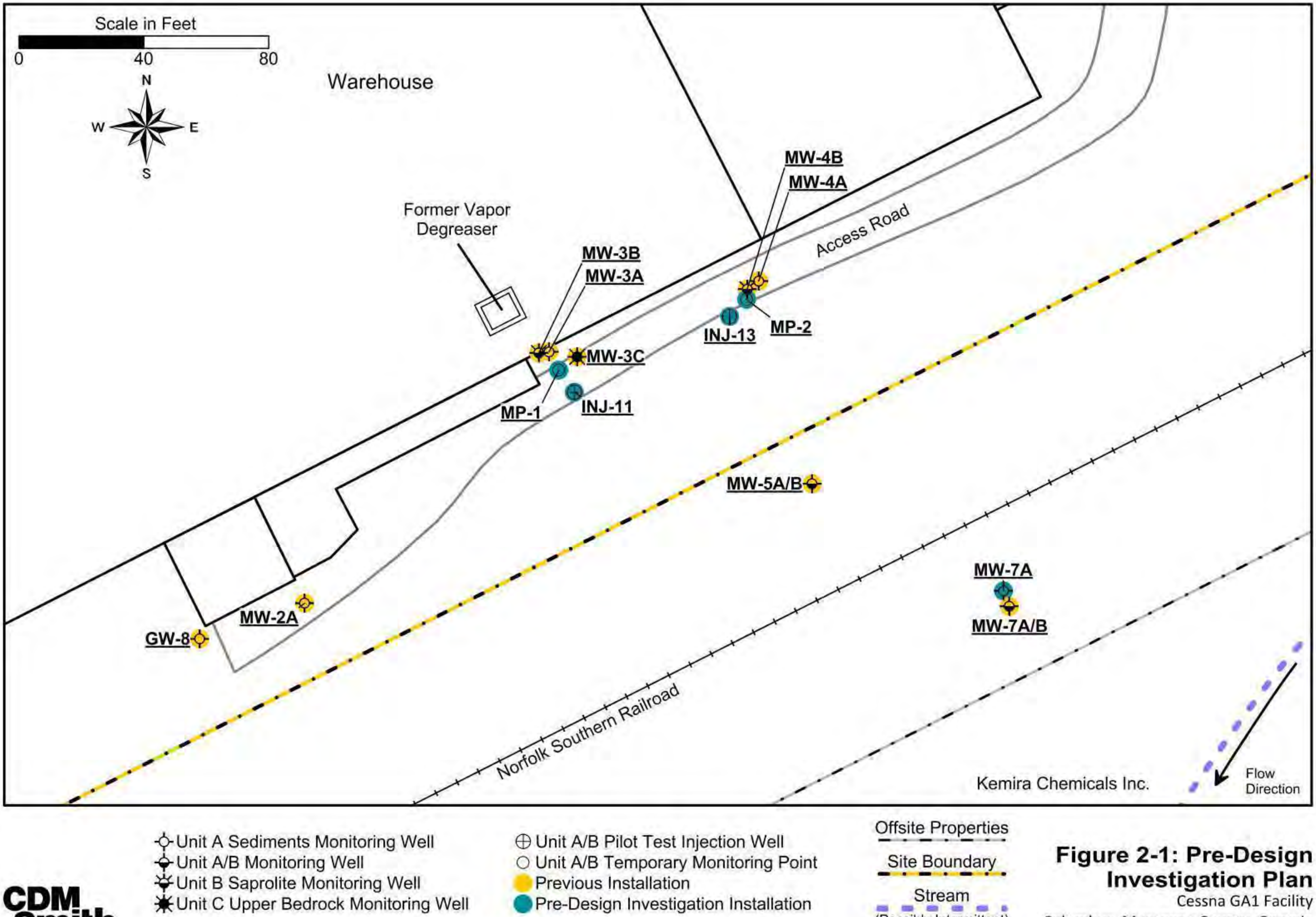

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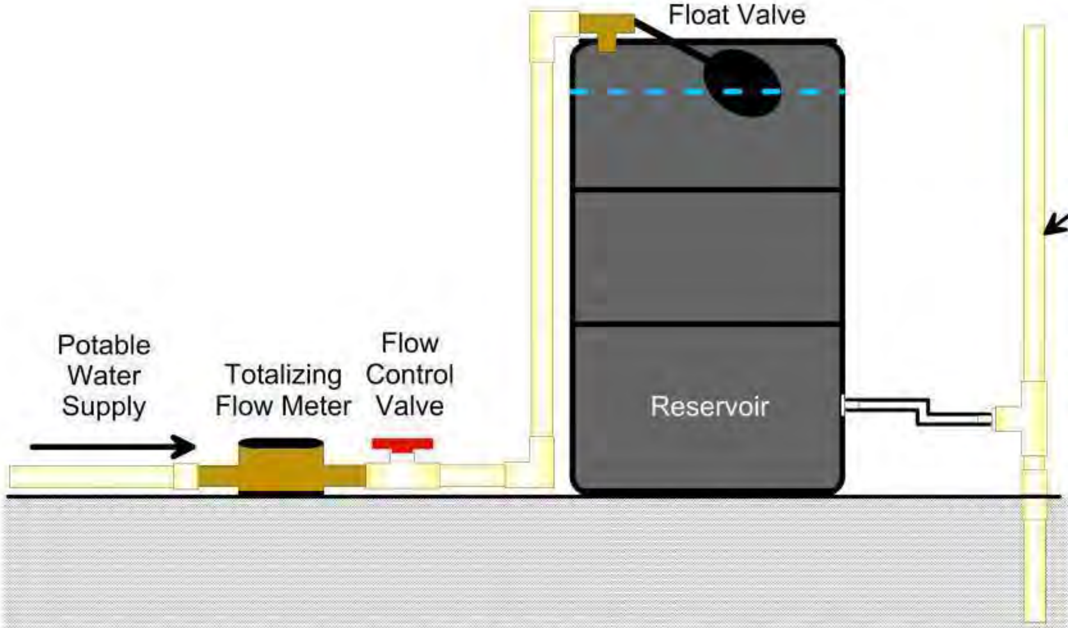
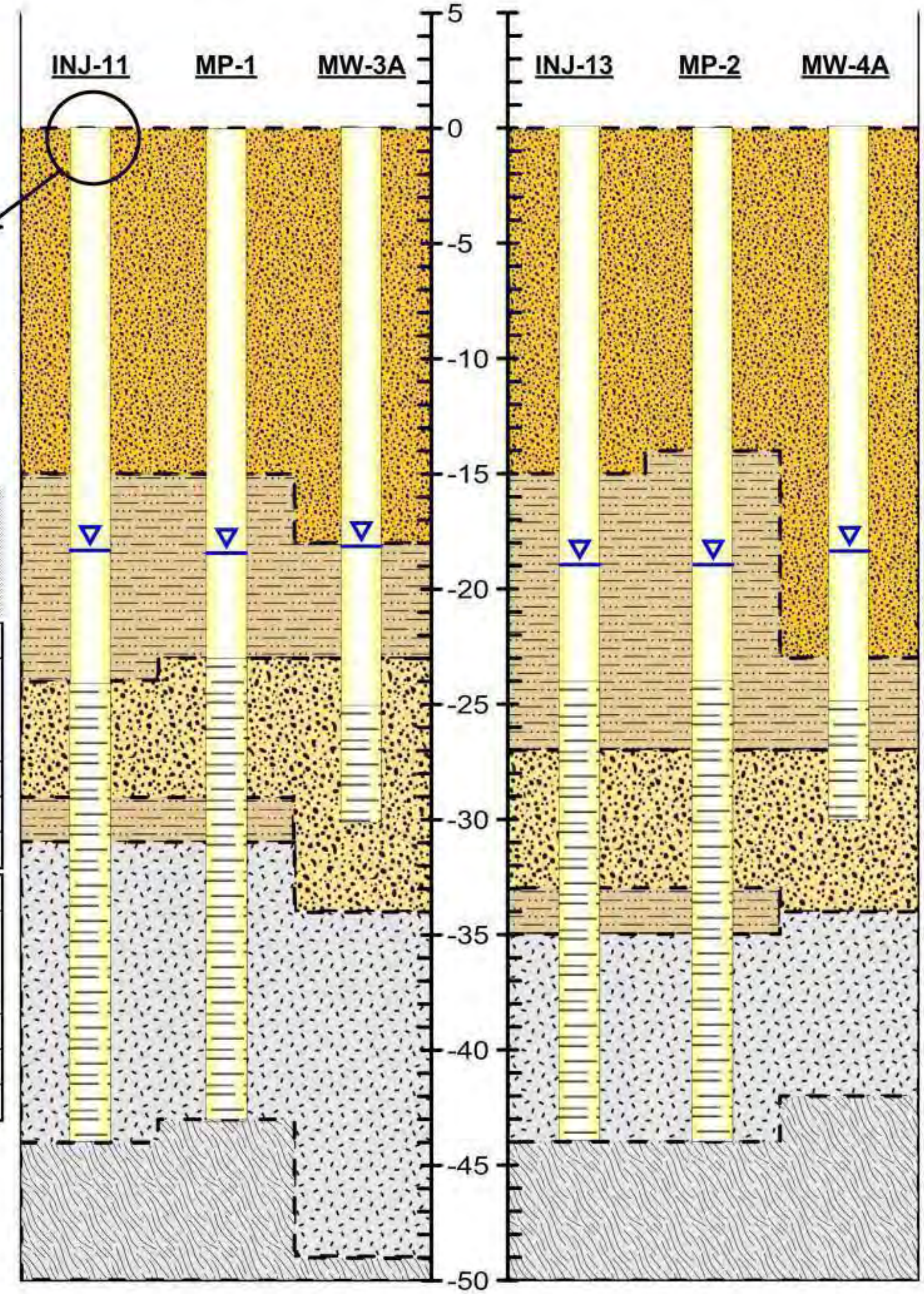
Figure 2-1: Pre-Design Investigation Plan

Cessna GA1 Facility

Columbus, Muscogee County, Georgia





INJ-11 Test									
Code	Radial Distance	Screen Interval	Upper Sand	Semi-Confining Clay	Water Level	Sand & Gravel	Lower Clay	Saprolite	Bedrock
INJ-11	0'	24'-44'	0'-15'	15'-24'	18.37	24'-29'	29'-31'	31'-44'	@44'
MP-1	8.7'	23'-43'	0'-15'	15'-23'	18.50	23'-29'	29'-31'	31'-43'	@43'
MW-3A	15.2	25'-30'	0'-18'	18'-23'	18.20	23'-34'	Absent	34'-49'	@49'

INJ-13 Test									
Code	Radial Distance	Screen Interval	Upper Sand	Semi-Confining Clay	Water Level	Sand & Gravel	Lower Clay	Saprolite	Bedrock
INJ-13	0'	24'-44'	0'-15'	15'-27'	18.92	27'-33'	33'-35'	35'-44'	@44'
MP-2	7.5'	24'-44'	0'-14'	14'-27'	19.05	27'-33'	33'-35'	35'-44'	@44'
MW-4A	14.6	25'-30'	0'-23'	23'-27'	19.38	27'-34'	Absent	34'-42'	@42'

UNIT A

- Primarily Silt & Clay, Sandy
- Primarily Sand, Silty to Clayey
- Medium-Coarse Grained Sand

UNIT B

- Saprolite, Silty Sandy Clay

UNIT C

- Bedrock, Biotite Gniess

▽ Potentiometric Surface

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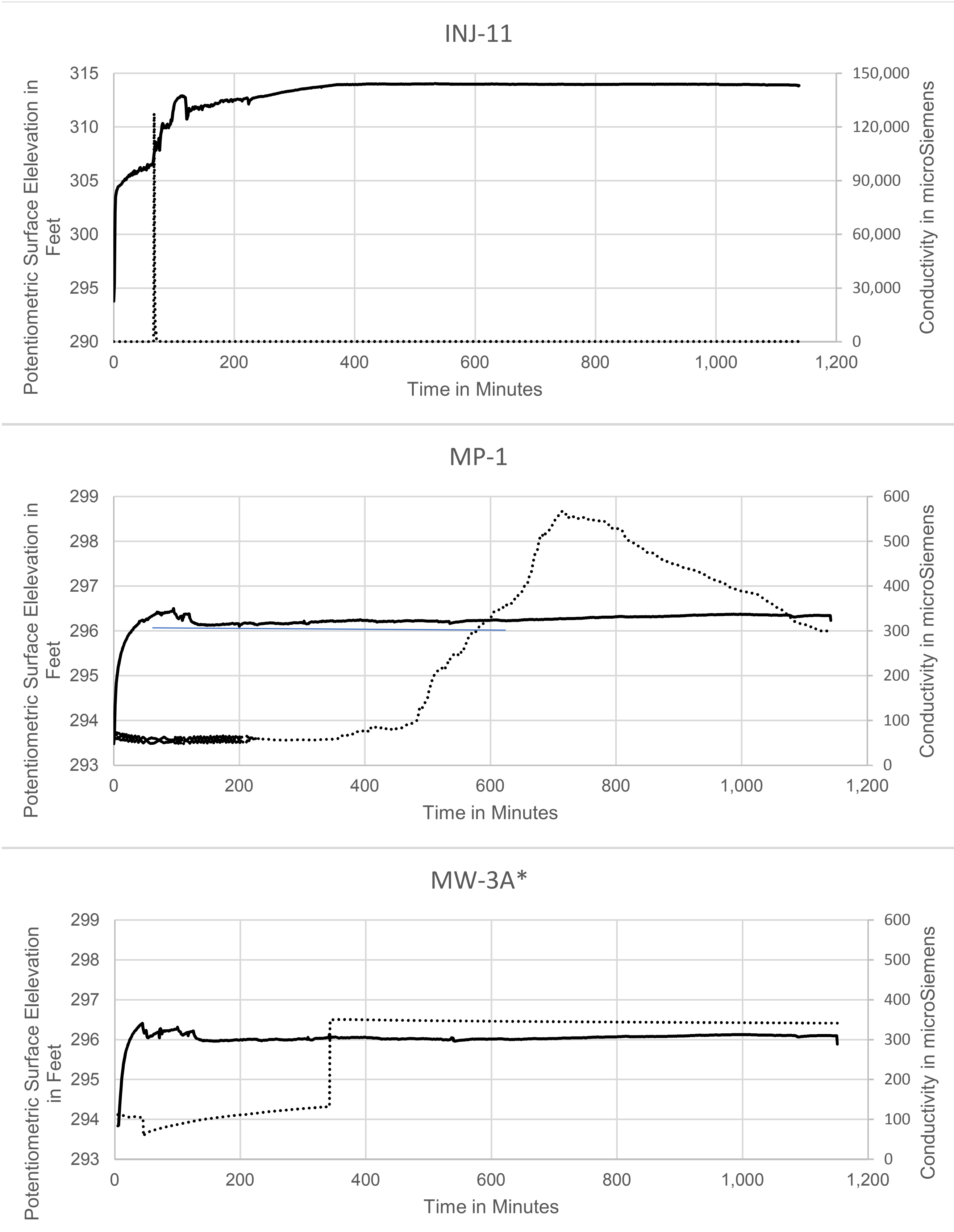
Figure 2-2: Tracer Test Layout

Cessna GA1 Facility

Columbus, Muscogee County, Georgia



* - Conductivity transducer not responsive to aquifer conditions.

Potentiometric Surface ——————

Specific Conductivity ··············

Figure 2-3: INJ-11 Tracer Test Hydrographs

Cessna GA1 Facility
Columbus, Muscogee County, Georgia

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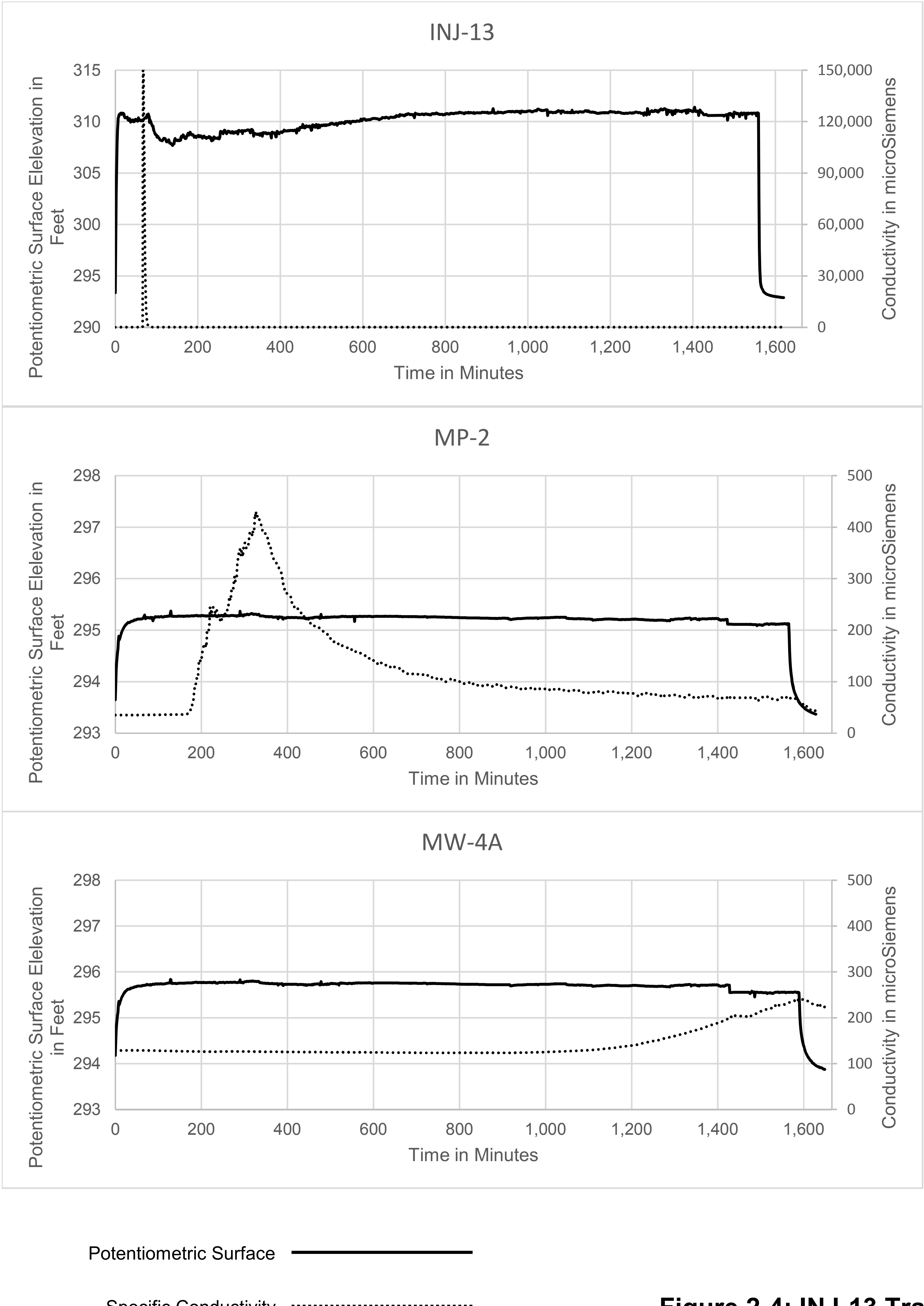

Figure 2-4: INJ-13 Tracer Test Hydrographs

Cessna GA1 Facility

Columbus, Muscogee County, Georgia

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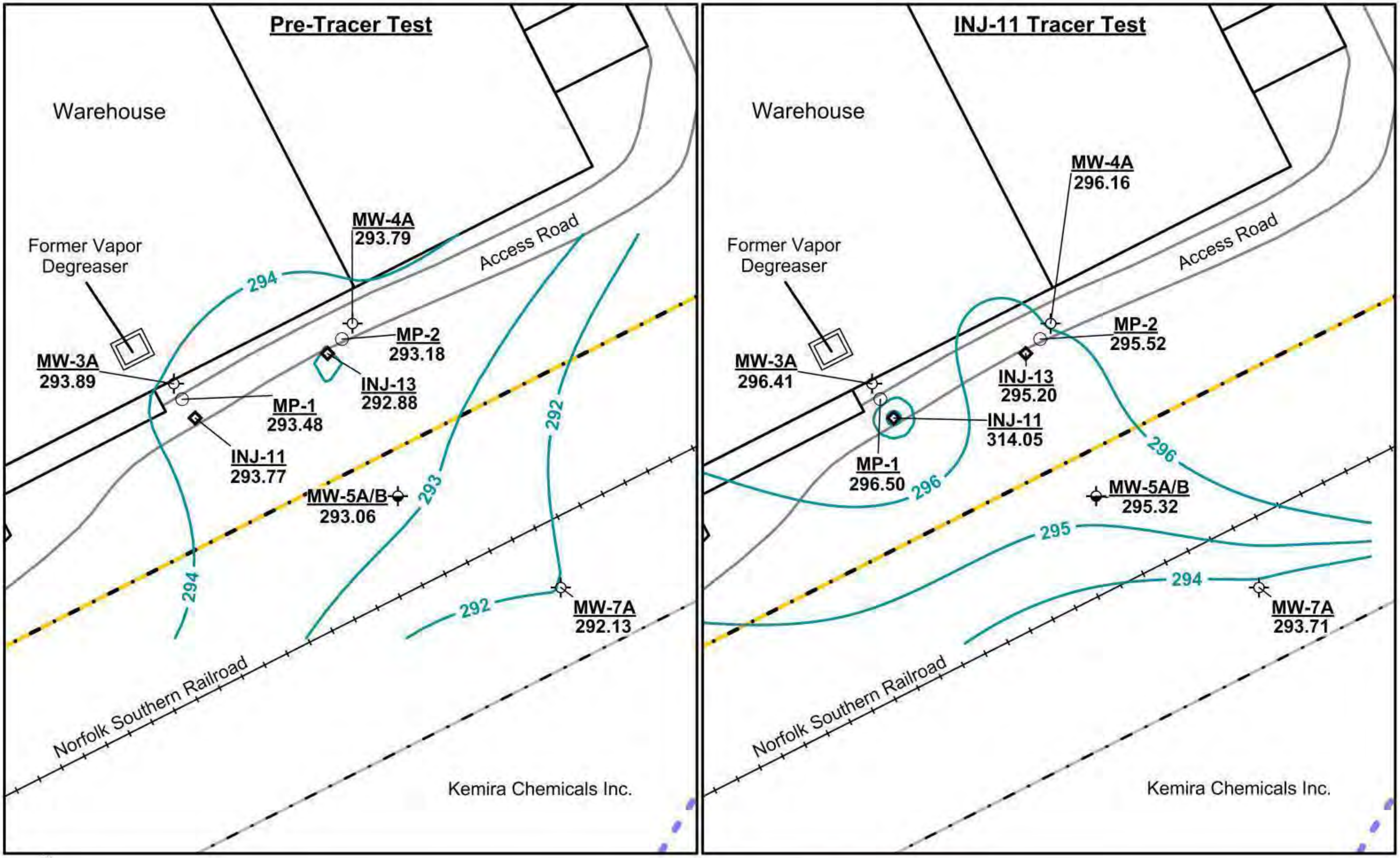

Unit A Sediments Monitoring Well
Unit A/B Monitoring Well
Unit A/B Pilot Test Injection Well
Unit A/B Temporary Monitoring Point

Offsite Properties
Site Boundary
Stream (Possibly Intermittent)

Potentiometric Surface
294
Contour Interval = 1 Foot

Scale in Feet
0 50 100

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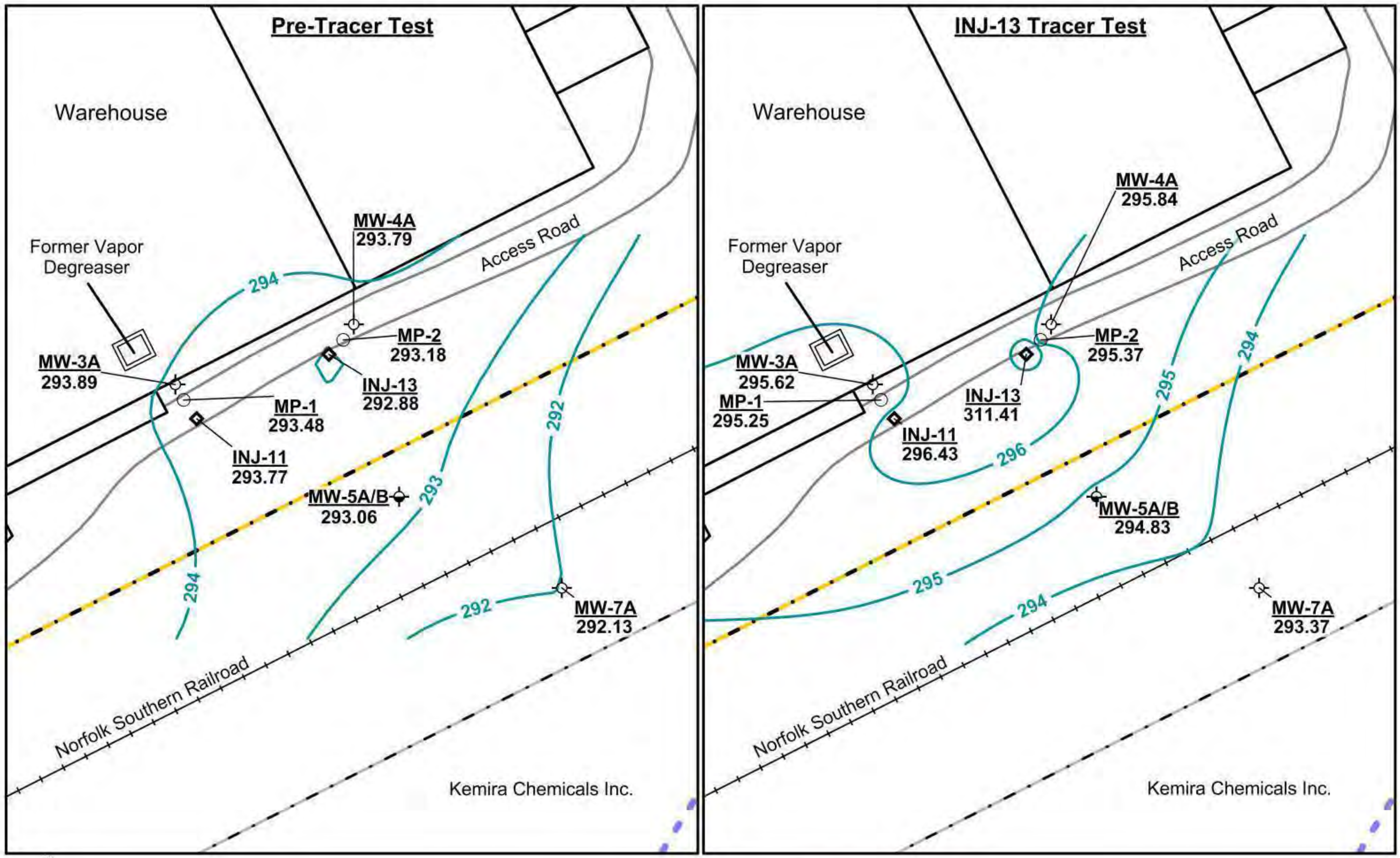
Figure 2-5: INJ-11 Tracer Potentiometric Surface

Cessna GA1 Facility
Columbus, Muscogee County, Georgia



N
W E
S

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- Unit A Sediments Monitoring Well
- Unit A/B Monitoring Well
- Unit A/B Pilot Test Injection Well
- Unit A/B Temporary Monitoring Point

Offsite Properties
Site Boundary
Stream
(Possibly Intermittent)

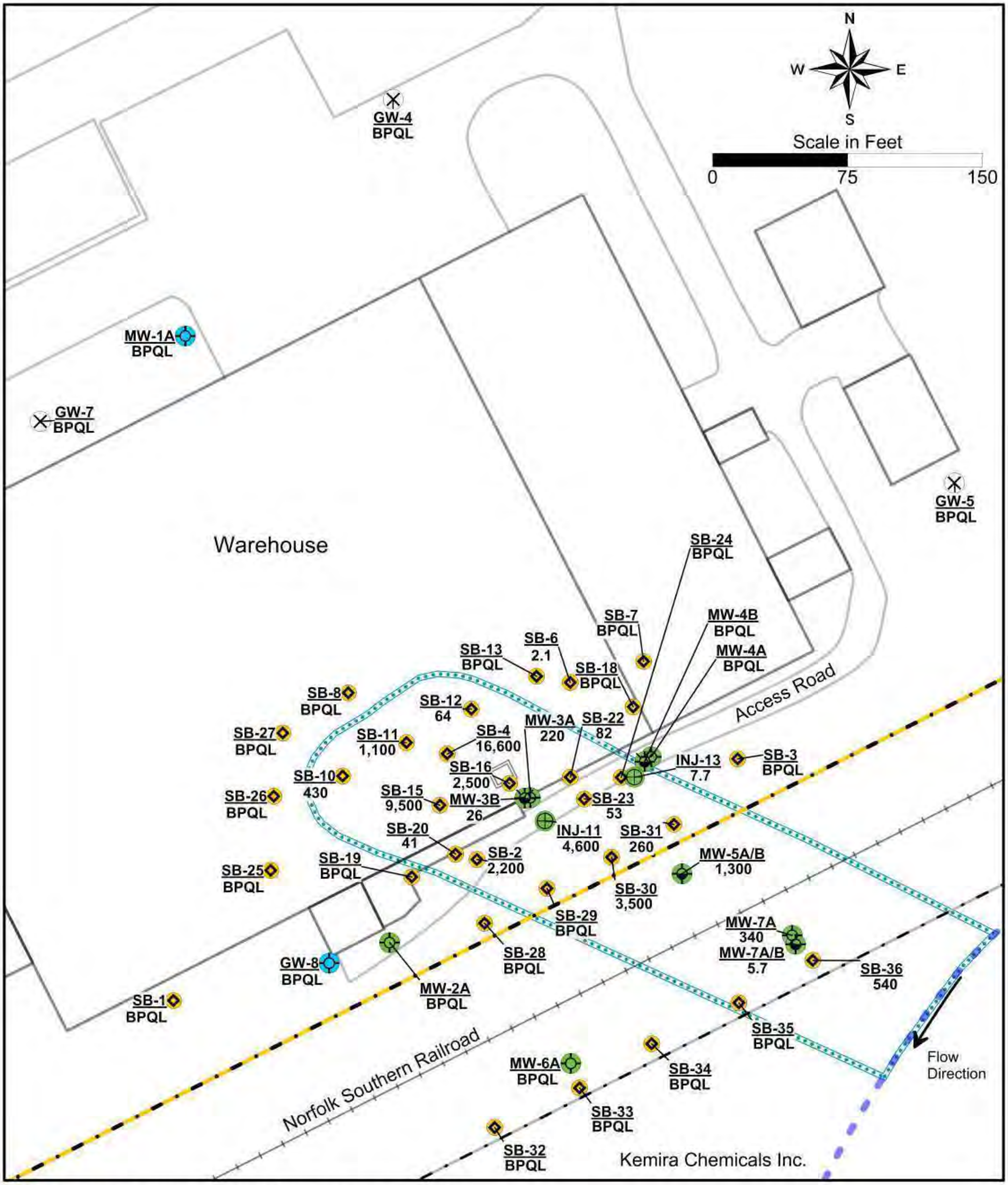
Potentiometric Surface
294
Contour Interval = 1 Foot

Scale in Feet
0 50 100

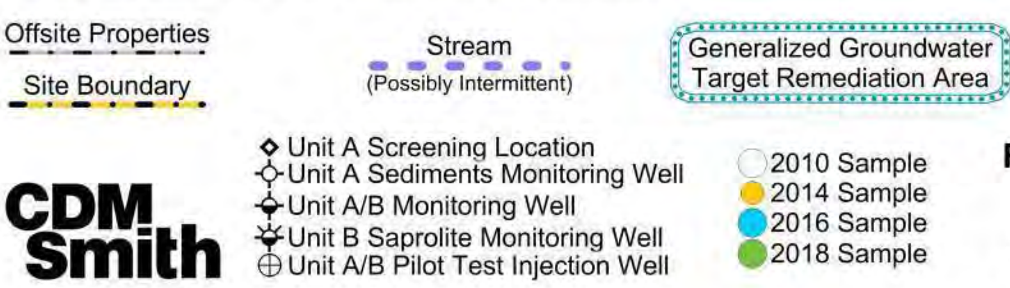
Figure 2-6: INJ-13 Tracer Potentiometric Surface

Cessna GA1 Facility

Columbus, Muscogee County, Georgia



Posted values are most recent trichloroethene in groundwater.

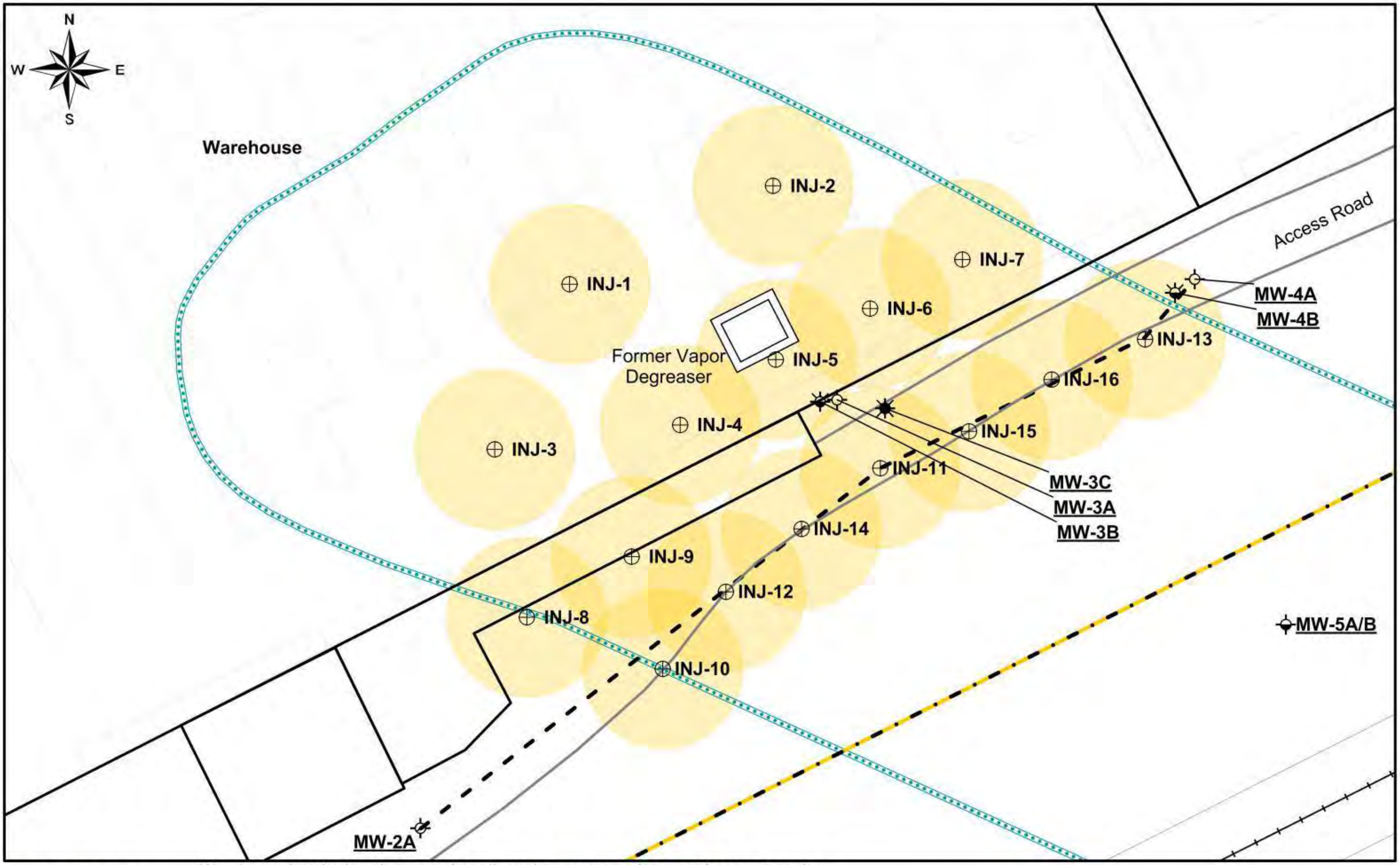


CDM Smith

Figure 3-1: Groundwater RRS Exceedances

Cessna GA1 Facility

Columbus, Muscogee County, Georgia



Warehouse interior locations may be adjusted to accommodate warehouse operations.

Offsite Properties

Site Boundary

Unit A Sediments Monitoring Well

Unit A/B Monitoring Well

Unit B Saprolite Monitoring Well

Unit C Bedrock Monitoring Well

Unit A/B Pilot Test Injection Well

Radius of Influence (15 Feet)

Generalized Groundwater Target Remediation Area

Cross Section Location

Scale in Feet

0 25 50

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Figure 4-1: 2018 Injection Well Plan

Cessna GA1 Facility

Columbus, Muscogee County, Georgia

			2018						2019								2020				2021			
Task	**Start**	**End**	7	8	9	10	11	12	1	2	3	4	5	6	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
EPD Biobarrier Design Approval	7/25/18	10/23/18																						
EPD UIC Permitting	10/23/18	12/4/18																						
Remedial Construction																								
Biobarrier Installation	1/7/19	1/21/19																						
Initial Injection	1/28/19	2/12/19																						
Groundwater Testing	4/8/19	5/6/19																						
Bioaugmentation	5/27/19	6/1/19																						
Second EVO Injection	6/3/19	6/18/19																						
Biobarrier Operation & Maintenance	As Needed																							
EPD Compliance Status Report Review	6/17/21	9/15/21																						
Monitoring/Reporting	Semi-Annual																							

CDM Smith

Figure 4-2
Groundwater Remediation Schedule
Cessna GA1 Facility
Columbus, Muscogee County, Georgia

Tables

Substance	CAS No.	Groundwater RRSs, µg/L			
		Residential (off site)		Non-Residential (on site)	
		Type 1	Type 2	Type 3	Type 4
Acetone	67641		8,000		46,000
Arsenic	7440382	10		10	
Barium	7440393		3,100		20,000
Bromodichloromethane	75274	80		80	
Butanone, 2-	78933		2,300		12,000
Carbon Disulfide	75150	4,000		4,000	
Chloroform	67663	80		80	
Chromium (total)	7440473	100		100	
Cumene	98828		210		1,000
Dichloroethane, 1,1-	75343	4,000		4,000	
Dichloroethene, 1,1-	75354		100		520
Dichloroethene, 1,2-cis-	156592	70			200
Ethylbenzene	100414	700		700	
Lead	7439921	15		15	
Manganese	7439965		380		2,500
Naphthalene	91203	20		20	
Toluene	108883	1,000			5,200
Trichloroethane, 1,1,1-	71556		2,700		14,000
Trichloroethane, 1,1,2-	79005	5		5	
Trichloroethene	79016	5			5.2
Xylenes	1330207	10,000		10,000	
Vinyl Chloride (1)	75014	2			3.3
Zinc	7440666		4,700		31,000

RRS - Risk Reduction Standard CAS - Chemical Abstract System

Type 1 - Default based on standard exposure assumptions and defined risk levels for residential properties.

Type 2 - Based on site-specific risk assessment for residential properties.

Type 3 - Default based on standard exposure assumptions and defined risk levels for non-residential properties.

Type 4 - Based on site-specific risk assessment for non-residential properties.

1 - Vinyl chloride has not been previously detected but anticipated during treatment.

	Compound	1,1-DCA	1,1-DCE	MEK	CD	cis-1,2-DCE	TCE
	On-Site RRS	4,000	520	12,000	4,000	200	5.2
MW-2A	2/27/2018	BRL	BRL	BRL	BRL	BRL	BRL
MW-3A	2/27/2018	BRL	BRL	BRL	BRL	6.7	**220**
MW-3B	2/27/2018	BRL	BRL	BRL	BRL	BRL	**26**
MW-3C	2/27/2018	BRL	BRL	BRL	37	BRL	BRL
MW-4A	2/27/2018	BRL	BRL	BRL	BRL	BRL	BRL
MW-4B	2/27/2018	BRL	BRL	BRL	BRL	BRL	BRL
INJ-11	3/14/2018	16	11	BRL	BRL	11	**4,600**
INJ-13	3/14/2018	BRL	BRL	BRL	BRL	BRL	**7.7**

	Compound	Arsenic	Bariuim	Chromium	Lead	Manganese	Turbidity
	On-Site RRS	10	20,000	100	15	2,500	NA
MW-3A	2/27/2018	BRL*	86.1	BRL	BRL	48.9	5.2
MW-3B	2/27/2018	BRL*	155	BRL	BRL	16.6	8
MW-4A	2/27/2018	BRL*	176	BRL	BRL	701	4
MW-4B	2/27/2018	BRL*	655	BRL	BRL	224	6.8

	Compound	1,1-DCA	1,1-DCE	MEK	CD	cis-1,2-DCE	TCE
	Off-Site RRS	4,000	100	2,300	4,000	70	5
MW-6A	2/27/2018	BRL	BRL	BRL	BRL	BRL	BRL
MW-5A/B	2/27/2018	BRL	BRL	BRL	BRL	17	**1,300**
MW-7A	3/14/2018	BRL	BRL	BRL	BRL	BRL	**340**
MW-7A/B	2/27/2018	BRL	BRL	BRL	BRL	BRL	**5.7**

	Compound	Arsenic	Bariuim	Chromium	Lead	Manganese	Turbidity
	Off-Site RRS	10	3,100	100	15	380	NA
MW-5A/B	2/27/2018	BRL*	140	BRL	BRL	94.6	7

Concentrations are µg/L RRS - Risk Reduction Standard Shaded values exceed the RRS.

DCA - Dichloroethane MEK - 2-Butanone BRL - Below reporting level

DCE - Dichloroethene CD - Carbon Disulfide TCE - Trichloroethene

* - Reporting level exceeded the RRS. NA - Not applicable

A - Unconsolidated Coastal Plain sediments and recent alluvium

B - Piedmont saprolite C - Piedmont upper bedrock

CDM Smith

Table 2-1: Groundwater Analytical Results

Cessna GA1 Facility

Columbus, Muscogee County, Georgia

Date	Code	INJ-11	INJ-13	MP-1	MP-2	MW-3A	MW-3B	MW-3C	MW-4A	MW-4B	MW-5A/B	MW-7A	MW-7A/B
	Unit	A/B	A/B	A/B	A/B	A	B	C	A	B	A/B	A	A/B
	Ft to INJ-11	0	55	8.7	62	15.2	16.8	11.2	69	65	82	152	156
	Ft to INJ-13	55	0	58	7.5	59	62	50	14.6	10.6	60	124	129
	TOC Elev.	312.14	311.80	311.98	312.23	312.09	312.32	312.32	313.17	313.11	299.59	297.49	297.88
4/23/2018	9:10	18.37	18.92	18.50	19.05	18.20	17.94	67.01	19.38	19.67	6.53	5.36	6.46
	Δ WL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11:00	INJ-11 Injection	--	--	--	--	--	--	--	--	--	--	--
	12:05		2.44	1.99	2.45	1.82	2.82	0.06	2.48	0.16	--	--	--
	14:05		2.30	1.72	2.26	1.59	2.51	0.07	2.29	0.34	--	--	--
	15:05		2.09	1.71	2.29	1.59	2.52	0.06	2.34	0.41	--	--	--
	16:03		2.29	1.71	2.27	1.60	2.54	0.09	2.30	0.48	--	--	--
	17:00		2.35	1.78	2.33	1.64	2.54	0.02	2.35	0.51	2.20	1.54	0.39
4/24/2018	5:40		2.46	1.89	2.44	1.76	2.58	0.16	2.46	1.94	2.31	1.62	1.00
	6:21		--	--	--	--	--	--	--	--	--	--	--
	7:09	2.25	0.57	0.80	-0.22	0.81	0.53	0.14	-0.19	0.88	0.72	0.53	1.05
	7:30	--	INJ-13 Injection	--	--	--	--	--	--	--	--	--	--
	8:22	2.87		2.33	1.29	1.85	1.47	0.16	1.27	0.89	--	--	--
	9:30	2.83		1.75	1.32	1.75	1.41	0.18	1.32	0.90	1.78	--	--
	10:30	2.79		1.75	1.32	1.77	1.40	0.16	1.33	0.89	1.81	--	--
	11:30	2.75		1.73	1.32	1.73	1.41	0.15	1.32	0.91	1.79	--	--
	12:30	2.74		1.75	1.34	1.74	1.43	0.19	1.35	0.93	1.80	--	--
	14:30	2.67		1.69	1.31	1.71	1.40	0.16	1.30	0.95	1.75	--	--
	15:30	2.63		1.73	1.28	1.71	1.40	0.21	1.30	0.95	1.78	--	--
	17:00	2.62		1.71	1.31	1.74	1.40	0.22	1.32	0.95	1.75	1.26	1.14
4/25/2018	7:10	2.45		1.66	1.19	1.64	1.36	0.28	1.25	1.05	1.73	1.24	1.22
	8:30	2.46		1.65	1.25	1.67	1.34	0.29	1.26	1.02	--	--	--
	9:15	2.48		1.68	1.23	1.67	1.33	0.32	1.24	0.83	1.73	1.23	1.23
	9:30	--		--	--	--	--	--	--	--	--	--	--
	10:25	1.61		0.53	-0.47	0.65	0.25	0.33	-0.39	0.97	0.50	0.36	1.22

Δ WL - Relative change in static water level in feet from pre-test level (4/23/2018 @ 9:10 AM

Values in RED are increases from the previous measurement.

Values in BLUE are decreases from the previous measurement.

Values in BLACK are the same as the previous measurement.

TOC - Top of casing

A - Unconsolidated Coastal Plain sediments and recent alluvium

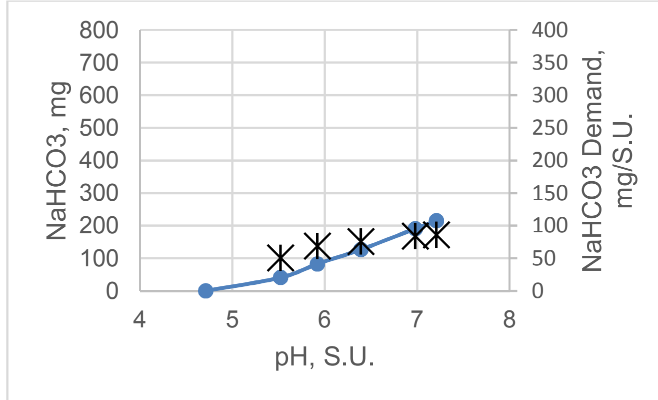
B - Piedmont saprolite

C - Piedmont upper bedrock

Columbus Airport Rainfall Data		
Date	24-Hour Rainfall (In.)	Cumulative
4/17/2018	0	0
4/18/2018	0	0
4/19/2018	0	0
4/20/2018	0	0
4/21/2018	0	0
4/22/2018	1.02	1.02
4/23/2018	0.75	1.77
4/24/2018	0.14	1.91
4/25/2018	0	1.91

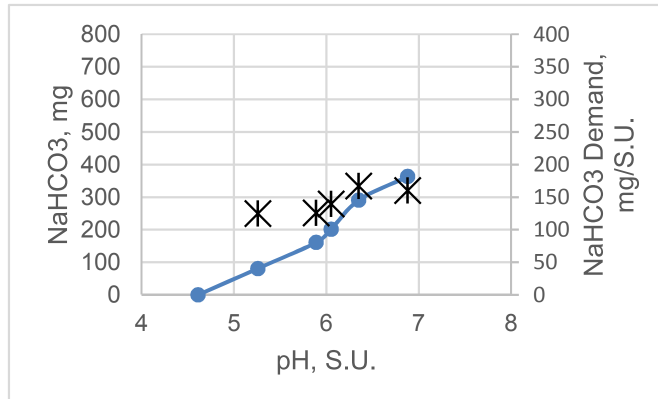
Sample Type: MW-3A Groundwater Only

Groundwater Volume	100 ml	
Total $NaHCO_3$ addition (mg)	pH (S.U.)	mg/S.U.
0	4.71	
41	5.52	51
83	5.92	69
127	6.39	76
191	6.98	84
215	7.21	86
Total $NaHCO_3$ Demand (mg/S.U.)		86



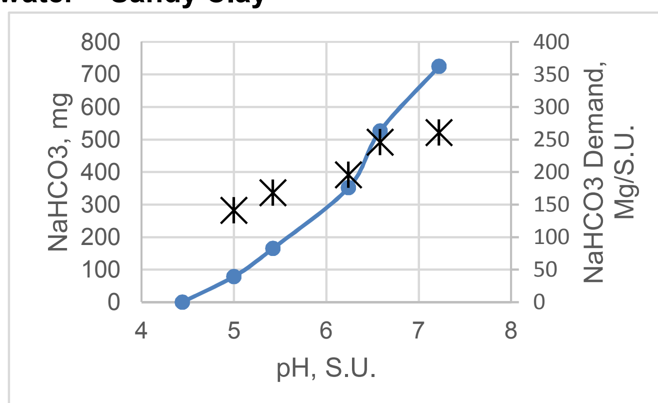
Sample Type: Groundwater + Sand and Gravel

GW Volume	100 ml	
Soil Mass	50 g	
Total $NaHCO_3$ addition (mg)	pH (S.U.)	mg/S.U.
0	4.61	
81	5.26	125
161	5.89	126
201	6.05	140
291	6.35	167
363	6.88	160
Total $NaHCO_3$ Demand (mg/S.U.)		160



Sample Type: Groundwater + Sandy Clay

GW Volume	100 ml	
Soil Mass	50 g	
Total $NaHCO_3$ addition (mg)	pH (S.U.)	mg/S.U.
0	4.44	
79	5	141
165	5.42	168
352	6.24	196
526	6.58	246
725	7.22	261
Total $NaHCO_3$ Demand (mg/S.U.)		261



Sample Type: Groundwater + Sandy Clay Duplicate

GW Volume	100 ml	
Soil Mass	50 g	
Total $NaHCO_3$ addition (mg)	pH (S.U.)	mg/S.U.
0	4.46	
83	4.9	189
186	5.39	200
299	6.12	180
504	6.38	263
702	7.01	275
Total $NaHCO_3$ Demand (mg/S.U.)		275

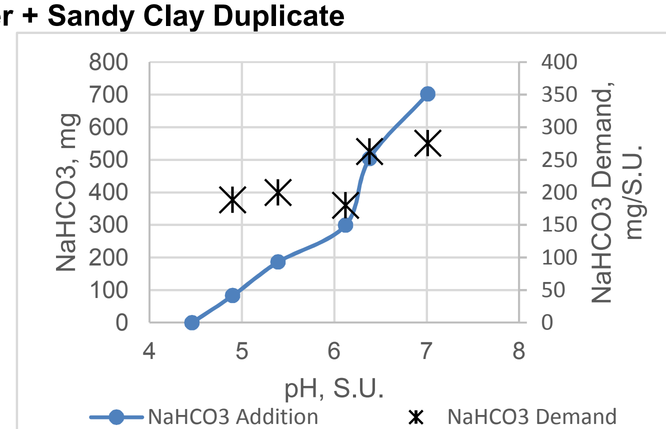


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Table 2-3: Ph Testing Results

Cessna GA1 Facility

Columbus, Muscogee County, Georgia

Compound		1,1-DCA	1,1-DCE	MEK	CD	cis-1,2-DCE	TCE
On-Site RRS		4,000	520	12,000	4,000	200	5.2
MW-2A	8/4/2014	BRL	BRL	BRL	BRL	BRL	BRL
	Duplicate	BRL	BRL	BRL	BRL	BRL	BRL
	1/19/2016	BRL	BRL	BRL	BRL	BRL	BRL
	2/1/2017	BRL	BRL	BRL	BRL	BRL	BRL
	Duplicate	BRL	BRL	BRL	BRL	BRL	BRL
	8/15/2017	BRL	BRL	BRL	BRL	BRL	BRL
	2/27/2018	BRL	BRL	BRL	BRL	BRL	BRL
MW-3A	8/4/2014	BRL	BRL	BRL	BRL	BRL	**160**
	1/20/2016	8.6	BRL	BRL	BRL	12	**1,000**
	2/1/2017	6.6	BRL	BRL	BRL	16	**1,300**
	8/15/2017	5.1	BRL	BRL	BRL	11	**710**
	2/27/2018	BRL	BRL	BRL	BRL	6.7	**220**
MW-3B	8/4/2014	BRL	BRL	BRL	BRL	BRL	**71**
	1/20/2016	BRL	BRL	BRL	BRL	BRL	**11**
	2/1/2017	BRL	BRL	BRL	BRL	BRL	**23**
	8/15/2017	BRL	BRL	BRL	BRL	BRL	**25**
	Duplicate	BRL	BRL	BRL	BRL	BRL	**24**
	2/27/2018	BRL	BRL	BRL	BRL	BRL	**26**
MW-3C	1/20/2016	BRL	BRL	BRL	BRL	BRL	BRL
	2/1/2017	BRL	BRL	BRL	18	BRL	**12**
	8/15/2017	BRL	BRL	BRL	63	BRL	BRL
	2/27/2018	BRL	BRL	BRL	37	BRL	BRL
MW-4A	8/4/2014	BRL	BRL	BRL	BRL	BRL	BRL
	1/20/2016	BRL	BRL	BRL	BRL	BRL	BRL
	2/1/2017	BRL	BRL	BRL	BRL	BRL	BRL
	8/15/2017	BRL	BRL	BRL	BRL	BRL	BRL
	2/27/2018	BRL	BRL	BRL	BRL	BRL	BRL
MW-4B	8/4/2014	BRL	BRL	BRL	6.8	BRL	BRL
	1/20/2016	BRL	BRL	BRL	BRL	BRL	BRL
	2/1/2017	BRL	BRL	BRL	BRL	BRL	BRL
	8/15/2017	BRL	BRL	BRL	BRL	BRL	BRL
	2/27/2018	BRL	BRL	BRL	BRL	BRL	BRL

Compound		1,1-DCA	1,1-DCE	MEK	CD	cis-1,2-DCE	TCE
Off-Site RRS		4,000	100	2,300	4,000	70	5
MW-6A	1/19/2016	BRL	BRL	BRL	BRL	BRL	BRL
	2/1/2017	BRL	BRL	BRL	BRL	BRL	BRL
	8/15/2017	BRL	BRL	BRL	BRL	BRL	BRL
	2/27/2018	BRL	BRL	BRL	BRL	BRL	BRL
MW-5A/B	1/19/2016	10	6.9	BRL	BRL	30	**1,900**
	2/1/2017	6	5.7	BRL	BRL	18	**1,500**
	8/15/2017	5.1	BRL	BRL	BRL	24	**1,400**
	2/27/2018	BRL	BRL	BRL	BRL	17	**1,300**
MW-7A/B	1/19/2016	BRL	BRL	190	BRL	49	**100**
	Duplicate	BRL	BRL	110	BRL	34	**120**
	2/1/2017	BRL	BRL	BRL	BRL	8	**17**
	8/15/2017	BRL	BRL	BRL	BRL	BRL	**8.2**
	2/27/2018	BRL	BRL	BRL	BRL	BRL	**5.7**

Shaded values exceed the RRS.

RRS - Risk Reduction Standard

Concentrations are µg/L

DCA - Dichloroethane

MEK - 2-Butanone

BRL - Below reporting level

DCE - Dichloroethene

CD - Carbon Disulfide

TCE - Trichloroethene

Table 3-1: Groundwater VOC Trends

Cessna GA1 Facility

Columbus, Muscogee County, Georgia

CDM Smith

Domenico, P.A. and F.W. Schwartz, 1990
Continuous Source, Steady-State Model with Retardation & First-Order Decay

$$\frac{C(x,y,z,t)}{C_o} = (1/8)\ exp\left[\frac{x}{2\alpha_x}\left[1-\sqrt{1+\frac{4\lambda\alpha_x}{v}}\right]\right] \times erfc\left[\frac{\left[(x-vt)\sqrt{1+\frac{4\lambda\alpha_x}{v}}\right]}{2\sqrt{\alpha_x \times v \times t}}\right] \times \left[erf\left[\frac{(y+Y/2)}{2\sqrt{\alpha_y x}}\right] - erf\left[\frac{(y-Y/2)}{2\sqrt{\alpha_y x}}\right]\right] \times \left[erf\left[\frac{(z+\delta_{gw})}{2\sqrt{\alpha_z x}}\right] - erf\left[\frac{(z-\delta_{gw})}{2\sqrt{\alpha_z x}}\right]\right]$$

General Terms		Value	Source
poc	Distance to point of compliance [ft]	145	Site Specific
x_{max}	Maximum model distance [ft]	300	Site Specific
x_{nodes}	Incremental calculation distances [ft]	5	Site Specific
x	Distance downgradient from source [ft]	variable	Site Specific
y	Distance from plume centerline perpendicular to groundwater flow [ft]	0	Site Specific
z	= 0, concentration assumed to be at top of water table [ft]	0	Site Specific
t_{SS}	Time to reach steady state [year] = $\{R_S\ x_{max}\} / \{v\ (1+4\alpha_x\lambda R_S/v)\}$, GSI, 1997	18.3	Calculated
Y	Source width perpendicular to groundwater flow [ft], thickness = δ^{gw}	20	Site Specific
δ_{gw}	Groundwater mixing zone thickness [ft]	14	Site Specific
α_x	Longitudinal dispersivity [ft] = $0.83[\log_{10}(x)]^{2.414}$, Xu, M. & Y. Eckstein, 199	variable	Calculated
α_y	Lateral dispersivity [ft] = αx * 0.215, average from Gelhar et al., 1992	variable	Calculated
α_z	Vertical dispersivity [ft] = α_x * 0.05, ASTM, 1995	variable	Calculated
K	Hydraulic conductivity [ft/year]	5,110	Site Specific
i	Hydraulic gradient [--]	0.01	Site Specific
θ_e	Effective porosity [--]	0.2	Site Specific
θ_{TS}	Total porosity [--]	0.35	Site Specific
ρ_{ss}	Soil dry bulk density [grams/cm^3]	1.8	Estimate
f_{oc}	Fraction organic carbon [--]	0.020	Calibration

Chemical-Specific Terms		TCE	Source
C_0	Average source area concentration [mg/L]	16.6	Site Specific
C_{poc}	Point of compliance concentration [µg/L]	1,900	Calculated
λ	First order decay rate [1/year]	0.3	Site Specific
v	Retarded seepage velocity [ft/year] = $(Ki)/(R_S\ \theta_e)$	36	Calculated
R_s	Retardation Factor [--] = $1 + [(K_d\ \rho_{ss})/\theta_{TS}]$	7.2	Calculated
K_d	Soil-water sorption coefficient [cm^3/gram] = $K_{oc}\ f_{oc}$	1.20	Calculated
K_{oc}	Soil-water partitioning coefficient [ml/gram]	60.7	EPA Default
DAF_{poc}	POC dilution attenuation factor [--] = C_0/C_{poe}	9	Calculated

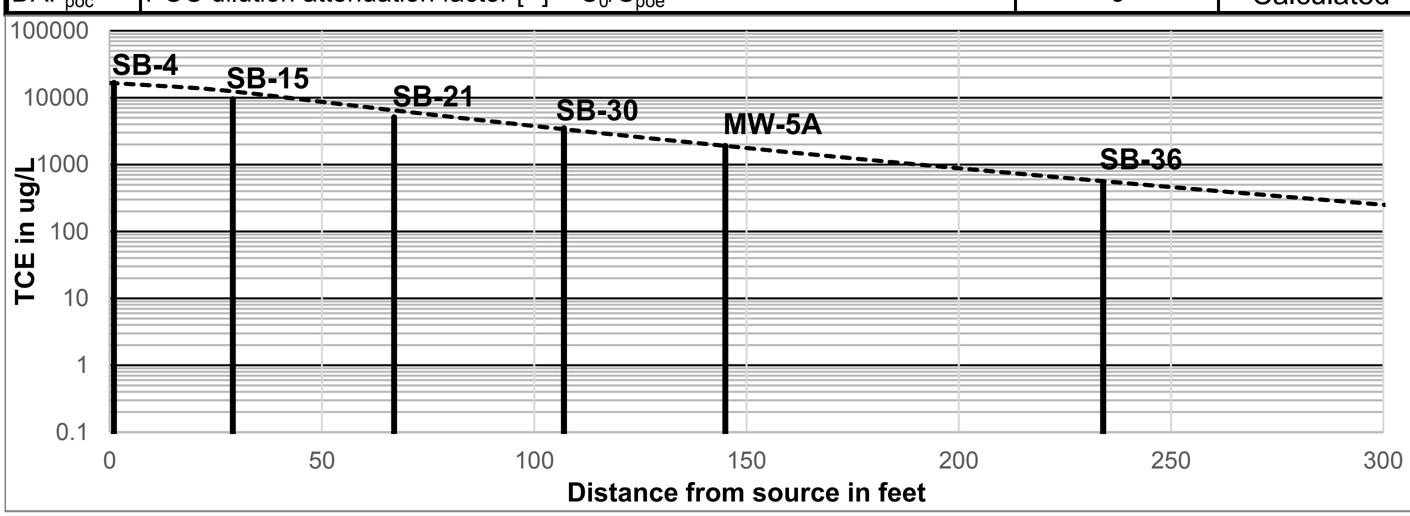

Table 3-2: Model Calibration

Cessna GA1 Facility
Columbus, Muscogee County, Georgia

CDM Smith

Domenico, P.A. and F.W. Schwartz, 1990
Continuous Source, Steady-State Model with Retardation & First-Order Decay

$$\frac{C(x,y,z,t)}{C_o} = (1/8)\ exp\left[\frac{x}{2\alpha_x}\left[1-\sqrt{1+\frac{4\lambda\alpha_x}{v}}\right]\right] \times erfc\left[\frac{\left[(x-vt)\sqrt{1+\frac{4\lambda\alpha_x}{v}}\right]}{2\sqrt{\alpha_x \times v \times t}}\right] \times \left[erf\left[\frac{(y+Y/2)}{2\sqrt{\alpha_y x}}\right] - erf\left[\frac{(y-Y/2)}{2\sqrt{\alpha_y x}}\right]\right] \times \left[erf\left[\frac{(z+\delta_{gw})}{2\sqrt{\alpha_z x}}\right] - erf\left[\frac{(z-\delta_{gw})}{2\sqrt{\alpha_z x}}\right]\right]$$

General Terms		Value	Source
poc	Distance to point of compliance [ft]	145	Site Specific
x_{max}	Maximum model distance [ft]	300	Site Specific
x_{nodes}	Incremental calculation distances [ft]	5	Site Specific
x	Distance downgradient from source [ft]	variable	Site Specific
y	Distance from plume centerline perpendicular to groundwater flow [ft]	0	Site Specific
z	= 0, concentration assumed to be at top of water table [ft]	0	Site Specific
t_{SS}	Time to reach steady state [year] = $\{R_S\ x_{max}\}$ / $\{v\ (1+4\alpha_x\lambda R_S/v)\}$, GSI, 199	variable	Calculated
Y	Source width perpendicular to groundwater flow [ft], thickness = δ^{gw}	105	Site Specific
δ_{gw}	Groundwater mixing zone thickness [ft]	17	Site Specific
α_x	Longitudinal dispersivity [ft] = $0.83[\log_{10}(x)]^{2.414}$, Xu, M. & Y. Eckstein, 199	variable	Calculated
α_y	Lateral dispersivity [ft] = αx * 0.215, average from Gelhar et al., 1992	variable	Calculated
α_z	Vertical dispersivity [ft] = α_x * 0.05, ASTM, 1995	variable	Calculated
K	Hydraulic conductivity [ft/year]	4,380	Site Specific
i	Hydraulic gradient [--]	0.01	Site Specific
θ_e	Effective porosity [--]	0.2	Site Specific
θ_{TS}	Total porosity [--]	0.35	Site Specific
ρ_{ss}	Soil dry bulk density [grams/cm^3]	1.8	Site Specific
f_{oc}	Fraction organic carbon [--]	0.020	Calibration

DCE - Dichloroethene
TCE - Trichloroethene

References
Domenico, P.A. and F. W. Schwartz, 1990, Physical and Chemical Hydrogeology, Wiley, New York, NY.
Gelhar, L.W., C. Welty, and K.R. Rehfeldt, 1992. "A Critical Review of Data on Field-Scale Dispersion in Aquifers." J. Water Resources Research, Vol. 28, No. 7.
Nevin, J.P., J.A. Connor, C.J. Newell, GSI, J.B. Gustafson, Shell Research Limited, K.A. Lyons, Shell Development Co., 1997, FATE 5: A Natural Attenuation Calibration Tool for Groundwater Fate and Transport Modeling, NGWA Petroleum Hydrocarbons Conference.
Xu, M. and Y. Eckstein, 1995, Use of Weighted Least-Squares Method in Evaluation of the Relationship Between Dispersivity and Scale, J. Ground Water, 33(6).

Chemical-Specific Terms		TCE	1,2-DCE	Vinyl Chloride	Source
C_0	Average source area concentration [mg/L]	3.0	2.213	1.427	Site Specific
C_{poe}	Point of exposure concentration [µg/L]	0.5	5.1	0.4	Calculated
λ	First order decay rate [1/year]	2.4	2.2	4.9	Calibration
v	Retarded seepage velocity [ft/year] = $(Ki)/(R_S\ \theta_e)$	30	43	68	Calculated
R_s	Retardation Factor [--] = $1 + [(K_d\ \rho_{ss})/\theta_{TS}]$	7.2	5.0	3.2	Calculated
K_d	Soil-water sorption coefficient [cm^3/gram] = $K_{oc}\ f_{oc}$	1.20	0.79	0.43	Calculated
t_{SS}	Time to reach steady state [year] = $\{R_S\ x_{max}\}$ / $\{v\ (1+4\alpha_x\lambda R_S/v)\}$, GSI, 199	20	11	5	Calculated
K_{oc}	Soil-water partitioning coefficient [ml/gram]	60.7	39.6	21.7	EPA Default
DAF_{poe}	POE dilution attenuation factor [--] = C_0/C_{poe}	6,150	433	3,327	Calculated

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Table 3-3: Biobarrier Model

Cessna GA1 Facility
Columbus, Muscogee County, Georgia

(A x X) + (B x Y) = (C x Z)

Where

A =	Groundwater pH, S.U.	X =	Groundwater mass in g
B =	Formation pH, S.U.	Y =	Formation mass in g
C =	Combined pH, S.U.		

pH TEST SOLUTIONS							
MW-3A Groundwater				**A =**	**4.71**	**S.U.**	
Groundwater + Sand & Gravel							
(A x	**X)**	**+**	**(B x**	**Y)**	**=**	**(C x**	**(X + Y))**
4.71	100		B	50		4.61	150
			B =	**4.41**	**S.U.**		
Groundwater + Sandy Clay (average)							
(A x	**X)**	**+**	**(B x**	**Y)**	**=**	**(C x**	**(X + Y))**
4.71	100		B	50		4.45	150
			B =	**3.93**	**S.U.**		

AQUIFER ASSUMPTIONS

Sand & Gravel ~50% and Sandy Clay ~50%

B = 4.17 S.U. for aquifer (average of sand & gravel and sandy clay)

Aquifer Dry Density = ~1.8 g/cm^3

At 35% total porosity ~0.63 g groundwater per 1.8 g of aquifer

AQUIFER ESTIMATED pH							
(A x	**X)**	**+**	**(B x**	**Y)**	**=**	**(C x**	**(X + Y))**
4.71	0.63		4.17	1.8		C	2.43
			C =	**4.31**	**S.U.**		

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Table 3-4: Aquifer pH Estimates

Cessna GA1 Facility

Columbus, Muscogee County, Georgia

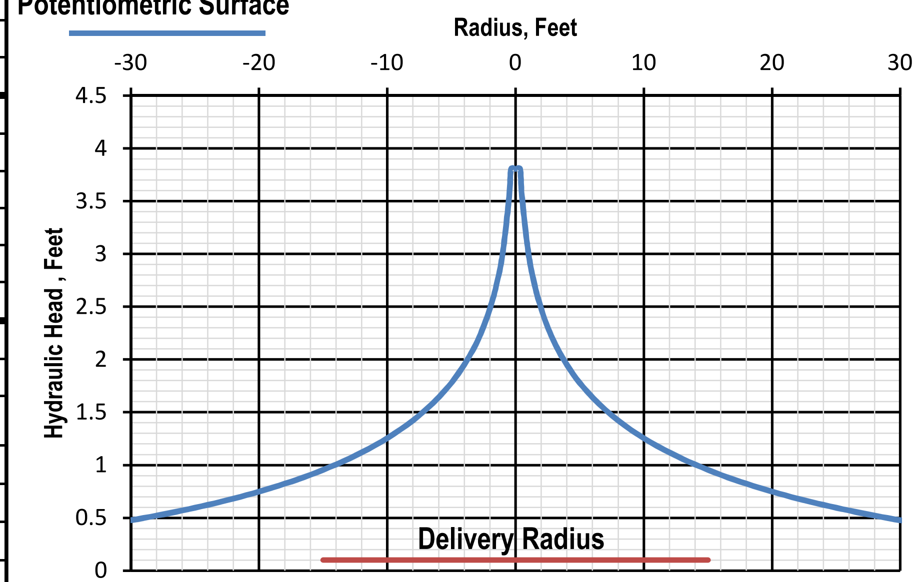
Electron Donor Quantity Estimates

Treatment Zone Characteristics		
9,720	Ft^2	Treatment Zone Area
19	Ft	Top of Treatment Zone
44	Ft	Bottom of Treatment Zone
25	Ft	Treatment Zone Thickness (Unit A + Unit B)
10%	%	Treatment Zone Effective Porosity (Unit A velocity)
20%	%	Treatment Zone Effective Porosity (Unit A + Unit B volume)
1.5	Tons / Yd^3	Treatment Zone Dry Bulk Density
13,500	Tons	Formation Mass
363,553	Gal	Treatment Zone Water Volume
3,033,999	Lbs.	Treatment Zone Water Mass
Electron Donor Requirements		
5,500	Mg / L	Target Active Electron Donor Concentration
0.55%	%	
16,687	Lbs.	Target Active Electron Donor Mass
8.09	Lbs. / Gal	EVO Density
64%	%	Percent Active Electron Donor in Product
26,073	Lbs.	EVO Mass Requirements
3,223	Gal	EVO Volume Requirements
Electron Donor Solution Formulation		
4.7%	%	Target Donor Product Concentration (mass)
554,754	Lbs.	Mass of Total Solution
66,573	Gal	Volume of Total Solution
63,351	Gal	Total Water Addition for Injection Solution
4.8%	%	Target Donor Product in Solution (volume)
Injection Well Delivery Calculations		
16	Each	Number of Injection Points
4,161	Gal	Solution Injected Per Point
5	Gal / Min	Injection Flow Rate Per Point
13.9	Hrs.	Injection Duration Per Point
4	Points	Well Set Manifold Size
4.0	Sets	Well Set Quantity
55	Hrs.	Total Injection Event Duration

Injection Performance Simulation

Injection Performance Parameters		
4.25	In	Injection Well Sand Pack Radius
13	Ft	Depth to Top of Sand Pack
15	Ft	Depth to Groundwater
8.5	PSI	Maximum Injection Pressure (15% contingency)
0.0	PSI	Simulated Maximum Injection Pressure
15	Ft	Delivery Radius Under Injection
Aquifer Characteristics		
1,496	GPD / Ft^2	Transmissivity
14	Ft / D	Hydraulic Conductivity
15	Ft	Target Injection Radius
0.01	Ft/Ft	Ambient Hydraulic Gradient
1.43	Ft/D	Ambient Groundwater Velocity
14.0	Ft	Aquifer Thickness (Unit A)

Potentiometric Surface



60% SRS®-FRL Large Droplet EVO Injection Design

Table 4-1: Full-Scale Injection Design

Cessna GA1 Facility
Columbus, Muscogee County, Georgia

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Sodium Bicarbonate Quantity Estimates		
pH Control Zone Physical Characteristics		
9,720	Ft^2	pH Control Zone Area
19	Ft	Top of pH Control Zone
33	Ft	Bottom of pH Control Zone
14	Ft	pH Control Zone Thickness
35%	%	pH Control Zone Total Porosity (volume)
1.5	Tons / Yd^3	pH Control Zone Dry Bulk Density
136,080	FT^3	pH Control Zone Volume
356,281	Gal	pH Control Zone Water Volume
1,348,671	kg	pH Control Zone Water Mass
Sodium Bicarbonate Dosing		
2.75	g Sodium Bicarbonate / kg Groundwater / Standard Unit pH	Groundwater Sodium Bicarbonate Demand
4.3	Standard Units	Initial pH
6.5	Standard Units	Target pH
2.2	Standard Units	pH Change
6.05	g Sodium Bicarbonate / kg Groundwater	Sodium Bicarbonate Dosing Rate
8,159,461	g	Sodium Bicarbonate Total Mass
17,988	Lbs.	
Sodium Bicarbonate Injection Solution		
7	2,500 Lb. Pallets	Supplied Sodium Bicarbonate Quantity
17,500	Lbs.	
63,351	Gal	Total Water Addition Volume
239,808	L	
33,101	mg/L	Sodium Bicarbonate Concentration
3.3%	% (by weight)	
181	Gal Water / 50 Lb. Sack	Sodium Bicarbonate Addition Rate

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Table 4-1: Full-Scale Injection Design

Cessna GA1 Facility

Columbus, Muscogee County, Georgia

Appendix A

Soil Boring Logs and Well Construction Diagrams

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INJ-11 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/12/2018
Project No.:	1727-226789	End Date:	3/12/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	44'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab
Well Construction			
Total Borehole Depth/Dia.:	44' / 8.5"	Surface Completion:	Flush Mount
Grout Depth/Type:	0'-20' / Neat Cement	Casing +/- Grade Level:	
Bentonite Seal Depth/Type:	20'-22' / 3/8" Bentonite Chips	Sand Pack Depth:	22'-44'
Casing Type/Depth/Dia.:	PVC / 0'-24' / 2"	Screen Type/Depth/Dia./Slots:	PVC / 24'-44' / 2" / 0.01"
Development Method/Gallons:	Submersible Pump / 25 Gal.	Bottom Backfill Depth/Material:	N/A
Additional Information:			
Drilling/Sampling Method: 8.25" OD/4.25" ID Hollow-Stem Auger / Macro Core			

Depth (feet)	Formation Description
0.5	0-0.25' Asphalt
1	0.25' - 6': Dry, loose, orange-brown clayey **SAND**, some silt. Mottled with pieces of gray clay, non-Plastic
1.5	
2	
2.5	
3	
3.5	
4	
4.5	
5	
5.5	
6	
6.5	6' - 11': Dry, tight, orange-brown clayey **SAND**, some silt, mottled with gray, non-plastic
7	
7.5	
8	
8.5	
9	
9.5	
10	

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INJ-11 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/12/2018
Project No.:	1727-226789	End Date:	3/12/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	44'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

Depth	Description
10.5	6' - 11': Dry, tight, orange-brown clayey **SAND**, some silt, mottled with gray, non-plastic
11	
11.5	11' - 15': Dry, loose, tan silty/clayey **SAND**, non-plastic
12	
12.5	
13	
13.5	
14	
14.5	
15	
15.5	15' - 24': Damp, tight, orange sandy **CLAY**. Mottled with gray, moderate plasticity
16	
16.5	
17	
17.5	
18	
18.5	
19	
19.5	
20	
20.5	
21	
21.5	
22	
22.5	
23	
23.5	
24	
24.5	24' - 29': Loose, wet, orange-brown coarse **SAND**, well graded, sub-angular grains, little silt/clay
25	

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INJ-11 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/12/2018
Project No.:	1727-226789	End Date:	3/12/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	44'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

Depth	Description
25.5	
26	24' - 29': Loose, wet, orange-brown coarse **SAND**, well graded, sub-angular grains, little silt/clay
26.5	
27	
27.5	27' - 29' - thin layer of fine to medium **GRAVEL**, mostly quartz, some k feldspar
28	
28.5	24' - 29': Loose, wet, orange-brown coarse **SAND**, well graded, sub-angular grains, little silt/clay
29	
29.5	
30	29' - 31': Loose, wet, orange-brown **CLAY**. High plasticity
30.5	
31	
31.5	
32	
32.5	
33	
33.5	
34	
34.5	
35	
35.5	31' - 44': **SAPROLITE**. Moist, tight, dark red-brown silt, some clay. Foliated relic structure (gneiss/schist), micaceous
36	
36.5	
37	
37.5	
38	
38.5	
39	
39.5	
40	

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INJ-11 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/12/2018
Project No.:	1727-226789	End Date:	3/12/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	44'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

40.5	31' - 44': **SAPROLITE**. Moist, tight, dark red-brown silt, some clay. Foliated relic structure (gneiss/schist), micaceous BORING TERMINATED AT 44' BGS, MACRO CORE REFUSAL
41	
41.5	
42	
42.5	
43	
43.5	
44	

INJ-13 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/13/2018
Project No.:	1727-226789	End Date:	3/13/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	44'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

Well Construction

Total Borehole Depth/Dia.:	44' / 8.5"	Surface Completion:	Flush Mount
Grout Depth/Type:	0'-20' / Neat Cement	Casing +/- Grade Level:	
Bentonite Seal Depth/Type:	20'-22' / 3/8" Bentonite Chips	Sand Pack Depth:	22'-44'
Casing Type/Depth/Dia.:	PVC / 0'-24' / 2"	Screen Type/Depth/Dia./Slots:	PVC / 24'-44' / 2" / 0.01"
Development Method/Gallons:	Submersible Pump / 25 Gal.	Bottom Backfill Depth/Material:	N/A

Additional Information:

Drilling/Sampling Method: 8.25" OD/4.25" ID Hollow-Stem Auger / Macro Core

Depth (feet)	Formation Description
0.5	0-0.25' Asphalt
1	0.25' - 11': Dry, loose, orange-brown clayey **SAND**, some silt. Mottled with pieces of gray clay, non-plastic
1.5	
2	
2.5	
3	
3.5	
4	
4.5	
5	
5.5	
6	
6.5	
7	
7.5	
8	
8.5	
9	
9.5	
10	

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INJ-13 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/13/2018
Project No.:	1727-226789	End Date:	3/13/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	44'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

10.5	0.25' - 11': Dry, loose, orange-brown clayey **SAND**, some silt. Mottled with pieces of gray clay, non-plastic
11	
11.5	11' - 15': Dry, loose, tan silty/clayey **SAND**, non-plastic
12	
12.5	
13	
13.5	
14	
14.5	
15	
15.5	15' - 27': Damp, tight, gray sandy **CLAY**. Mottled with orange, moderate plasticity
16	
16.5	
17	
17.5	
18	
18.5	
19	
19.5	
20	
20.5	
21	
21.5	
22	
22.5	
23	Thin layer of coarse **SAND** at 23' bgs
23.5	
24	15' - 27': Damp, tight, gray sandy **CLAY**. Mottled with orange, moderate plasticity
24.5	
25	

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INJ-13 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/13/2018
Project No.:	1727-226789	End Date:	3/13/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	44'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

25.5	15' - 27': Damp, tight, gray sandy **CLAY**. Mottled with orange, moderate plasticity
26	
26.5	
27	
27.5	27' - 33': Loose, wet, orange-brown coarse **SAND**, well graded, sub-angular grains, little silt/clay
28	
28.5	
29	
29.5	
30	
30.5	
31	
31.5	
32	
32.5	
33	
33.5	33' - 35': Loose, wet, orange-brown **CLAY**. High plasticity
34	
34.5	
35	
35.5	35' - 44': **SAPROLITE**. Moist, tight, dark red-brown silt, some clay. Foliated relic structure (gneiss/schist), micaceous
36	
36.5	
37	
37.5	
38	
38.5	
39	
39.5	
40	

INJ-13 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/13/2018
Project No.:	1727-226789	End Date:	3/13/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	44'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

40.5	31' - 44': **SAPROLITE**. Moist, tight, dark red-brown silt. Foliated relic structure (gneiss/schist), micaceous BORING TERMINATED AT 44' BGS, MACRO CORE REFUSAL
41	
41.5	
42	
42.5	
43	
43.5	
44	

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MP-1 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/12/2018
Project No.:	1727-226789	End Date:	3/12/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	43'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab
Well Construction			
Total Borehole Depth/Dia.:	43' / 8.5"	Surface Completion:	Flush Mount
Grout Depth/Type:	0'-19' / Neat Cement	Casing +/- Grade Level:	
Bentonite Seal Depth/Type:	19'-21' / 3/8" Bentonite Chips	Sand Pack Depth:	21'-43'
Casing Type/Depth/Dia.:	PVC / 0'-23' / 2"	Screen Type/Depth/Dia./Slots:	PVC / 23'-43' / 2" / 0.01"
Development Method/Gallons:	Submersible Pump / 25 Gal.	Bottom Backfill Depth/Material:	N/A
Additional Information:			
Drilling/Sampling Method: 8.25" OD/4.25" ID Hollow-Stem Auger / Macro Core			

Depth (feet)	Formation Description
0.5	0-0.25' Asphalt
1	0.25' - 7': Dry, loose, orange-brown clayey **SAND**, some silt. Mottled with pieces of gray clay, non-plastic
1.5	
2	
2.5	
3	
3.5	
4	
4.5	
5	
5.5	
6	
6.5	
7	
7.5	7' - 11': Dry, tight, orange-brown clayey **SAND**, some silt, mottled with gray, non-plastic
8	
8.5	
9	
9.5	
10	

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MP-1 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/12/2018
Project No.:	1727-226789	End Date:	3/12/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	43'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

Depth	Description
10.5	7' - 11': Dry, tight, orange-brown clayey **SAND**, some silt, mottled with gray, non-plastic
11	
11.5	11' - 15': Dry, loose, tan silty/clayey **SAND**, non-plastic
12	
12.5	
13	
13.5	
14	
14.5	
15	
15.5	15' - 23': Damp, tight, gray sandy **CLAY**. Mottled with orange, moderate plasticity
16	
16.5	
17	
17.5	
18	
18.5	
19	
19.5	
20	
20.5	
21	
21.5	
22	
22.5	
23	
23.5	23' - 29': Loose, wet, orange-brown coarse **SAND**, well graded, sub-angular grains, little silt/clay
24	
24.5	
25	

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MP-1 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/12/2018
Project No.:	1727-226789	End Date:	3/12/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	43'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

Depth	Description
25.5	
26	24' - 29': Loose, wet, orange-brown coarse **SAND**, well graded, sub-angular grains, little silt/clay
26.5	
27	
27.5	27' - 29' - thin layer of fine to medium **GRAVEL**, mostly quartz, some k feldspar
28	
28.5	24' - 29': Loose, wet, orange-brown coarse **SAND**, well graded, sub-angular grains, little silt/clay
29	
29.5	
30	29' - 31': Loose, wet, orange-brown **CLAY**. High plasticity
30.5	
31	
31.5	
32	
32.5	
33	
33.5	
34	
34.5	
35	
35.5	31' - 43': **SAPROLITE**. Moist, tight, dark red silt, some clay. Foliated relic structure (gneiss/schist), micaceous
36	
36.5	
37	
37.5	
38	
38.5	
39	
39.5	
40	

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MP-1 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/12/2018
Project No.:	1727-226789	End Date:	3/12/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	43'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

40.5	31' - 43': **SAPROLITE**. Moist, tight, dark red-brown silt, some clay. Foliated relic structure (gneiss/schist), micaceous BORING TERMINATED AT 43' BGS, MACRO CORE REFUSAL
41	
41.5	
42	
42.5	
43	

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MP-2 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/13/2018
Project No.:	1727-226789	End Date:	3/13/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	44'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

Well Construction

Total Borehole Depth/Dia.:	44' / 8.5"	Surface Completion:	Flush Mount
Grout Depth/Type:	0'-20' / Neat Cement	Casing +/- Grade Level:	
Bentonite Seal Depth/Type:	20'-22' / 3/8" Bentonite Chips	Sand Pack Depth:	22'-44'
Casing Type/Depth/Dia.:	PVC / 0'-24' / 2"	Screen Type/Depth/Dia./Slots:	PVC / 24'-44' / 2" / 0.01"
Development Method/Gallons:	Submersible Pump / 25 Gal.	Bottom Backfill Depth/Material:	N/A

Additional Information:

Drilling/Sampling Method: 8.25" OD/4.25" ID Hollow-Stem Auger / Macro Core

Depth (feet)	Formation Description
0.5	0-0.25' Asphalt
1	0.25' - 10': Dry, loose, orange-brown clayey **SAND**, some silt. Mottled with pieces of gray clay, non-plastic
1.5	
2	
2.5	
3	
3.5	
4	
4.5	
5	
5.5	
6	
6.5	
7	
7.5	
8	
8.5	
9	
9.5	
10	

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MP-2 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/13/2018
Project No.:	1727-226789	End Date:	3/13/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	44'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

10.5	
11	
11.5	
12	10' - 14': Dry, loose, tan clayey **SAND**, fine grained, non-plastic
12.5	
13	
13.5	
14	
14.5	
15	
15.5	
16	
16.5	
17	
17.5	
18	
18.5	14' - 27': Damp, tight, gray sandy **CLAY**. Mottled with orange, moderate plasticity
19	
19.5	
20	
20.5	
21	
21.5	
22	
22.5	
23	Thin layer of coarse **SAND** at 23' bgs
23.5	
24	14' - 27': Damp, tight, gray sandy **CLAY**. Mottled with orange, moderate plasticity
24.5	
25	

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MP-2 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/13/2018
Project No.:	1727-226789	End Date:	3/13/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	44'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

Depth	Description
25.5	14' - 27': Damp, tight, gray sandy **CLAY**. Mottled with orange, moderate plasticity
26	
26.5	
27	
27.5	27' - 33': Loose, wet, orange-brown coarse **SAND**, well graded, sub-angular grains, little silt/clay
28	
28.5	
29	
29.5	
30	
30.5	
31	
31.5	
32	
32.5	
33	
33.5	33' - 35': Loose, wet, orange-brown **CLAY**. High plasticity
34	
34.5	
35	
35.5	35' - 44': **SAPROLITE**. Moist, tight, dark red-brown silt, some clay. Foliated relic structure (gneiss/schist), micaceous
36	
36.5	
37	
37.5	
38	
38.5	
39	
39.5	
40	

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MP-2 Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/13/2018
Project No.:	1727-226789	End Date:	3/13/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	44'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

40.5	35' - 44': **SAPROLITE**. Moist, tight, dark red-brown silt. Foliated relic structure (gneiss/schist), micaceous BORING TERMINATED AT 44' BGS, MACROCORE REFUSAL
41	
41.5	
42	
42.5	
43	
43.5	
44	

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MW-7A Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/14/2018
Project No.:	1727-226789	End Date:	3/14/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	16'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab
Well Construction			
Total Borehole Depth/Dia.:	16' / 8.5"	Surface Completion:	Flush Mount
Grout Depth/Type:	0'-4' / Neat Cement	Casing +/- Grade Level:	
Bentonite Seal Depth/Type:	2'-4' / 3/8" Bentonite Chips	Sand Pack Depth:	4'-16'
Casing Type/Depth/Dia.:	PVC / 0'-6' / 2"	Screen Type/Depth/Dia./Slots:	PVC / 6'-16' / 2" / 0.01"
Development Method/Gallons:	Submersible Pump / 25 Gal.	Bottom Backfill Depth/Material:	N/A
Additional Information:			
Drilling/Sampling Method: 8.25" OD/4.25" ID Hollow-Stem Auger / Macro Core			

Depth (feet)	Formation Description
0.5	
1	
1.5	
2	
2.5	
3	
3.5	
4	0' - 7.5': Damp, tight, gray sandy **CLAY**. Mottled with orange, low plasticity
4.5	
5	
5.5	
6	
6.5	
7	
7.5	
8	
8.5	
9	7.5 - 12.5: Wet, loose orange coarse **SAND**. Well graded
9.5	
10	

CDM Smith

MW-7A Boring/Well Construction Log

Project:	Cessna GA1 Facility	Start Date:	3/14/2018
Project No.:	1727-226789	End Date:	3/14/2018
Logged/Checked By:	Daniel Good/Tom Duffey	Total Depth:	16'
Location:	Columbus, GA	Driller: Ben Wallace	Geo Lab

Depth	Description
10.5	7.5 - 12.5: Wet, loose orange coarse **SAND**. Well graded
11	
11.5	
12	
12.5	
13	12.5' - 16': Wet, loose, gray/white coarse **SAND & GRAVEL**, Angular to subangular grains, well graded BORING TERMINATED AT 16' BGS
13.5	
14	
14.5	
15	
15.5	
16	

CDM Smith

Appendix B

Analytical Laboratory Reports and Well Purge Records

CDM Smith

March 21, 2018

Nicholas Fuller
CDM Smith Inc.

3200 Windy Hill Road
Atlanta GA 30339

RE: Cessna

Dear Nicholas Fuller: Order No: 1803F14

Analytical Environmental Services, Inc. received 4 samples on 3/15/2018 7:50:00 AM for the analyses presented in following report.

No problems were encountered during the analyses. Additionally, all results for the associated Quality Control samples were within EPA and/or AES established limits. Any discrepancies associated with the analyses contained herein will be noted and submitted in the form of a project Case Narrative.

AES's accreditations are as follows:

-NELAP/State of Florida Laboratory ID E87582 for analysis of Non-Potable Water, Solid & Chemical Materials, Air & Emissions Volatile Organics, and Drinking Water Microbiology & Metals, effective 07/01/17-06/30/18.

State of Georgia, Department of Natural Resources ID #800 for analysis of Drinking Water Metals, effective 07/01/17-06/30/18 and Total Coliforms/ E. coli, effective 04/25/17-04/24/20.

-NELAP/Louisiana Agency Interest No. 100818 for or analysis of Non-Potable Water and Solid & Chemical Materials, effective 07/01/17-06/30/18.

-AIHA-LAP, LLC Laboratory ID: 100671 for Industrial Hygiene samples (Organics, Metals, PCM Asbestos, Gravimetric), Environmental Lead (Paint, Soil, Dust Wipes, Air), and Environmental Microbiology (Fungal) Direct Examination, effective until 11/01/19.

These results relate only to the items tested. This report may only be reproduced in full.

If you have any questions regarding these test results, please feel free to call.

Sincerely,

Ioana Pacurar

Ioana Pacurar

Project Manager

ANALYTICAL ENVIRONMENTAL SERVICES, INC.
3080 Presidential Drive Atlanta, GA 30340-3704
Phone: (770) 457-8177 / Toll-Free: (800) 972-4889 / Fax: (770) 457-8188

CHAIN OF CUSTODY

Work Order: 1803F14

Date: ______ Page 1 of 1

COMPANY: CDMSmith
ADDRESS: 3200 Windy Hill Rd Ste 210 W Atlanta, GA 30339
PHONE: 404 720 1330
EMAIL: ndfuller@cdmsmith.com
SAMPLED BY: Daniel Good
SIGNATURE: [signature]

ANALYSIS REQUESTED: VOCs

Visit our website www.aesatlanta.com for downloadable COCs and to log in to your AESAccess account.

#	SAMPLE ID	SAMPLED: DATE	SAMPLED: TIME	GRAB	COMPOSITE	MATRIX (see codes)	VOCs	REMARKS	Number of Containers
1	MW-7A	3-14-15	1450	✓		SO	✓		
2	INJ-11	↓	1615	↓		↓	✓		
3	INJ-13	↓	1720	↓		↓	✓		
4							✓		
5	Trip Blank								
6	Temp Blank								
7									
8									
9									
10									
11									
12									
13									
14									

PRESERVATION (see codes)

RELINQUISHED BY:	DATE/TIME:	RECEIVED BY:	DATE/TIME:
1. [signature]	3/15-18/ ~~0800~~ 0750	1. [signature]	3/15/18 750
2.		2.	
3.		3.	

SPECIAL INSTRUCTIONS/COMMENTS:

SHIPMENT METHOD
OUT: / / VIA:
IN: / / VIA:
client (circled) FedEx UPS US mail courier Greyhound
other: ______

PROJECT INFORMATION
PROJECT NAME: Cessna
PROJECT #:
SITE ADDRESS:
SEND REPORT TO: ndfuller@cdmsmith.com
INVOICE TO:
(IF DIFFERENT FROM ABOVE)
QUOTE #: ______ PO#: ______

RECEIPT
Total # of Containers

Turnaround Time (TAT) Request
- [x] Standard 5 Business Days
- [ ] 2 Business Day Rush
- [ ] Next Business Day Rush
- [ ] Same-Day Rush (auth req.)
- [ ] Other ______

STATE PROGRAM (if any): ______
E-mail? ☐ Fax? ☐
DATA PACKAGE: I ○ II ○ III ○ IV ○

Submission of samples to the laboratory constitutes acceptance of AES's Terms & Conditions. Samples received after 3PM or on Saturday are considered as received the following business day. If no TAT is marked on COC, AES will proceed with standard TAT. Samples are disposed of 30 days after completion of report unless other arangements are made.

Matrix Codes: A = Air GW = Groundwater SE = Sediment SO = Soil SW = Surface Water WW = Waste Water W = Water (Blanks) DW = Drinking Water (Blanks) O = Other (specify)

Preservative Codes: H+I = Hydrochloric acid + ice I = Ice only N = Nitric acid S+I = Sulfuric acid + ice S/M+I = Sodium Bisulfate/Methanol + ice O = Other (specify) NA = None

White Copy - Original; Yellow Copy - Client

Client: CDM Smith Inc.
Project: Cessna
Lab ID: 1803F14

Case Narrative

Sample Receiving Non-conformance:

The matrix illustrated on the Chain of Custody is soil, but the samples received were aqueous samples.

Analytical Environmental Services, Inc

Date: 21-Mar-18

Client:	CDM Smith Inc.	**Client Sample ID:**	MW-7A
Project Name:	Cessna	**Collection Date:**	3/14/2018 2:50:00 PM
Lab ID:	1803F14-001	**Matrix:**	Aqueous

TCL VOLATILE ORGANICS SW8260B (SW5030B)

Analyses	Result	Reporting Limit	Qual	Units	BatchID	Dilution Factor	Date Analyzed	Analyst
1,1,1-Trichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
1,1,2,2-Tetrachloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
1,1,2-Trichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
1,1-Dichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
1,1-Dichloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
1,2,4-Trichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
1,2-Dibromo-3-chloropropane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
1,2-Dibromoethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
1,2-Dichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
1,2-Dichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
1,2-Dichloropropane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
1,3-Dichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
1,4-Dichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
2-Butanone	BRL	50		ug/L	257622	1	03/19/2018 13:53	NP
2-Hexanone	BRL	10		ug/L	257622	1	03/19/2018 13:53	NP
4-Methyl-2-pentanone	BRL	10		ug/L	257622	1	03/19/2018 13:53	NP
Acetone	BRL	50		ug/L	257622	1	03/19/2018 13:53	NP
Benzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Bromodichloromethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Bromoform	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Bromomethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Carbon disulfide	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Carbon tetrachloride	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Chlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Chloroethane	BRL	10		ug/L	257622	1	03/19/2018 13:53	NP
Chloroform	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Chloromethane	BRL	10		ug/L	257622	1	03/19/2018 13:53	NP
cis-1,2-Dichloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
cis-1,3-Dichloropropene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Cyclohexane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Dibromochloromethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Dichlorodifluoromethane	BRL	10		ug/L	257622	1	03/19/2018 13:53	NP
Ethylbenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Freon-113	BRL	10		ug/L	257622	1	03/19/2018 13:53	NP
Isopropylbenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
m,p-Xylene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Methyl acetate	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Methyl tert-butyl ether	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Methylcyclohexane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Methylene chloride	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
o-Xylene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP

Qualifiers:

*	Value exceeds maximum contaminant level	E	Estimated (value above quantitation range)
BRL	Below reporting limit	S	Spike Recovery outside limits due to matrix
H	Holding times for preparation or analysis exceeded	Narr	See case narrative
N	Analyte not NELAC certified	NC	Not confirmed
B	Analyte detected in the associated method blank	<	Less than Result value
>	Greater than Result value	J	Estimated value detected below Reporting Limit

Analytical Environmental Services, Inc

Date: 21-Mar-18

Client:	CDM Smith Inc.	**Client Sample ID:**	MW-7A
Project Name:	Cessna	**Collection Date:**	3/14/2018 2:50:00 PM
Lab ID:	1803F14-001	**Matrix:**	Aqueous

Analyses	Result	Reporting Limit	Qual	Units	BatchID	Dilution Factor	Date Analyzed	Analyst
TCL VOLATILE ORGANICS SW8260B				**(SW5030B)**				
Styrene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Tetrachloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Toluene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
trans-1,2-Dichloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
trans-1,3-Dichloropropene	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Trichloroethene	340	50		ug/L	257622	10	03/19/2018 15:05	NP
Trichlorofluoromethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:53	NP
Vinyl chloride	BRL	2.0		ug/L	257622	1	03/19/2018 13:53	NP
Surr: 4-Bromofluorobenzene	79.9	68-127		%REC	257622	1	03/19/2018 13:53	NP
Surr: 4-Bromofluorobenzene	80.3	68-127		%REC	257622	10	03/19/2018 15:05	NP
Surr: Dibromofluoromethane	107	84.4-122		%REC	257622	1	03/19/2018 13:53	NP
Surr: Dibromofluoromethane	113	84.4-122		%REC	257622	10	03/19/2018 15:05	NP
Surr: Toluene-d8	98.3	80.1-116		%REC	257622	1	03/19/2018 13:53	NP
Surr: Toluene-d8	98.4	80.1-116		%REC	257622	10	03/19/2018 15:05	NP

Qualifiers:

*	Value exceeds maximum contaminant level	E	Estimated (value above quantitation range)
BRL	Below reporting limit	S	Spike Recovery outside limits due to matrix
H	Holding times for preparation or analysis exceeded	Narr	See case narrative
N	Analyte not NELAC certified	NC	Not confirmed
B	Analyte detected in the associated method blank	<	Less than Result value
>	Greater than Result value	J	Estimated value detected below Reporting Limit

Analytical Environmental Services, Inc

Date: 21-Mar-18

Client:	CDM Smith Inc.	**Client Sample ID:**	INJ-11
Project Name:	Cessna	**Collection Date:**	3/14/2018 4:15:00 PM
Lab ID:	1803F14-002	**Matrix:**	Aqueous

Analyses	Result	Reporting Limit	Qual	Units	BatchID	Dilution Factor	Date Analyzed	Analyst
TCL VOLATILE ORGANICS SW8260B				**(SW5030B)**				
1,1,1-Trichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
1,1,2,2-Tetrachloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
1,1,2-Trichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
1,1-Dichloroethane	16	5.0		ug/L	257622	1	03/19/2018 14:17	NP
1,1-Dichloroethene	11	5.0		ug/L	257622	1	03/19/2018 14:17	NP
1,2,4-Trichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
1,2-Dibromo-3-chloropropane	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
1,2-Dibromoethane	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
1,2-Dichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
1,2-Dichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
1,2-Dichloropropane	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
1,3-Dichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
1,4-Dichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
2-Butanone	BRL	50		ug/L	257622	1	03/19/2018 14:17	NP
2-Hexanone	BRL	10		ug/L	257622	1	03/19/2018 14:17	NP
4-Methyl-2-pentanone	BRL	10		ug/L	257622	1	03/19/2018 14:17	NP
Acetone	BRL	50		ug/L	257622	1	03/19/2018 14:17	NP
Benzene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Bromodichloromethane	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Bromoform	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Bromomethane	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Carbon disulfide	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Carbon tetrachloride	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Chlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Chloroethane	BRL	10		ug/L	257622	1	03/19/2018 14:17	NP
Chloroform	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Chloromethane	BRL	10		ug/L	257622	1	03/19/2018 14:17	NP
cis-1,2-Dichloroethene	11	5.0		ug/L	257622	1	03/19/2018 14:17	NP
cis-1,3-Dichloropropene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Cyclohexane	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Dibromochloromethane	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Dichlorodifluoromethane	BRL	10		ug/L	257622	1	03/19/2018 14:17	NP
Ethylbenzene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Freon-113	BRL	10		ug/L	257622	1	03/19/2018 14:17	NP
Isopropylbenzene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
m,p-Xylene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Methyl acetate	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Methyl tert-butyl ether	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Methylcyclohexane	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Methylene chloride	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
o-Xylene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP

Qualifiers:

*	Value exceeds maximum contaminant level	E	Estimated (value above quantitation range)
BRL	Below reporting limit	S	Spike Recovery outside limits due to matrix
H	Holding times for preparation or analysis exceeded	Narr	See case narrative
N	Analyte not NELAC certified	NC	Not confirmed
B	Analyte detected in the associated method blank	<	Less than Result value
>	Greater than Result value	J	Estimated value detected below Reporting Limit

Analytical Environmental Services, Inc

Date: 21-Mar-18

Client:	CDM Smith Inc.	**Client Sample ID:**	INJ-11
Project Name:	Cessna	**Collection Date:**	3/14/2018 4:15:00 PM
Lab ID:	1803F14-002	**Matrix:**	Aqueous

Analyses	Result	Reporting Limit	Qual	Units	BatchID	Dilution Factor	Date Analyzed	Analyst
TCL VOLATILE ORGANICS SW8260B				**(SW5030B)**				
Styrene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Tetrachloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Toluene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
trans-1,2-Dichloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
trans-1,3-Dichloropropene	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Trichloroethene	4600	250		ug/L	257622	50	03/19/2018 14:41	NP
Trichlorofluoromethane	BRL	5.0		ug/L	257622	1	03/19/2018 14:17	NP
Vinyl chloride	BRL	2.0		ug/L	257622	1	03/19/2018 14:17	NP
Surr: 4-Bromofluorobenzene	80.9	68-127		%REC	257622	50	03/19/2018 14:41	NP
Surr: 4-Bromofluorobenzene	78.5	68-127		%REC	257622	1	03/19/2018 14:17	NP
Surr: Dibromofluoromethane	107	84.4-122		%REC	257622	1	03/19/2018 14:17	NP
Surr: Dibromofluoromethane	105	84.4-122		%REC	257622	50	03/19/2018 14:41	NP
Surr: Toluene-d8	98.8	80.1-116		%REC	257622	50	03/19/2018 14:41	NP
Surr: Toluene-d8	98	80.1-116		%REC	257622	1	03/19/2018 14:17	NP

Qualifiers:

*	Value exceeds maximum contaminant level	E	Estimated (value above quantitation range)
BRL	Below reporting limit	S	Spike Recovery outside limits due to matrix
H	Holding times for preparation or analysis exceeded	Narr	See case narrative
N	Analyte not NELAC certified	NC	Not confirmed
B	Analyte detected in the associated method blank	<	Less than Result value
>	Greater than Result value	J	Estimated value detected below Reporting Limit

Analytical Environmental Services, Inc

Date: 21-Mar-18

Client:	CDM Smith Inc.	**Client Sample ID:**	INJ-13
Project Name:	Cessna	**Collection Date:**	3/14/2018 5:20:00 PM
Lab ID:	1803F14-003	**Matrix:**	Aqueous

Analyses	Result	Reporting Limit	Qual	Units	BatchID	Dilution Factor	Date Analyzed	Analyst
TCL VOLATILE ORGANICS SW8260B				**(SW5030B)**				
1,1,1-Trichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
1,1,2,2-Tetrachloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
1,1,2-Trichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
1,1-Dichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
1,1-Dichloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
1,2,4-Trichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
1,2-Dibromo-3-chloropropane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
1,2-Dibromoethane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
1,2-Dichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
1,2-Dichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
1,2-Dichloropropane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
1,3-Dichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
1,4-Dichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
2-Butanone	BRL	50		ug/L	257622	1	03/19/2018 17:06	NP
2-Hexanone	BRL	10		ug/L	257622	1	03/19/2018 17:06	NP
4-Methyl-2-pentanone	BRL	10		ug/L	257622	1	03/19/2018 17:06	NP
Acetone	BRL	50		ug/L	257622	1	03/19/2018 17:06	NP
Benzene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Bromodichloromethane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Bromoform	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Bromomethane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Carbon disulfide	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Carbon tetrachloride	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Chlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Chloroethane	BRL	10		ug/L	257622	1	03/19/2018 17:06	NP
Chloroform	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Chloromethane	BRL	10		ug/L	257622	1	03/19/2018 17:06	NP
cis-1,2-Dichloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
cis-1,3-Dichloropropene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Cyclohexane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Dibromochloromethane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Dichlorodifluoromethane	BRL	10		ug/L	257622	1	03/19/2018 17:06	NP
Ethylbenzene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Freon-113	BRL	10		ug/L	257622	1	03/19/2018 17:06	NP
Isopropylbenzene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
m,p-Xylene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Methyl acetate	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Methyl tert-butyl ether	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Methylcyclohexane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Methylene chloride	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
o-Xylene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP

Qualifiers:

*	Value exceeds maximum contaminant level	E	Estimated (value above quantitation range)
BRL	Below reporting limit	S	Spike Recovery outside limits due to matrix
H	Holding times for preparation or analysis exceeded	Narr	See case narrative
N	Analyte not NELAC certified	NC	Not confirmed
B	Analyte detected in the associated method blank	<	Less than Result value
>	Greater than Result value	J	Estimated value detected below Reporting Limit

Analytical Environmental Services, Inc

Date: 21-Mar-18

Client:	CDM Smith Inc.	**Client Sample ID:**	INJ-13
Project Name:	Cessna	**Collection Date:**	3/14/2018 5:20:00 PM
Lab ID:	1803F14-003	**Matrix:**	Aqueous

Analyses	Result	Reporting Limit	Qual	Units	BatchID	Dilution Factor	Date Analyzed	Analyst
TCL VOLATILE ORGANICS SW8260B				**(SW5030B)**				
Styrene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Tetrachloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Toluene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
trans-1,2-Dichloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
trans-1,3-Dichloropropene	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Trichloroethene	7.7	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Trichlorofluoromethane	BRL	5.0		ug/L	257622	1	03/19/2018 17:06	NP
Vinyl chloride	BRL	2.0		ug/L	257622	1	03/19/2018 17:06	NP
Surr: 4-Bromofluorobenzene	77.9	68-127		%REC	257622	1	03/19/2018 17:06	NP
Surr: Dibromofluoromethane	107	84.4-122		%REC	257622	1	03/19/2018 17:06	NP
Surr: Toluene-d8	95.5	80.1-116		%REC	257622	1	03/19/2018 17:06	NP

Qualifiers:

*	Value exceeds maximum contaminant level	E	Estimated (value above quantitation range)
BRL	Below reporting limit	S	Spike Recovery outside limits due to matrix
H	Holding times for preparation or analysis exceeded	Narr	See case narrative
N	Analyte not NELAC certified	NC	Not confirmed
B	Analyte detected in the associated method blank	<	Less than Result value
>	Greater than Result value	J	Estimated value detected below Reporting Limit

Analytical Environmental Services, Inc

Date: 21-Mar-18

Client:	CDM Smith Inc.	**Client Sample ID:**	TRIP BLANK
Project Name:	Cessna	**Collection Date:**	3/14/2018
Lab ID:	1803F14-004	**Matrix:**	Aqueous

Analyses	Result	Reporting Limit	Qual	Units	BatchID	Dilution Factor	Date Analyzed	Analyst
TCL VOLATILE ORGANICS SW8260B				**(SW5030B)**				
1,1,1-Trichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
1,1,2,2-Tetrachloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
1,1,2-Trichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
1,1-Dichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
1,1-Dichloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
1,2,4-Trichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
1,2-Dibromo-3-chloropropane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
1,2-Dibromoethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
1,2-Dichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
1,2-Dichloroethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
1,2-Dichloropropane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
1,3-Dichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
1,4-Dichlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
2-Butanone	BRL	50		ug/L	257622	1	03/19/2018 13:29	NP
2-Hexanone	BRL	10		ug/L	257622	1	03/19/2018 13:29	NP
4-Methyl-2-pentanone	BRL	10		ug/L	257622	1	03/19/2018 13:29	NP
Acetone	BRL	50		ug/L	257622	1	03/19/2018 13:29	NP
Benzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Bromodichloromethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Bromoform	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Bromomethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Carbon disulfide	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Carbon tetrachloride	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Chlorobenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Chloroethane	BRL	10		ug/L	257622	1	03/19/2018 13:29	NP
Chloroform	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Chloromethane	BRL	10		ug/L	257622	1	03/19/2018 13:29	NP
cis-1,2-Dichloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
cis-1,3-Dichloropropene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Cyclohexane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Dibromochloromethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Dichlorodifluoromethane	BRL	10		ug/L	257622	1	03/19/2018 13:29	NP
Ethylbenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Freon-113	BRL	10		ug/L	257622	1	03/19/2018 13:29	NP
Isopropylbenzene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
m,p-Xylene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Methyl acetate	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Methyl tert-butyl ether	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Methylcyclohexane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Methylene chloride	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
o-Xylene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP

Qualifiers:

*	Value exceeds maximum contaminant level	E	Estimated (value above quantitation range)
BRL	Below reporting limit	S	Spike Recovery outside limits due to matrix
H	Holding times for preparation or analysis exceeded	Narr	See case narrative
N	Analyte not NELAC certified	NC	Not confirmed
B	Analyte detected in the associated method blank	<	Less than Result value
>	Greater than Result value	J	Estimated value detected below Reporting Limit

Analytical Environmental Services, Inc

Date: 21-Mar-18

Client:	CDM Smith Inc.	**Client Sample ID:**	TRIP BLANK
Project Name:	Cessna	**Collection Date:**	3/14/2018
Lab ID:	1803F14-004	**Matrix:**	Aqueous

Analyses	Result	Reporting Limit	Qual	Units	BatchID	Dilution Factor	Date Analyzed	Analyst
TCL VOLATILE ORGANICS SW8260B				**(SW5030B)**				
Styrene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Tetrachloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Toluene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
trans-1,2-Dichloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
trans-1,3-Dichloropropene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Trichloroethene	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Trichlorofluoromethane	BRL	5.0		ug/L	257622	1	03/19/2018 13:29	NP
Vinyl chloride	BRL	2.0		ug/L	257622	1	03/19/2018 13:29	NP
Surr: 4-Bromofluorobenzene	78.5	68-127		%REC	257622	1	03/19/2018 13:29	NP
Surr: Dibromofluoromethane	106	84.4-122		%REC	257622	1	03/19/2018 13:29	NP
Surr: Toluene-d8	97.5	80.1-116		%REC	257622	1	03/19/2018 13:29	NP

Qualifiers:

*	Value exceeds maximum contaminant level	E	Estimated (value above quantitation range)
BRL	Below reporting limit	S	Spike Recovery outside limits due to matrix
H	Holding times for preparation or analysis exceeded	Narr	See case narrative
N	Analyte not NELAC certified	NC	Not confirmed
B	Analyte detected in the associated method blank	<	Less than Result value
>	Greater than Result value	J	Estimated value detected below Reporting Limit

Analytical Environmental Services, Inc

Date: 21-Mar-18

SUMMARY OF ANALYTES DETECTED

Analyses	Result	Qual	MDL	Reporting Limit	Units	BatchID	Dilution Factor
Client Sample ID: MW-7A				**Lab ID:** 1803F14-001			
Collection Date: 3/14/2018 2:50:00 PM				**Matrix:** Aqueous			
TCL VOLATILE ORGANICS SW8260B				**(SW5030B)**			
Trichloroethene	340		3.0	50	ug/L	257622	10
Client Sample ID: INJ-11				**Lab ID:** 1803F14-002			
Collection Date: 3/14/2018 4:15:00 PM				**Matrix:** Aqueous			
TCL VOLATILE ORGANICS SW8260B				**(SW5030B)**			
1,1-Dichloroethane	16		0.43	5.0	ug/L	257622	1
1,1-Dichloroethene	11		0.40	5.0	ug/L	257622	1
cis-1,2-Dichloroethene	11		0.28	5.0	ug/L	257622	1
Trichloroethene	4600		15	250	ug/L	257622	50
Client Sample ID: INJ-13				**Lab ID:** 1803F14-003			
Collection Date: 3/14/2018 5:20:00 PM				**Matrix:** Aqueous			
TCL VOLATILE ORGANICS SW8260B				**(SW5030B)**			
Trichloroethene	7.7		0.30	5.0	ug/L	257622	1

Qualifiers:

- * Value exceeds maximum contaminant level
- BRL Below reporting limit
- H Holding times for preparation or analysis exceeded
- N Analyte not NELAC certified
- B Analyte detected in the associated method blank
- > Greater than Result value
- E Estimated (value above quantitation range)
- S Spike Recovery outside limits due to matrix
- Narr See case narrative
- NC Not confirmed
- < Less than Result value
- J Estimated value detected below Reporting Limit

Clear | Save as

ANALYTICAL ENVIRONMENTAL SERVICES, INC. (AES)

SAMPLE/COOLER RECEIPT CHECKLIST

1. Client Name: CDM Smith   AES Work Order Number: 1803F14

2. Carrier: FedEx ☐ UPS ☐ USPS ☐ Client ☒ Courier ☐ Other ____

#	Question	Yes	No	N/A	Details	Comments
3.	Shipping container/cooler received in good condition?	(X)			damaged ☐ leaking ☐ other ☐	
4.	Custody seals present on shipping container?		(X)			
5.	Custody seals intact on shipping container?			(X)		
6.	Temperature blanks present?	(X)				
7.	Cooler temperature(s) within limits of 0-6°C? [See item 13 and 14 for temperature recordings.]	(X)			Cooling initiated for recently collected samples / ice present ☐	
8.	Chain of Custody (COC) present?	(X)				
9.	Chain of Custody signed, dated, and timed when relinquished and received?	(X)				
10.	Sampler name and/or signature on COC?	(X)				
11.	Were all samples received within holding time?	(X)				
12.	TAT marked on the COC?	(X)			If no TAT indicated, proceeded with standard TAT per Terms & Conditions. ☐	

13. Cooler 1 Temperature 1.7 °C Cooler 2 Temperature ____ °C Cooler 3 Temperature ____ °C Cooler 4 Temperature ____ °C

14. Cooler 5 Temperature ____ °C Cooler 6 Temperature ____ °C Cooler 7 Temperature ____ °C Cooler 8 Temperature ____ °C

15. Comments:

I certify that I have completed sections 1-15 (dated initials). MJ 3/15/18

#	Question	Yes	No	N/A	Details	Comments
16.	Were sample containers intact upon receipt?	(X)				
17.	Custody seals present on sample containers?		(X)			
18.	Custody seals intact on sample containers?			(X)		
19.	Do sample container labels match the COC?	(X)			incomplete info ☐ illegible ☐ no label ☐ other ☐	
20.	Are analyses requested indicated on the COC?	(X)				
21.	Were all of the samples listed on the COC received?	(X)			samples received but not listed on COC ☐ samples listed on COC not received ☐	
22.	Was the sample collection date/time noted?	(X)				
23.	Did we receive sufficient sample volume for indicated analyses?	(X)				
24.	Were samples received in appropriate containers?	(X)				
25.	Were VOA samples received without headspace (< 1/4" bubble)?	(X)				
26.	Were trip blanks submitted?	(X)			listed on COC ☒ not listed on COC ☐	

27. Comments:

I certify that I have completed sections 16-27 (dated initials). KR 3/16/18

This section only applies to samples where pH can be checked at Sample Receipt.

#	Question	Yes	No	N/A	Details	Comments
28.	Have containers needing chemical preservation been checked? *			(X)		
29.	Containers meet preservation guidelines?			(X)		
30.	Was pH adjusted at Sample Receipt?			(X)		

* Note: Certain analyses require chemical preservation but must be checked in the laboratory and not upon Sample Receipt such as Coliforms, VOCs and Oil & Grease/TPH.

I certify that I have completed sections 28-30 (dated initials). KR 3/16/18

Checklist 6.9.17 Rev 2

Locked

Client: CDM Smith Inc.
Project Name: Cessna
Workorder: 1803F14

ANALYTICAL QC SUMMARY REPORT

BatchID: **257622**

Sample ID: **MB-257622** Client ID: Units: **ug/L** Prep Date: **03/19/2018** Run No: **365701**
SampleType: **MBLK** TestCode: **TCL VOLATILE ORGANICS SW8260B** BatchID: **257622** Analysis Date: **03/19/2018** Seq No: **8086230**

Analyte	Result	RPT Limit	SPK value	SPK Ref Val	%REC	Low Limit	High Limit	RPD Ref Val	%RPD	RPD Limit	Qual
1,1,1-Trichloroethane	BRL	5.0									
1,1,2,2-Tetrachloroethane	BRL	5.0									
1,1,2-Trichloroethane	BRL	5.0									
1,1-Dichloroethane	BRL	5.0									
1,1-Dichloroethene	BRL	5.0									
1,2,4-Trichlorobenzene	BRL	5.0									
1,2-Dibromo-3-chloropropane	BRL	5.0									
1,2-Dibromoethane	BRL	5.0									
1,2-Dichlorobenzene	BRL	5.0									
1,2-Dichloroethane	BRL	5.0									
1,2-Dichloropropane	BRL	5.0									
1,3-Dichlorobenzene	BRL	5.0									
1,4-Dichlorobenzene	BRL	5.0									
2-Butanone	BRL	50									
2-Hexanone	BRL	10									
4-Methyl-2-pentanone	BRL	10									
Acetone	BRL	50									
Benzene	BRL	5.0									
Bromodichloromethane	BRL	5.0									
Bromoform	BRL	5.0									
Bromomethane	BRL	5.0									
Carbon disulfide	BRL	5.0									
Carbon tetrachloride	BRL	5.0									
Chlorobenzene	BRL	5.0									
Chloroethane	BRL	10									
Chloroform	BRL	5.0									
Chloromethane	BRL	10									

Qualifiers:
- > Greater than Result value
- BRL Below reporting limit
- J Estimated value detected below Reporting Limit
- Rpt Lim Reporting Limit
- < Less than Result value
- E Estimated (value above quantitation range)
- N Analyte not NELAC certified
- S Spike Recovery outside limits due to matrix
- B Analyte detected in the associated method blank
- H Holding times for preparation or analysis exceeded
- R RPD outside limits due to matrix

Client: CDM Smith Inc.
Project Name: Cessna
Workorder: 1803F14

ANALYTICAL QC SUMMARY REPORT

BatchID: 257622

Sample ID: **MB-257622** Client ID: Units: **ug/L** Prep Date: **03/19/2018** Run No: **365701**
SampleType: **MBLK** TestCode: **TCL VOLATILE ORGANICS SW8260B** BatchID: **257622** Analysis Date: **03/19/2018** Seq No: **8086230**

Analyte	Result	RPT Limit	SPK value	SPK Ref Val	%REC	Low Limit	High Limit	RPD Ref Val	%RPD	RPD Limit	Qual
cis-1,2-Dichloroethene	BRL	5.0									
cis-1,3-Dichloropropene	BRL	5.0									
Cyclohexane	BRL	5.0									
Dibromochloromethane	BRL	5.0									
Dichlorodifluoromethane	BRL	10									
Ethylbenzene	BRL	5.0									
Freon-113	BRL	10									
Isopropylbenzene	BRL	5.0									
m,p-Xylene	BRL	5.0									
Methyl acetate	BRL	5.0									
Methyl tert-butyl ether	BRL	5.0									
Methylcyclohexane	BRL	5.0									
Methylene chloride	BRL	5.0									
o-Xylene	BRL	5.0									
Styrene	BRL	5.0									
Tetrachloroethene	BRL	5.0									
Toluene	BRL	5.0									
trans-1,2-Dichloroethene	BRL	5.0									
trans-1,3-Dichloropropene	BRL	5.0									
Trichloroethene	BRL	5.0									
Trichlorofluoromethane	BRL	5.0									
Vinyl chloride	BRL	2.0									
Surr: 4-Bromofluorobenzene	39.73	0	50.00		79.5	68	127				
Surr: Dibromofluoromethane	51.12	0	50.00		102	84.4	122				
Surr: Toluene-d8	47.36	0	50.00		94.7	80.1	116				

Qualifiers:

> Greater than Result value	< Less than Result value	B Analyte detected in the associated method blank
BRL Below reporting limit	E Estimated (value above quantitation range)	H Holding times for preparation or analysis exceeded
J Estimated value detected below Reporting Limit	N Analyte not NELAC certified	R RPD outside limits due to matrix
Rpt Lim Reporting Limit	S Spike Recovery outside limits due to matrix	

Client: CDM Smith Inc.
Project Name: Cessna
Workorder: 1803F14

ANALYTICAL QC SUMMARY REPORT

BatchID: 257622

Sample ID: **LCS-257622** Client ID: Units: **ug/L** Prep Date: **03/19/2018** Run No: **365701**
SampleType: **LCS** TestCode: **TCL VOLATILE ORGANICS SW8260B** BatchID: **257622** Analysis Date: **03/19/2018** Seq No: **8086228**

Analyte	Result	RPT Limit	SPK value	SPK Ref Val	%REC	Low Limit	High Limit	RPD Ref Val	%RPD	RPD Limit	Qual
1,1-Dichloroethene	59.92	5.0	50.00		120	69	136				
Benzene	48.68	5.0	50.00		97.4	73.7	126				
Chlorobenzene	55.76	5.0	50.00		112	73.5	124				
Toluene	51.17	5.0	50.00		102	76.8	125				
Trichloroethene	53.33	5.0	50.00		107	70.9	124				
Surr: 4-Bromofluorobenzene	41.06	0	50.00		82.1	68	127				
Surr: Dibromofluoromethane	51.17	0	50.00		102	84.4	122				
Surr: Toluene-d8	47.27	0	50.00		94.5	80.1	116				

Sample ID: **1803F14-003AMS** Client ID: **INJ-13** Units: **ug/L** Prep Date: **03/19/2018** Run No: **365701**
SampleType: **MS** TestCode: **TCL VOLATILE ORGANICS SW8260B** BatchID: **257622** Analysis Date: **03/19/2018** Seq No: **8087488**

Analyte	Result	RPT Limit	SPK value	SPK Ref Val	%REC	Low Limit	High Limit	RPD Ref Val	%RPD	RPD Limit	Qual
1,1-Dichloroethene	6555	500	5000		131	65.7	143				
Benzene	4772	500	5000		95.4	66.1	137				
Chlorobenzene	5300	500	5000		106	70.9	132				
Toluene	4841	500	5000		96.8	63.8	141				
Trichloroethene	5031	500	5000		101	70.6	128				
Surr: 4-Bromofluorobenzene	4158	0	5000		83.2	68	127				
Surr: Dibromofluoromethane	5246	0	5000		105	84.4	122				
Surr: Toluene-d8	4764	0	5000		95.3	80.1	116				

Sample ID: **1803F14-003AMSD** Client ID: **INJ-13** Units: **ug/L** Prep Date: **03/19/2018** Run No: **365701**
SampleType: **MSD** TestCode: **TCL VOLATILE ORGANICS SW8260B** BatchID: **257622** Analysis Date: **03/19/2018** Seq No: **8087489**

Analyte	Result	RPT Limit	SPK value	SPK Ref Val	%REC	Low Limit	High Limit	RPD Ref Val	%RPD	RPD Limit	Qual
1,1-Dichloroethene	6982	500	5000		140	65.7	143	6555	6.31	17.7	
Benzene	4948	500	5000		99.0	66.1	137	4772	3.62	20	

Qualifiers:
- > Greater than Result value
- BRL Below reporting limit
- J Estimated value detected below Reporting Limit
- Rpt Lim Reporting Limit
- < Less than Result value
- E Estimated (value above quantitation range)
- N Analyte not NELAC certified
- S Spike Recovery outside limits due to matrix
- B Analyte detected in the associated method blank
- H Holding times for preparation or analysis exceeded
- R RPD outside limits due to matrix

Client: CDM Smith Inc.
Project Name: Cessna
Workorder: 1803F14

ANALYTICAL QC SUMMARY REPORT

BatchID: **257622**

Sample ID: **1803F14-003AMSD** Client ID: **INJ-13** Units: **ug/L** Prep Date: **03/19/2018** Run No: **365701**
SampleType: **MSD** TestCode: **TCL VOLATILE ORGANICS SW8260B** BatchID: **257622** Analysis Date: **03/19/2018** Seq No: **8087489**

Analyte	Result	RPT Limit	SPK value	SPK Ref Val	%REC	Low Limit	High Limit	RPD Ref Val	%RPD	RPD Limit	Qual
Chlorobenzene	5383	500	5000		108	70.9	132	5300	1.55	20	
Toluene	4996	500	5000		99.9	63.8	141	4841	3.15	20	
Trichloroethene	5234	500	5000		105	70.6	128	5031	3.96	20	
Surr: 4-Bromofluorobenzene	3957	0	5000		79.1	68	127	4158	0	0	
Surr: Dibromofluoromethane	5512	0	5000		110	84.4	122	5246	0	0	
Surr: Toluene-d8	4790	0	5000		95.8	80.1	116	4764	0	0	

Qualifiers:

> Greater than Result value	< Less than Result value	B Analyte detected in the associated method blank
BRL Below reporting limit	E Estimated (value above quantitation range)	H Holding times for preparation or analysis exceeded
J Estimated value detected below Reporting Limit	N Analyte not NELAC certified	R RPD outside limits due to matrix
Rpt Lim Reporting Limit	S Spike Recovery outside limits due to matrix	

GROUNDWATER SAMPLING LOG

CDM Smith

SITE NAME:		SITE LOCATION:	
WELL NO:	SAMPLE ID: INJ-11		DATE: 3-14-16

PURGING DATA

WELL DIAMETER (inches): 2	TUBING DIAMETER (inches):	WELL SCREEN INTERVAL DEPTH: 24-44 (feet TOC)	STATIC DEPTH TO WATER (feet TOC): 18.72	PURGE PUMP TYPE: ESP

PURGE VOLUME: 1 WELL VOLUME = (TOTAL WELL DEPTH – STATIC DEPTH TO WATER) X WELL CAPACITY   PURGE METHOD: ~~Low-Flow~~ ☒ Traditional (3 Well Volume)

(44 feet TOC – 18.72 feet TOC) X .16 gallons/foot = 4.05 gallons X 3 = 12.14

INITIAL PUMP OR TUBING DEPTH IN WELL (feet bgl): 34	FINAL PUMP OR TUBING DEPTH IN WELL (feet bgl): 34	PURGING INITIATED AT: 1535	PURGING ENDED AT: 1615	TOTAL VOLUME PURGED (gallons): 45

TIME	VOLUME PURGED (gallons)	CUMUL. VOLUME PURGED (gallons)	PURGE RATE (mL/min)	DEPTH TO WATER (feet TOC)	pH (standard units)	TEMP. (°C)	SP. COND. (circle units) mmhos/cm or (mS/cm)	TURBIDITY (NTUs)	DISSOLVED OXYGEN (circle units) mg/L or % saturation	ORP (mV)	COLOR/ ODOR (describe)
1535 ~~0.5~~	5	5	1gpm	19.41	4.51	20.61	0.047	>1000	2.82	-18.1	
1540 ~~1~~		10		20.61	4.91	20.90	0.047	>1000	2.60	-12.0	
1545		15		21.83	4.92	20.92	0.050	581	2.89	-4.0	
1550		20		22.04	4.91	20.92	0.050	289	2.92	-3.8	
1555		25		23.00	4.95	20.92	0.051	104	2.92	-1.7	
1600		30		23.48	4.98	20.93	0.051	191	2.92	-0.1	
1605		35		23.78	5.01	20.95	0.053	103	2.90	9.8	
1610		40		23.81	5.00	20.97	0.053	40.7	2.89	22.6	
1615		45		23.81	5.03	20.98	0.054	28.3	2.89	41.4	

WELL CAPACITY (Gallons Per Foot): 0.75" = 0.02; 1" = 0.04; 1.25" = 0.06; 1.5" = 0.092; 2" = 0.16; 3" = 0.37; 4" = 0.65; 5" = 1.02; 6" = 1.47; 12" = 5.88

TUBING INSIDE DIA. CAPACITY (Gal./Ft.): 1/8" = 0.0006; 3/16" = 0.0014; 1/4" = 0.0026; 5/16" = 0.004; 3/8" = 0.006; 1/2" = 0.010; 5/8" = 0.016

PURGING EQUIPMENT CODES: B = Bailer; BP = Bladder Pump; ESP = Electric Submersible Pump; PP = Peristaltic Pump; O = Other (Specify)

SAMPLING DATA

SAMPLED BY (PRINT) / AFFILIATION: Daniel Gould /CDM Smith	SAMPLER(S) SIGNATURE(S): [signature]	SAMPLING INITIATED AT: 1615	SAMPLING ENDED AT:
PUMP OR TUBING DEPTH IN WELL (feet bgl): 34	TUBING MATERIAL CODE: PP	FIELD-FILTERED: Y N FILTER SIZE: ____ mm Filtration Equipment Type:	
FIELD DECONTAMINATION: PUMP Y N	TUBING Y N (replaced)	DUPLICATE: Y N	

SAMPLE ID CODE	# CONTAINERS	MATERIAL CODE	VOLUME	PRESERVATIVE USED	TOTAL VOL ADDED IN FIELD (mL)	FINAL pH	INTENDED ANALYSIS AND/OR METHOD	SAMPLING EQUIPMENT CODE	SAMPLE PUMP FLOW RATE (mL per minute)
	2	CG	40	HCl	80		VOCs		

SAMPLE CONTAINER SPECIFICATION / SAMPLE PRESERVATION (including wet ice)

REMARK/NOTES:

Hach Field Data: Final Ferrous Iron, mg/L Final Sulfate, mg/L Final CO_2, mg/L Final MNO_4, mg/L

Final Total Iron, mg/L Final Nitrate, mg/L Final Alkalinity, mg/L Dilution Ratio:

Field Instruments:

MATERIAL CODES: AG = Amber Glass; CG = Clear Glass; HDPE = High Density Polyethylene; LDPE = Low Density Polyethylene; PP = Polypropylene; S = Silicone; T = Teflon; O = Other (Specify)

SAMPLING EQUIPMENT CODES: APP = After (Through) Peristaltic Pump; B = Bailer; BP = Bladder Pump; ESP = Electric Submersible Pump; RFPP = Reverse Flow Peristaltic Pump; SM = Straw Method (Tubing Gravity Drain); O = Other (Specify)

NOTES: 1. Stabilization criteria for range of variation of at least three consecutive readings (required parameters in bold).
2. pH: + 0.1 units; Specific Conductance: + 5%; Turbidity: < 10 NTUs or until stable; Dissolved Oxygen: + 0.2 mg/L or 10% saturation (whichever is greater)

GROUNDWATER SAMPLING LOG

CDM Smith

SITE NAME:		SITE LOCATION:	
WELL NO:	SAMPLE ID: TNJ-13	DATE:	ESP 3-14-18

PURGING DATA

WELL DIAMETER (inches): 2	TUBING DIAMETER (inches): 3/8	WELL SCREEN INTERVAL DEPTH: 23-43 (feet TOC)	STATIC DEPTH TO WATER (feet TOC): 18.89	PURGE PUMP TYPE: ESP

PURGE VOLUME: 1 WELL VOLUME = (TOTAL WELL DEPTH – STATIC DEPTH TO WATER) X WELL CAPACITY PURGE METHOD: ☐ Low-Flow ☑ Traditional (3 Well Volume)

(43 feet TOC – 18.89 feet TOC) X 0.16 gallons/foot = 3.85 gallons X 3 = 11.5

INITIAL PUMP OR TUBING DEPTH IN WELL (feet bgl): 33	FINAL PUMP OR TUBING DEPTH IN WELL (feet bgl): 35	PURGING INITIATED AT: 1649	PURGING ENDED AT: 1720	TOTAL VOLUME PURGED (gallons):

TIME	VOLUME PURGED (gallons)	CUMUL. VOLUME PURGED (gallons)	PURGE RATE (~~mL~~/min)	DEPTH TO WATER (feet TOC)	pH (standard units)	TEMP. (°C)	SP. COND. (circle units) mmhos/cm or mS/cm	TURBIDITY (NTUs)	DISSOLVED OXYGEN (circle units) mg/L or % saturation	ORP (mV)	COLOR/ ODOR (describe)
1645	5		1gpm	19.45	4.52	21.06	0.115	21000	1.42	~~262~~ 262.1	
1650	10			19.91	4.61	21.06	0.116	21000	1.36	207.5	
1655	15			20.38	4.73	21.07	0.117	21000	1.32	160.1	
1700	20			20.96	4.79	21.08	0.117	441	1.31	157.1	
1705	25			21.41	4.83	21.08	0.117	208	1.30	165.3	
1710	30			21.68	4.85	21.09	0.118	93.5	1.30	170.1	
1715	35			21.74	4.95	21.10	0.118	41.2	1.29	171.8	
1720	40		↓	21.89	4.47	21.12	0.119	21.1	1.27	176.4	

WELL CAPACITY (Gallons Per Foot): 0.75" = 0.02; 1" = 0.04; 1.25" = 0.06; 1.5" = 0.092; 2" = 0.16; 3" = 0.37; 4" = 0.65; 5" = 1.02; 6" = 1.47; 12" = 5.88

TUBING INSIDE DIA. CAPACITY (Gal./Ft.): 1/8" = 0.0006; 3/16" = 0.0014; 1/4" = 0.0026; 5/16" = 0.004; 3/8" = 0.006; 1/2" = 0.010; 5/8" = 0.016

PURGING EQUIPMENT CODES: B = Bailer; BP = Bladder Pump; ESP = Electric Submersible Pump; PP = Peristaltic Pump; O = Other (Specify)

SAMPLING DATA

SAMPLED BY (PRINT) / AFFILIATION: Daniel Gopp / CDM Smith	SAMPLER(S) SIGNATURE(S): [signature]	SAMPLING INITIATED AT: 1720	SAMPLING ENDED AT:
PUMP OR TUBING DEPTH IN WELL (feet bgl): 33	TUBING MATERIAL CODE: PP	FIELD-FILTERED: Y N	FILTER SIZE: _____ mm Filtration Equipment Type:
FIELD DECONTAMINATION: PUMP Y N	TUBING Y N (replaced)	DUPLICATE: Y N	

SAMPLE ID CODE	# CONTAINERS	MATERIAL CODE	VOLUME	PRESERVATIVE USED	TOTAL VOL ADDED IN FIELD (mL)	FINAL pH	INTENDED ANALYSIS AND/OR METHOD	SAMPLING EQUIPMENT CODE	SAMPLE PUMP FLOW RATE (mL per minute)
	2	CG	40	HCl	80		VOCs		

(SAMPLE CONTAINER SPECIFICATION: SAMPLE ID CODE – VOLUME; SAMPLE PRESERVATION (including wet ice): PRESERVATIVE USED – FINAL pH)

REMARK/NOTES:

Hach Field Data: Final Ferrous Iron, mg/L Final Sulfate, mg/L Final CO_2, mg/L Final MNO_4, mg/L

Final Total Iron, mg/L Final Nitrate, mg/L Final Alkalinity, mg/L Dilution Ratio:

Field Instruments:

MATERIAL CODES: AG = Amber Glass; CG = Clear Glass; HDPE = High Density Polyethylene; LDPE = Low Density Polyethylene; PP = Polypropylene; S = Silicone; T = Teflon; O = Other (Specify)

SAMPLING EQUIPMENT CODES: APP = After (Through) Peristaltic Pump; B = Bailer; BP = Bladder Pump; ESP = Electric Submersible Pump; RFPP = Reverse Flow Peristaltic Pump; SM = Straw Method (Tubing Gravity Drain); O = Other (Specify)

NOTES: 1. Stabilization criteria for range of variation of at least three consecutive readings (required parameters in bold).
2. pH: + 0.1 units; Specific Conductance: + 5%; Turbidity: < 10 NTUs or until stable; Dissolved Oxygen: + 0.2 mg/L or 10% saturation (whichever is greater)

GROUNDWATER SAMPLING LOG

CDM Smith

SITE NAME:		SITE LOCATION:	
WELL NO:	SAMPLE ID: MW-7A		DATE: 3-14-16

PURGING DATA

WELL DIAMETER (inches): 2	TUBING DIAMETER (inches): 3/8	WELL SCREEN INTERVAL DEPTH: 6'-16' (feet TOC)	STATIC DEPTH TO WATER (feet TOC): 7.19	PURGE PUMP TYPE: ESP

PURGE VOLUME: 1 WELL VOLUME = (TOTAL WELL DEPTH – STATIC DEPTH TO WATER) X WELL CAPACITY PURGE METHOD: ☐ Low-Flow ☒ Traditional (3 Well Volume)

(16 feet TOC – 7.19 feet TOC) X .16 gallons/foot = 1.4 gallons X 3 = 4.2

INITIAL PUMP OR TUBING DEPTH IN WELL (feet bgl): 11	FINAL PUMP OR TUBING DEPTH IN WELL (feet bgl): 14	PURGING INITIATED AT: 1400	PURGING ENDED AT: 1450	TOTAL VOLUME PURGED (gallons):

TIME	VOLUME PURGED (gallons)	CUMUL. VOLUME PURGED (gallons)	PURGE RATE ~~(mL/min)~~ 0.5 gpm	DEPTH TO WATER (feet TOC)	pH (standard units)	TEMP. (°C)	SP. COND. (circle units) mmhos/cm or mS/cm	TURBIDITY (NTUs)	DISSOLVED OXYGEN (circle units) mg/L or % saturation	ORP (mV)	COLOR/ ODOR (describe)
1400	2.5		0.5 gpm	8.09	4.77	17.30	0.076	>1000	6.07	210.1	
1405	5			8.79	4.46	16.96	0.081	>100	6.96	207.5	
1410	7.5			9.41	4.23	17.26	0.082	912	5.47	160.1	
1415	10			9.97	4.17	17.36	0.080	781	5.31	154.7	
1420	12.5			10.76	4.14	17.37	0.079	316	5.28	145.3	
1425	15			11.01	4.10	17.39	0.078	91.1	5.22	138.1	
1430	17.5			11.12	4.10	17.38	0.076	38.4	5.18	122.6	
1435	20			11.16	4.09	17.39	0.076	31.6	5.16	117.7	
1440	22.5			11.16	4.08	17.42	0.076	24.8	5.16	116.1	
1445	25			11.16	4.07	17.45	0.076	29.7	5.16	114.3	
1450	27.5			11.16	4.06	17.46	0.076	21.1	5.15	113.1	

WELL CAPACITY (Gallons Per Foot): 0.75" = 0.02; 1" = 0.04; 1.25" = 0.06; 1.5" = 0.092; 2" = 0.16; 3" = 0.37; 4" = 0.65; 5" = 1.02; 6" = 1.47; 12" = 5.88

TUBING INSIDE DIA. CAPACITY (Gal./Ft.): 1/8" = 0.0006; 3/16" = 0.0014; 1/4" = 0.0026; 5/16" = 0.004; 3/8" = 0.006; 1/2" = 0.010; 5/8" = 0.016

PURGING EQUIPMENT CODES: B = Bailer; BP = Bladder Pump; ESP = Electric Submersible Pump; PP = Peristaltic Pump; O = Other (Specify)

SAMPLING DATA

SAMPLED BY (PRINT) / AFFILIATION: Daniel Gazz /CDM Smith	SAMPLER(S) SIGNATURE(S): [signature]	SAMPLING INITIATED AT: 1450	SAMPLING ENDED AT:
PUMP OR TUBING DEPTH IN WELL (feet bgl): 14	TUBING MATERIAL CODE: PP	FIELD-FILTERED: Y (N) Filtration Equipment Type:	FILTER SIZE: ____ mm
FIELD DECONTAMINATION: PUMP Y (N)	TUBING Y (N) (replaced)	DUPLICATE: Y (N)	

SAMPLE ID CODE	# CONTAINERS	MATERIAL CODE	VOLUME	PRESERVATIVE USED	TOTAL VOL ADDED IN FIELD (mL)	FINAL pH	INTENDED ANALYSIS AND/OR METHOD	SAMPLING EQUIPMENT CODE	SAMPLE PUMP FLOW RATE (mL per minute)
	2	CG	40	HCl	80		VOCs	ESP	

(SAMPLE CONTAINER SPECIFICATION: Sample ID Code through Volume; SAMPLE PRESERVATION (including wet ice): Preservative Used through Final pH)

REMARK/NOTES:

Hach Field Data: Final Ferrous Iron, mg/L Final Sulfate, mg/L Final CO_2, mg/L Final MNO_4, mg/L

Final Total Iron, mg/L Final Nitrate, mg/L Final Alkalinity, mg/L Dilution Ratio:

Field Instruments:

MATERIAL CODES: AG = Amber Glass; CG = Clear Glass; HDPE = High Density Polyethylene; LDPE = Low Density Polyethylene; PP = Polypropylene; S = Silicone; T = Teflon; O = Other (Specify)

SAMPLING EQUIPMENT CODES: APP = After (Through) Peristaltic Pump; B = Bailer; BP = Bladder Pump; ESP = Electric Submersible Pump; RFPP = Reverse Flow Peristaltic Pump; SM = Straw Method (Tubing Gravity Drain); O = Other (Specify)

NOTES: 1. Stabilization criteria for range of variation of at least three consecutive readings (required parameters in bold).
2. pH: + 0.1 units; Specific Conductance: + 5%; Turbidity: < 10 NTUs or until stable; Dissolved Oxygen: + 0.2 mg/L or 10% saturation (whichever is greater)

Appendix C
Microorganism and Functional Gene Laboratory Report

CDM Smith

10515 Research Drive
Knoxville, TN 37932
Phone: 865.573.8188
Fax: 865.573.8133
Web: www.microbe.com

SITE LOGIC Report

QuantArray®-Chlor Study

Contact:	Tom Duffey	Phone:	770-329-7143
Address:	CDM 3200 Windy Hill Road Suite 210W Atlanta, GA 30339	Email:	duffeyjt@cdmsmith.com

MI Identifier:	**083PB**	Report Date:	03/08/2018

Project: Cessna
Comments: Please note the total bacterial biomass on all samples was low, and the samples may have PCR inhibition.

NOTICE: This report is intended only for the addressee shown above and may contain confidential or privileged information. If the recipient of this material is not the intended recipient or if you have received this in error, please notify Microbial Insights, Inc. immediately. The data and other information in this report represent only the sample(s) analyzed and are rendered upon condition that it is not to be reproduced without approval from Microbial Insights, Inc. Thank you for your cooperation.

The QuantArray®-Chlor Approach

Quantification of *Dehalococcoides*, the only known bacterial group capable of complete reductive dechlorination of PCE and TCE to ethene, has become an indispensable component of assessment, remedy selection, and performance monitoring at sites impacted by chlorinated solvents. While undeniably a key group of halorespiring bacteria, *Dehalococcoides* are not the only bacteria of interest in the subsurface because reductive dechlorination is not the only potential biodegradation pathway operative at contaminated sites, and chlorinated ethenes are not always the primary contaminants of concern. The QuantArray®-Chlor not only includes a variety of halorespiring bacteria (*Dehalococcoides*, *Dehalobacter*, *Dehalogenimonas*, etc.) to assess the potential for reductive dechlorination of chloroethenes, chloroethanes, chlorobenzenes, chlorophenols, and chloroform, but also provides quantification of functional genes involved in aerobic (co)metabolic pathways for biodegradation of chlorinated solvents and even competing biological processes. Thus, the QuantArray®-Chlor will give site managers the ability to simultaneously yet economically evaluate the potential for biodegradation of a spectrum of common chlorinated contaminants through a multitude of anaerobic and aerobic (co) metabolic pathways to give a much more clear and comprehensive view of contaminant biodegradation.

The QuantArray®-Chlor is used to quantify specific microorganisms and functional genes to evaluate the following:

Anaerobic Reductive Dechlorination	Quantification of important halorespiring bacteria (e.g. *Dehalococcoides*, *Dehalobacter*, *Dehalogenimonas*, *Desulfitobacterium* spp.) and key functional genes (e.g. vinyl chloride reductases, TCE reductase, chloroform reductase) responsible for reductive dechlorination of a broad spectrum of chlorinated solvents.
Aerobic Cometabolism	Several different types of bacteria including methanotrophs and some toluene/phenol utilizing bacteria can co-oxidize TCE, DCE, and vinyl chloride. The QuantArray®-Chlor quantifies functional genes like soluble methane monooxygenase encoding enzymes capable of co-oxidation of chlorinated ethenes.
Aerobic (Co)metabolism of Vinyl Chloride	Ethene oxidizing bacteria are capable of cometabolism of vinyl chloride. In some cases, ethenotrophs can also utilize vinyl chloride as a growth supporting substrate. The QuantArray®-Chlor targets key functional genes in ethene metabolism.

How do QuantArrays® work?

The QuantArray®-Chlor in many respects is a hybrid technology combining the highly parallel detection of microarrays with the accurate and precise quantification provided by qPCR into a single platform. The key to highly parallel qPCR reactions is the nanoliter fluidics platform for low volume, solution phase qPCR reactions.

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Web: www.microbe.com

How are QuantArray® results reported?

One of the primary advantages of the QuantArray®-Chlor is the simultaneous quantification of a broad spectrum of different microorganisms and key functional genes involved in a variety of pathways for chlorinated hydrocarbon biodegradation. However, highly parallel quantification combined with the various metabolic and cometabolic capabilities of different target organisms can complicate data presentation. Therefore, in addition to Summary Tables, QuantArray® results will be presented as Microbial Population Summary and Comparison Figures to aid in data interpretation and subsequent evaluation of site management activities.

Types of Tables and Figures:

Microbial Population Summary	Figure presenting the concentrations of QuantArray®-Chlor target populations (e.g. *Dehalococcoides*) and functional genes (e.g. vinyl chloride reductase) relative to typically observed values.
Summary Tables	Tables of target population concentrations grouped by biodegradation pathway and contaminant type.
Comparison Figures	Depending on the project, sample results can be presented to compare changes over time or examine differences in microbial populations along a transect of the dissolved plume.

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Results

Table 1: Summary of the QuantArray®-Chlor results obtained for samples MW-5A and MW-3A.

Sample Name Sample Date	MW-5A 02/27/2018	MW-3A 02/27/2018
Reductive Dechlorination	cells/mL	cells/mL
Dehalococcoides (DHC)	<5.00E-01	<5.00E-01
tceA Reductase (TCE)	<5.00E-01	<5.00E-01
BAV1 Vinyl Chloride Reductase (BVC)	<5.00E-01	<5.00E-01
Vinyl Chloride Reductase (VCR)	<5.00E-01	<5.00E-01
Dehalobacter spp. (DHBt)	<4.50E+00	<4.50E+00
Dehalobacter DCM (DCM)	<4.50E+00	<4.50E+00
Dehalogenimonas spp. (DHG)	<4.50E+00	<4.50E+00
Desulfitobacterium spp. (DSB)	<4.50E+00	<4.50E+00
Dehalobium chlorocoercia (DECO)	<4.50E+00	<4.50E+00
Desulfuromonas spp. (DSM)	<4.50E+00	<4.50E+00
PCE Reductase (PCE-1)	<4.50E+00	<4.50E+00
PCE Reductase (PCE-2)	<4.50E+00	<4.50E+00
Vinyl Chloride Reductase (CER)	<4.50E+00	<4.50E+00
trans-1,2-DCE Reductase (TDR)	<4.50E+00	<4.50E+00
Chloroform Reductase (CFR)	<4.50E+00	<4.50E+00
1,1 DCA Reductase (DCA)	<4.50E+00	<4.50E+00
1,2 DCA Reductase (DCAR)	<4.50E+00	<4.50E+00
Aerobic (Co)Metabolic		
Soluble Methane Monooxygenase (SMMO)	<4.50E+00	<4.50E+00
Toluene Dioxygenase (TOD)	<4.50E+00	<4.50E+00
Phenol Hydroxylase (PHE)	<4.50E+00	<4.50E+00
Trichlorobenzene Dioxygenase (TCBO)	<4.50E+00	<4.50E+00
Toluene Monooxygenase 2 (RDEG)	<4.50E+00	<4.50E+00
Toluene Monooxygenase (RMO)	<4.50E+00	<4.50E+00
Ethene Monooxygenase (EtnC)	<4.50E+00	<4.50E+00
Epoxyalkane Transferase (EtnE)	<4.50E+00	<4.50E+00
Dichloromethane Dehalogenase (DCMA)	<4.50E+00	<4.50E+00
Other		
Total Eubacteria (EBAC)	**8.82E+01 (I)**	**1.89E+01 (I)**
Sulfate Reducing Bacteria (APS)	<4.50E+00	<4.50E+00
Methanogens (MGN)	<4.50E+00	<4.50E+00

Legend:
NA = Not Analyzed
NS = Not Sampled
J = Estimated Gene Copies Below PQL but Above LQL
I = Inhibited
< = Result Not Detected

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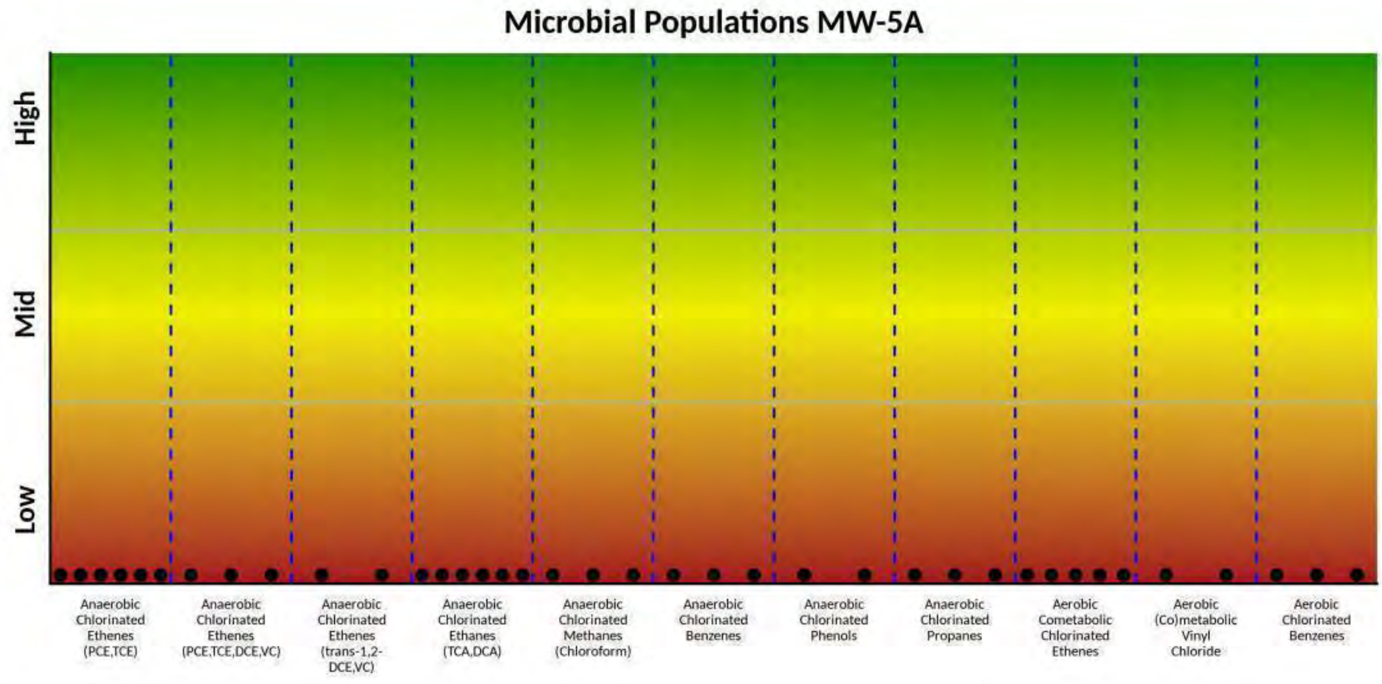

Figure 1: Microbial population summary to aid in evaluating potential pathways and biodegradation of specific contaminants.

Anaerobic - Reductive Dechlorination or Dichloroelimination		**Aerobic - (Co)metabolism**	
Chlorinated Ethenes (PCE, TCE)	DHC, DHBt, DSB, DSM, PCE-1, PCE-2	Chlorinated Ethenes (TCE,DCE,VC)	sMMO, TOD, PHE, RDEG, RMO
Chlorinated Ethenes (PCE, TCE, DCE, VC)	DHC, BVC, VCR	(Co)metabolic Vinyl Chloride	etnC, etnE
Chlorinated Ethenes (trans-1,2-DCE, VC)	TDR, CER	Chlorinated Benzenes	TOD, TCBO, PHE
Chlorinated Ethanes (TCA and 1,2-DCA)	DHC, DHBt, DHG, DSB[1], DCA, DCAR		
Chlorinated Methanes (Chloroform)	DHBt, DCM, CFR		
Chlorinated Benzenes	DHC, DHBt[2], DECO		
Chlorinated Phenols	DHC, DSB		
Chlorinated Propanes	DHC, DHG, DSB[1]		

[1] *Desulfitobacterium dichloroeliminans* DCA1. [2] Implicated in reductive dechlorination of dichlorobenzene and potentially chlorobenzene.

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Knoxville, TN 37932
Phone: 865.573.8188
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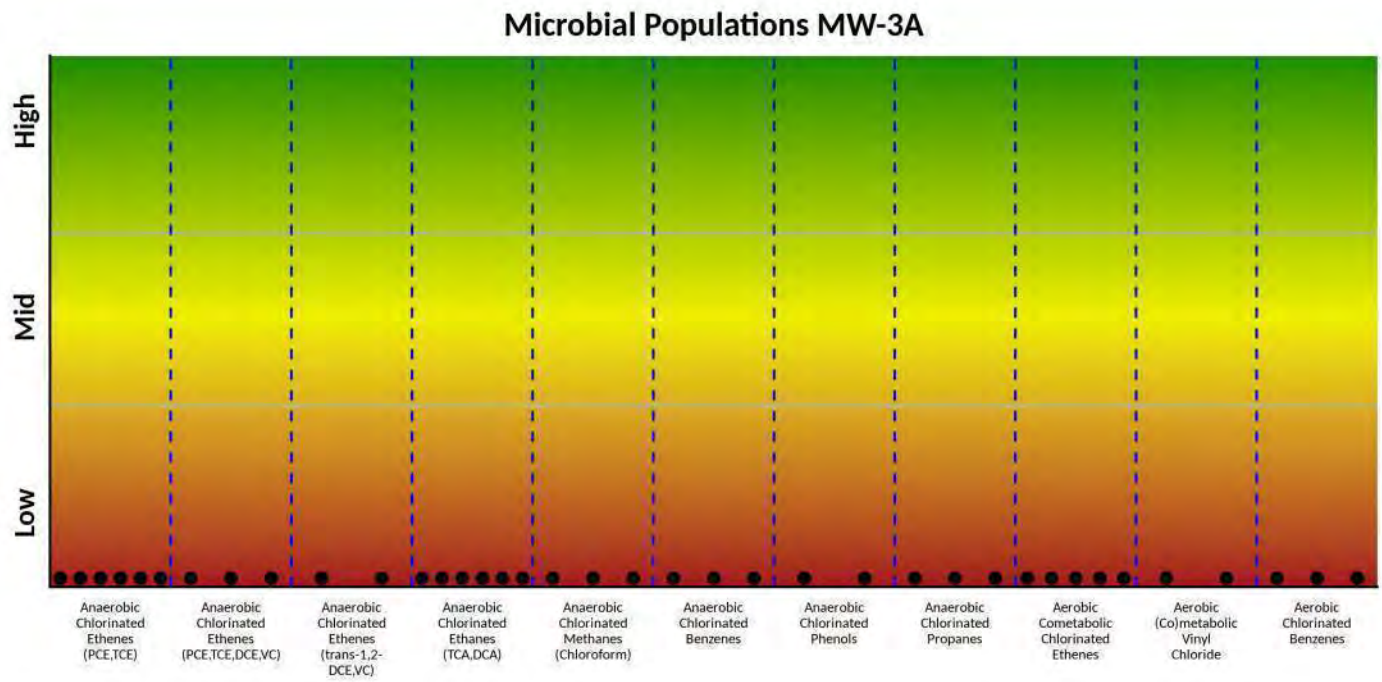

Figure 2: Microbial population summary to aid in evaluating potential pathways and biodegradation of specific contaminants.

Anaerobic - Reductive Dechlorination or Dichloroelimination		Aerobic - (Co)metabolism	
Chlorinated Ethenes (PCE, TCE)	DHC, DHBt, DSB, DSM, PCE-1, PCE-2	Chlorinated Ethenes (TCE,DCE,VC)	sMMO, TOD, PHE, RDEG, RMO
Chlorinated Ethenes (PCE, TCE, DCE, VC)	DHC, BVC, VCR	(Co)metabolic Vinyl Chloride	etnC, etnE
Chlorinated Ethenes (trans-1,2-DCE, VC)	TDR, CER	Chlorinated Benzenes	TOD, TCBO, PHE
Chlorinated Ethanes (TCA and 1,2-DCA)	DHC, DHBt, DHG, DSB[1], DCA, DCAR		
Chlorinated Methanes (Chloroform)	DHBt, DCM, CFR		
Chlorinated Benzenes	DHC, DHBt[2], DECO		
Chlorinated Phenols	DHC, DSB		
Chlorinated Propanes	DHC, DHG, DSB[1]		

[1]*Desulfitobacterium dichloroeliminans* DCA1. [2]Implicated in reductive dechlorination of dichlorobenzene and potentially chlorobenzene.

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Table 2: Summary of the QuantArray®-Chlor results for microorganisms responsible for reductive dechlorination for samples MW-5A and MW-3A.

Sample Name	MW-5A	MW-3A
Sample Date	02/27/2018	02/27/2018
Reductive Dechlorination	cells/mL	cells/mL
Dehalococcoides (DHC)	<5.00E-01	<5.00E-01
tceA Reductase (TCE)	<5.00E-01	<5.00E-01
BAV1 Vinyl Chloride Reductase (BVC)	<5.00E-01	<5.00E-01
Vinyl Chloride Reductase (VCR)	<5.00E-01	<5.00E-01
Dehalobacter spp. (DHBt)	<4.50E+00	<4.50E+00
Dehalobacter DCM (DCM)	<4.50E+00	<4.50E+00
Dehalogenimonas spp. (DHG)	<4.50E+00	<4.50E+00
Desulfitobacterium spp. (DSB)	<4.50E+00	<4.50E+00
Dehalobium chlorocoercia (DECO)	<4.50E+00	<4.50E+00
Desulfuromonas spp. (DSM)	<4.50E+00	<4.50E+00

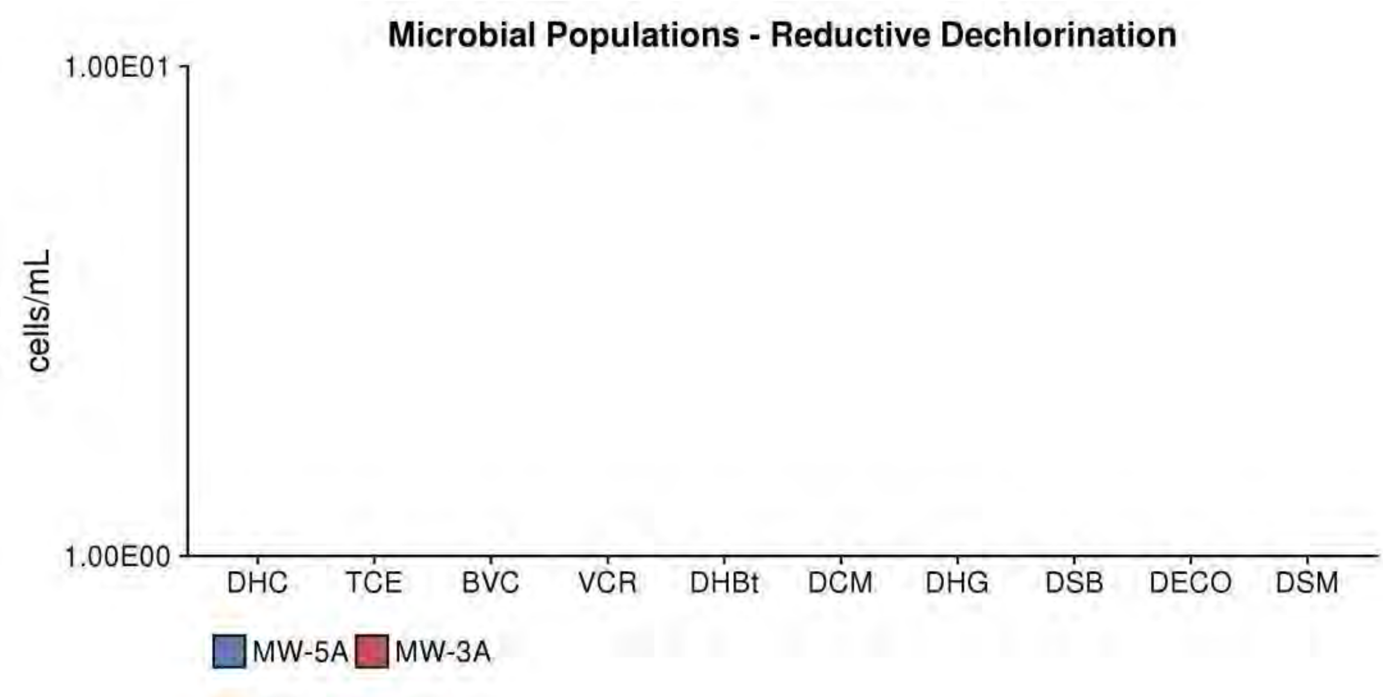

Figure 3: Comparison - microbial populations involved in reductive dechlorination.

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Table 3: Summary of the QuantArray®-Chlor results for microorganisms responsible for reductive dechlorination for samples MW-5A and MW-3A.

Sample Name Sample Date	MW-5A 02/27/2018	MW-3A 02/27/2018
Reductive Dechlorination	cells/mL	cells/mL
Chloroform Reductase (CFR)	<4.50E+00	<4.50E+00
1,1 DCA Reductase (DCA)	<4.50E+00	<4.50E+00
1,2 DCA Reductase (DCAR)	<4.50E+00	<4.50E+00
PCE Reductase (PCE-1)	<4.50E+00	<4.50E+00
PCE Reductase (PCE-2)	<4.50E+00	<4.50E+00
trans-1,2-DCE Reductase (TDR)	<4.50E+00	<4.50E+00
Vinyl Chloride Reductase (CER)	<4.50E+00	<4.50E+00

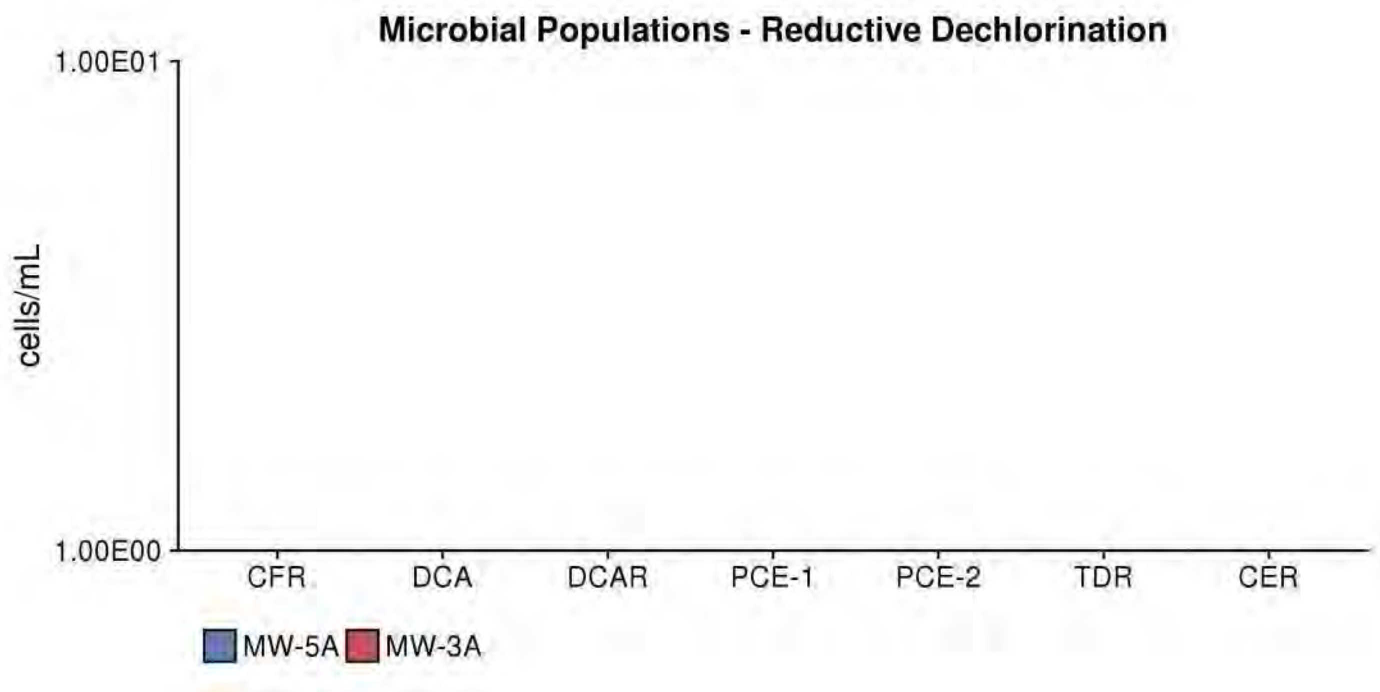

Figure 4: Comparison - microbial populations involved in reductive dechlorination.

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Table 4: Summary of the QuantArray®-Chlor results for microorganisms responsible for aerobic (co)metabolism for samples MW-5A and MW-3A.

Sample Name Sample Date	MW-5A 02/27/2018	MW-3A 02/27/2018
Aerobic (Co)Metabolic	cells/mL	cells/mL
Soluble Methane Monooxygenase (SMMO)	<4.50E+00	<4.50E+00
Toluene Dioxygenase (TOD)	<4.50E+00	<4.50E+00
Phenol Hydroxylase (PHE)	<4.50E+00	<4.50E+00
Trichlorobenzene Dioxygenase (TCBO)	<4.50E+00	<4.50E+00
Toluene Monooxygenase 2 (RDEG)	<4.50E+00	<4.50E+00
Toluene Monooxygenase (RMO)	<4.50E+00	<4.50E+00
Ethene Monooxygenase (EtnC)	<4.50E+00	<4.50E+00
Epoxyalkane Transferase (EtnE)	<4.50E+00	<4.50E+00
Dichloromethane Dehalogenase (DCMA)	<4.50E+00	<4.50E+00

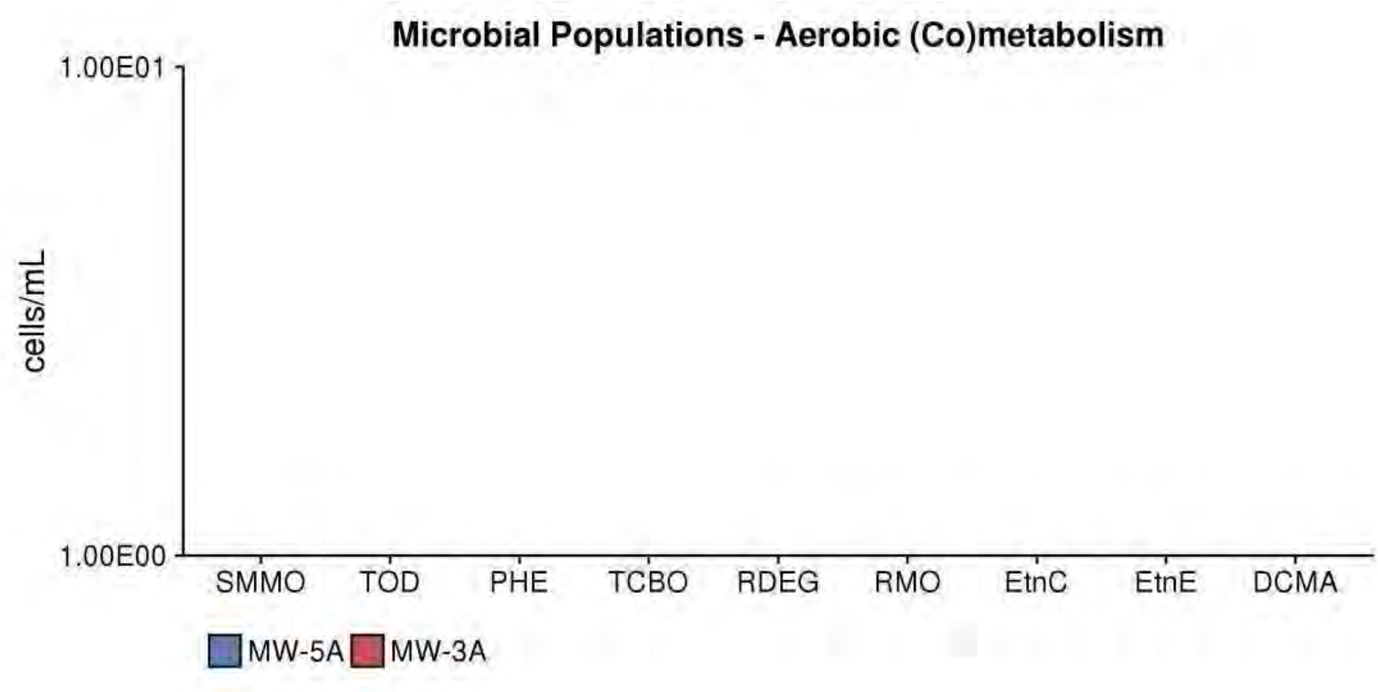

Figure 5: Comparison - microbial populations involved in aerobic (co)metabolism.

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Table 5: Summary of the QuantArray® results for total bacteria and other populations for samples MW-5A and MW-3A.

Sample Name Sample Date	MW-5A 02/27/2018	MW-3A 02/27/2018
Other	cells/mL	cells/mL
Total Eubacteria (EBAC)	**8.82E+01 (I)**	**1.89E+01 (I)**
Sulfate Reducing Bacteria (APS)	<4.50E+00	<4.50E+00
Methanogens (MGN)	<4.50E+00	<4.50E+00

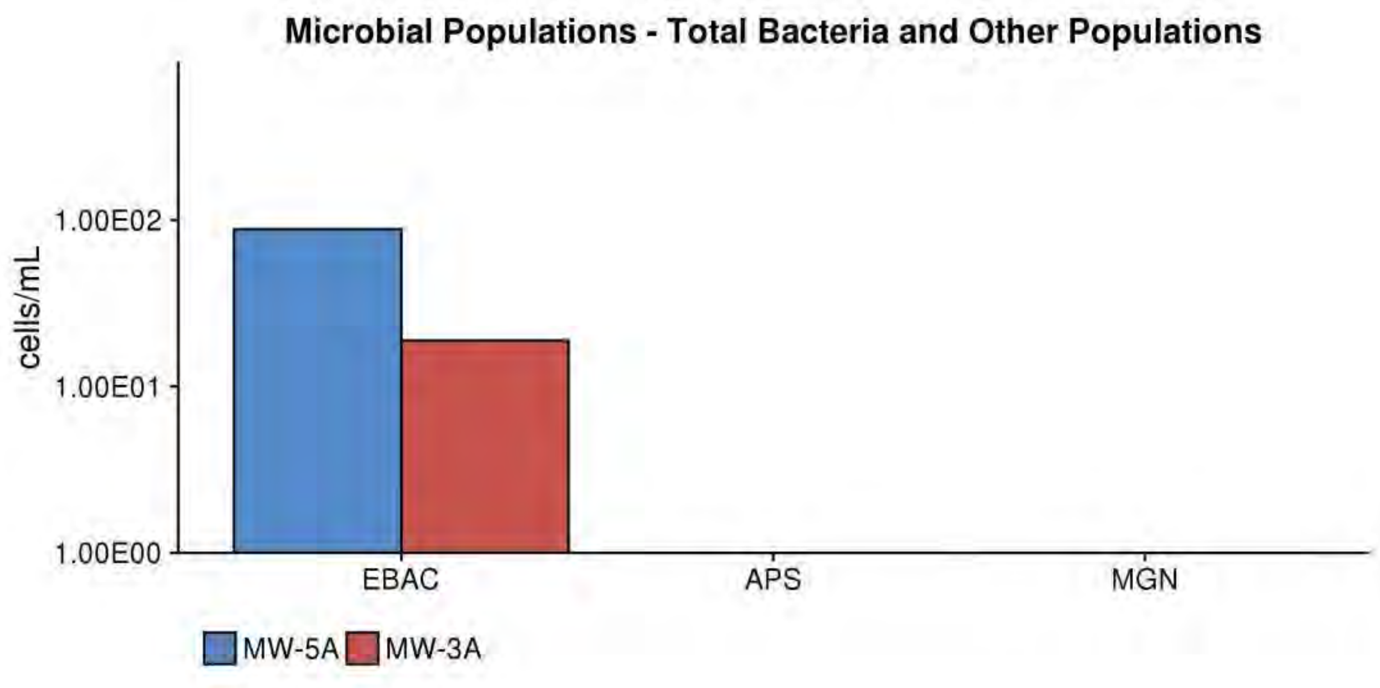

Figure 6: Comparison - microbial populations.

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Interpretation

The overall purpose of the QuantArray®-Chlor is to give site managers the ability to simultaneously yet economically evaluate the potential for biodegradation of a spectrum of common chlorinated contaminants through a multitude of anaerobic and aerobic (co)metabolic pathways in order to provide a clearer and more comprehensive view of contaminant biodegradation. The following discussion describes the interpretation of results in general terms and is meant to serve as a guide.

Reductive Dechlorination - Chlorinated Ethenes: While a number of bacterial cultures including *Dehalococcoides*, *Dehalobacter*, *Desulfitobacterium*, and *Desulfuromonas* spp. capable of utilizing PCE and TCE as growth-supporting electron acceptors have been isolated [1–5], *Dehalococcoides* may be the most important because they are the only bacterial group that has been isolated to date which is capable of complete reductive dechlorination of PCE to ethene [6]. In fact, the presence of *Dehalococcoides* has been associated with complete reductive dechlorination to ethene at sites across North America and Europe [7], and Lu et al. [8] have proposed using a *Dehalococcoides* concentration of 1×10^4 cells/mL as a screening criterion to identify sites where biological reductive dechlorination is predicted to proceed at "generally useful" rates.

At chlorinated ethene sites, any "stall" leading to the accumulation of daughter products, especially vinyl chloride, would be a substantial concern. While *Dehalococcoides* concentrations greater than 1×10^4 cells/mL correspond to ethene production and useful rates of dechlorination, the range of chlorinated ethenes degraded varies by strain within the *Dehalococcoides* genus [6, 9], and the presence of co-contaminants and competitors can have complex impacts on the halorespiring microbial community [10–15]. Therefore, QuantArray®-Chlor also provides quantification of a suite of reductive dehalogenase genes (PCE, TCE, BVC, VCR, CER, and TDR) to more definitively confirm the potential for reductive dechlorination of all chlorinated ethene compounds including vinyl chloride.

Perhaps most importantly, QuantArray®-Chlor quantifies TCE reductase (TCE) and both known vinyl chloride reductase genes (BVC, VCR) from *Dehalococcoides* to conclusively evaluate the potential for complete reductive dechlorination of chlorinated ethenes to non-toxic ethene [16–18]. In addition, the analysis also includes quantification of reductive dehalogenase genes from *Dehalogenimonas* spp. capable of reductive dechlorination of chlorinated ethenes. More specifically, these are the trans-1,2-DCE dehalogenase gene (TDR) from strain WBC-2 [19] and the vinyl chloride reductase gene (CER) from GP, the only known organisms other than *Dehalococcoides* capable of vinyl chloride reduction [20]. Finally, PCE reductase genes responsible for sequential reductive dechlorination of PCE to *cis*-DCE by *Sulfurospirillum* and *Geobacter* spp. are also quantified. In mixed cultures, evidence increasingly suggests that partial dechlorinators like *Sulfurospirillum* and *Geobacter* may be responsible for the majority of reductive dechlorination of PCE to TCE and *cis*-DCE while *Dehalococcoides* functions more as *cis*-DCE and vinyl chloride reducing specialists [10, 21].

Reductive Dechlorination - Chlorinated Ethanes: Under anaerobic conditions, chlorinated ethanes are susceptible to reductive dechlorination by several groups of halorespiring bacteria including *Dehalobacter*, *Dehalogenimonas*, and *Dehalococcoides*. While the reported range of chlorinated ethanes utilized varies by genus, species, and sometimes at the strain level, several general observations can be made regarding biodegradation pathways and daughter product formation. *Dehalobacter* spp. have been isolated that are capable of sequential reductive dechlorination of 1,1,1-TCA through 1,1-DCA to chloroethane [13]. Biodegradation of 1,1,2-TCA by several halorespiring bacteria including *Dehalobacter* and *Dehalogenimonas* spp. proceeds via dichloroelimination producing vinyl chloride [22–24]. Similarly, 1,2-DCA biodegradation by *Dehalobacter*, *Dehalogenimonas*, and *Dehalococcoides* occurs via dichloroelimination producing ethene. While not utilized by many *Desulfitobacterium* isolates, at least one strain, *Desulfitobacterium dichloroeliminans* strain DCA1, is also capable of dichloroelimination of 1,2-DCA [25]. The 1,2-dichloroethane reductive dehalogenase gene (DCAR) from members of *Desulfitobacterium* and *Dehalobacter* is known to dechlorinate 1,2-DCA to ethene, while the 1,1-dichloroethane reductive dehalogenase (DCA) targets the gene responsible for 1,1-DCA dechlorination in some strains of *Dehalobacter*. In addition to chloroform,chloroform reductase (CFR) has also been shown to be responsible for reductivedechlorination of 1,1,1-TCA [26].

Reductive Dechlorination - Chlorinated Methanes: Chloroform is a common co-contaminant at chlorinated solvent sites and can inhibit reductive dechlorination of chlorinated ethenes. Grostern et al. demonstrated that a *Dehalobacter* population was capable of reductive dechlorination of chloroform to produce dichloromethane [27]. The *cfrA* gene encodes the reductase which catalyzes this initial step in chloroform biodegradation [26]. Justicia-Leon et al. have since shown that dichloromethane can support growth of a distinct group of *Dehalobacter* strains via fermentation [28]. The *Dehalobacter* DCM assay targets the 16S rRNA gene of these strains.

Reductive Dechlorination - Chlorinated Benzenes: Chlorinated benzenes are an important class of industrial solvents and chemical intermediates in the production of drugs, dyes, herbicides, and insecticides. The physical-chemical properties of chlorinated benzenes as well as susceptibility to biodegradation are functions of their degree of chlorination and the positions of chlorine substituents. Under anaerobic conditions, reductive dechlorination of higher chlorinated benzenes including hexachlorobenzene (HCB),

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pentachlorobenzene (PeCB), tetrachlorobenzene (TeCB) isomers, and trichlorobenzene (TCB) isomers has been well documented [29], although biodegradation of individual compounds and isomers varies between isolates. For example, *Dehalococcoides* strain CBDB1 reductively dechlorinats HCB, PeCB, all three TeCB isomers, 1,2,3-TCB, and 1,2,4-TCB [9, 30]. *Dehalobium chlorocoercia* DF-1 has been shown to be capable of reductive dechlorination of HCB, PeCB, and 1,2,3,5-TeCB [31]. The dichlorobenzene (DCB) isomers and chlorobenzene (CB) were considered relatively recalcitrant under anaerobic conditions. However, new evidence has demonstrated reductive dechlorination of DCBs to CB and CB to benzene [32] with corresponding increases in concentrations of *Dehalobacter* spp. [33].

Reductive Dechlorination - Chlorinated Phenols: Pentachlorophenol (PCP) was one of the most widely used biocides in the U.S. and despite residential use restrictions, is still extensively used industrially as a wood preservative. Along with PCP, the tetrachlorophenol and trichlorophenol isomers were also used as fungicides in wood preserving formulations. 2,4-Dichlorophenol and 2,4,5-TCP were used as chemical intermediates in herbicide production (e.g. 2,4-D) and chlorophenols are known byproducts of chlorine bleaching in the pulp and paper industry. While the range of compounds utilized varies by strain, some *Dehalococcoides* isolates are capable of reductive dechlorination of PCP and other chlorinated phenols. For example, *Dehalococcoides* strain CBDB1 is capable of utilizing PCP, all three tetrachlorophenol (TeCP) congeners, all six trichlorophenol (TCP) congeners, and 2,3-dichlorophenol (2,3-DCP). PCP dechlorination by strain CBDB1 produces a mixture of 3,5-DCP, 3,4-DCP, 2,4-DCP, 3-CP, and 4-CP [34]. In the same study, however, *Dehalococcoides* strain 195 dechlorinated a more narrow spectrum of chlorophenols which included 2,3-DCP, 2,3,4-TCP, and 2,3,6-TCP, but no other TCPs or PCP. Similar to *Dehalococcoides*, some species and strains of *Desulfitobacterium* are capable of utilizing PCP and other chlorinated phenols. *Desulfitobacterium hafniense* PCP-1 is capable of reductive dechlorination of PCP to 3-CP [35]. However, the ability to biodegrade PCP is not universal among *Desulfitobacterium* isolates. *Desulfitobacterium* sp. strain PCE1 and *D. chlororespirans* strain Co23, for example, can utilize some TCP and DCP isomers, but not PCP for growth [2, 36].

Reductive Dechlorination - Chlorinated Propanes: *Dehalogenimonas* is a recently described bacterial genus of the phylum Chloroflexi which also includes the well-known chloroethene-respiring *Dehalococcoides* [23]. The *Dehalogenimonas* isolates characterized to date are also halorespiring bacteria, but utilize a rather unique range of chlorinated compounds as electron acceptors including chlorinated propanes (1,2,3-TCP and 1,2-DCP) and a variety of other vicinally chlorinated alkanes including 1,1,2,2-tetrachloroethane, 1,1,2-trichloroethane, and 1,2-dichloroethane [23].

Aerobic - Chlorinated Ethene Cometabolism: Under aerobic conditions, several different types of bacteria including methane-oxidizing bacteria (methanotrophs), and many benzene, toluene, ethylbenzene, xylene, and (BTEX)-utilizing bacteria can cometabolize or co-oxidize TCE, DCE, and vinyl chloride [37]. In general, cometabolism of chlorinated ethenes is mediated by monooxygenase enzymes with "relaxed' specificity that oxidize a primary (growth supporting) substrate (*e.g.* methane) and co-oxidize the chlorinated compound (*e.g.*TCE). QuantArray®-Chlor provides quantification of a suite of genes encoding oxygenase enzymes capable of co-oxidation of chlorinated ethenes including soluble methane monooxygenase (sMMO). Soluble methane monooxygenases co-oxidize a broad range of chlorinated compounds [38–41] including TCE, *cis*-DCE, and vinyl chloride. Furthermore, soluble methane monooxygenases are generally believed to support greater rates of aerobic cometabolism [40]. QuantArray®-Chlor also quantifies aromatic oxygenase genes encoding ring hydroxylating toluene monooxygenase genes (RMO, RDEG), toluene dioxygenase (TOD) and phenol hydroxylases (PHE) capable of TCE co-oxidation [42–46]. TCE or a degradation product has been shown to induce expression of toluene monooxygenases in some laboratory studies [43, 47] raising the possibility of TCE cometabolism with an alternative (non-aromatic) growth substrate. Moreover, while a number of additional factors must be considered, recent research under ESTCP Project 201584 has shown positive correlations between concentrations of monooxygenase genes (soluble methane monooxygenase, ring hydroxylating monooxygenases, and phenol hydroxylase) and the rate of TCE degradation [48].

Aerobic - Chlorinated Ethane Cometabolism: While less widely studied than cometabolism of chlorinated ethenes, some chlorinated ethanes are also susceptible to co-oxidation. As mentioned previously, soluble methane monooxygenases (sMMO) exhibit very relaxed specificity. In laboratory studies, sMMO has been shown to co-oxidize a number of chlorinated ethanes including 1,1,1-TCA and 1,2-DCA [38, 40].

Aerobic - Vinyl Chloride Cometabolism: Beginning in the early 1990s, numerous microcosm studies demonstrated aerobic oxidation of vinyl chloride under MNA conditions without the addition of exogenous primary substrates. Since then, strains of

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Mycobacterium, *Nocardioides*, *Pseudomonas*, *Ochrobactrum*, and *Ralstonia* species have been isolated which are capable of aerobic growth on both ethene and vinyl chloride (see Mattes et al. [49] for a review). The initial steps in the pathway are the monooxygenase (*etn*ABCD) catalyzed conversion of ethene and vinyl chloride to their respective epoxyalkanes (epoxyethane and chlorooxirane), followed by epoxyalkane:CoM transferase (*etn*E) mediated conjugation and breaking of the epoxide [50].

Aerobic - Chlorinated Benzenes: In general, chlorobenzenes with four or less chlorine groups are susceptible to aerobic biodegradation and can serve as growth-supporting substrates. Toluene dioxygenase (TOD) has a relatively relaxed substrate specificity and mediates the incorporation of both atoms of oxygen into the aromatic ring of benzene and substituted benzenes (toluene and chlorobenzene). Comparison of TOD levels in background and source zone samples from a CB-impacted site suggested that CBs promoted growth of TOD-containing bacteria [51]. In addition, aerobic biodegradation of some trichlorobenzene and even tetrachlorobenzene isomers is initiated by a group of related trichlorobenzene dioxygenase genes (TCBO). Finally, phenol hydroxylases catalyze the continued oxidation and in some cases, the initial oxidation of a variety of monoaromatic compounds. In an independent study, significant increases in numbers of bacteria containing PHE genes corresponded to increases in biodegradation of DCB isomers [51].

Aerobic - Chlorinated Methanes: Many aerobic methylotrophic bacteria, belonging to diverse genera (*Hyphomicrobium*, *Methylobacterium*, *Methylophilus*, *Pseudomonas*, *Paracoccus*, and *Alibacter*) have been isolated which are capable of utilizing dichloromethane (DCM) as a growth substrate. The DCM metabolic pathway in methylotrophic bacteria is initiated by a dichloromethane dehalogenase (DCMA) gene. DCMA is responsible for aerobic biodegradation of dichloromethane by methylotrophs by first producing formaldehyde which is then further oxidized [52]. As discussed in previous sections, soluble methane monooxygenase (sMMO) exhibits relaxed specificity and co-oxidizes a broad spectrum of chlorinated hydrocarbons. In addition to chlorinated ethenes, sMMO has been shown to co-oxidize chloroform in laboratory studies [38, 41].

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Fax: 865.573.8133
Web: www.microbe.com

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10515 Research Drive
Knoxville, TN 37932
Phone: 865.573.8188
Fax: 865.573.8133
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Appendix D

UIC Program Pilot Test Notification Form

CDM Smith

Underground Injection Control (UIC) Program

Pilot Test Notification Form

Purpose

This procedure allows Class V injection Pilot Test Wells (PTW) related to a proposed remediation plan to be constructed and operated for up to 90 days prior to obtaining a UIC permit. The attached Pilot Test Notification form must be **submitted to the EPD no later than 30 days prior to the proposed injection start date.**

This procedure applies only to Class V wells. The injected media will meet the Clean Air Act standards for air quality, the Georgia rules for Underground Injection Control, Chapter 391-6-3-.13, the Georgia Rules for Water Quality Control (Revised), and the Georgia Rules for Safe Drinking Water (Revised).

The procedure does not replace the requirements for permitting injection wells, but allows consultants flexibility in evaluating the most efficient, economical and effective remediation method for a corrective action plan (CAP). The pilot tests are allowed for up to, but not to exceed, 90 days after which time a UIC permit must be applied for per the appropriate UIC procedures.

Procedure

The attached Pilot Test Notification form must be completed in its entirety and submitted to the EPD for review. Provide a brief narrative describing the goal and purpose of the pilot test. Upon satisfactory review and concurrence with the pilot test specifications, EPD will issue a written consent to conduct the pilot test. EPD reserves the right to request additional information or impose limiting conditions on the pilot test prior to issuing written consent.

STATE OF GEORGIA
DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION

GEORGIA Department of Natural Resources
Environmental Protection Division

Pilot Test Notification

SECTION I. FACILITY INFORMATION

Facility Name: Cessna GA1 Facility		
Phone: (401) 457-2635	River Basin: Chattahoochee	
Facility Address: 4800 Cargo Drive		
City: Columbus	State: Georgia	ZIP Code: 31907
Latitude (Decimal): 32.511385	Longitude (Decimal): -84.877363	County: Muscogee

Is the pilot test part of a corrective action or remediation plan?: (check box) ☒ Yes ☐ No

HSI File No.: HW File No.:

UST File No.: Other: VRP1460391735

SECTION II. OWNER CONTACT INFORMATION

Name of Owner or Authorized Representative: Greg Simpson, Textron Inc.		
Title: Director, Site Remediation		
Phone: (401) 457-2635	E-mail: gsimpson@textron.com	Fax: (401) 457-6028
Owner Mailing Address: 40 Westminster Street		
City: Providence	State: Rhode Island	ZIP Code: 02903

SECTION III. DRILLER INFORMATION

GA Licensed Water Well Contractor or Bonded Environmental Drilling Company Name: F. Joe Grantham / Geo Lab Drilling		
Phone: (770) 868-5407	E-mail: jgrantham@geolabdrilling.com	Fax: (770) 868-5408
Address: 800 Bill Rutledge Road		
City: Winder	State: Georgia	ZIP Code: 30680
License No.: GA 627	Bond No.: NAVI-00003917	

SECTION IV. INJECTION WELL INFORMATION

1. No. of injection wells: 2		
2. Well Depth (ft.): 44	3. Borehole Diameter(in.): 6	4. Csg. Depth (ft.): 24
5. Csg. Diameter (in.): 2 inches	6. Csg. Material: PVC	
7. Screen Type: PVC, 0.01 slot	8. Screen Diameter: 2 inches	
9. Screen Interval from 24 to 44	10. Grout Type (if applicable): Neat Cement (Portland)	
11. Grout Interval from (if applicable) 0 to 20	12. Grout Thickness (if applicable): 2 inches	

STATE OF GEORGIA
DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION

GEORGIA
Department of Natural Resources
Environmental Protection Division

Pilot Test Notification

SECTION V. INJECTION SYSTEM DATA

1. Type of Fluid: Potable water with sodium chloride tracer
2. Source of Fluid: City of Columbus public supply
3. Purpose of the Injection/source of the contamination: Aquifer characterization for remediation of solvent release from a vapor degreaser
4. Proposed Injection Rate Range (gallons/minute/well) (SCFM for air): Up to 5 gpm/well
5. Proposed Injection Volume (daily max) (gallons/minute/well) (SCFM for air): 7,200 gallons potable water with 20 lbs. NaCl per well, 5 gpm, 1 well per day
6. Proposed Injection Pressure Range (lbs./sq. inch) (psi): Gravity drainage only
7. Dates of proposed pilot test injection: 4/16/2018 to 4/20/2018

SECTION VI. GOAL & PURPOSE OF THE PILOT TEST

1. Provide a brief narrative describing the goal and purpose of the pilot test below.

A groundwater treatment barrier is being designed that will use bioremediation in the Surficial Aquifer. The pilot test is designed to provide design parameters including groundwater velocity, transmissivity, effective porosity, and hydraulic conductivity for the final design. Two tracer tests will be conducted separately, and will use approximately ?? pounds of non-iodized, sodium chloride mixed with potable water in each pilot test injection well. The tracer solution will be introduced into the pilot test injection wells under the pressure of gravity to drive the sodium chloride tracer. Water levels and specific conductance will be recorded from monitoring wells using automated data loggers.

The tracer test injection system will consist of a small water reservoir with a potable water supply controlled by a float valve to keep the reservoir water level constant. The hydraulic head in the injection wells will be controlled by the water level in the reservoir. The float valve will allow water to fill the reservoir to the set point and match the flow rate of water accepted by the injection well under the pressure of gravity.

SECTION VII. CERTIFICATION

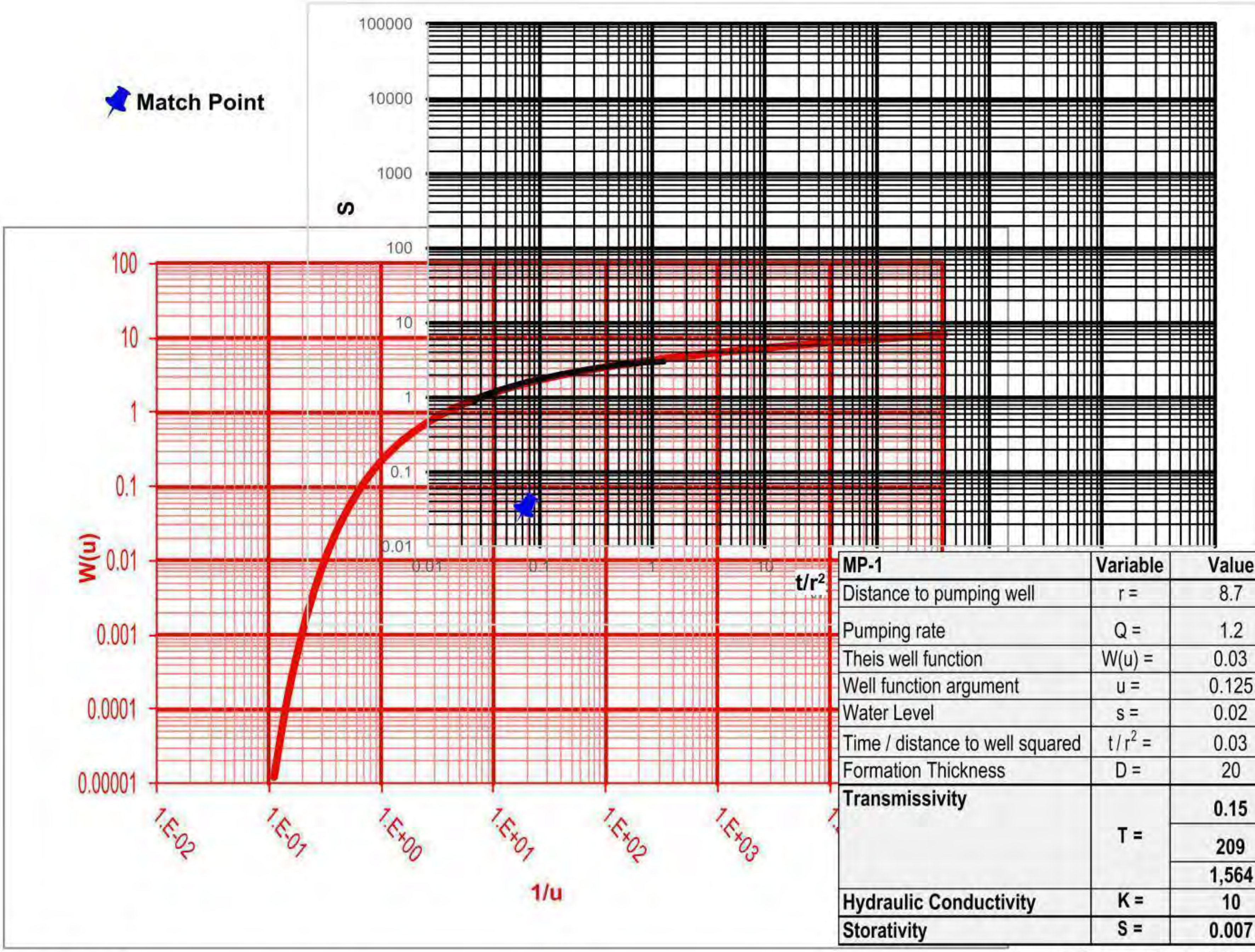
I certify under the penalty of law that I have examined and am familiar with the information contained in this document and attachments and the information is true, accurate and complete. I am aware of the associated penalties for submitting false documentation, including but not limited to monetary penalties and or imprisonment

Name of Applicant: James T. Duffey, PG000899, CDM Smith	**Date:** 3/16/2018
Signature of Applicant: JTDuffey	**Date:** 3/16/2018

Appendix E

Hydraulic Analysis Calculations

CDM Smith

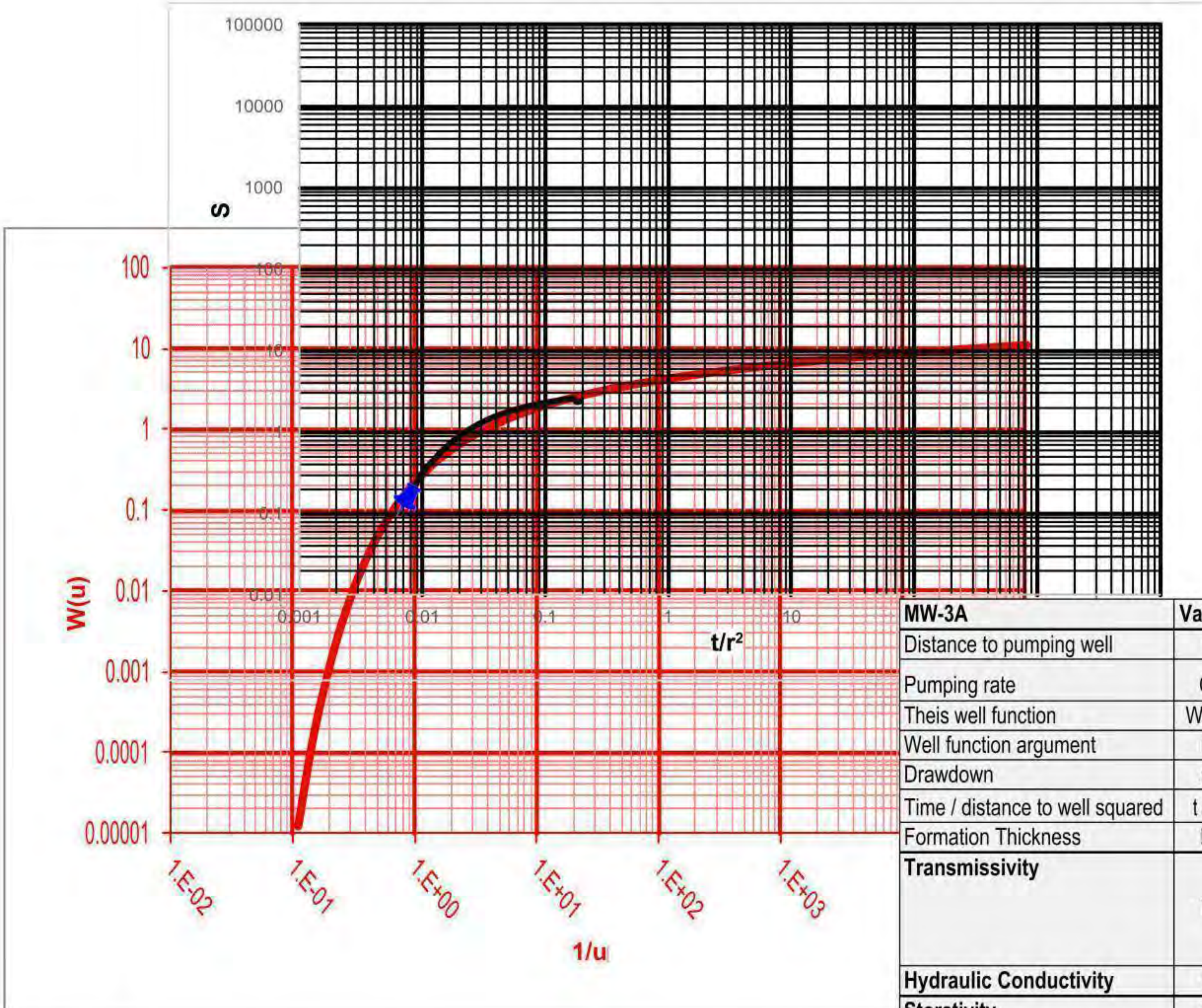


MP-1	Variable	Value	Units
Distance to pumping well	r =	8.7	Feet
Pumping rate	Q =	1.2	$Feet^3$/minute
Theis well function	W(u) =	0.03	Dimensionless
Well function argument	u =	0.125	Dimensionless
Water Level	s =	0.02	Feet
Time / distance to well squared	t / r^2 =	0.03	Minutes/$Feet^2$
Formation Thickness	D =	20	Feet
Transmissivity	**T =**	**0.15**	**$Feet^2$/Minute**
		209	**$Feet^2$/Day**
		1,564	**Gallons/Day/Foot**
Hydraulic Conductivity	**K =**	**10**	**Feet/Day**
Storativity	**S =**	**0.007**	**Dimensionless**

CDM Smith

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

Figure E-1: MP-1 Theis Solution
Cessna GA1 Facility
Columbus, Muscogee County, Georgia



MW-3A	Variable	Value	Units
Distance to pumping well	r =	15.2	Feet
Pumping rate	Q =	1.2	Feet^3/minute
Theis well function	W(u) =	0.09	Dimensionless
Well function argument	u =	1.4	Dimensionless
Drawdown	s =	0.09	Feet
Time / distance to well squared	t / r^2 =	0.006	Minutes/Feet^2
Formation Thickness	D =	20	Feet
Transmissivity	**T =**	**0.10**	**Feet^2/Minute**
		139	**Feet^2/Day**
		1,043	**Gallons/Day/Foot**
Hydraulic Conductivity	**K =**	**7**	**Feet/Day**
Storativity	**S =**	**0.010**	**Dimensionless**

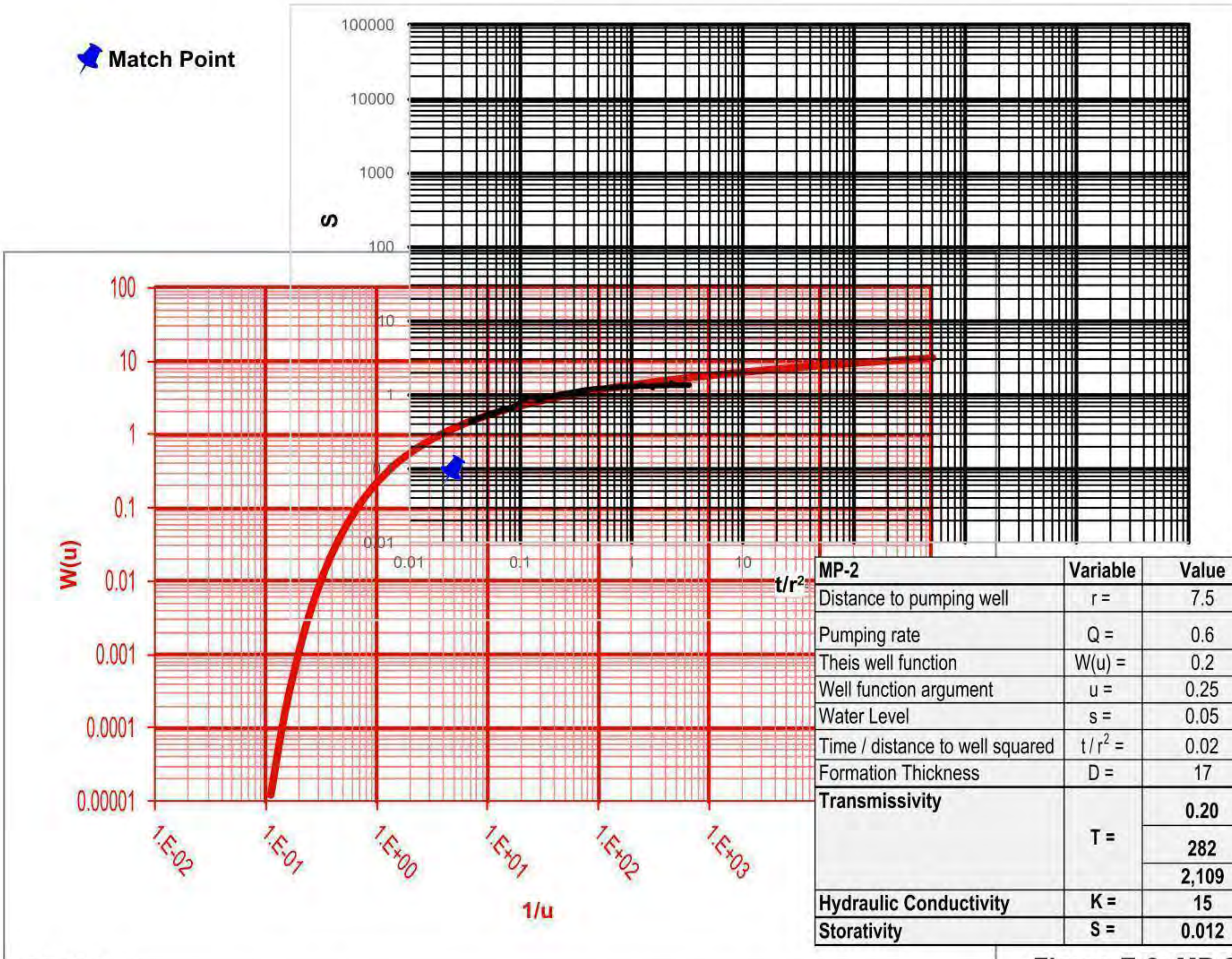
CDM Smith

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

Figure E-2: MW-3A Theis Solution

Cessna GA1 Facility

Columbus, Muscogee County, Georgia



MP-2	Variable	Value	Units
Distance to pumping well	r =	7.5	Feet
Pumping rate	Q =	0.6	$Feet^3$/minute
Theis well function	W(u) =	0.2	Dimensionless
Well function argument	u =	0.25	Dimensionless
Water Level	s =	0.05	Feet
Time / distance to well squared	t / r^2 =	0.02	Minutes/$Feet^2$
Formation Thickness	D =	17	Feet
Transmissivity	**T =**	**0.20**	**$Feet^2$/Minute**
		282	**$Feet^2$/Day**
		2,109	**Gallons/Day/Foot**
Hydraulic Conductivity	**K =**	**15**	**Feet/Day**
Storativity	**S =**	**0.012**	**Dimensionless**

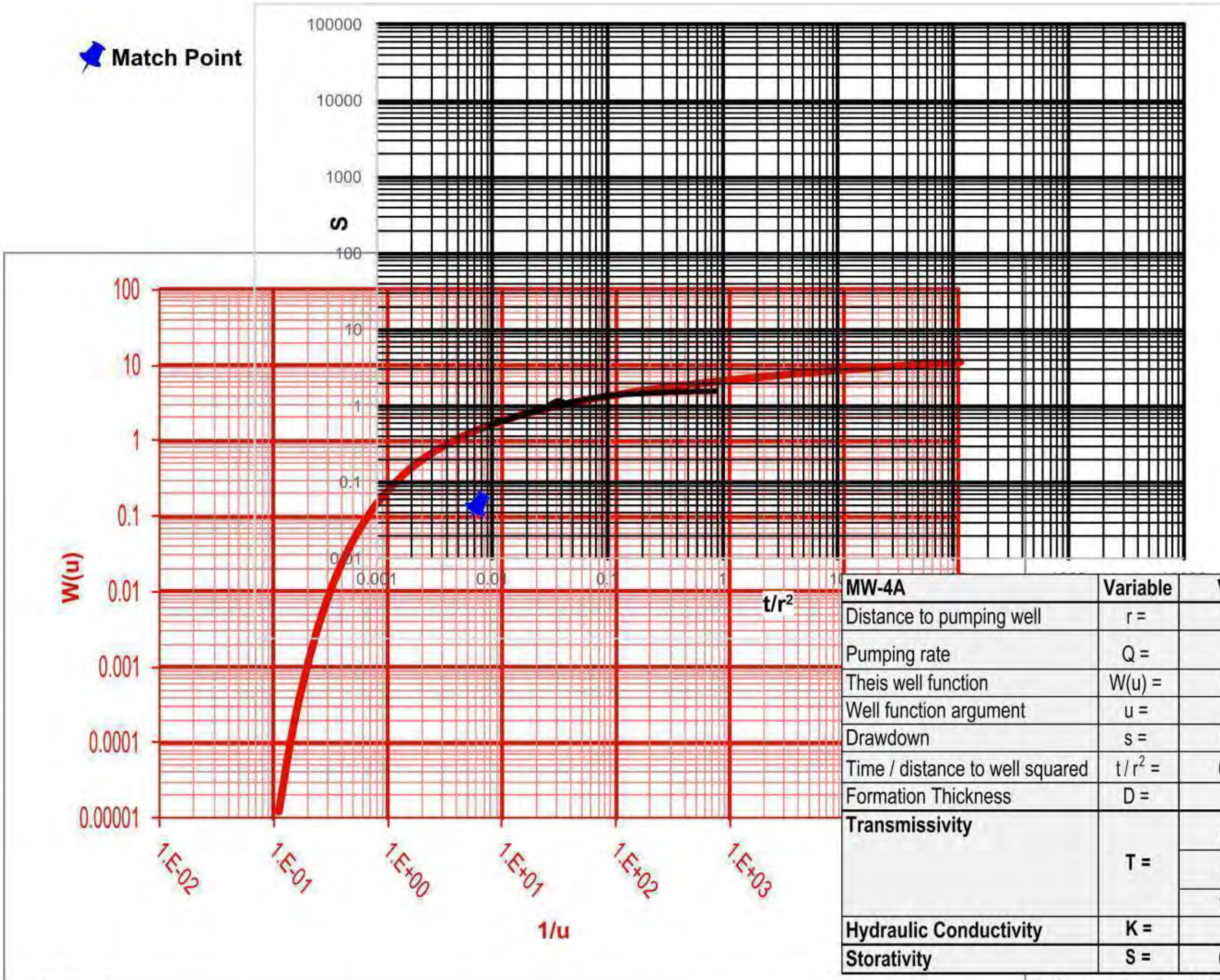
CDM Smith

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

Figure E-3: MP-2 Theis Solution

Cessna GA1 Facility

Columbus, Muscogee County, Georgia

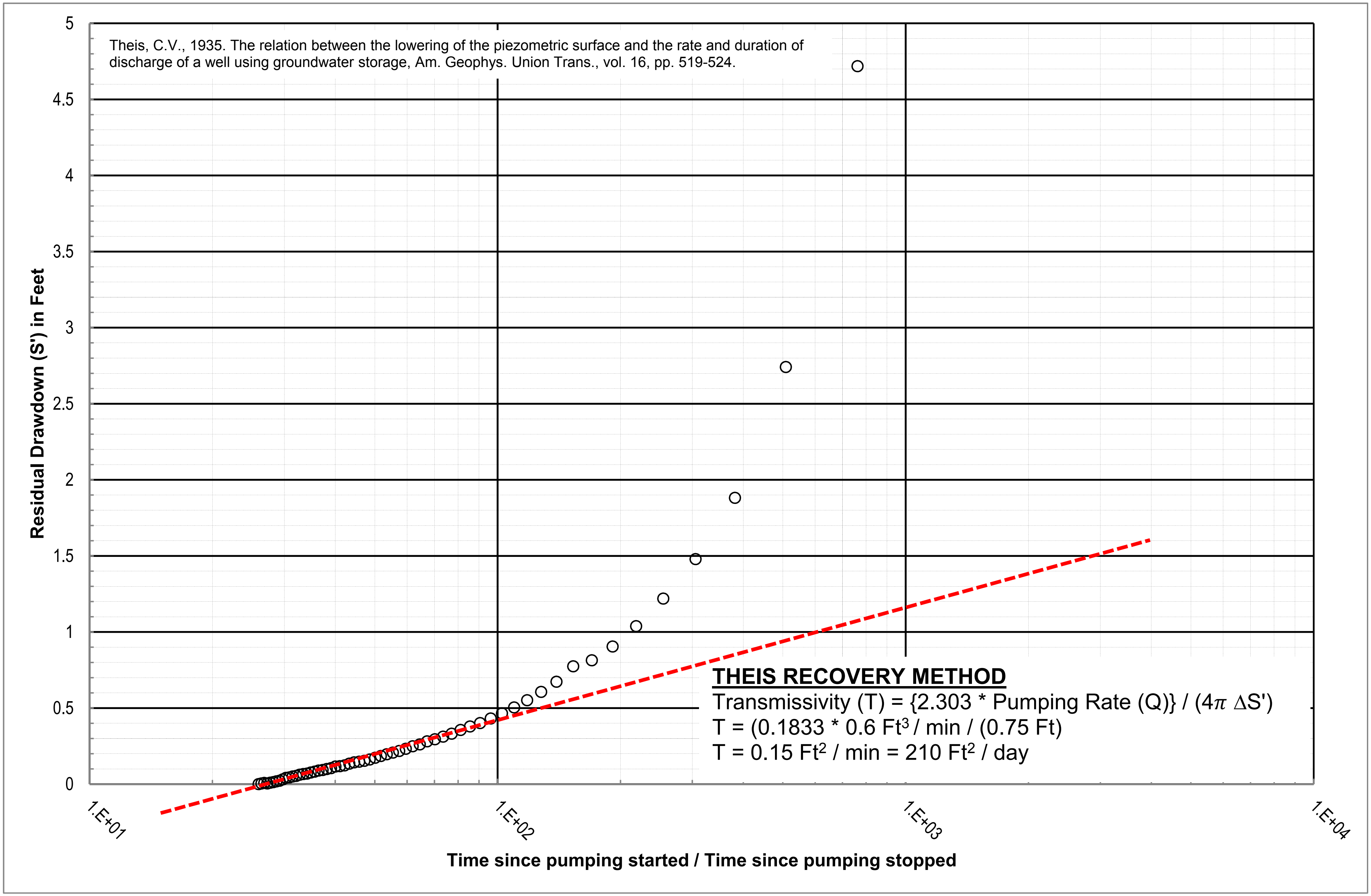


MW-4A	Variable	Value	Units
Distance to pumping well	r =	14.6	Feet
Pumping rate	Q =	0.6	Feet^3/minute
Theis well function	W(u) =	0.09	Dimensionless
Well function argument	u =	0.2	Dimensionless
Drawdown	s =	0.03	Feet
Time / distance to well squared	t / r^2 =	0.006	Minutes/Feet^2
Formation Thickness	D =	17	Feet
Transmissivity	**T =**	**0.15**	**Feet^2/Minute**
		211	**Feet^2/Day**
		1,581	**Gallons/Day/Foot**
Hydraulic Conductivity	**K =**	**12**	**Feet/Day**
Storativity	**S =**	**0.002**	**Dimensionless**

CDM Smith

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

Figure E-4: MW-4A Theis Solution
Cessna GA1 Facility
Columbus, Muscogee County, Georgia

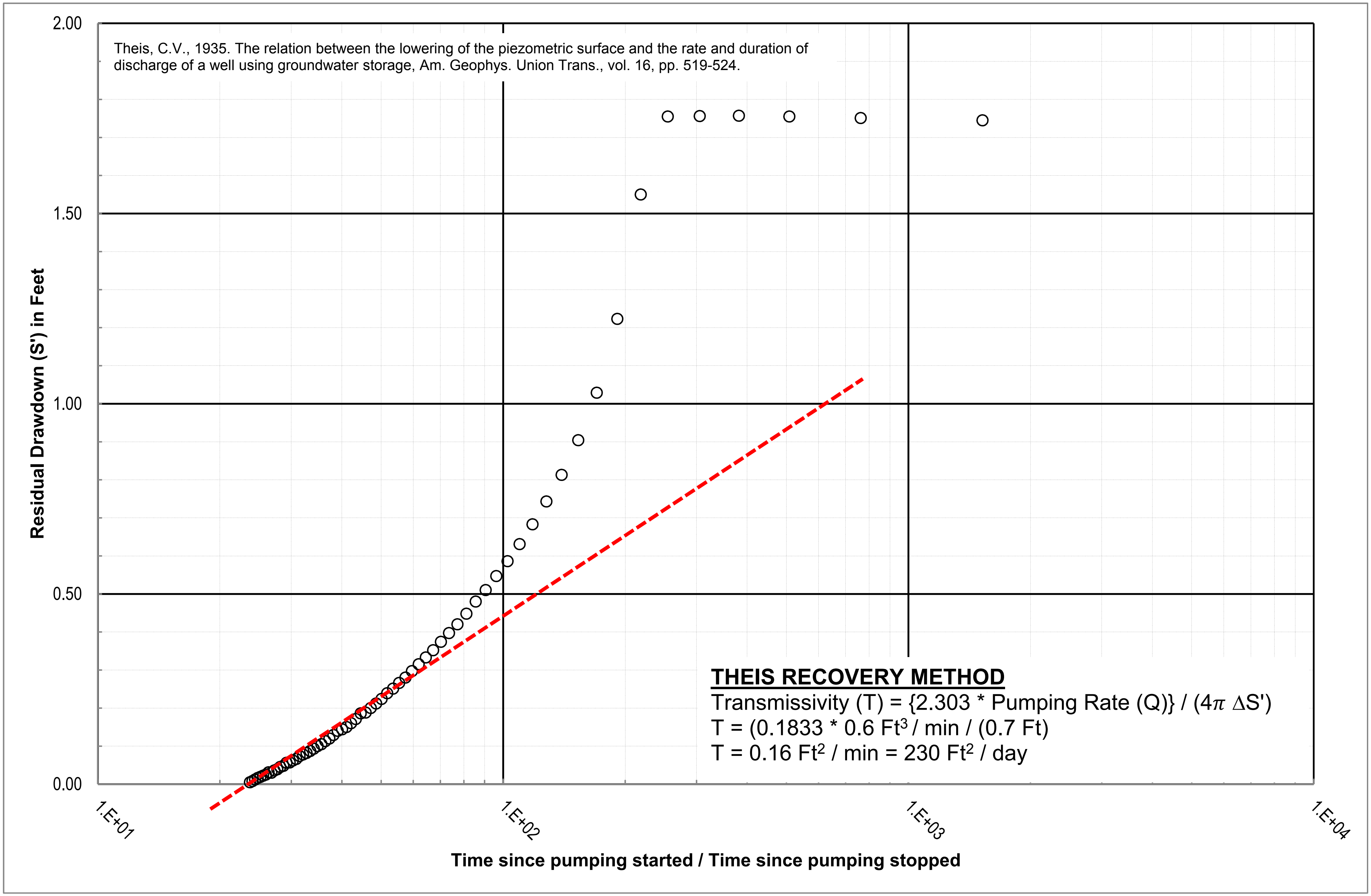


E-5: INJ-13 Theis Recovery Solution

Cessna GA1 Facility

Columbus, Muscogee County, Georgia

CDM Smith

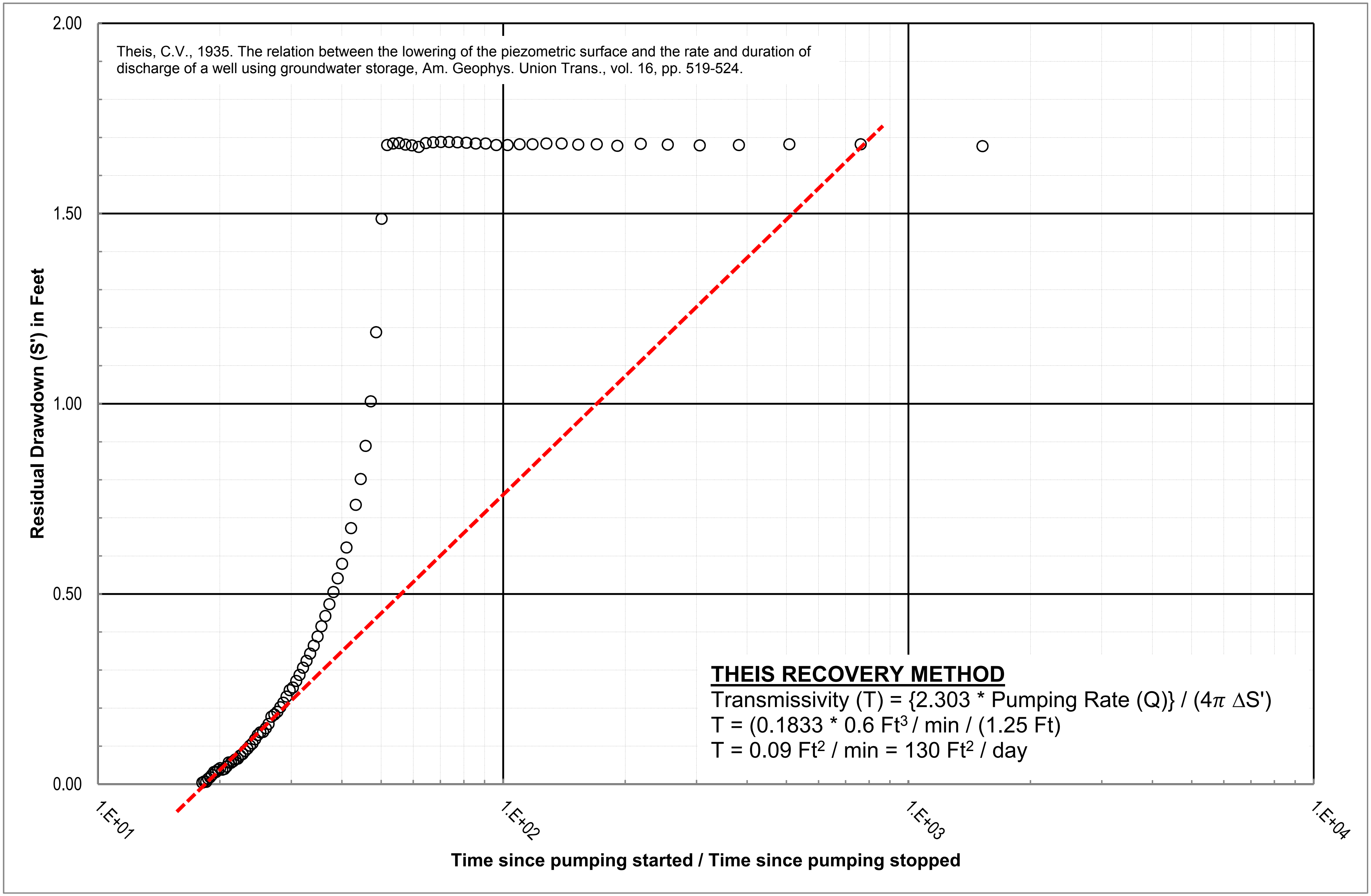


CDM Smith

E-6: MP-2 Theis Recovery Solution

Cessna GA1 Facility

Columbus, Muscogee County, Georgia



CDM Smith

E-7: MW-4A Theis Recovery Solution

Cessna GA1 Facility

Columbus, Muscogee County, Georgia

Appendix F

Tracer Test Calculations

CDM Smith

Aquifer Test Parameters					
r_{OB}	Radial distance from injection well [ft] =	8.7	S	Storativity [dimensionless] =	0.007
Q	Injection rate [gpm] =	9.1	T	Transmissivity [ft^2/d] =	209
	Injection rate [ft^2/d] =	1,752	K	Hydraulic conductivity [ft/d] =	10
r_{inj}	Injection well borehole radius [in] =	4.25	t_{inj}	Time since water injection began [min] =	Variable Input
	Injection well borehole radius [ft] =	0.35	D	Aquifer saturated thickness [ft]	20

Tracer Test Observations - Maximum Peak					
$t_{T\text{-}INJ}$	Tracer injection time [min] =	67	$t_{T\text{-}TT}$	Tracer travel time [d] =	0.45
	Tracer injection time [d] =	0.05	t_{inj}	Time since water injection began [d] =	0.55
$t_{T\text{-}MT}$	Tracer maximum time [min] =	720	$s_{INJ\text{-}avg}$	INJ well average s since $t_{T\text{-}INJ}$ [ft] =	19.51
	Tracer maximum time [d] =	0.50	$s_{OB\text{-}avg}$	OB well average s since $t_{T\text{-}INJ}$ [ft] =	2.74
$s_{INJ\text{-}max}$	INJ well s at $t_{T\text{-}MT}$ [ft] =	20.2	$s_{OB\text{-}max}$	OB well s at $t_{T\text{-}MT}$ [ft] =	2.79
i_{avg}	Average hydraulic gradient [dimensionless] =	1.93	V_T	Tracer velocity [ft/d] =	19
θ_{eff}	Effective porosity [dimensionless] =	1.05	Value is unreasonably high		

$s = Q \times W(u) / (4 \times \pi \times T)$ & $u = r^2 \times S / (T \times t)$ (Theis, 1985)

W(u) estimated by polynomial approximation (Walton, 1989)

$\theta_{eff} = K \times i / V_T$ (Darcy's Law)

Tracer Test Simulations - Maximum Peak					
$s_{SINJ\text{-}max}$	INJ well simulated s at $t_{T\text{-}MT}$ [ft] =	8.33	INJ_{loss}	Injection well loss [%] =	41%
$s_{SINJ\text{-}avg}$	INJ well simulated average s since $t_{T\text{-}INJ}$ [ft] =	7.83	INJ_{loss}	Injection well loss [%] =	40%
$i_{S\ avg}$	Average hydraulic gradient [dimensionless] =	0.59			
θ_{eff}	Effective porosity [dimensionless] =	0.32	Value is at the top of the range for sand/gravel of 0.1 to 0.35 (Wiedemeier et. al., 1995)		

CDM Smith

Table F-1: MP-1 Tracer Solution

Cessna GA1 Facility

Columbus, Muscogee County, Georgia

Aquifer Test Parameters					
r_{OB}	Radial distance from injection well [ft] =	7.5	S	Storativity [dimensionless] =	0.006
Q	Injection rate [gpm] =	4.6	T	Transmissivity [ft^2/d] =	256
	Injection rate [ft^2/d] =	**886**	K	Hydraulic conductivity [ft/d] =	**15**
r_{inj}	Injection well borehole radius [in] =	4.25	t_{inj}	Time since water injection began [min] =	Variable Input
	Injection well borehole radius [ft] =	**0.35**	D	Aquifer saturated thickness [ft]	17

Tracer Test Observations - Maximum Peak					
$t_{T\text{-}INJ}$	Tracer injection time [min] =	67	$t_{T\text{-}TT}$	Tracer travel time [d] =	**0.18**
	Tracer injection time [d] =	**0.05**	t_{inj}	Time since water injection began [d] =	**0.28**
$t_{T\text{-}MT}$	Tracer maximum time [min] =	330	$s_{INJ\text{-}avg}$	INJ well average s since $t_{T\text{-}INJ}$ [ft] =	15.39
	Tracer maximum time [d] =	**0.23**	$s_{OB\text{-}avg}$	OB well average s since $t_{T\text{-}INJ}$ [ft] =	1.63
$s_{INJ\text{-}max}$	INJ well s at $t_{T\text{-}MT}$ [ft] =	15.87	$s_{OB\text{-}max}$	OB well s at $t_{T\text{-}AT}$ [ft] =	1.65
i_{avg}	Average hydraulic gradient [dimensionless] =	**1.83**	V_T	Tracer velocity [ft/d] =	**41**
θ_{eff}	Effective porosity [dimensionless] =	**0.67**	Value is unreasonably high		

$$s = Q \times W(u) / (4 \times \pi \times T) \ \& \ u = r^2 \times S / (T \times t) \text{ (Theis, 1985)}$$

W(u) estimated by polynomial approximation (Walton, 1989)

$$\theta_{eff} = K \times i / V_T \text{ (Darcy's Law)}$$

Tracer Test Simulations - Maximum Peak					
$s_{SINJ\text{-}max}$	INJ well simulated s at $t_{T\text{-}MT}$ [ft] =	**2.88**	INJ_{loss}	Injection well loss [%] =	**18%**
$s_{SINJ\text{-}avg}$	INJ well simulated average s since $t_{T\text{-}INJ}$ [ft] =	**3.16**	INJ_{loss}	Injection well loss [%] =	**21%**
$i_{S\ avg}$	Average hydraulic gradient [dimensionless] =	**0.20**			
θ_{eff}	Effective porosity [dimensionless] =	**0.07**	Value is below the range for sand/gravel of 0.1 to 0.35 (Wiedemeier et. al., 1995)		

CDM Smith

Table F-2: MP-2 Tracer Solution

Cessna GA1 Facility
Columbus, Muscogee County, Georgia

Aquifer Test Parameters					
r_{OB}	Radial distance from injection well [ft] =	14.6	S	Storativity [dimensionless] =	0.006
Q	Injection rate [gpm] =	4.6	T	Transmissivity [ft^2/d] =	171
	Injection rate [ft^2/d] =	**886**	K	Hydraulic conductivity [ft/d] =	**10**
r_{inj}	Injection well borehole radius [in] =	4.25	t_{inj}	Time since water injection began [min] =	Variable Input
	Injection well borehole radius [ft] =	**0.35**	D	Aquifer saturated thickness [ft]	17

Tracer Test Observations - Maximum Peak					
$t_{T\text{-}INJ}$	Tracer injection time [min] =	67	$t_{T\text{-}TT}$	Tracer travel time [d] =	**1.06**
	Tracer injection time [d] =	**0.05**	t_{inj}	Time since water injection began [d] =	**1.16**
$t_{T\text{-}MT}$	Tracer maximum time [min] =	1,600	$s_{INJ\text{-}avg}$	INJ well average s since $t_{T\text{-}INJ}$ [ft] =	16.37
	Tracer maximum time [d] =	**1.11**	$s_{OB\text{-}avg}$	OB well average s since $t_{T\text{-}INJ}$ [ft] =	1.53
$s_{INJ\text{-}max}$	INJ well s at $t_{T\text{-}MT}$ [ft] =	17.48	$s_{OB\text{-}max}$	OB well s at $t_{T\text{-}AT}$ [ft] =	1.66
i_{avg}	Average hydraulic gradient [dimensionless] =	**1.02**	V_T	Tracer velocity [ft/d] =	**14**
θ_{eff}	Effective porosity [dimensionless] =	**0.75**	Value is unreasonably high		

$$s = Q \times W(u) / (4 \times \pi \times T) \quad \& \quad u = r^2 \times S / (T \times t) \text{ (Theis, 1985)}$$

W(u) estimated by polynomial approximation (Walton, 1989)

$$\theta_{eff} = K \times i / V_T \text{ (Darcy's Law)}$$

Tracer Test Simulations - Maximum Peak					
$s_{SINJ\text{-}max}$	INJ well simulated s at $t_{T\text{-}MT}$ [ft] =	**5.46**	INJ_{loss}	Injection well loss [%] =	**31%**
$s_{SINJ\text{-}avg}$	INJ well simulated average s since $t_{T\text{-}INJ}$ [ft] =	**5.10**	INJ_{loss}	Injection well loss [%] =	**31%**
$i_{S\ avg}$	Average hydraulic gradient [dimensionless] =	**0.24**			
θ_{eff}	Effective porosity [dimensionless] =	**0.18**	Value is at the bottom of the range for sand/gravel of 0.1 to 0.35 (Wiedemeier et. al., 1995)		

CDM Smith

Table F-3: MW-4A Tracer Solution

Cessna GA1 Facility
Columbus, Muscogee County, Georgia

Appendix G

Draft UIC Permit Application

CDM Smith

STATE OF GEORGIA
DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION

Underground Injection Control Program

Class V Injection Well
Permit Application

Part 1. Permit Application

SECTION I. FACILITY INFORMATION

Facility Name: Cessna Aircraft Company Former GA1 Facility		
Phone: Not Applicable	River Basin: Chattahoochee	
Facility Address: 4800 Cargo Drive		
City: Columbus	State: GA	ZIP Code: 31907
Latitude (DD/MM/SS): 32.511385	Longitude (DD/MM/SS): -84.877363	County: Muscogee

Is the unground injection part of a corrective action or remediation plan to be included in another Georgia EPD permit? If yes, please explain:

The work is being conducted under the Voluntary Remediation Program (VRP1460391735).

SECTION II. OWNER CONTACT INFORMATION

Name of Owner or Authorized Representative: Greg Simpson, Textron, Inc.		
Title: Director, Site Remediation		
Phone: (401) 457-2635	E-mail: gsimpson@textron.com	Fax: (401) 457-6028
Owner Mailing Address: 40 Westminster Street		
City: Providence	State: RI	ZIP Code: 02903

SECTION III. DRILLER INFORMATION

GA Licensed Water Well Contractor or Bonded Environmental Drilling Company Name:

F. Joe Grantham, Geo Lab Drilling

Phone: (770) 868-5407	E-mail: jgrantham@geolabdrilling.com	Fax: (770) 868-5408
Address: 800 Bill Rutledge Road		
City: Winder	State: GA	ZIP Code: 30680
License No.: GA 627	Bond No.: NAVI-00003917	

SECTION IV. INJECTION WELL INFORMATION

1. Are the wells or devices proposed or existing: 2 existing wells, 14 proposed wells
2. No. of injection wells: 16
3. Classification of injection well(s) or devices (check box): ☐ Class I ☐ Class II ☐ Class III ☐ Class IV ☒ Class V

STATE OF GEORGIA
DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION

Part 1. Permit Application

4. Well Depth: 45 feet	5. Borehole Diameter: 8.5 inches	6. Csg. Depth: 24 feet
7. Csg. Diameter: 2 inches	8. Csg. Material: PVC	
9. Screen Type: Mill-slotted PVC	10. Screen Diameter: 2 inches	
11. Screen Interval from 24' to 44'	12. Grout Type: Neat cement	
13. Grout Interval from 0' to 20'	14. Grout Thickness: 3 inches	

SECTION V. INJECTION SYSTEM DATA

1. Type of Fluid: Potable water, emulsified vegetable oil, sodium bicarbonate, sodium ascorbate, bioremediation culture
2. Source of Fluid: Columbus Water Works
3. Purpose of the Injection/source of the contamination: Remediation of VOCs in groundwater
4. Proposed Injection Rate (daily max) (gallons/minute/well) (SCFM for air): 10 gallons / minute / well
5. Proposed Injection Volume (daily max) (gallons/minute/well) (SCFM for air): 4,160 gallons / well
6. Proposed Injection Pressure (max daily) (lbs./sq. inch) (psi)): 7.5 lbs. / sq. inch

SECTION VI. CERTIFICATION

I certify under the penalty of law that I have examined and am familiar with the information contained in this document and attachments and the information is true, accurate and complete. I am aware of the associated penalties for submitting false documentation, including but not limited to monetary penalties and or imprisonment

Name of Applicant:	**Date:**
Signature of Applicant:	**Date:**

STATE OF GEORGIA
DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION

Part II. Application Documents[1]

Please include the following documentation with the application:

1. A detailed diagram of the injection well(s) or device(s) showing the items described in Part I. Section IV of this Application.

2. A chemical analysis of the injected fluid. The analysis must include all constituents specified in the currently applicable Georgia Rules for Safe Drink Water, as amended.

3. A detailed diagram showing the engineering layout of the injection equipment and all piping associated with the system.

4. A comprehensive subsurface report, prepared by a Georgia registered Professional Geologist (PG) or Professional Engineer (PE), including all the geological and hydrogeological parameters of the site.

5. A notarized statement from the applicable local government stating the injection project is consistent with the local land use plan or zoning requirements.

6. A detailed map orientating the injection well (s) and any other wells to two (2) nearby reference points such as roads, streams, or nearby structures, etc. Please clearly mark the distances from the wells to the reference points.

7. If applicable, the approved Corrective Action Plan for the UIC File.

Submit the Completed Application to:

Georgia Environmental Protection Division
Underground Injection Control Program
2 Martin Luther King Jr. Drive
Suite 1152
Atlanta, Georgia 30334

[1] Please refer to the Georgia Rules and Regulations for Water Quality Control, Chapter 391-3-6-.13.

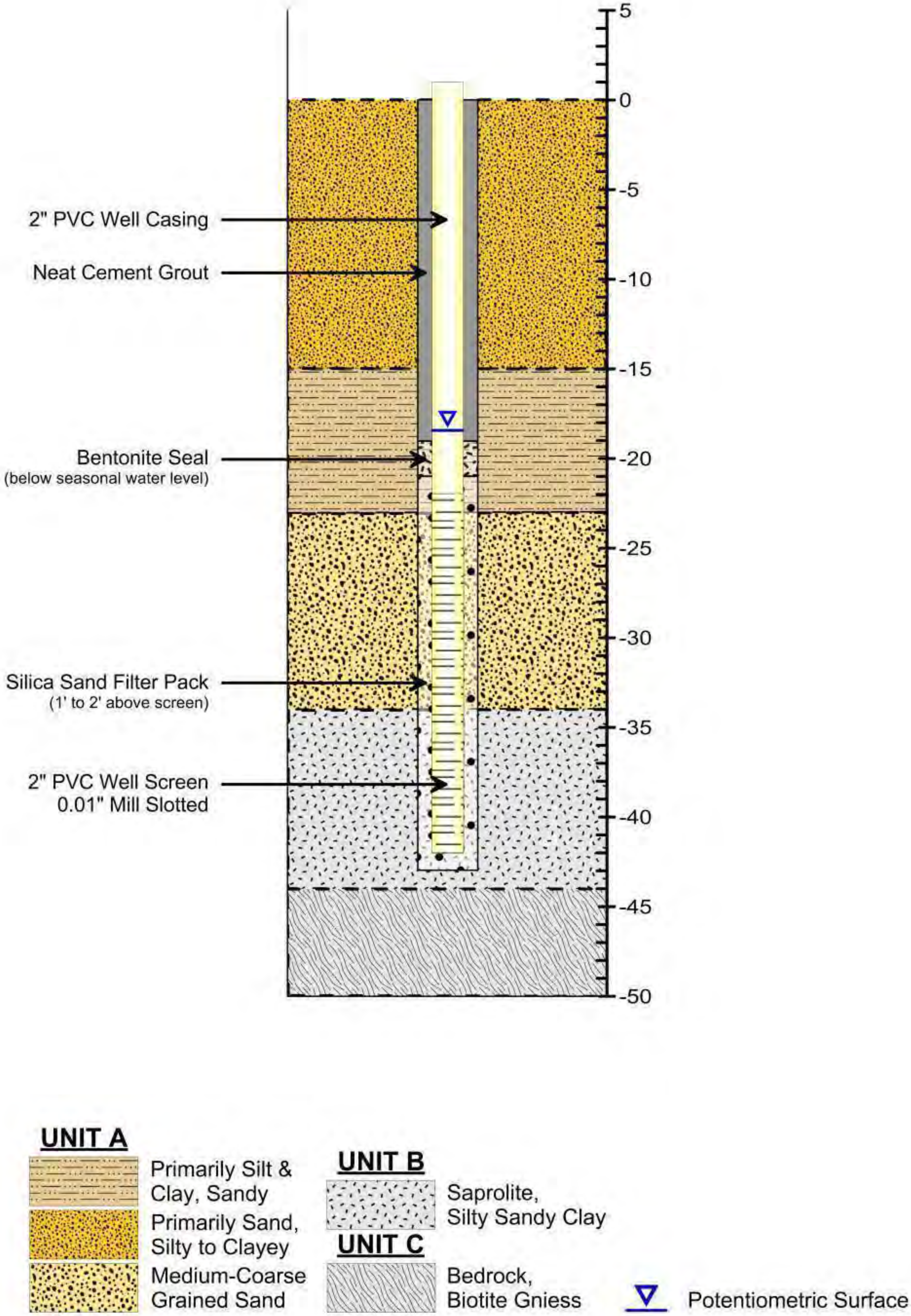
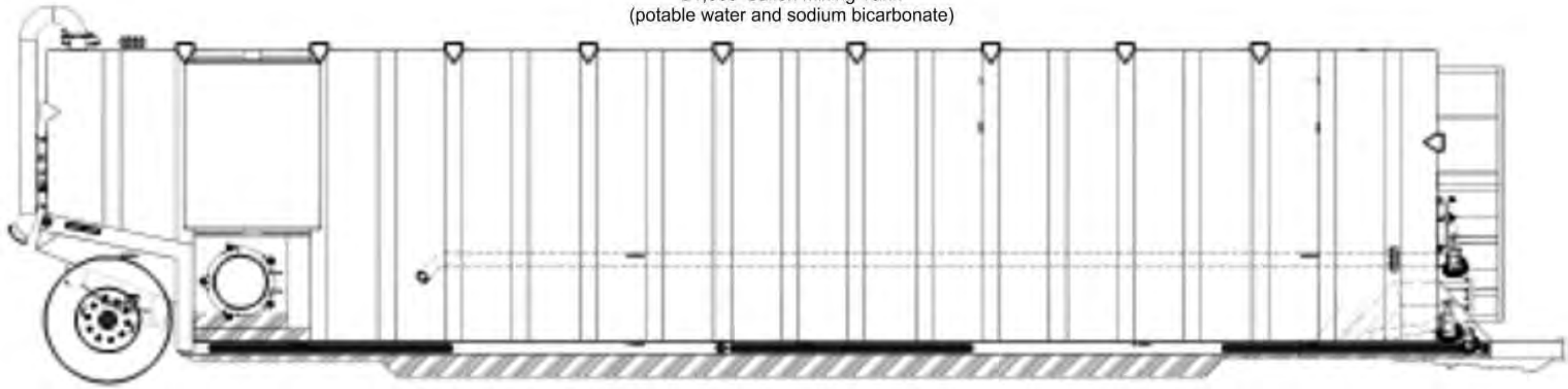
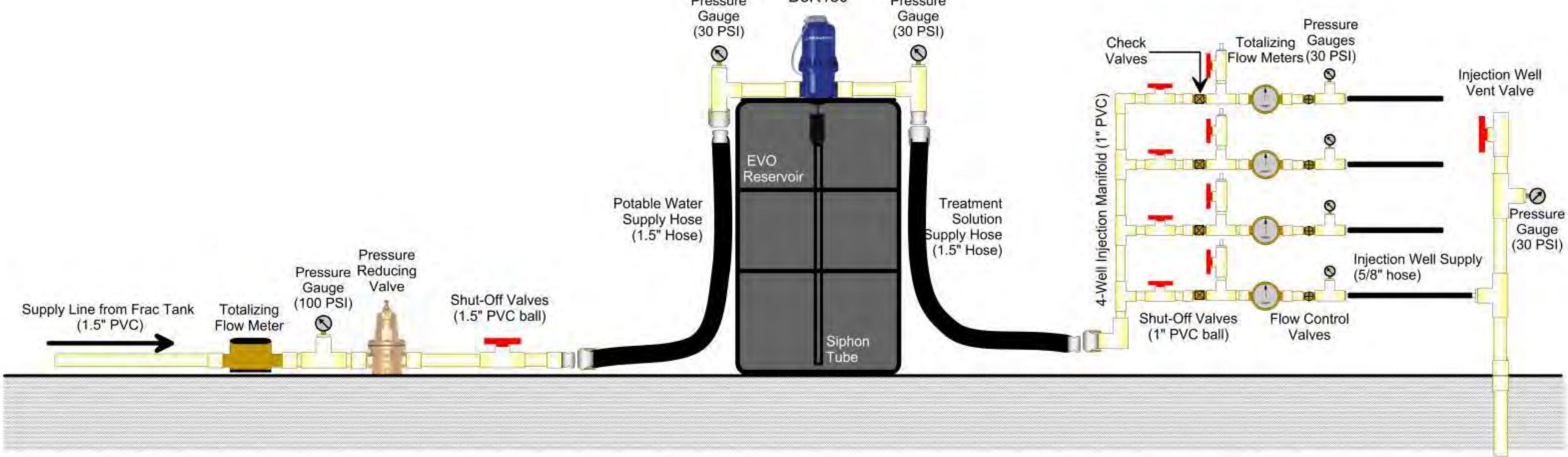


Figure 1: Injection Well Typical Construction

Cessna GA1 Facility
Columbus, Muscogee County, Georgia

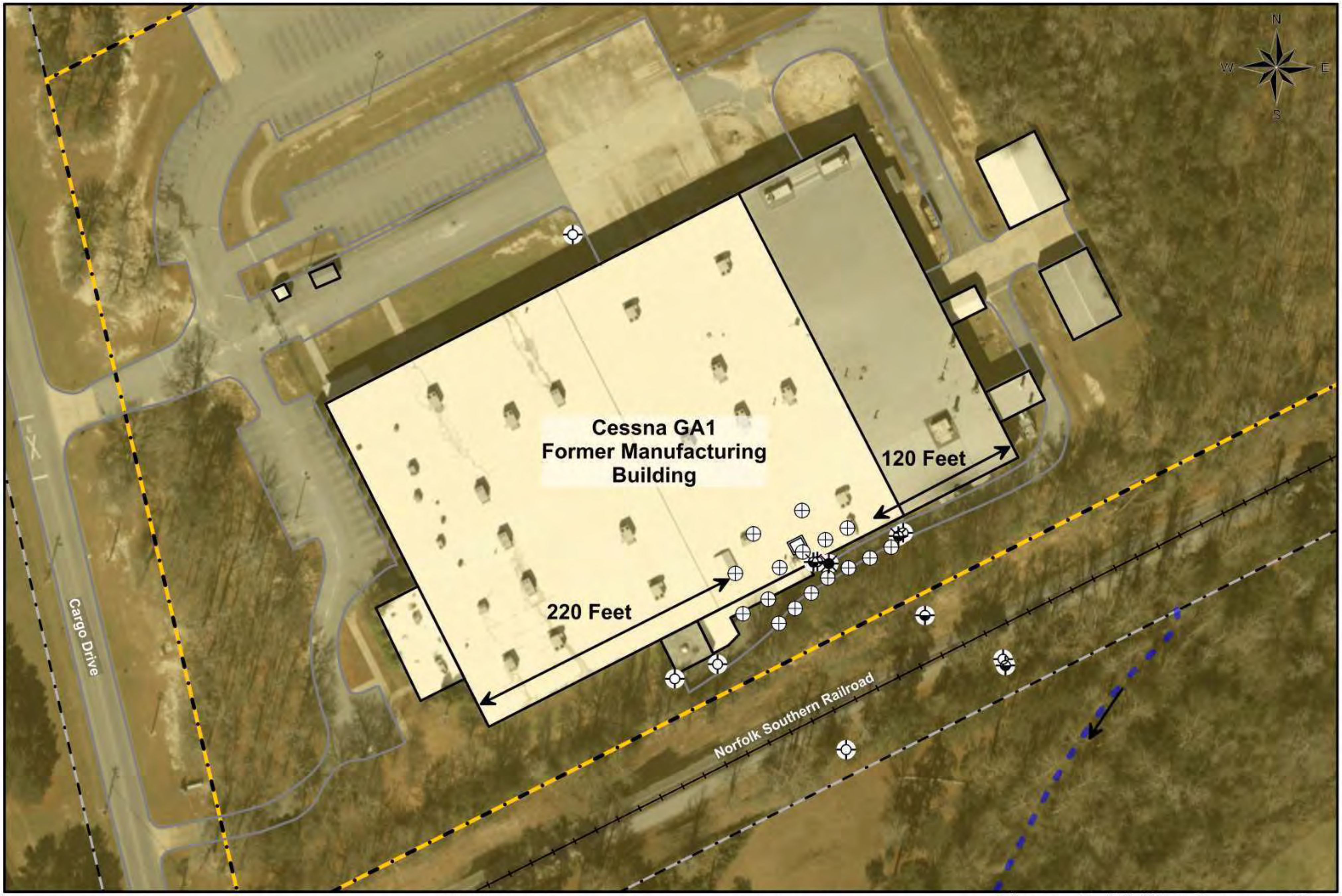




CDM Smith

Figure 2: Injection System

Cessna GA1 Facility
Columbus, Muscogee County, Georgia



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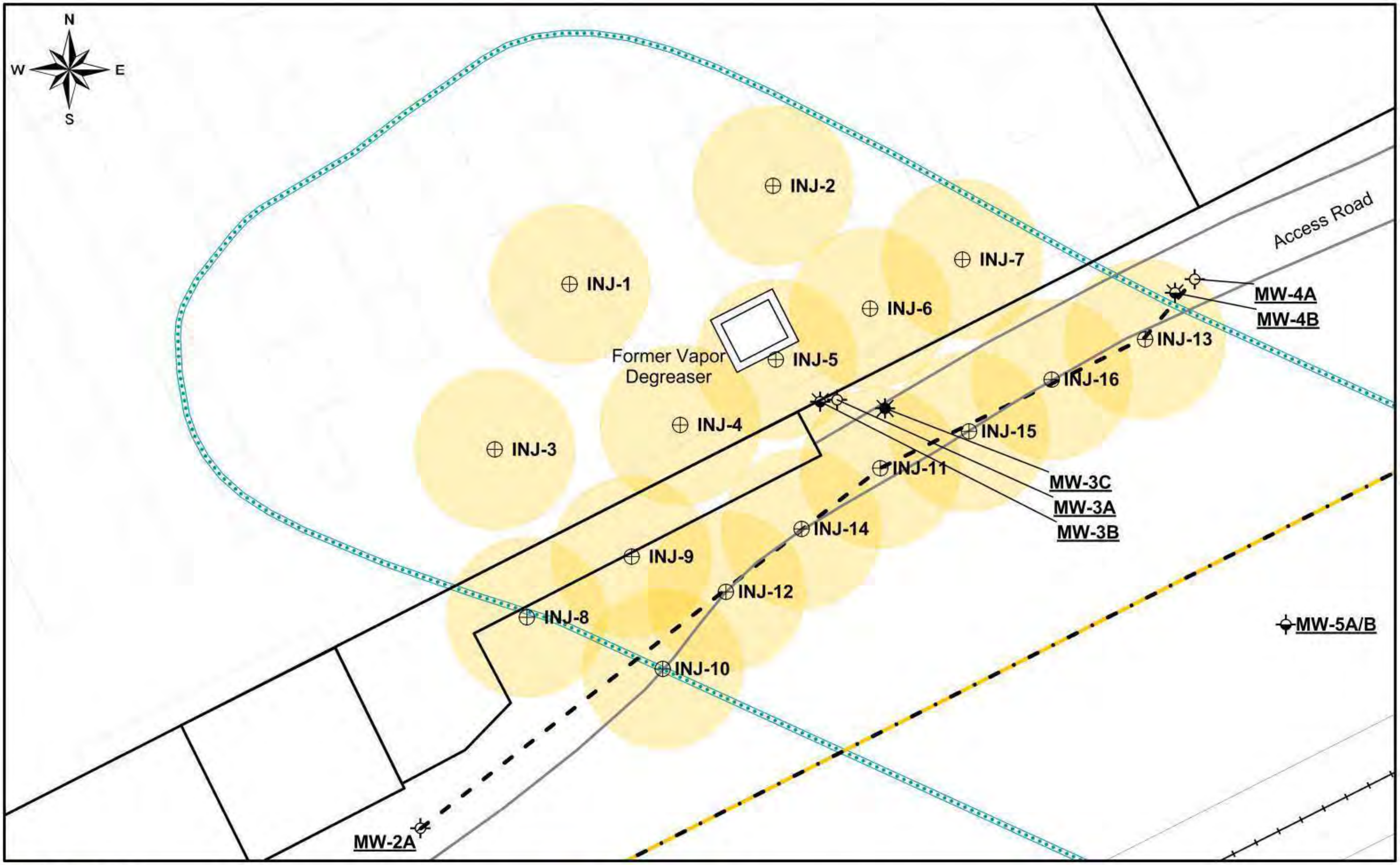
Stream
(Possibly Intermittent)
Site Boundary
Offsite Properties
Scale in Feet
0 100 200

Figure 3: Well Reference Map

Cessna GA1 Facility

Columbus, Muscogee County, Georgia



Offsite Properties
Site Boundary

Unit A Sediments Monitoring Well
Unit A/B Monitoring Well
Unit B Saprolite Monitoring Well
Unit C Bedrock Monitoring Well
Unit A/B Pilot Test Injection Well

Radius of Influence (15 Feet)

Generalized Groundwater Target Remediation Area

Cross Section Location

Scale in Feet
0 25 50

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Figure 4: 2018 Injection Well Plan

Cessna GA1 Facility
Columbus, Muscogee County, Georgia

Appendix H

Safety Data Sheets

CDM Smith

60% SRS®-FRL Large Droplet Emulsified Vegetable Oil (EVO) Substrate for Maximum Retention

United States Patent# RE40,448

The anaerobic bioremediation process uses native or introduced microorganisms (*Dehalococcoides*) to degrade chlorinated solvents such as tetrachloroethene (PCE) and trichloroethene (TCE) to innocuous end products including ethene and ethane. Terra Systems patented **SRS®-FRL** Large Droplet Emulsified Vegetable Oil Substrate includes an anionic emulsifier, which sticks to soil particles and is specifically designed when adherence to the formation is key to making contact with the bacteria. It is particularly useful in high groundwater flow formations such as fractured bedrock formations and is added to the groundwater to rapidly generate reducing conditions and provide the necessary carbon and hydrogen to support biodegradation of the chlorinated solvents.

Table I: SRS®-FRL Large Droplet Emulsified Vegetable Oil Substrate Specifications

Ingredient	Percent	Description	Benefit
Food Grade U.S. Grown Soybean Oil	60%	Terra Systems operates its own state-of-the-art manufacturing facility.	Long lasting source of carbon and hydrogen, consistent product quality, uniform droplet size, neutral pH, QA/QC lab on floor to check product before shipment.
Food Grade Sodium or Potassium Lactate	4%	Rapidly biodegradable soluble substrate	Rapidly generate anaerobic conditions
Proprietary Food Grade Nutrients	<1%	Proprietary organic and inorganic nutrients such as yeast extract, nitrogen and phosphorus.	Nutrients have been demonstrated to support the growth of the anaerobic microbial population.
Proprietary Food Grade Emulsifiers and Preservatives	7.5%	Proprietary anionic emulsifier	Maximum retention in high groundwater flow-rate aquifers
Vitamin B_{12}	<1%	At least 250 µg/L of Vitamin B_{12}	He et al. 2007 demonstrated Vitamin B_{12} to be an important micronutrient to enhance dechlorination activity with 25 µg/L providing maximum stimulation
Median Oil Droplet Size (microns)	NA	5 µm	Maximum retention in high groundwater flow-rate aquifers
pH	6.5 - 7	6.5 - 7	Optimum microbial activity

Application: Terra Systems **patented**, nutrient enriched, proven slow release SRS®-FRL **large droplet** emulsified vegetable oil substrate with an **anionic emulsifier** is used when a long lasting carbon substrate is desired that provides maximum retention in high groundwater flow-rate aquifers. SRS®-FRL sticks to soil particles and is specifically designed when adherence to the formation is key to making contact with the bacteria.

130 Hickman Road – Suite 1 – Claymont – Delaware – 19703
For More Information Call Michael Free at 302-798-9553 or Email: mfree@terrasystems.net

Customers: SRS®-FRL is used extensively by consultants working with the Air Force, DOD, Navy, and EPA, current and former drycleaners, semiconductor plants and private firms to remediate chlorinated solvent sites and is designed for fractured rock formations, PRBs and high groundwater flow-rate aquifers. SRS®-FRL releases bio-available hydrogen over a period of 3 to 5 years thus enhancing the long-term anaerobic biodegradation of the chlorinated solvents and reducing the frequency of reinjection.

Manufactured vs. Field Emulsion

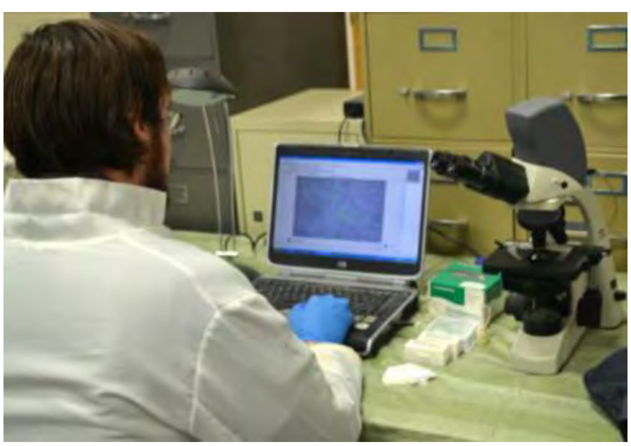
In the early days of in-situ bioremediation when Terra Systems first patented the technology, it was common to bring the water, emulsifiers, oil, and other ingredients to the site and using trash or other pumps to mix the ingredients together to form an emulsion. It soon became apparent that poor emulsion consistency and a broad range of droplet sizes resulted in inadequate and uneven distribution when injected. This resulted in higher long-term costs due to higher reinjection frequency and higher substrate volumes to adequately make contact with the COC.

Don't be "***penny wise and pound foolish***".

Consider:

- ✓ The labor and equipment time and cost of mixing in the field.
- ✓ The need to mix the nutrients and Vitamin B_{12} longer to achieve consistency.
- ✓ The cost of inadequate distribution due to droplet size and emulsion inconsistency
- ✓ The inability to accurately determine if you have 100% emulsification.
- ✓ The lack of QA/QC in the field

- Terra Systems owns and operates a state of the art US based manufacturing plant with an in-house quality control laboratory for strict quality assurance of the emulsion, droplet size and pH.
- SRS®-FRL arrives at the site "***injection ready***" with all the ingredients – Vitamin B_{12}, proprietary nutrients, sodium or potassium lactate and anionic emulsifier(s) already blended together.
- At the PM's request Terra Systems will blend 2-8 g/L of sodium bicarbonate into the SRS®-FRL during manufacturing to counter the acids produced during the fermentation process in the aquifer. This is especially beneficial for marginal pH aquifers of pH 5 – 6.



A Digital Microscope is connected to a laptop computer with proprietary "***Droplet Size Calculation Software***"

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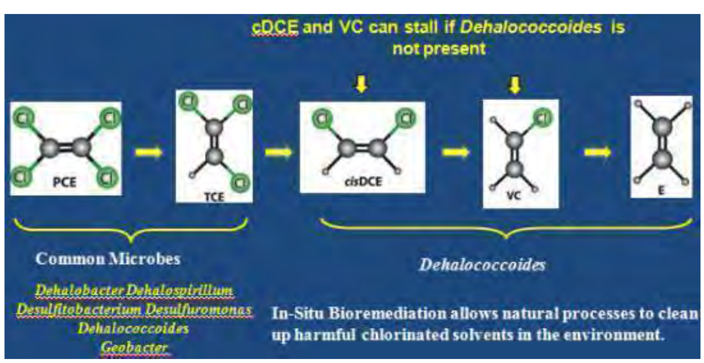
Terra Systems
INCORPORATED

- SRS®-FRL optimizes the naturally occurring biodegradation system by supplying the rate limiting factor (in this case hydrogen) in the degradation of CVOC's, certain pesticides/herbicides, perchlorate, and immobilization of certain metals (Chromium, Arsenic, and some radionucleides).
- The **large droplet size** of **5 µm** combined with the **negative surface charge** on the droplets results in a higher retention in the subsurface.
- Terra Systems holds United States Patent#**RE40,448** for the use of emulsified vegetable oil for remediation of chlorinated solvents.
- The soy bean oil is grown in the United States and provides a **slow release** biodegradable carbon source, which promotes long-term biological activity.
- SRS®-FRL comes **standard** with **biostimulating vitamins** like Vitamin B_{12}, which He et al. 2007 demonstrated is an important micronutrient to enhance dechlorination activity.
- SRS®-FRL contains proprietary organic and inorganic nutrients such as yeast extract, nitrogen and phosphorus, which have been demonstrated to support the growth of the anaerobic microbial population.
- SRS®-FRL comes with **at least 4% sodium** or **potassium lactate** a quick release biodegradable substrate, which helps to "*jump start*" bacterial growth.
- SRS®-FRL emulsified vegetable oil substrate has been validated by the Florida DEP, California Water Board and others.
- SRS®-FRL contains only non-toxic food grade materials, which results in green, sustainable remediation.

<u>Packaging</u>: Terra Systems patented SRS®-FRL can be shipped in 5-gallon buckets, 55-gallon drums, 275-gallon IBC totes, 275-gallon cardboard totes or bulk tankers.

If the *Dehalococcoides* are not present or are in small numbers Terra Systems **<u>TSI DC®</u>** Bioaugmentation Culture can also be injected.



130 Hickman Road – Suite 1 – Claymont – Delaware – 19703
For More Information Call Michael Free at 302-798-9553 or Email: mfree@terrasystems.net

LINK TO:
SRS-FRL
Product Sheet

60% LARGE DROPLET SLOW RELEASE EMULSIFIED VEGETABLE OIL SUBSTRATE (SRS®-FRL) SAFETY DATA SHEET

1. Product Identification

Synonyms:	60% Large Droplet Slow Release Substrate (SRS®-FRL) Emulsified Vegetable Oil (EVO)
Recommended Use:	Treatment of groundwater contaminated with chlorinated solvents and other anaerobically degradable compounds.
Supplier:	Terra Systems, Inc. 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Telephone (302) 798-9553 Fax (302) 798-9554 www.terrasystems.net

2. Hazards Identification

Emergency Overview	
Caution:	May cause eye irritation.
Health Rating:	1 - Slight
Flammability Rating:	1 - Slight
Reactivity Rating:	1 - Slight
Contact Rating:	1 - Slight
Protective Equipment:	Goggles; Proper Gloves
Storage Color Code:	Green (General Storage)
Potential Health Effects	
Inhalation:	Not expected to be a health hazard. If heated, may produce vapors or mists that irritate the mucous membranes and cause irritation, dizziness, and nausea. Remove to fresh air.
Ingestion:	Not expected to be a health hazard via ingestion. Large doses may produce abdominal spasms, diarrhea.
Skin Contact:	No adverse effects expected. May cause irritation or sensitization in sensitive individuals.
Eye Contact:	May cause mild irritation, possible reddening.
Chronic Exposure:	No information found.
Aggravation of Pre-existing Conditions:	No information found.

3. Composition/Information on Ingredients

Ingredient	Synonyms	CAS #	Percent	Hazardous
Soy bean oil	Soya oil	8001-22-7	60%	No
Emulsifiers, lecithin, and proprietary nutrient package containing nitrogen, phosphorus and vitamin B_{12}		Mixture	5 – 15%	No
Sodium lactate	2-hydroxpropionic acid sodium salt	72-17-3	<5%	Yes
Water		7732-18-5	20 - 30%	No

The emulsifiers, lecithin, and nutrient package mixture is a trade secret and consists of ingredients of unknown acute toxicity.

4. First Aid Measures

Inhalation: Not expected to require first aid measures. Remove to fresh air. Get medical attention for any breathing difficulty.

Ingestion: If large amounts were swallowed, give water to drink and get medical advice.

Skin Contact: Not expected to require first aid measures. Wash exposed area with soap and water. Get medical advice if irritation develops.

Eye Contact: Immediately flush eyes with plenty of water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get medical attention if irritation persists.

5. Fire Fighting Measures

Fire: Flash point: >200 C (>392 F). Not considered to be a fire hazard. Isolate from heat and open flame.

Explosion: Not considered to be an explosion hazard. Closed containers may explode if exposed to extreme heat.

Fire Extinguishing Media: Dry chemical, foam, or carbon dioxide. Water spray may be ineffective on fire, but can protect fire-fighters and cool closed containers. Use fog nozzles if water is used.

Special Information: In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode.

6. Accidental Release Measures

Clean-up personnel may require protective clothing. Absorb in sand, paper towels, “Oil Dry”, or other inert material. Scoop up and containerize for disposal. Flush trace residues to sewer with soap and water. Containerized waste may be sent to an approved waste disposal facility.

7. Handling and Storage

Keep in a tightly closed container, stored in a cool, dry, ventilated area. Protect against physical damage. Containers of this material are not hazardous when empty since they do vapors or harmful substances; observe all warnings and precautions listed for the product. Do not store above 49 C (120 F). Keep container tightly closed and upright when not in use to prevent leakage.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:	None established.
Ventilation System:	Not expected to require any special ventilation.
Personal Respirators (NIOSH Approved):	Not expected to require personal respirator usage.
Skin Protection:	Wear protective gloves and clean body-covering clothing.
Eye Protection:	Use chemical safety goggles and/or a full face shield where splashing is possible. Provide readily accessible eye wash stations and safety showers.
Slips, Trips, and Falls:	Material is slippery when spilled. Clean up with sand, paper towels, “Oil Dry”, or other inert material.

9. Physical and Chemical Properties

Appearance:	White liquid.
Odor:	Vegetable oil.
Solubility:	Miscible in water.
Specific Gravity (water=1):	0.95-0.98. 8.09 pounds per gallon.
pH:	6-7 (40% aqueous solution)
% Volatiles by volume @ 21C (70F):	Negligible.
Boiling Point:	$\geq$ 100C ($\geq$ 212F)
Melting Point:	No information found.
Flash Point (F):	No information found.
Autoignition Temperature:	No information found.
Decomposition Temperature:	No information found.
Vapor Density (Air=1):	No information found.
Vapor Pressure (mm Hg):	< 1.0 @ 20C (68F).
Evaporation Rate (BuAc=1):	No information found.
Viscosity @23 C (73 F):	213 centipoises (1.2 centipoises diluted 1:10)
Partition Coefficient (octanol/water):	No information found.

10. Stability and Reactivity

Stability: Stable under ordinary conditions of use and storage.
Reactivity: Not reactive under ordinary conditions.
Hazardous Decomposition Products: Carbon dioxide and carbon monoxide may form when heated to decomposition.
Hazardous Polymerization: Will not occur.
Incompatibilities: Strong oxidizers, acids.
Conditions to Avoid: Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

Soybean Oil: No information found on toxicology. It is not a carcinogen listed by IARC, NTP, NIOSH, OSHA, or ACGIH.
Emulsifier/Nutrient Mixture: No information found on toxicology. It is not a carcinogen listed by IARC, NTP, NIOSH, OSHA, or ACGIH.
Sodium Lactate: Oral rat LD50: 2,000 mg/kg. 100 mg caused mild irritation to rabbit eye in Draize test. This compound is not listed as a carcinogen by IARC, NRP, NIOSH, OSHA, or ACGIM.
SRS-SD: The toxicity of the mixture has not been measured.

12. Ecological Information

Environmental Fate: No information found.
Environmental Toxicity: No information found.
Degradability: This product is completely biodegradable under both aerobic and anaerobic conditions.
Soil Mobility: This compound will move with groundwater until the adsorbed onto the soil. Degradation products may be mobile.
Bioaccumulation Potential: No information found.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste disposal facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Not regulated.

15. Regulatory Information

OSHA STATUS: This product is not hazardous under the criteria of the Federal OSHA hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in Section 10.

TSCA STATUS: No component of this product is listed on the TSCA inventory.

CERCLA (Comprehensive Response Compensation, and Liability Act): Not reportable.

SARA TITLE III (Superfund Amendments and Reauthorization Act)
Section 312 Extremely Hazardous Substances: None
Section 311/312 Hazard Categories: Non-hazardous Under Section 311/312
Section 313 Toxic Chemicals: None

RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste. (40 CFR 261.20-24)

CALIFORNIA PROPOSITION 65: The following statement is made in order to comply with the California safe Drinking Water and Toxic Enforcement Act of 1986. The product contains no chemicals known to the State of California to cause cancer.

16. Other Information

NFPA Ratings:	Health: **1** Flammability: **1** Reactivity: **1**
Date Prepared:	June 19, 2014
Revision Information:	SDS Section(s) changed since last revision of document include: None.
Disclaimer:	Terra Systems, Inc. provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their independent judgment in determining its appropriateness for a particular purpose. TERRA SYSTEMS, INC. MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE INFORMATION SET FORTH HEREIN OR THE PRODUCT TO WHICH THE INFORMATION REFERS. ACCORDINGLY, TERRA

	SYSTEMS, INC. WILL NOT BE RESPONSIBLE FOR DAMAGES RESULTING FROM USE OF OR RELIANCE UPON THIS INFORMATION.
Prepared by:	Terra Systems, Inc.
Phone Number:	(302) 798-9553 (U.S.A.)

Anaerobic Water for Bioaugmentation (DO <0.5 mg/L, <0 mV ORP, Free Chlorine <0.1 mg/L, pH 6-8)

Chemical	Benefits	Drawbacks	Dosage per 1,000 Gallons of Fluid
Sodium Ascorbate or Vitamin C ($NaC_6H_8O_6$)	Non-toxic, food grade Neutral pH Soluble at 620 g/L at 25 C	None	2.5 pounds
Sodium Sulfite (Na_2SO_3)	Soluble at 270 g/L at 20 C	Biocidal Alkaline pH (9.0)	20.9 pounds
Sodium Bisulfite ($NaHSO_3$)	Soluble at 420 g/L at 20 C, removes chlorine	Toxic (preservative) and acidic when dissolved	20.9 pounds
Sodium Thiosulfate Pentrahydrate ($Na_2S_2O_3 \cdot 5H_20$)	Neutral pH Soluble at 701 g/L at 20 C	Biocidal	8.3 pounds
Home Brew of yeast, sugar and site soil	Use soil from local site Inexpensive	Can take several days to a week to drive the water anaerobic	Site specific

SODIUM ASCORBATE
SAFETY DATA SHEET

1. Product Identification

Synonyms:	Sodium Salt of Vitamin C
Recommended Use:	Additive for treatment of water to remove dissolved oxygen.
CAS#:	134-03-2
Supplier:	Terra Systems, Inc. 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Telephone (302) 798-9553 Fax (302) 798-9554 www.terrasystems.net

2. Hazards Identification

Emergency Overview	
Caution:	May cause eye or skin irritation.
Health Rating:	2 - Moderate
Flammability Rating:	1 - Slight
Reactivity Rating:	0 - None
Contact Rating:	1 - Slight
Protective Equipment:	Goggles; Proper Gloves
Storage Color Code:	Green (General Storage)
Potential Health Effects	
Inhalation:	Not expected to be a health hazard.
Ingestion:	Hazard via ingestion.
Skin Contact:	May cause irritation or sensitization in sensitive individuals.
Eye Contact:	May cause mild irritation.
Chronic Exposure:	No information found.
Aggravation of Pre-existing Conditions:	No information found.

3. Composition/Information on Ingredients

Ingredient	Synonyms	CAS #	Percent	Hazardous
Sodium Ascorbate	Sodium Salt of Vitamin C	134-03-2	100	No

4. First Aid Measures

Inhalation: Not expected to require first aid measures. Remove to fresh air. Get medical attention for any breathing difficulty.

Ingestion: If large amounts were swallowed, give water to drink and get medical advice.

Skin Contact: Not expected to require first aid measures. Wash exposed area with soap and water. Get medical advice if irritation develops.

Eye Contact: Immediately flush eyes with plenty of water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get medical attention if irritation persists.

5. Fire Fighting Measures

Fire: Flash point and auto ignition: not available. May be combustible at high temperature. Isolate from heat and open flame.

Explosion: Slightly explosive in presence of open flames and sparks. Non-flammable in presence of shocks.

Fire Extinguishing Media: Dry chemical powder for small fires. Water spray, fog, or foam may be effective for large fires. Do not use water jet. .

Special Information: In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode. Fine dust dispersed in air at sufficient concentrations with an ignition source is a potential dust explosion hazard.

6. Accidental Release Measures

Clean-up personnel may require protective clothing. Scoop up and containerize for disposal. Flush trace residues to sewer with soap and water. Containerized waste may be sent to an approved waste disposal facility.

7. Handling and Storage

Keep in a tightly closed container, stored in a cool, dry, ventilated area away from sources of heat or ignition. Protect against physical damage. Containers of this material may pose a fire risk due to dusts. Keep container tightly closed and upright when not in use to prevent leakage. Sensitive to light. Store in light-resistant containers.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits: None established.

Ventilation System: Use ventilation to keep exposure below exposure limits.

Personal Respirators (NIOSH

Approved):	Use dust respirator usage.
Skin Protection:	Wear protective gloves and clean body-covering clothing.
Eye Protection:	Use chemical safety goggles and/or a full face shield where splashing is possible. Provide readily accessible eye wash stations and safety showers.

9. Physical and Chemical Properties

Appearance:	White to yellowish granular or crystalline solid
Molecular Weight:	198.11 g/mole
Odor:	Odorless.
Solubility:	620 g/L solubility in water at 25 C.
Specific Gravity (water=1):	1.66 (water = 1).
pH:	Not available
% Volatiles by volume @ 21C (70F):	Negligible.
Boiling Point:	No information found.
Melting Point:	No information found.
Flash Point (F):	No information found.
Autoignition Temperature:	No information found.
Decomposition Temperature:	Decomposition temperature 200 C (392 F)
Vapor Density (Air=1):	No information found.
Vapor Pressure (mm Hg):	Not applicable.
Evaporation Rate (BuAc=1):	Not applicable.
Partition Coefficient (octanol/water):	No information found.

10. Stability and Reactivity

Stability:	Stable under ordinary conditions of use and storage.
Reactivity:	Not reactive under ordinary conditions.
Hazardous Decomposition Products:	Carbon dioxide and carbon monoxide may form when heated to decomposition.
Hazardous Polymerization:	Will not occur.
Incompatibilities:	Strong oxidizers, reducing agents, acids, alkalis.
Conditions to Avoid:	Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

Routes of Entry	Inhalation and ingestion.
Toxicity to Animals:	Acute oral toxicity (LD50): 16300 mg/kg Rat.
Chronic Effects on Humans:	Carcinogenic effects – classified 4 (no evidence) by NTP and none by OSHA. Mutagenic effects – mutagenic to mammalian somatic cells. May cause damage to kidneys, gastrointestinal tract, and upper respiratory tract. May affect genetic material (mutagenic) based on animal test data. No human data found

	(Registry of Toxic Effects of Chemicals). May cause cancer based on animal test data. No human data found (Registry of Toxic Effects of Chemicals).
Other Toxic Effects:	Hazardous in case of ingestion. Slightly hazardous in case of skin contact (irritant) or inhalation.

12. Ecological Information

Environmental Fate:	No information found.
Environmental Toxicity:	No information found.
Degradability:	This product is inherently biodegradable under both aerobic and anaerobic conditions.
Soil Mobility:	No information found.
Bioaccumulation Potential:	Does not bioaccumulate.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste disposal facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Not regulated.

15. Regulatory Information

OSHA STATUS: This product is not hazardous under the criteria of the Federal OSHA hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in Section 10.

TSCA STATUS: No component of this product is listed on the TSCA inventory.

CERCLA (Comprehensive Response Compensation, and Liability Act): Not reportable.

SARA TITLE III (Superfund Amendments and Reauthorization Act)
Section 312 Extremely Hazardous Substances: None
Section 311/312 Hazard Categories: Non-hazardous Under Section 311/312
Section 313 Toxic Chemicals: None

RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste. (40 CFR 261.20-24)

CALIFORNIA PROPOSITION 65: The following statement is made in order to comply with the California safe Drinking Water and Toxic Enforcement Act of 1986. The product contains no chemicals known to the State of California to cause cancer.

16. Other Information

NFPA Ratings:	Health: **2** Flammability: **1** Reactivity: **0**
Date Prepared:	February 3, 2015
Revision Information:	SDS Section(s) changed since last revision of document include: None.
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Prepared by:	Terra Systems, Inc.
Phone Number:	(302) 798-9553 (U.S.A.)

Terra Systems INCORPORATED

LINK TO:
TSI-DC
Safety Data Sheet

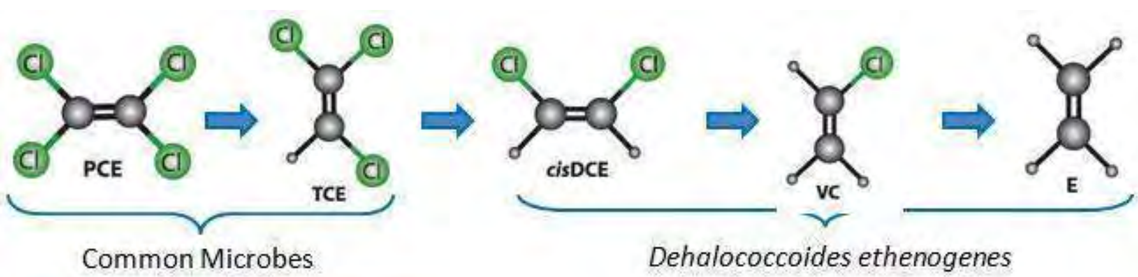
TSI DC *Dehalococcoides mccartyii* Bioaugmentation Culture®

>1 x 10^{11} Dehalococcoides cells/L

TSI DC *Dehalococcoides mccartyii* Bioaugmentation Culture® is an enriched natural bacteria culture that contains *Dehalococcoides* species for bioaugmentation. This culture dechlorinates tetrachloroethene (PCE) and trichloroethene (TCE) to the non-toxic product ethene. The culture also biodegrades 1,1,1-trichloroethane to 1,1-dichloroethene, 1,1-dichloroethane, and chloroethane. It also can biodegrade carbon tetrachloride and chloroform to methylene chloride and innocuous products. It can be used at sites where bacteria capable of complete reductive dechlorination are not present or there is a need to decrease the remediation time frame. It is estimated that *Dehalococcoides* are not present in 10 to 40 percent of chlorinated solvent contaminated sites.

Key Benefits of TSI DC *Dehalococcoides mccartyii* Bioaugmentation Culture®

The TSI-DC® Bioaugmentation Culture has been proven to be effective with a growing body of laboratory and field data demonstrating that the *Dehalococcoides* group of microorganisms is solely responsible for the complete dechlorination of PCE and TCE to ethene. At sites where *Dehalococcoides* microorganisms are not present or are found at low numbers, the process will often "**stall**" at cis-1,2-dichloroethene. The TSI-DC® Bioaugmentation Culture will promote the complete dechlorination of PCE or TCE. The TSI-DC® Bioaugmentation Culture contains greater than **1 x 10^{11}** *Dehalococcoides*/L.



130 Hickman Road, Suite 1
Claymont, Delaware 19703
Phone: 302-798-9553 • Email: mfree@terrasystems.net
On the Web: www.terrasystems.net

The TSI-DC® Bioaugmentation Culture is cost effective and is typically a minor component of the total remediation project cost. At sites where the *Dehalococcoides* is present, but at low numbers or poorly distributed, bioaugmentation can be used to reduce the treatment time. Bioaugmentation can also reduce the time required to grow the *Dehalococcoides* population to effective cell densities. Therefore, future costs can be reduced.

- The TSI-DC® Bioaugmentation Culture is competitively priced at less than $150 per liter of culture plus shipping depending on volume ordered.
- The TSI-DC® Bioaugmentation Culture works with all commonly used electron donors.
- The TSI-DC® Bioaugmentation Culture is not genetically modified or engineered.
- The TSI-DC® Bioaugmentation Culture is certified to be free of known human pathogens.
- The TSI-DC® Bioaugmentation Culture has rigorous quality control procedures in place to ensure that each shipment is of the highest quality, stable, safe, effective and free of chlorinated volatile organic compounds.
- The TSI-DC® Bioaugmentation Culture is shipped overnight in specially designed stainless steel containers that prevent exposure to air and are safe & easy to handle.

Each purchase comes with free technical phone support from an experienced Terra Systems microbiologist. A senior level microbiologist is also available to be on-site to support the successful application at $1,200 per day.

LINK TO:
TSI-DC
Product Sheet

TERRA SYSTEMS, INC DECHLORINATING BIOAUGMENTATION CULTURE (TSI-DC) SAFETY DATA SHEET

1. Product Identification

Synonyms:	*Dehalococcoides* or DHC Microbial Consortium (TSI-DC)
Recommended Use:	Bioremediation of groundwater contaminated with chlorinated solvents such as tetrachloroethene and trichloroethene.
Supplier:	Terra Systems, Inc. 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Telephone (302) 798-9553 Fax (302) 798-9554 www.terrasystems.net

2. Hazards Identification

The available data indicates no known hazards associated with exposure to this product. Nevertheless, individuals who are allergic to enzymes or other related proteins should avoid exposure and handling. Health effects associated with exposure to similar organisms are listed below.

Emergency Overview

Caution:	May cause eye irritation or discomfort if ingested or inhaled or allergic reaction to sensitive individuals.
Health Rating:	1 - Slight
Flammability Rating:	0 - None
Reactivity Rating:	0 - None
Contact Rating:	1 - Slight
Protective Equipment:	Goggles; Proper Gloves
Storage Color Code:	Green (General Storage)

Potential Health Effects

Inhalation:	Not expected to be a health hazard. Hypersensitive individuals may experience breathing difficulties after inhalation of aerosols.
Ingestion:	Not expected to be a health hazard via ingestion. Ingestion of large quantities may result in abdominal discomfort including nausea, vomiting, cramps, diarrhea, and fever.
Skin Contact:	No adverse effects expected. May cause irritation or sensitization in sensitive individuals upon prolonged contact.
Eye Contact:	May cause mild irritation, possible reddening unless immediately rinsed.

Chronic Exposure: No information found.
Aggravation of Pre-existing Conditions: No information found.

3. Composition/Information on Ingredients

Ingredient	Synonyms	CAS #	Percent	Hazardous
Non-hazardous ingredients	DHC	Not applicable	100%	No

4. First Aid Measures

Inhalation: Not expected to require first aid measures. Remove to fresh air. Get medical attention for any breathing difficulty or if allergic symptoms develop.

Ingestion: Thoroughly rinse mouth with water. Do not induce vomiting unless directed to do so by medical personnel. Get immediate medical attention. Never give anything by mouth to an unconscious or convulsing person.

Skin Contact: Not expected to require first aid measures. Wash exposed area with soap and water. Get medical advice if irritation develops.

Eye Contact: Immediately flush eyes with plenty of water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get medical attention if irritation persists.

Note to Physicians: All treatments should be based on observed signs and symptoms of distress in the patient. Consideration should be given to the possibility that overexposure to materials other than this material may have occurred.

5. Fire Fighting Measures

Fire: Non-flammable. Flash point and flammable limits are not available.

Explosion: Not considered to be an explosion hazard.

Fire Extinguishing Media: Dry chemical, foam, carbon dioxide, or water.

Special Information: In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode.

6. Accidental Release Measures

Clean-up personnel may require protective clothing and avoid skin contact. Absorb in sand, paper towels, or other inert material. Scoop up and containerize for disposal. Flush trace residues to sewer with soap and water. Containerized waste may be sent to an approved waste disposal facility. After clean-up, disinfect all cleaning materials and storage containers that come in contact with the spilled liquid.

7. Handling and Storage

Avoid breathing breathe aerosol. Avoid contact with skin. Use personal protective equipment recommended in Section 8. Keep containers tightly closed in a cool, well-ventilated area. The DHC microbial consortium (TSI-DC) can be supplied in stainless steel kegs designed for maximum working pressure of 130 psi and equipped with pressure relief valves. The kegs are pressurized with nitrogen gas up to the pressure of 15 psi. Do not exceed pressure of 15 psi during transfer of DHC microbial consortium (TSI-DC) from kegs. Don't open keg if content of the keg is under pressure. DHC microbial consortium (TSI-DC) may be stored for up to 3 weeks at temperature 2-4°C without aeration. Avoid freezing.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:	None established.
Ventilation System:	Not expected to require any special ventilation. Provide adequate ventilation to remove odors.
Personal Respirators (NIOSH Approved):	Not expected to require personal respirator usage. If aerosols might be generated, use N95 respirator.
Skin Protection:	Wear protective rubber, nitrile, or vinyl gloves and clean body-covering clothing.
Eye Protection:	Use chemical safety goggles and/or a full face shield where splashing is possible. Provide readily accessible eye wash stations and safety showers.

9. Physical and Chemical Properties

Appearance:	Light greenish, murky liquid.
Odor:	Musty.
Solubility:	Soluble in water.
Specific Gravity (water=1):	1.0. 8.34 pounds per gallon.
pH:	6-8
% Volatiles by volume @ 21C (70F):	Negligible.
Boiling Point:	100C (212F)
Melting Point:	0C (32F)
Flash Point (F):	No information found.
Autoignition Temperature:	No information found.
Decomposition Temperature:	No information found.
Vapor Density (Air=1):	No information found.
Vapor Pressure (mm Hg):	24 mm @ 25C (77F).
Evaporation Rate (BuAc=1):	No information found.
Viscosity @23 C (73 F):	1 centipoises

Partition Coefficient (octanol/water): No information found.

10. Stability and Reactivity

Stability: Stable under ordinary conditions of use and storage.
Reactivity: Not reactive under ordinary conditions.
Hazardous Decomposition Products: None.
Hazardous Polymerization: Will not occur.
Incompatibilities: Strong oxidizers, acids, water reactive materials.
Conditions to Avoid: Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

TSI-DC No information found on toxicology. It is not a carcinogen listed by IARC, NTP, NIOSH, OSHA, or ACGIH. It has tested negative for pathogenic microorganisms such as *Bacillus cereus, Listeria monocytogens, Salmonella* sp., *Pseudomonas* sp., fecal coliform, total coliform, yeast, and mold.

12. Ecological Information

Environmental Fate: No information found.
Environmental Toxicity: No information found.
Degradability: This product is completely biodegradable under both aerobic and anaerobic conditions.
Soil Mobility: This compound will move with groundwater until the adsorbed onto the soil.
Bioaccumulation Potential: No information found.

13. Disposal Considerations

Waste Disposal Method: No special disposal methods are required. The material is compatible with all known biological treatment methods. To reduce odors and permanently inactivate microorganisms, mix 100 parts (by volume) of TSI-DC consortium with 1 part (by volume) of bleach. Dispose of in accordance with local, state and federal regulations.

14. Transport Information

DOT Classification: N/A
Labeling: NA
Shipping Name: Not regulated

15. Regulatory Information

OSHA STATUS: This product is not hazardous under the criteria of the Federal OSHA hazard Communication Standard 29 CFR 1910.1200.

TSCA STATUS: No component of this product is listed on the TSCA inventory.
CERCLA (Comprehensive Response Compensation, and Liability Act): Not reportable.

SARA TITLE III (Superfund Amendments and Reauthorization Act)
Section 312 Extremely Hazardous Substances: None
Section 311/312 Hazard Categories: Non-hazardous Under Section 311/312
Section 313 Toxic Chemicals: None

RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste. (40 CFR 261.20-24)

CALIFORNIA PROPOSITION 65: The following statement is made in order to comply with the California safe Drinking Water and Toxic Enforcement Act of 1986. The product contains no chemicals known to the State of California to cause cancer.

16. Other Information

NFPA Ratings:	Health: **1** Flammability: **0** Reactivity: **0**
Date Prepared:	March 26, 2014
Revision Information:	SDS Section(s) changed since last revision of document include: None.
Disclaimer:	Terra Systems, Inc. provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their independent judgment in determining its appropriateness for a particular purpose. TERRA SYSTEMS, INC. MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE INFORMATION SET FORTH HEREIN OR THE PRODUCT TO WHICH THE INFORMATION REFERS. ACCORDINGLY, TERRA SYSTEMS, INC. WILL NOT BE RESPONSIBLE FOR DAMAGES RESULTING FROM USE OF OR RELIANCE UPON THIS INFORMATION.
Prepared by:	Terra Systems, Inc.
Phone Number:	(302) 798-9553 (U.S.A.)

MATERIAL SAFETY DATA SHEET

SODIUM BICARBONATE, SOLID

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Brenntag Canada Inc.
43 Jutland Rd.
Toronto, ON
M8Z 2G6
(416) 259-8231

WHMIS#:	00060700
Index:	GCD0050/14A
Effective Date:	2014 March 31
Date of Revision:	2014 March 31

Website: http://www.brenntag.ca

EMERGENCY TELEPHONE NUMBER (For Emergencies Involving Chemical Spills or Releases)

1 855 273 6824

PRODUCT IDENTIFICATION

Product Name:	Sodium Bicarbonate, Solid.
Chemical Name:	Carbonic Acid, Monosodium Salt.
Synonyms:	Baking Soda; Bicarbonate of Soda; Sodium Acid Carbonate; Sodium Hydrogen Carbonate; Monosodium Carbonate; Sodium Bicarbonate Tech; Sodium Bicarbonate USP No. 1, No. 4, No. 5; Sodium Bicarbonate Industrial; Sodium Bicarbonate Industrial NSF; Sodium Bicarbonate FG..
Chemical Family:	Sodium salts.
Molecular Formula:	$NaCHO_3$.
Product Use:	Fire extinguishing agent. Pharmaceutical. Baking powder. Chemical intermediate. Food additive.

WHMIS Classification / Symbol:

Not WHMIS Regulated.

READ THE ENTIRE MSDS FOR THE COMPLETE HAZARD EVALUATION OF THIS PRODUCT.

2. COMPOSITION, INFORMATION ON INGREDIENTS (Not Intended As Specifications)

Ingredient	*CAS#*	*ACGIH TLV (TWA)*	*% Concentration*
Sodium Bicarbonate	144-55-8	---	95 - 100

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW:	Low hazard for usual industrial or commercial handling. Dust may cause mechanical irritation to skin, eyes and respiratory tract. See "Other Health Effects" Section. Can decompose at high temperatures forming toxic gases.

POTENTIAL HEALTH EFFECTS

Inhalation:	Product may be mildly irritating to the nose, throat and respiratory tract and may cause coughing and sneezing. Excessive contact with powder may cause drying of mucous membranes of nose and throat due to absorption of moisture and oils. See "Other Health Effects" Section.
Skin Contact:	This product may cause irritation due to abrasive action. Excessive contact with powder may cause drying of the skin due to absorption of moisture and oils.
Skin Absorption:	Not likely to be absorbed through the skin.

Eye Contact:	This product may cause irritation, redness and possible damage due to abrasiveness. Excessive contact with powder may cause drying of mucous membranes of the eyes due to absorption of moisture and oils.
Ingestion:	Ingestion is not a likely route of exposure. This product may cause mild gastrointestinal discomfort.
Other Health Effects:	Low hazard for usual industrial or commercial handling.

May cause central nervous system (CNS) depression, metabolic alkalosis, hypernatremia and pneumoconiosis. CNS depression is characterized by headache, dizziness, drowsiness, nausea, vomiting and incoordination. Severe overexposures may lead to coma and possible death due to respiratory failure.

Pneumoconiosis is the deposition of dust in the lungs and the tissue's reaction to its presence. When exposure to the dust is severe or prolonged, the lungs' defenses are overwhelmed. In general, long-term exposure to high concentrations of dust may cause increased mucous flow in the nose and respiratory system airways. This condition usually disappears after exposure stops. Controversy exists as to the role exposure to dust has in the development of chronic bronchitis (inflammation of the air passages into the lungs). Other factors such as smoking and general air pollution are more important, but dust exposure may contribute.

Sodium salts have a hypothetical risk of hypernatremia. Hypernatraemia is a term that describes an abnormally high plasma concentration of sodium ions. This condition may lead to weakness, restlessness, dizziness, headache, convulsions and coma. (6) Metabolic alkalosis is a condition wherein the concentration of the arterial plasma bicarbonate concentration increases.

4. FIRST AID MEASURES

FIRST AID PROCEDURES

Inhalation:	If respiratory problems arise, move the victim to fresh air. Give artificial respiration ONLY if breathing has stopped. Give cardiopulmonary resuscitation (CPR) if there is no breathing AND no pulse. Obtain medical advice IMMEDIATELY.
Skin Contact:	Start flushing while removing contaminated clothing. Wash affected areas thoroughly with soap and water. If irritation, redness, or a burning sensation develops and persists, obtain medical advice.
Eye Contact:	Immediately flush eyes thoroughly for 5 minutes with running water. Hold eyelids open during flushing. If irritation persists, repeat flushing. Obtain medical attention. Do not allow victim to rub eyes. Do not attempt to manually remove anything stuck to the eye(s). (4)
Ingestion:	Do not attempt to give anything by mouth to an unconscious person. If victim is alert and not convulsing, rinse mouth out and give 1/2 to 1 glass of water to dilute material. DO NOT induce vomiting. If spontaneous vomiting occurs, have victim lean forward with head down to avoid breathing in of vomitus, rinse mouth and administer more water. Obtain medical attention IMMEDIATELY.
Note to Physicians:	Treat symptomatically. Sodium salts have a hypothetical risk of hypernatremia. In addition to calcium levels, sodium and phosphate levels should be monitored.

Medical conditions that may be aggravated by exposure to this product include diseases of the skin, eyes or respiratory tract.

5. FIRE-FIGHTING MEASURES

		Flammability Limits in Air (%):	
Flashpoint (°C)	***AutoIgnition Temperature (°C)***	***LEL***	***UEL***
Not Flammable. (3)	Not available.	Not available.	Not available.

Flammability Class (WHMIS):	Not regulated.
Hazardous Combustion Products:	Thermal decomposition products are toxic and may include soda ash (sodium carbonate), oxides of sodium, carbon and irritating gases.

Sodium bicarbonate begins to decompose at 50°C, releasing carbon dioxide, sodium carbonate and water. Total decomposition occurs at 270°C. (4)

Unusual Fire or Explosion Hazards:	Avoid accumulation and dispersion of dust. Spilled material may cause floors and contact surfaces to become slippery. Do not flush with water as aqueous solutions or powders that become wet render surfaces extremely slippery. Enforce NO SMOKING rules.
Sensitivity to Mechanical Impact:	Not expected to be sensitive to mechanical impact.
Rate of Burning:	Not available.

Explosive Power:	Not available.
Sensitivity to Static Discharge:	Not expected to be sensitive to static discharge.

EXTINGUISHING MEDIA

Fire Extinguishing Media:	Is used as an extinguishing agent for all classes of fires. Use media appropriate for surrounding fire and/or materials.

FIRE FIGHTING INSTRUCTIONS

Instructions to the Fire Fighters:	Isolate materials that are not involved in the fire and protect personnel. Do not flush with water as aqueous solutions or powders that become wet render surfaces extremely slippery. Spilled material may cause floors and contact surfaces to become slippery.
Fire Fighting Protective Equipment:	Use self-contained breathing apparatus and protective clothing.

6. ACCIDENTAL RELEASE MEASURES

Information in this section is for responding to spills, leaks or releases in order to prevent or minimize the adverse effects on persons, property and the environment. There may be specific reporting requirements associated with spills, leaks or releases, which change from region to region.

Containment and Clean-Up Procedures:	In all cases of leak or spill contact vendor at Emergency Number shown on the front page of this MSDS. Minimize air borne spreading of dust. Wear respirator, protective clothing and gloves. Avoid dry sweeping. Do not use compressed air to clean surfaces. Vacuuming or wet sweeping is preferred. Return all material possible to container for proper disposal. Do not allow to enter sewers or watercourses. Any recovered product can be used for the usual purpose, depending on the extent and kind of contamination. Where a package (drum or bag) is damaged and / or leaking, repair it, or place it into an over-pack drum immediately so as to avoid or minimize material loss and contamination of surrounding environment. Replace damaged containers immediately to avoid loss of material and contamination of surrounding atmosphere. Ventilate enclosed spaces. Notify applicable government authority if release is reportable or could adversely affect the environment.

7. HANDLING AND STORAGE

HANDLING

Handling Practices:	Use normal "good" industrial hygiene and housekeeping practices. Avoid accumulation and dispersion of dust. Clean up immediately to eliminate slipping hazard.
Ventilation Requirements:	See Section 8, "Engineering Controls".
Other Precautions:	Use only with adequate ventilation and avoid breathing dusts. Avoid contact with eyes, skin or clothing. Wash thoroughly with soap and water after handling. Wash contaminated clothing thoroughly before re-use.

STORAGE

Storage Temperature (°C):	See below.
Ventilation Requirements:	General exhaust is acceptable.
Storage Requirements:	Store in a cool, dry and well-ventilated area. Keep away from heat, sparks and flames. Keep containers closed. Avoid moisture contamination. Prolonged storage may result in lumping or caking. Protect from direct sunlight. Protect against physical damage.
Special Materials to be Used for Packaging or Containers:	Materials of construction for storing the product include: Multi-layer bags or sacks. Confirm suitability of any material before using.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Recommendations listed in this section indicate the type of equipment, which will provide protection against overexposure to this product. Conditions of use, adequacy of engineering or other control measures, and actual exposures will dictate the need for specific protective devices at your workplace.

ENGINEERING CONTROLS

Engineering Controls:	General exhaust is acceptable. Local exhaust ventilation preferred. Make up air should be supplied to balance air that is removed by local or general exhaust ventilation. Ventilate low lying areas such as sumps or pits where dense dust may collect.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

Eye Protection:	Safety glasses with side shields are recommended to prevent eye contact. Use chemical safety goggles when there is potential for eye contact. Contact lenses should not be worn when working with this material.
Skin Protection:	Gloves and protective clothing made from cotton, leather, rubber or plastic should be impervious under conditions of use. Prior to use, user should confirm impermeability. Discard contaminated gloves.
Respiratory Protection:	No specific guidelines available. A NIOSH/MSHA approved dust mask for concentrations of nuisance dust up to 100 mg/m³ particulate. An air-supplied respirator if concentrations are higher or unknown.
Other Personal Protective Equipment:	Wear regular work clothing. The use of coveralls is recommended. Locate safety shower and eyewash station close to chemical handling area. Take all precautions to avoid personal contact.

EXPOSURE GUIDELINES

Particulate Not Otherwise Classified:

ACGIH	OSHA
10 mg/m³ - Inhalable particulate	50 mppcf* or 15 mg/m³ - Total Dust
3 mg/m³ - Respirable particulate	15 mppcf* or 5 mg/m³ - Respirable Fraction

* mppcf = million particles per cubic foot

9. PHYSICAL AND CHEMICAL PROPERTIES (Not intended as Specifications)

Physical State:	Solid.
Appearance:	White granular solid.
Odour:	Odourless.
Odour Threshold (ppm):	Not applicable.
Boiling Range (°C):	Not available.
Melting/Freezing Point (°C):	Not applicable.
Vapour Pressure (mm Hg at 20° C):	Not available.
Vapour Density (Air = 1.0):	Not applicable.
Relative Density (g/cc):	2.22. (3)
Bulk Density:	500 - 1 200 kg/m³. (3)
Viscosity:	Not applicable.
Evaporation Rate (Butyl Acetate = 1.0):	Not applicable.
Solubility:	Soluble in water. Hygroscopic (readily absorbs water).
% Volatile by Volume:	Not available.
pH:	8.3 - 8.6 (1 % solution). (3)
Coefficient of Water/Oil Distribution:	Not available.
Volatile Organic Compounds (VOC):	Not applicable.
Flashpoint (°C):	Not Flammable. (3)

10. STABILITY AND REACTIVITY

CHEMICAL STABILITY

Under Normal Conditions:	Stable.
Under Fire Conditions:	Not flammable.
Hazardous Polymerization:	Will not occur.
Conditions to Avoid:	High temperatures, sparks, open flames and all other sources of ignition. Minimize air borne spreading of dust. Avoid direct sunlight. Avoid moisture contamination. Hygroscopic.
Materials to Avoid:	Strong oxidizers. Lewis or mineral acids. Vigourous effervescence results on mixture with acids. Potassium-Sodium alloys. Monoammonium Phosphate. 2-Furaldehyde. (4)
Decomposition or Combustion Products:	Thermal decomposition products are toxic and may include soda ash (sodium carbonate), oxides of sodium, carbon and irritating gases. Sodium bicarbonate begins to decompose at 50°C, releasing carbon dioxide, sodium carbonate and water. Total decomposition occurs at 270°C. (4)

11. TOXICOLOGICAL INFORMATION

TOXICOLOGICAL DATA:

SUBSTANCE	***LD50 (Oral, Rat)***	***LD50 (Dermal, Rabbit)***	***LC50 (Inhalation, Rat, 4h)***
Sodium Bicarbonate	4 220 mg/kg (1)	---	---

Carcinogenicity Data:	The ingredient(s) of this product is (are) not classed as carcinogenic by ACGIH, IARC, OSHA or NTP.
Reproductive Data:	No adverse reproductive effects are anticipated.
Mutagenicity Data:	No adverse mutagenic effects are anticipated.
Teratogenicity Data:	No adverse teratogenic effects are anticipated.
Respiratory / Skin Sensitization Data:	None known.
Synergistic Materials:	None known.
Other Studies Relevant to Material:	Application of 0.2 g of 100 % Sodium Bicarbonate caused moderate eye irritation lasting at least 7 days. In another study, application of 0.86 g caused slight redness. Application to the skin of 0.3 g for 4 hours caused very slight irritation in 1/3 animals tested (graded 0.11 out of 8). (4) An increase in bladder cancer was observed in rats fed a known carcinogen for 4 weeks, then 3 % Sodium Bicarbonate in the diet for 32 weeks, compared to animals receiving only the know carcinogen. An increase in bladder cancer was also observed in rats fed 0.64 % Sodium Bicarbonate and 1.25 % of another known carcinogen for 104 weeks (compared to the non-exposed animals). An increase in DNA synthesis and morphological alterations in the bladder epithelium was observed after feeding rats 3 % Sodium Bicarbonate in their diets for 8 weeks. These studies were conducted to investigate the mechanism by which carbonate salts promote bladder cancer in animals exposed to known carcinogen. (4) No adverse effects were observed after feeding up to 580 mg/Kg to mice, up to 340 mg/Kg to rats and up to 330 mg/Kg to rabbits. Screening tests using both yeast and bacterial cultures were negative with and without metabolic activation. (4)

12. ECOLOGICAL INFORMATION

Ecotoxicity:	May be harmful to aquatic life. Sodium Bicarbonate: 96-hour LC50 (Lepomis macrochirus) = 7 100 mg/l. (3) 48-hour LC50 (Culex sp. Larvae or mosquito) = 2 000 mg/l. (3)
Environmental Fate:	Product has an unaesthetic appearance and can be a nuisance. Can be dangerous if allowed to enter drinking water intakes. Do not contaminate domestic or irrigation water supplies, lakes, streams, ponds, or rivers.

13. DISPOSAL CONSIDERATIONS

Deactivating Chemicals:	None required.
Waste Disposal Methods:	This information applies to the material as manufactured. Reevaluation of the product may be required by the user at the time of disposal since the product uses, transformations, mixtures and processes may influence waste classification. Dispose of waste material at an approved (hazardous) waste treatment/disposal facility in accordance with applicable local, provincial and federal regulations. Do not dispose of waste with normal garbage, or to sewer systems.
Safe Handling of Residues:	Empty containers retain product residue. No special treatment required.
Disposal of Packaging:	Recycling is encouraged. Treat package in the same manner as the product. Empty package may be disposed of with normal garbage.

14. TRANSPORTATION INFORMATION

CANADIAN TDG ACT SHIPPING DESCRIPTION:

This product is not regulated by TDG.

Label(s): Not applicable. Placard: Not applicable.

ERAP Index: -----. Exemptions: None known.

US DOT CLASSIFICATION (49CFR 172.101, 172.102):

This product is not regulated by DOT.

Label(s): Not applicable. Placard: Not applicable.

CERCLA-RQ: Not available. Exemptions: Not available.

15. REGULATORY INFORMATION

CANADA

CEPA - NSNR:	This material is included on the DSL under the CEPA.
CEPA - NPRI:	Not included.
CANADIAN FOOD AND DRUG ACT/REGULATIONS:	The use of this material/product as a food additive is regulated by Health Canada in the Food and Drug Act and the Food and Drug Regulations. It is incumbent on the user of this material/product to ensure any intended food application is consistent with Health Canada guidelines. Food Grade designation in no way implies that the product is safe for consumption by humans.

Controlled Products Regulations Classification (WHMIS):

Not WHMIS Regulated.

USA

Environmental Protection Act:	This material is included on the TSCA Inventory.
OSHA HCS (29CFR 1910.1200):	Not regulated.
U.S. FOOD AND DRUG ADMINISTRATION:	This material/product is regulated for use by the US FDA. It is incumbent on the user of this material/product to ensure any intended food application is consistent with US FDA guidelines. Food Grade designation in no way implies that the product is safe for consumption by humans.

NFPA: 0 Health, 0 Fire, 0 Reactivity (3)

HMIS: 0 Health, 0 Fire, 0 Reactivity (3)

INTERNATIONAL

Sodium Bicarbonate is found on the following inventories: EINECS (European Inventory of Existing Commercial Chemical Substances).

16. OTHER INFORMATION

REFERENCES

1. RTECS-Registry of Toxic Effects of Chemical Substances, Canadian Centre for Occupational Health and Safety RTECS database.
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6. Regulatory Affairs Group, Brenntag Canada Inc.
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British Columbia: 20333-102B Avenue, Langley, BC, V1M 3H1
Phone: (604) 513-9009 Facsimile: (604) 513-9010

Alberta: 6628 - 45 th. Street, Leduc, AB, T9E 7C9
Phone: (780) 986-4544 Facsimile: (780) 986-1070

Manitoba: 681 Plinquet Street, Winnipeg, MB, R2J 2X2
Phone: (204) 233-3416 Facsimile: (204) 233-7005

Ontario: 43 Jutland Road, Toronto, ON, M8Z 2G6
Phone: (416) 259-8231 Facsimile: (416) 259-5333

Quebec: 2900 Jean Baptiste Des., Lachine, PQ, H8T 1C8
Phone: (514) 636-9230 Facsimile: (514) 636-0877

Atlantic: A-105 Akerley Boulevard, Dartmouth, NS, B3B 1R7
Phone: (902) 468-9690 Facsimile: (902) 468-3085

Prepared By: Regulatory Affairs Group, Brenntag Canada Inc., (416) 259-8231.

CDM
Smith