REPORT

SITE CHARACTERIZATION REPORT

September 9, 2015
Project No.: 1524461

Submitted to

Mid-Atlantic Regional Spaceport

VIRGINIA COMMERCIAL SPACE FLIGHT AUTHORITY
NASA Wallops Flight Facility
Wallops Island, VA

Golder Associates

SITE CHARACTERIZATION REPORT

Mid-Atlantic Regional Spaceport, Wallops Island, Virginia

Submitted To: Daryl Moore, Safety & Environmental Manager
Virginia Commercial Space Flight Authority
Mid-Atlantic Regional Spaceport
Bldg. N-134, NASA Wallops Flight Facility
Wallops Island, VA 23337

Dale K. Nash, Executive Director
Virginia Commercial Space Flight Authority
4111 Monarch Way, Suite 303
Norfolk, VA 23508

Submitted By: Golder Associates Inc.
2108 W. Laburnum Avenue, Suite 200
Richmond, VA 23227

Date: September 9, 2015

Project No. 1524461

A world of capabilities delivered locally

Golder, Golder Associates and the GA globe design are trademarks of Golder Associates Corporation

September 9, 2015

Golder Reference No.: 1524461

Virginia Commercial Space Flight Authority
Mid-Atlantic Regional Spaceport
Bldg. N-134, NASA Wallops Flight Facility
Wallops Island, VA 23337

Attn: Mr. Daryl Moore, Safety & Environmental Manager

RE: SITE CHARACTERIZATION REPORT
MID-ATLANTIC REGIONAL SPACEPORT, WALLOPS ISLAND, VIRGINIA

Dear Mr. Moore:

Golder Associates, Inc. (Golder) is pleased to submit the attached report titled "Site Characterization Report, Mid-Atlantic Regional Spaceport, Wallops Island, Virginia." The study has been conducted in accordance with the approved *Preliminary Screening Work Plan* dated June 22, 2015, and Golder proposal dated May 6, 2015. The purpose of the site characterization study is to document groundwater flow directions and the possible presence and extent of perchlorate and diesel-range volatile organics resulting from the October 2014 Antares launch failure. The incident resulted in the formation of a crater near the launch pad and the release of rocket fuel consisting primarily of RP-1, a highly refined form of kerosene, and ammonium perchlorate, which are the main constituents of concern (COC). The information gathered from this investigation will be used to characterize the site sufficiently to determine if a No Further Action remedy can be recommended based on a site-specific risk assessment, which will be completed following two additional rounds of groundwater sampling from selected monitoring wells in August and September, 2015.

If you have any questions or require any additional information, please do not hesitate to contact us at (804) 358-7900.

Sincerely,
GOLDER ASSOCIATES INC.

Brent B. Waters, C.P.G.
Principal Hydrogeologist

Michael Williams, C.P.G.
Senior Consultant

cc: Dale K. Nash, Executive Director, Virginia Commercial Space Flight Authority (electronic copy)

Attachments: Site Characterization Report

Table of Contents

EXECUTIVE SUMMARY 1
1.0 INTRODUCTION 2
1.1 Scope of Work 2
2.0 HYDROGEOLOGIC SETTING 4
2.1 Topography and Surface Water Drainage 4
2.2 Adjacent Land Cover / Land Use 5
2.3 Climate 5
2.4 Geology 6
2.5 Hydrogeology 9
2.5.1 Surficial Aquifer 9
2.5.2 Yorktown-Eastover Aquifer System 9
2.6 Groundwater Occurrence and Flow 9
3.0 DETAILED SITE CHARACTERIZATION 11
3.1 Soil Boring Investigation and Temporary Piezometer Installations 11
3.2 Groundwater Flow Directions 14
3.3 External Influences on Groundwater Levels 16
3.3.1 Barometric Influences 16
3.3.2 Precipitation Influences 17
3.3.3 Tidal Influences 17
4.0 WATER QUALITY RESULTS 19
4.1 Water Sampling Procedures 19
4.2 Water Quality Results 19
5.0 CONCLUSIONS AND RECOMMENDATIONS 22
6.0 REFERENCES 24

Table of Contents, continued

List of Tables

Table 1 Summary of Climatic Data for Accomack County, VA. 5
Table 2 Geologic Formations and Hydrogeologic Units 7
Table 3 Monitoring Well Construction Details and Synoptic Groundwater Level Measurements 13
Table 4 Summary of Water Quality Results (Detected Parameters Only) 20

List of Figures

Figure 1 General site location map showing approximate location of the Launch Pad 0A on Wallops Island 4
Figure 2 General geologic map of Accomack County 7
Figure 3 Geologic cross section A-A' from Hillis-Carnes Engineering Associates, Inc. 8
Figure 4 Schematic of a freshwater lens in island or peninsula setting 10
Figure 5 Soil boring, piezometer, and cross-section location map 12
Figure 6 Geologic Cross-sections (A-A' and B-B') Across the Area of Concern 13
Figure 7 Groundwater Table Contour Map (June 30, 2015) 15
Figure 8 Groundwater Table Contour Map (July 21, 2015) 15
Figure 9 Hydrographs of Groundwater Levels, Tides, and Precipitation 17
Figure 10 Water Quality Results (June 30, 2015) 21

List of Appendices

Appendix A Photographic Documentation of Field Investigation
Appendix B Soil Boring and Piezometer Construction Logs
Appendix C Micropurge Sampling Logs and Water Quality Laboratory Reports

EXECUTIVE SUMMARY

The Virginia Commercial Space Flight Authority through its Subconsultant, Golder Associates, has completed an initial screening-type site characterization investigation at Pad-0A at the Mid-Atlantic Regional Spaceport located at NASA's Wallops Flight Facility in Accomack County, Virginia. The investigation was performed to characterize groundwater quality and groundwater flow directions in the vicinity of the October 2014 Antares launch failure, which resulted in the release of rocket fuel consisting primarily of RP-1, a highly refined form of kerosene, and ammonium perchlorate. The primary area of potential concern from this incident is a former crater area located seaward of the launch pad where approximately 241 tons of soil and 400,000 gallons of groundwater were removed as part of the initial response activities for the site. As part of this investigation, 13 piezometers were installed and sampled for VOCs, SVOCs, and perchlorate. In addition, a detailed study of groundwater flow directions and external influences on groundwater flow directions was conducted to determine likely groundwater flow pathways in the vicinity of the area of concern.

The results of the investigation reveal that low concentrations of benzene, toluene, ethylbenzene, xylenes, styrene and perchlorate are present in the groundwater near and immediately downgradient of the former crater that formed during the explosion of the Antares rocket. With the exception of benzene and perchlorate, the constituent of concern concentrations are mostly below the Laboratory Quantitation Limits. Benzene was detected at one location with a concentration above the United States Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) for Benzene of 5 µg/L and perchlorate was detected at two locations with concentrations above the EPA Interim Lifetime Drinking Water Health Advisory of 15 µg/L. None of the reported constituents of concern concentrations exceeded the Virginia Department of Environmental Quality (DEQ) Voluntary Remediation Program (VRP) Tier III Commercial Groundwater Screening Level, which are designated as the groundwater protection standards for the site.

1.0 INTRODUCTION

Golder Associates Inc. (Golder) is pleased to present the Virginia Commercial Space Flight Authority (VCSFA) the results from the preliminary screening investigation at Pad-0A of the Mid-Atlantic Regional Spaceport (MARS) located on the National Aeronautics and Space Administration (NASA) Wallops Flight Facility (WFF) in Accomack County, Virginia. The purpose of the screening investigation is to help further characterize groundwater quality and groundwater flow directions in the vicinity of the October 2014 Antares launch failure. The October 2014 incident resulted in the release of rocket fuel consisting primarily of RP-1, a highly refined form of kerosene, and ammonium perchlorate, most of which reportedly oxidized in the ensuing fire (ORB-3 Mishap Environmental Summary Report, March 2015). VCSFA and NASA conducted extensive emergency abatement activities at the site, which included removing approximately 241 tons of soil and 400,000 gallons of groundwater from the crater, or area of concern (AOC), next to the launch pad. As a result of these cleanup measures, the concentrations of perchlorate and diesel-range organics (DRO), which are the main constituents of concern (COC) in the groundwater near the crater, reportedly decreased by 96 to 99.99 percent, respectively by December 2014. The crater has since been backfilled and equipped with a gravel drain accessible with a standpipe if further pumping or sampling is warranted.

Based on the investigative results obtained through December 2014, the Virginia Department of Environmental Quality (DEQ) requested additional investigations to identify the nature and extent of any remaining groundwater impacts. The results presented herein document the findings from the recently completed investigation. The information from this investigation will be used to optimize a groundwater monitoring system (GMS) for future groundwater monitoring activities and will be used to determine if a No Further Action remedy can be recommended. Delineation of the extent of potential COCs and future groundwater monitoring will be critical steps in complying with requirements of the DEQ under a Voluntary Remediation Program (VRP) and will assist with site closure.

1.1 Scope of Work

The purpose of the investigation was to help delineate the horizontal extent of COCs. As originally proposed, this information would then be used to optimize the number of recommended wells in the *GMS Work Plan* to be submitted to the DEQ following the completion of this preliminary investigation. The scope of work completed during this preliminary investigation included:

- Thirteen (13) temporary 1-inch piezometers were installed at locations approved by the DEQ using direct-push technology (*e.g.*, Geoprobe®). Continuous core samples were completed to a depth of 15 feet below ground surface (ft bgs) or greater in some instances, generally into the top of a laterally extensive shallow clay layer previously delineated beneath Pad-0A in recent geotechnical borings. Soil cores were logged in the field by a qualified geologist from Golder. The investigation-derived wastes (IDW), including soil cores, were containerized for disposal based on characterization results.

- The temporary piezometers were screened across the water table and were typically constructed with 10 feet of 1-inch inner diameter (ID) 0.010-inch slotted polyvinyl chloride (PVC) screen, 5 feet of PVC riser pipe, and 2.5 feet of stickup. After setting the well screen and casing, the annular space in the borehole was filled with #1 silica sand to at least 2 feet above the top of the screen. The remaining annulus was filled to grade with a high-solids hydrated bentonite grout.
- The piezometers were positioned at varying distances extending radially away from the center of the AOC. Additional piezometers were located near possible surface water discharge points including the Atlantic Ocean, Ponds 1, 2, 3, and 4, the LOX Dump Pond, and the Deluge Retention Pond.
- The piezometers were developed using a surge block and a pump to remove silts and other fines in order to improve the hydraulic connection with the water table aquifer. IDW, including piezometer development water, was containerized and awaits characterization for disposal.
- The piezometers were subsequently sampled using low flow or micropurge sampling procedures. Wells were purged and sampled with a peristaltic pump and disposable tubing. During the micropurge, samples will be obtained every 3 to 5 minutes for analysis of pH, temperature, specific conductivity, dissolved oxygen, oxidation-reduction potential (ORP), and turbidity using a flow-through cell and a field calibrated water quality meter to determine when water quality stabilized for sampling.
- The groundwater samples were placed in a cooler on ice under chain-of-custody control, shipped to a state-accredited laboratory, and analyzed volatile organic compounds (VOCs) using EPA SW-846 Method 624, semi-volatile organic compounds (SVOCs) using EPA SW-846 Method 625, and perchlorate using EPA SW-846 Method 6850.
- Synoptic groundwater elevation data was collected during high tide and low tide to determine temporal variations in hydraulic gradients and groundwater flow directions. Six piezometers were equipped with water level data loggers to record water level changes on a near-continuous basis for a period of 3 weeks to ensure that tidal influences on groundwater levels and flow gradients are understood. Groundwater levels were monitored during a spring tide and neap tide cycle.
- The piezometers were surveyed horizontally to the nearest 0.1 feet and vertically to the nearest 0.01 feet using a differential global positioning system (GPS) and a licensed professional surveyor.
- This preliminary report has been prepared to document field investigative procedures and our findings from this preliminary investigation. The report includes soil boring logs, piezometer construction diagrams, hydrogeologic cross sections, groundwater level hydrographs illustrating external influences such as tides and precipitation, groundwater contour maps, groundwater flow directions, estimates of groundwater flow velocity, and analytical results in table format and graphically on plan view groundwater contour maps.

2.0 HYDROGEOLOGIC SETTING

2.1 Topography and Surface Water Drainage

The MARS facility is located on Wallops Island, a barrier island along the Atlantic Coast south of Assateague Island. The facility is bordered by the Atlantic Ocean to the east and by marshland surrounding Hog Creek and Woman's Bay to the west (Figure 1). The topography is generally flat on the island with the highest elevations found along the upper beachfront-dune area sloping either steeply towards the Atlantic Ocean or gently towards the back-barrier bay and marsh area. The upper shoreline and the back-bay perimeter road have been built up artificially to reduce impacts from flooding. On the launch pad, surface water drains towards a series of ponds that are interconnected so that surface water drains sequentially from Pond 4 to Pond 1. Pond 1 is connected directly to a dredged tidal channel into Hog Creek. During periods of low rainfall, standing water in the ponds is likely predominantly groundwater and the surface elevation of the ponds likely represent the surface of the groundwater table.

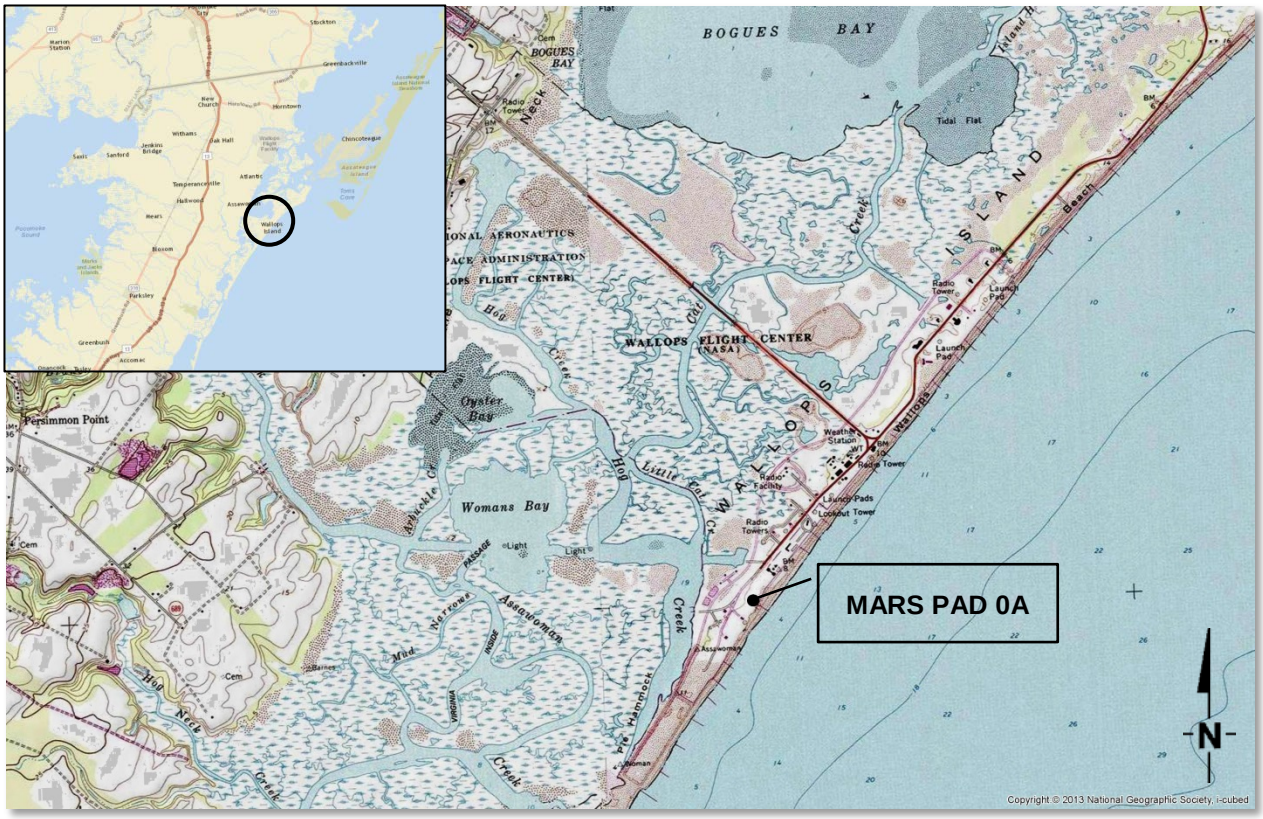


Figure 1 - General site location map showing approximate location of the Launch Pad-0A on Wallops Island.

2.2 Adjacent Land Cover / Land Use

Surrounding lands are comprised of beach and tidal marsh or open water environments. The land is owned by NASA and has historically been used as a rocket launch facility and will continue to be used as a launch facility into the foreseeable future. It is highly unlikely that the property will ever be transferred to private ownership or that it will accommodate permanent residential human inhabitation. Furthermore, the groundwater on the island is not potable and is not currently and will likely never be used as a drinking water source. Google Map Imagery© of the site is presented here.

2.3 Climate

The Eastern Shore Region of Virginia has a subtropical climate with hot, humid summers and cool to mild winters. The climate is tempered by its low elevation and the proximity and moderating presence of the Chesapeake Bay and the Atlantic Ocean. Temperature and precipitation data were obtained from the Southeast Regional Climate Center (SERCC, http://www.sercc.com/) for the Painter 2W observation station (COOP ID 446475-1) for the period of record between 1955 to 2010, and National Climatic Data Center for Wallops Island Wallops Flight Facility (GHCND:USW00093739). Based on this data, average temperatures in January are about 39°F and in July are about 78°F. These temperatures provide growing seasons of up to eight months. The average snowfall during the winter is between 9 and 10 inches. The average snowfall depth is 0 inches for all winter months, indicating that ice and snow does not persist for long periods of time due to the mild temperate climate and the moderating effects of surrounding water bodies. The average annual precipitation is 42 inches at the Wallops Island station. Monthly precipitation varies seasonally between 2.8 and 4.2 inches; with the highest precipitation generally observed in March, July and August, and the lowest in February and November. Annually, the wettest year on record at Wallops Island occurred in 2009 with a total of 62.83 inches. Over the last 10 years, wet years, with more than 50 inches of recorded precipitation, occurred in 2004 and 2009.

Table 1: Summary of Climatic Data for Accomack County, VA

Month	Average Precipitation Wallops Is.	Average Precipitation Painter	Potential Evapotran-spiration PET Painter	Average Temperature Painter	Average Snowfall Painter
	inches	inches	inches	°F	inches
January	3.04	3.48	0.18	38.7	3.9
February	2.76	3.22	0.25	40.4	2.7
March	4.00	4.16	0.89	47.6	1.2
April	3.07	3.12	2.06	56.2	0.1
May	2.95	3.38	3.66	65.2	0
June	3.29	3.82	5.14	73.5	0
July	4.09	4.61	6.07	78.3	0
August	4.19	4.17	5.50	76.5	0
September	3.98	3.6	3.93	70.9	0
October	3.17	3.66	2.20	60.2	0

Month	Average Precipitation Wallops Is.	Average Precipitation Painter	Potential Evapotran-spiration PET Painter	Average Temperature Painter	Average Snowfall Painter
November	2.87	2.99	1.02	51.3	0
December	3.43	3.62	0.37	42.9	1.6
Total	**41.90**	**43.82**	**31.27**	**58.5**	**9.4**

Notes: Precipitation data for Wallops Is. presented are 30-yr normals based on years 1981-2010. Mean Temperature for Painter are 30-yr normals based on years 1971-2000. Painter precipitation and snowfall data are calculated from the period of record (59 years). Source: Southeast Regional Climate Center (http://www.sercc.com/climateinfo/historical/historical_va.html)

2.4 Geology

The site is located within the easternmost part of Virginia's Coastal Plain physiographic province and is underlain by unconsolidated sedimentary deposits that thicken and dip southeastward and extend to a depth of approximately 5,000 ft bgs. These sediments date from early Cretaceous through the present and were deposited during a series of marine transgressions and regressions separated by intervals of non-deposition and erosion. The lower 70% of the sediments are of Early to Late Cretaceous age and were deposited in fluvial environments. The remaining 30% of the sediments are Tertiary and Quaternary (Cenozoic) in age and were deposited in mostly marine environments. The Yorktown and Eastover Formations underlie the Virginia portion of the Eastern Shore and consist of shelly, very-fine to coarse quartz sand interbedded with sandy and silty clay to clayey silt that ranges between approximately 100 to 300 feet thick. These formations are stratigraphically equivalent to the Pensauken Formation (*i.e.*, Pocomoke aquifer) in southern Maryland. Table 2 summarizes the local geologic formations and their equivalent hydrogeologic units in the Eastern Shore region of Virginia and Maryland.

During the Pleistocene glaciations, sea levels fluctuated by up to 300 feet producing a wide range of depositional environments. River channels were eroded across the Eastern Shore into previously deposited Yorktown sediments as deep as 200 feet and then were filled during high sea level stands. Three such major paleochannels are known to exist near the towns of Cape Charles, Eastville, and Exmore (Mixon, 1985). Additional paleochannels are located near Salisbury, Maryland (Mixon, 1985). The remaining Pleistocene and post-glaciation Holocene sediments were deposited in marginal-marine and estuarine environments, including salt-marsh, back-bay, bayside and oceanside terraces and barrier-island sediments. The sediments of Quaternary age range in thickness from approximately 40-150 feet.

Figure 2 presents a generalized geologic map of Accomack County. The seaward side of Wallops Island is underlain by Quaternary-age sand (Qs) described as pale gray to light yellowish gray, fine to coarse, shelly sand deposited in a coastal barrier island and narrow beach-dune ridge environment. Deposits are typically up to 40 feet thick. The area between the mainland and the barrier-beach complex is underlain by soft organic mud and sandy mud (Qm and Qsm) described as medium to dark gray mud and peat locally containing abundant shell material and sand. These deposits are typically found in shallow bays

and tidal creeks and typically range up to 30 feet thick (Mixon, 1985; Mixon and Powars, 1985). During the post-glaciation transgressive sequence, the barrier shoreline complex has likely migrated from east to west over finer-grained, lower energy near-shore and back-barrier marsh and tidal flat deposits. This sequence has been observed in geotechnical borings where 15 to 20 feet of beach sand is observed over fine-grained mud and peat deposits that are reported to be 20 to 40 feet in thickness (Figure 3).

Table 2 - Geologic formations and hydrogeologic units of the Cenozoic Sediments of the Eastern Shore of Virginia and Maryland (Adapted from Sanford and others, 2009).

GEOLOGIC EPOCH AND AGE	GEOLOGIC FORMATIONS			HYDROGEOLOGIC UNITS	
	Virginia Eastern Shore		Maryland Eastern Shore	Virginia Eastern Shore	Southeastern Maryland
	Bayside	Oceanside			
Holocene 0.01 My	Bay tidal muds	Bay tidal muds and barrier dunes	Bay tidal muds and barrier dunes	Surficial or "Columbia" aquifer	Absent
Pleistocene	Kent Island Formation	Wachapreague Formation	Parsonsburg Sand		Columbia aquifer
			Kent Island Formation		
		Joynes Neck Sand	Sinepuxent Formation		
	Nassawadox Formation		Ironshire Formation		
	Omar Formation				
1.8 My	Absent		Walston Silt		
			Beaverdam Sand		
Pliocene	Yorktown Formation		Absent	Upper Yorktown-Eastover confining unit	Absent
				Upper Yorktown-Eastover aquifer	Pocomoke aquifer
				Middle Yorktown-Eastover confining unit	
5.3 My			Pensauken Formation	Middle Yorktown-Eastover aquifer	
				Lower Yorktown-Eastover confining unit	
Miocene	Eastover Formation		Manokin Formation	Lower Yorktown-Eastover aquifer	
	St. Marys Formation			St. Marys confining unit	
	Choptank Formation				
23.8 My	Calvert Formation				

EXPLANATION

Chesapeake Group | Aquifer | Confining unit

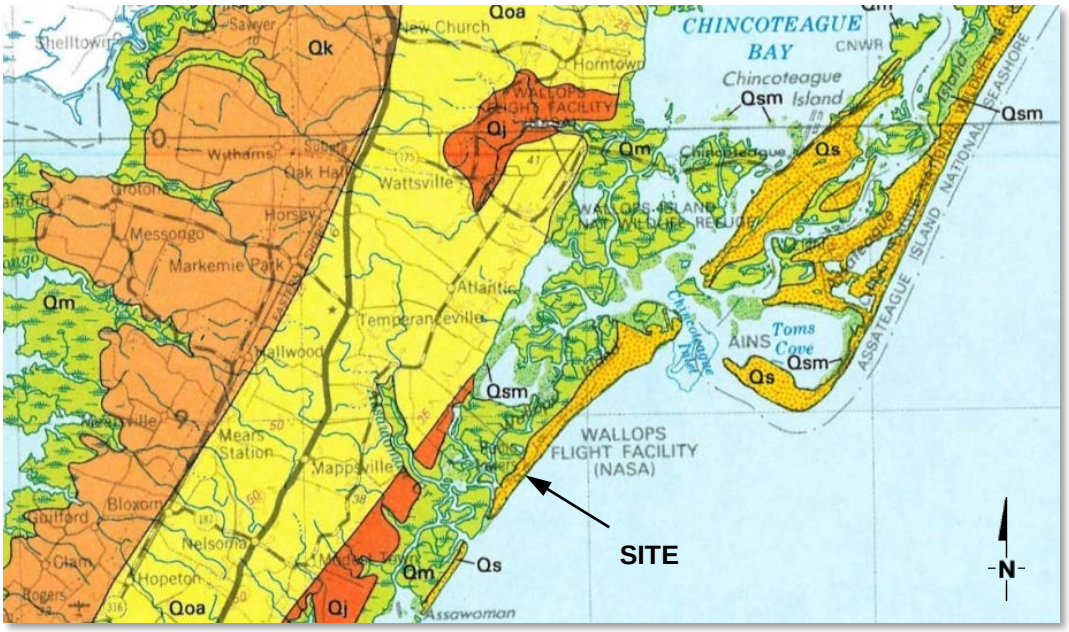


Figure 2 - General geologic map of Accomack County (Mixon and others, 1989)

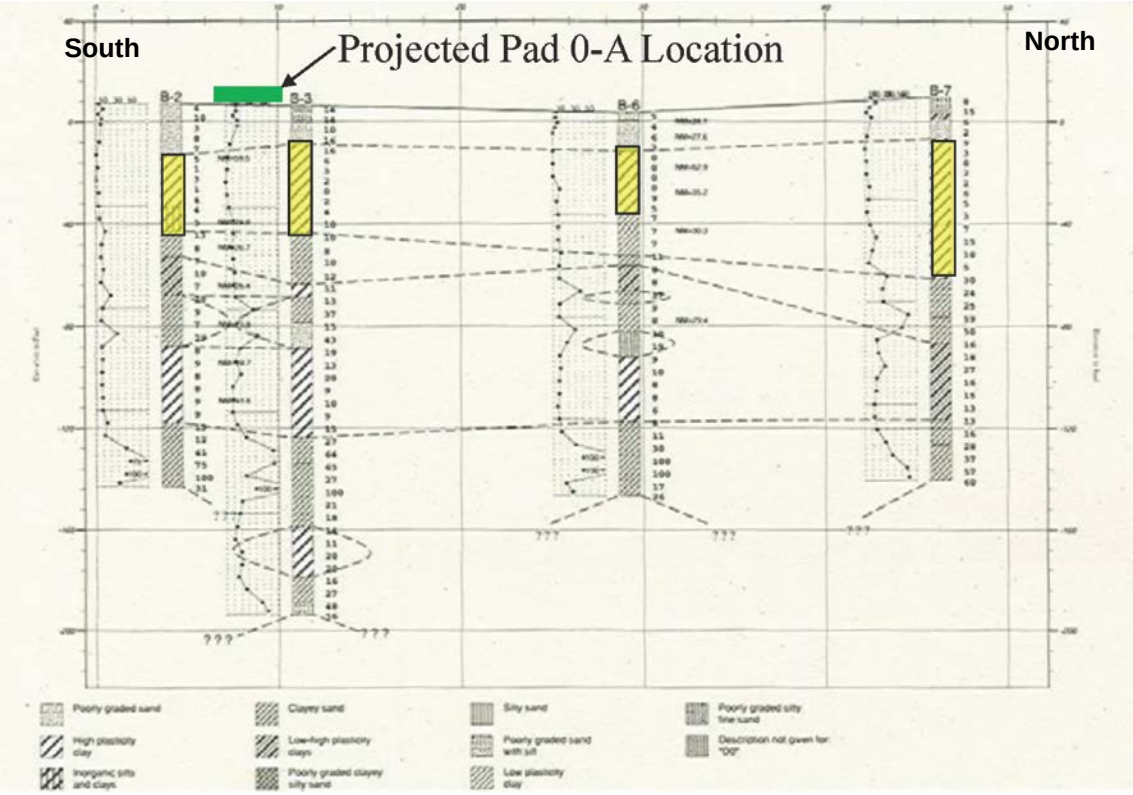


Figure 3 – Geologic cross section A-A' from Hillis-Carnes Engineering Associates, Inc. dated February, 2009. The yellow highlighted area is described as a high plasticity clay.

2.5 Hydrogeology

2.5.1 Surficial Aquifer

The surficial aquifer is unconfined and consists primarily of Quaternary sand deposits (Qs) described in Section 3.4. The aquifer is thin, only approximately 15 to 20 feet thick, and overlies fine-grained silt and clay confining unit deposits that appear to be over 20 feet thick (Figure 3; Hillis-Carnes, 2009). Estimates of hydraulic conductivity are unknown at this time, but based on the United States Geological Survey (USGS) Eastern Shore Groundwater Flow Model (Sanford *et al.*, 2009), the calibrated hydraulic conductivity for the model cell occupying Wallops Island is approximately 75 ft/day.

2.5.2 Yorktown-Eastover Aquifer System

The upper Yorktown-Eastover (UYE) aquifer underlies the surficial aquifer, separated by greenish-gray silty clay belonging to the UYE confining unit that has an estimated vertical hydraulic conductivity of 1.39 x 10^{-5} ft/day (Richardson, 1994). The UYE aquifer consists of greenish-gray, fine to medium-grained, glauconitic quartz sands with some fine pebbly gravel. The UYE aquifer has a calibrated hydraulic conductivity of approximately 25 ft/day and thickness of 65 feet based on the Eastern Shore Model. The middle Yorktown-Eastover (MYE) aquifer consists of greenish-gray, fine to very coarse-grained, shelly, glauconitic, and pebbly quartz sands. The lower Yorktown-Eastover (LYE) aquifer consists primarily of fine-grained to very fine-grained, greenish-gray, clayey, silty, and shelly quartz sand. The LYE aquifer is brackish and not used for public water supplies in northeastern Accomack County.

2.6 Groundwater Occurrence and Flow

Limited fresh groundwater supplies exist on narrow barrier island complexes such as Wallops Island. The island is narrow and is bordered by the Atlantic Ocean and saline tidal creeks that open to the ocean. If present, fresh groundwater is derived from infiltrating precipitation. Due to density contrasts, fresh groundwater occurs as a thin lens that essentially floats on top of denser saltwater. The thickness of the freshwater lens is governed primarily by the density contrast and the elevation of the water table above sea level. According to the Ghyben-Herzberg principle (Figure 4), the thickness of the freshwater lens should be approximately 40 times the height of the water table above sea level based on density contrasts alone. The actual thickness and seaward extent of the freshwater lens will be a function of the amount of fresh groundwater recharging the aquifer, the transmissivity of the aquifer sediments, the presence of confining units, and the hydraulic gradient. At Wallops Island, it is likely that the thin surficial aquifer down to the top of the clay layer is mostly fresh water. The presence of confining layers will tend to reduce the thickness of the freshwater lens and shift the interface seaward as shown in Figure 4. In deeper confined aquifers, the interface will shift landward due to lower amounts of freshwater recharge. In addition, minor fluctuations in the saltwater-freshwater interface occur from tidal actions, storm surge events, and seasonal changes in the rate of groundwater recharge and discharge. This movement of the

saltwater-freshwater interface creates a brackish-water mixing zone. This transitional brackish zone is typically thin compared to the overall thickness of the freshwater lens.

Groundwater occurs within pore spaces of the main water-bearing aquifers and will flow from areas of higher elevation to areas of lower elevation. In this case, groundwater flow is expected to be bi-directional either towards the Atlantic Ocean or towards the back barrier bay and tidal creeks with some radial flow divergent away from groundwater highs and convergent towards groundwater lows or sinks such as the on-site ponds. Groundwater flow is expected to be primarily horizontal within the aquifer, however in recharge areas, a small portion of groundwater may flow downward into underlying confined aquifers or in discharge areas upward from the underlying confined aquifers. It is unlikely that there is much vertical flow from the surficial aquifer at the site due to the expected high horizontal hydraulic conductivity, the strong gradient towards the Atlantic Ocean, and the moderately large thickness and low permeability of the shallow and laterally extensive clay confining layer underlying the unconfined portion of the surficial aquifer.

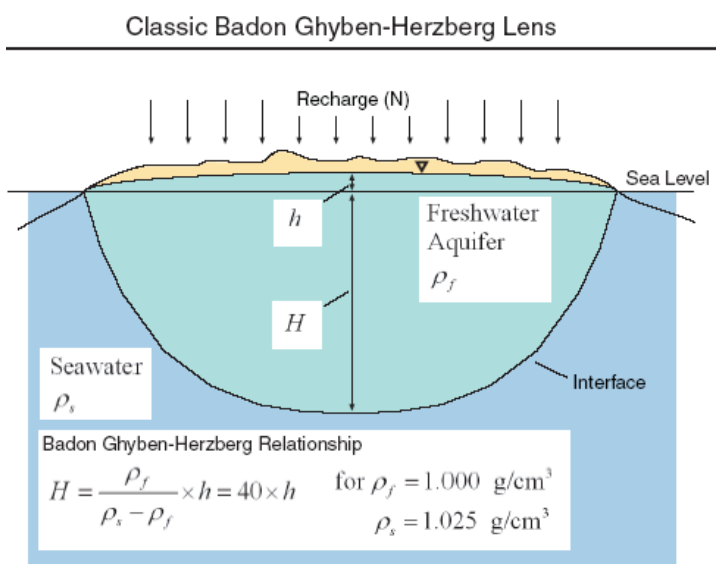


Figure 4 – Schematic of a freshwater lens in island or peninsula setting. The thickness of freshwater lens below sea level should be approximately 40 times the height of the water table above sea level based on density contrasts alone. The presence of confining layers tends to reduce the thickness of the lens and allow the freshwater lens to extend out beneath the surrounding ocean or bay. Source: USGS

3.0 DETAILED SITE CHARACTERIZATION

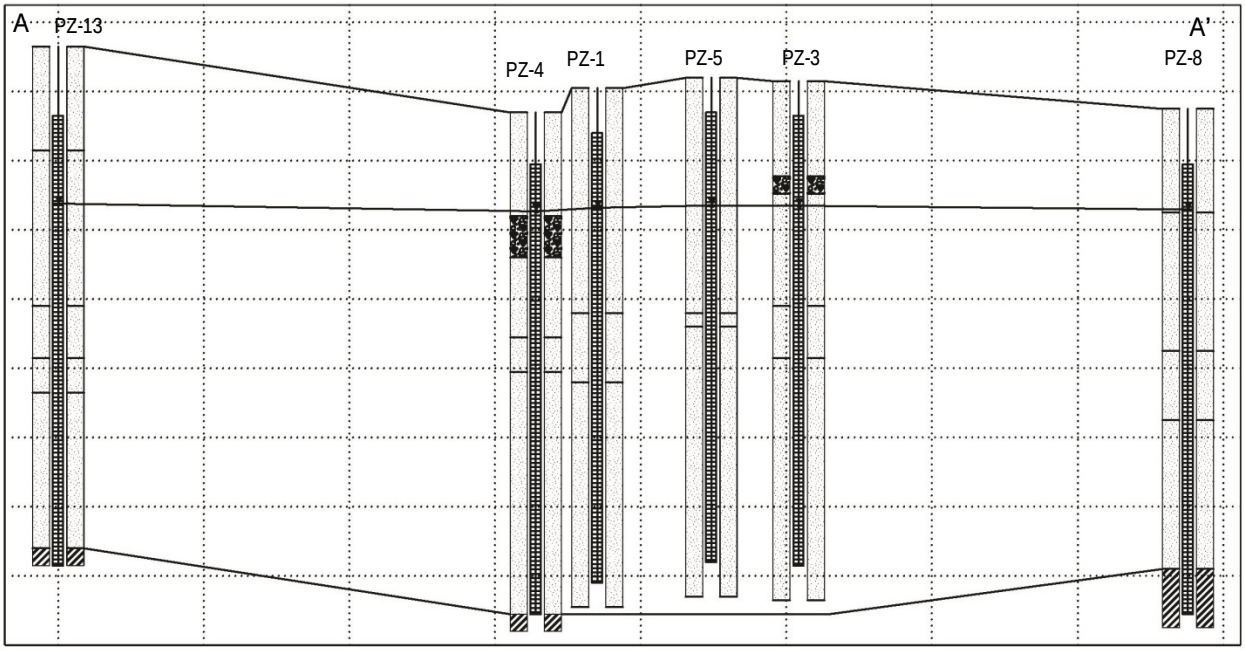
3.1 Soil Boring Investigation and Temporary Piezometer Installations

Thirteen continuously cored soil borings were completed using direct-push Geoprobe® drilling methods. The borings were completed to a depth of up to 15 feet generally terminating in a shallow clay layer that is believed to be laterally extensive beneath the site. The borings/piezometers, identified as PZ-1 through PZ-13, were positioned at varying distances extending radially away from the center of the AOC and were located near possible downgradient surface water discharge points including the Atlantic Ocean, and Ponds 1, 2, 3, and 4. Figure 5 illustrates the locations of the temporary piezometers. The soil borings were drilled by John D. Hynes & Associates, Inc of Salisbury, Maryland using a GeoProbe® 7822DT track- mounted system. The borings were completed on June 23-24, 2015, and were logged by an on-site geologist from Golder. Golder personnel described the lithology and identified potential low permeability zones, confining units, and water table indicators. Photographs of the cores are provided in Appendix A. Soil boring logs and piezometer well construction diagrams are presented in Appendix B. Stratigraphic sections across the AOC are illustrated in Figure 6.

The sediments encountered in the Geoprobe borings typically consisted of fine to medium-grained, pale brown sand. The sand was well sorted, loose and cross-bedded grading downward into finer-grained sand with dark gray to dark brown organic mud layers. Borehole collapse from liquefied or “running” sands was a persistent problem. Thin layers with slightly higher concentrations of silt and clay, and thin silty clay layers were encountered in some of the borings. The underlying clay layer was gray and had a high plasticity.

Screened piezometers were constructed in each of the Geoprobe borings to allow monitoring of groundwater levels to determine groundwater flow directions, and to sample for COCs to document potential impacts to groundwater. Each piezometer was constructed with generally approximately 13 to 14 feet of 0.010-inch factory-slotted, 1-inch ID PVC screen installed across the anticipated water table. The piezometers were completed with 1-inch PVC casing stick ups and a PVC cap. A filter pack was placed in the annulus surrounding the well screen and the remaining portion of the annulus was backfilled with bentonite chips and hydrated to provide a protective seal. Well construction diagrams are presented with the boring logs in Appendix B. The top of PVC casing and ground elevation for each piezometer was surveyed to the nearest 0.01 foot. Groundwater level data collected from the piezometers was used to characterize tidal fluctuations in the water table surface and groundwater flow directions at the site. Well construction and water level data from the piezometers are summarized in Table 3.

Figure 5 – Soil boring, piezometer, and cross-section location map.



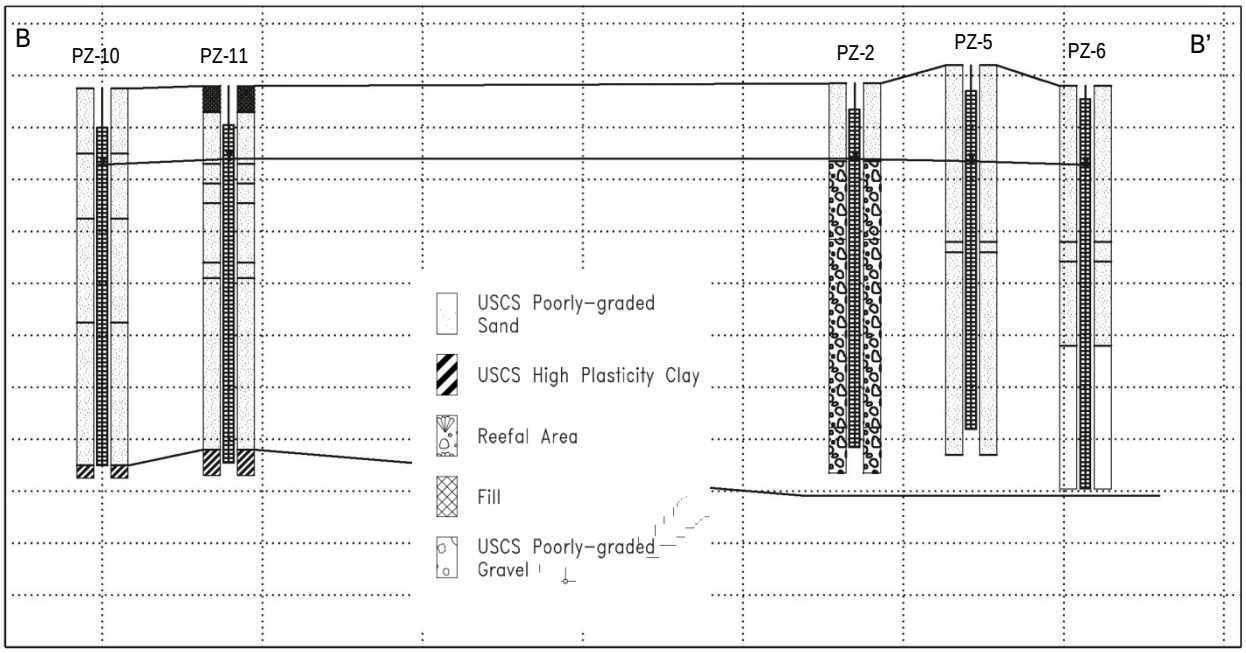


Figure 6 – Geologic Cross Sections (A-A' and B-B') Across the Area of Concern.

Table 3: Monitoring Well Construction Details and Synoptic Groundwater Level Measurements

Well	Screen Interval (ft bgs)	Stickup (ft gs)	Top of Casing Elev. (ft msl)	Ground Elev. (ft msl)	Time	DTW (ft btoc)	GW Elev. (ft msl)	Time	DTW (ft btoc)	GW Elev. (ft msl)
					June 30, 2015			**July 21, 2015**		
PZ-1	1.3-14.3	3.7	9.84	6.1	1808	7.11	2.73	1006	7.20	2.64
PZ-2	1.5-14.5	4.0	9.74	5.7	1807	6.88	2.86	1004	6.94	2.80
PZ-3	1.0-14.0	4.1	10.38	6.3	1810	7.59	2.79	1000	7.68	2.70
PZ-4	1.5-14.5	3.6	8.98	5.4	1806	6.33	2.65	958	6.44	2.54
PZ-5	1.0-14.0	4.3	10.71	6.4	1803	7.92	2.79	955	8.00	2.71
PZ-6	0.5-14.5	4.7	10.29	5.6	1800	7.6	2.69	953	7.72	2.57
PZ-7	2.0-15.0	2.9	9.42	6.5	1759	6.5	2.92	952	6.57	2.85
PZ-8	1.6-14.6	3.4	8.91	5.5	1757	6.25	2.66	948	6.32	2.59
PZ-9	1.5-14.5	3.4	8.99	5.6	1752	6.26	2.73	945	6.25	2.74
PZ-10	1.5-14.5	3.2	8.66	5.5	1751	6.06	2.60	941	6.08	2.58
PZ-11	1.5-14.5	3.5	9.13	5.6	1749	6.27	2.86	939	6.33	2.80
PZ-12	1.5-14.5	3.4	8.96	5.6	1747	6.21	2.75	937	6.28	2.68
PZ-13	2.0-15.0	3.2	10.47	7.3	1745	7.69	2.78	934	7.71	2.76

Notes: ft bgs – feet below ground surface
ft msl – feet relative to mean sea level
ft btoc – feet below top of casing
DTW– depth to water
GW– groundwater

3.2 Groundwater Flow Directions

Synoptic depth to groundwater measurements were collected from the piezometers on June 30, 2015, and again on July 21, 2015. Groundwater elevations were calculated and a contour map of the water table surface was developed for the June and July water level monitoring events. These are shown in Figures 7 and 8. The water table surface is a subdued reflection of the surface topography with the highest groundwater elevations following the linear ridge that occurs just landward of the beach ridge/dune complex. The water table surface slopes gently towards the back-barrier tidal flats and marshes as well as the ocean. Groundwater flow directions converge towards the ponds which are situated in low topographic areas and represent local groundwater discharge areas. Groundwater elevation increases to the south mimicking a slight increase in the ground surface elevation to the south. In general, groundwater flow will occur perpendicular to water table contours from topographically high areas to low areas and from groundwater recharge areas to groundwater discharge areas. In this case, groundwater is recharged primarily along the high ground near the launch pad and will flow bi-directionally and in places radially towards the Atlantic Ocean to the southeast and the ponds or tidal creeks to the northwest.

Groundwater flow velocities are much slower than surface water runoff, but are expected to be relatively fast in this area due to the presence of coarse sandy aquifer material. The effective groundwater flow velocity can be calculated using a variation of Darcy's Law:

$$V = \frac{Ki}{n} \qquad (1)$$

where:
V = average groundwater flow velocity, in ft/day
K = hydraulic conductivity of the aquifer, in ft/day
i = hydraulic gradient (slope of the water table), in ft/ft
n = porosity of the aquifer material, dimensionless

The hydraulic gradient from the AOC towards the Atlantic Ocean is moderately steep (0.0032 and 0.0024 ft/ft as measured between PZ-2 and PZ-6 during the June and July water level monitoring event respectively). The effective porosity of the aquifer material is estimated to be 22.5% (Driscoll, 1986). The estimated hydraulic conductivity of surficial aquifer sediments is estimated to range from at 20 ft/day to 75 ft/day (Sanford *et al.*, 2009). Based on these general assumptions, the probable groundwater flow velocity is estimated to range from 0.21 ft/day to 1.07 ft/day and average 0.59 ft/day. This is equivalent to groundwater advectively traveling between 76 and 390 feet per year. The actual groundwater velocity will likely vary greatly due to local variations in the effective hydraulic conductivity and porosity of the aquifer material.

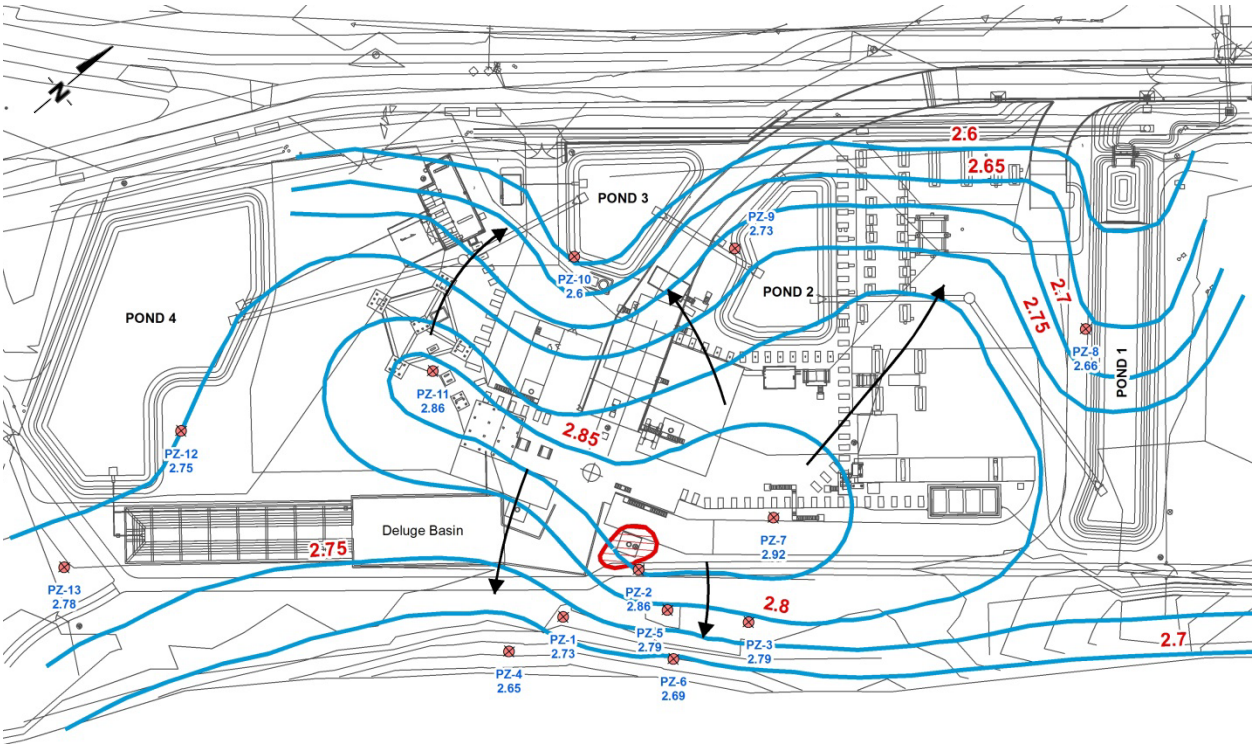


Figure 7 – Groundwater table contour map of the water table surface showing predicted groundwater flow directions based on synoptic groundwater level measurements collected on June 30, 2015.

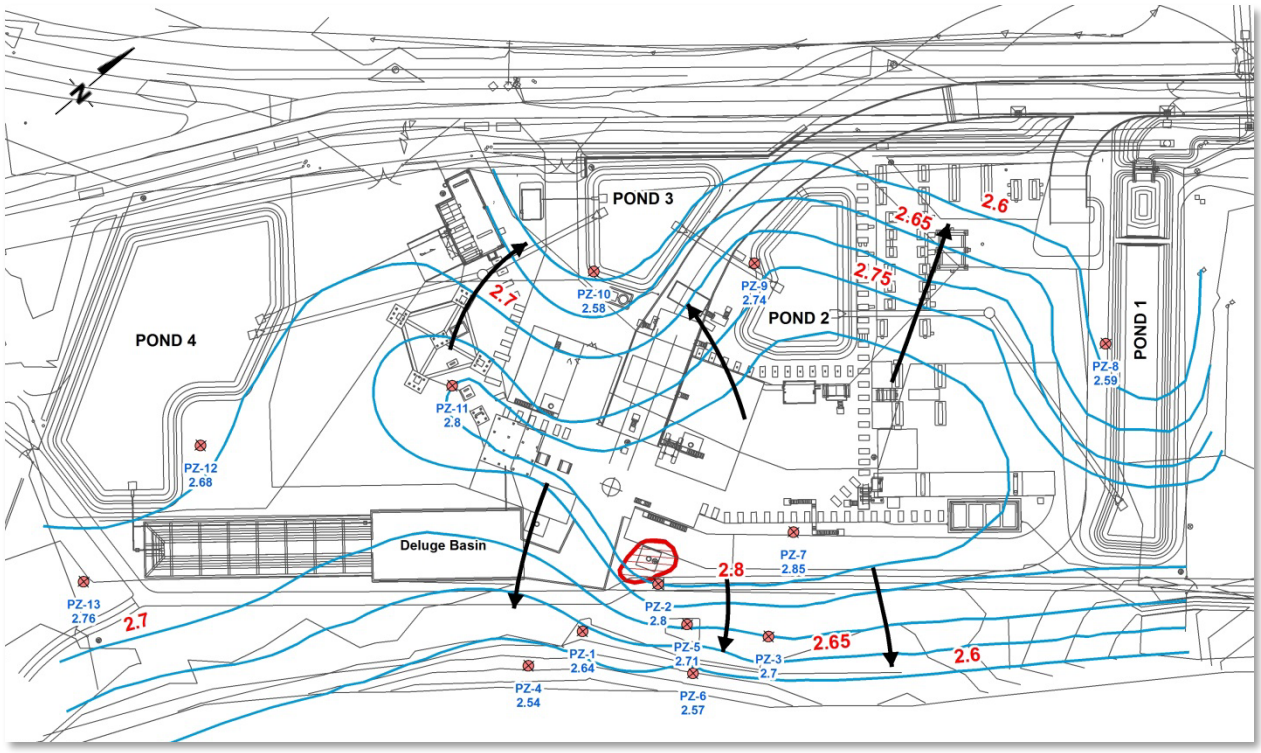


Figure 8 - Groundwater table contour map of the water table surface showing predicted groundwater flow directions based on synoptic groundwater level measurements collected on July 21, 2015.

3.3 External Influences on Groundwater Levels

Solinst Levelogger® gold-series pressure transducers with data logging capabilities were installed in piezometers PZ-1, PZ-2, PZ-6, PZ-8, PZ-10, and PZ-12. Groundwater levels were recorded in these piezometers every 10 minutes from June 24, 2015 through July 21, 2015. The purpose of the near continuous water level monitoring was to document the external influences such as barometric changes, precipitation, and tidal fluctuations on the altitude of the water table beneath the site and the possible effects of these influences on groundwater flow directions. Continuous hydrographs of groundwater elevations are presented with precipitation data and with tidal data in Figure 9.

3.3.1 Barometric Influences

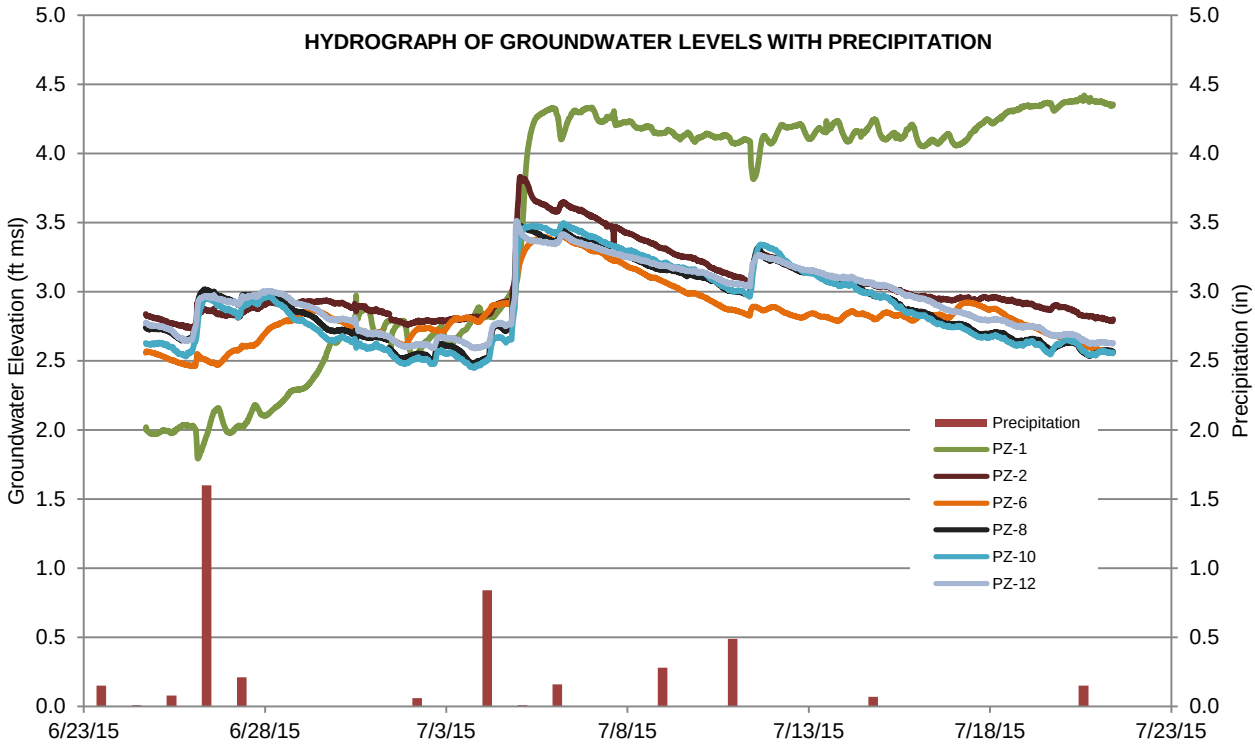
Non-vented pressure transducers were used for the monitoring. These transducers measure both atmospheric and water pressure above the sensor. The data therefore was compensated for barometric pressure fluctuations by subtracting the local atmospheric pressure from the readings so that measurements of just water head above the transducer remained. Atmospheric pressure was measured on site using a Solinist Barologger® gold-series pressure transducer and was subtracted from the transducer data using software provided by Solinist. No other corrections for barometric effects were deemed necessary.

3.3.2 Precipitation Influences

Precipitation data was obtained from Wallops Island weather station. Noticeable increases in site groundwater levels were observed after heavy rainfall events on June 26 (1.6 inches of precipitation), July 3 (0.84 inches), and July 11 (0.49 inches) causing groundwater levels to rise on average 0.4 feet, 0.8 feet, and 0.3 feet, respectively. After each rapid rise, groundwater levels declined slowly back to pre-rainfall levels within a week or so. Groundwater elevations consistently remain highest in monitoring wells near the launch pad including PZ-1 and PZ-2. Groundwater elevations are lowest in the monitoring wells closest to groundwater discharge locations including PZ-6 (Atlantic Ocean), PZ-8 (Pond 1), PZ-10 (Pond 3), and PZ-12 (Pond 4). This confirms the consistent shape of the groundwater table surface and the bi-directional nature of groundwater flow beneath the site regardless of external influences on groundwater levels from barometric pressure, precipitation, and tidal influences.

3.3.3 Tidal Influences

The response of the aquifers to cyclic tidal fluctuations was assessed by comparing predicted tides on Wallops Island to aquifer water level trends observed at the MARS site. Hourly tide elevations were calculated using WXTide32 V.4.7 software. The program calculates tide and current predictions using algorithms based on data from harmonics files developed for tide stations by the National Oceanic Service (NOS). Full moon occurred on July 2 and the new moon phase occurred on July 16.



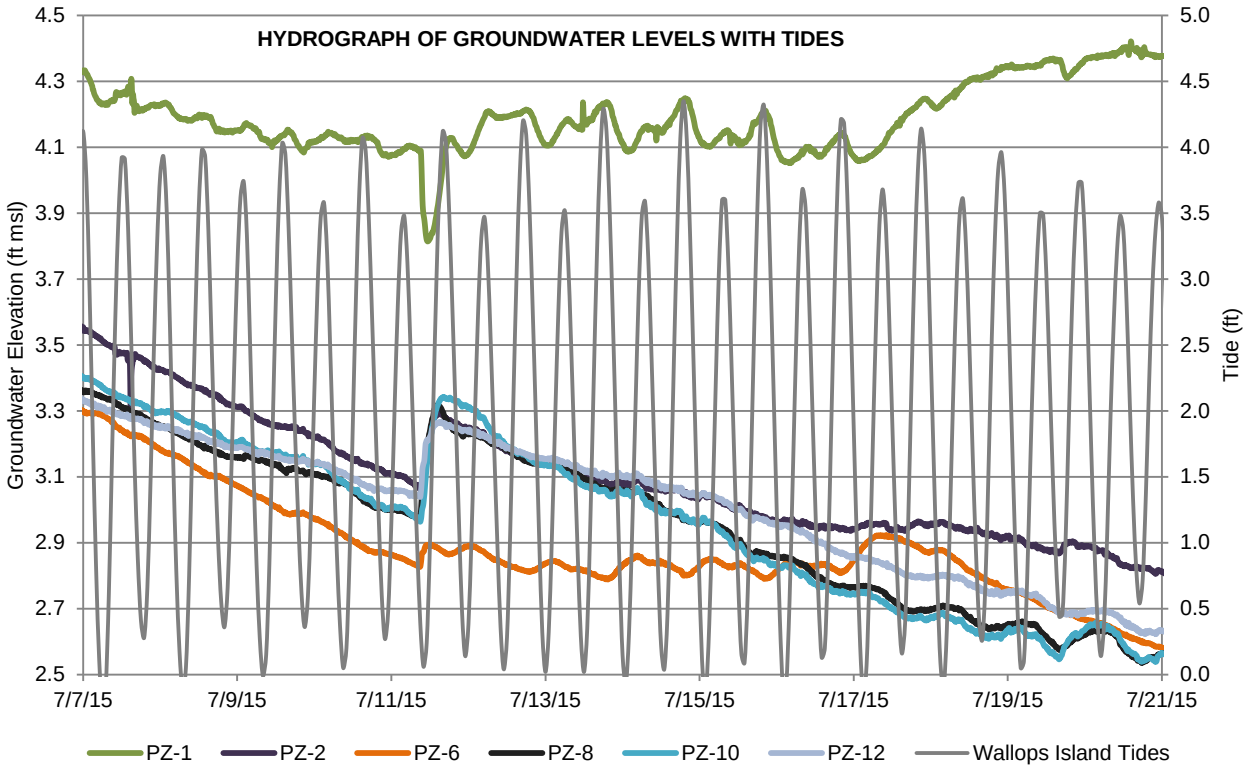


Figure 9 - Hydrographs of Groundwater Levels, Tides, and precipitation.

Groundwater levels in certain wells appear to fluctuate in response to predicted tidal fluctuations. The most direct and rapid response is observed in PZ-1 with amplitude fluctuations of 0.05 to 0.15 feet that closely follow the predicted tidal cycles at Wallops Island. Tidal fluctuations are also observed in the other piezometers but are subdued or masked possibly by steep water level declines following precipitation events. The tidal cycles observed in the piezometers near surface water discharge bodies also appear to be delayed or offset by approximately 6 hours so that groundwater highs occur during the predicted low tide and groundwater lows occur during predicted high tides. PZ-2, closest to the AOC, does not appear to be effected by tidal influences possibly due to the groundwater storage effects of the nearby, gravel-filled French drain structure.

4.0 WATER QUALITY RESULTS

4.1 Water Sampling Procedures

Groundwater samples were collected using micropurging techniques, consistent with EPA's Low-Flow Purging guidance, with a peristaltic pump and disposable tubing. Low flow techniques were used to minimize possible interference from turbidity. During the micropurge, samples were obtained every 3 to 5 minutes for analysis of pH, temperature, specific conductivity, dissolved oxygen, oxidation-reduction potential (ORP), and turbidity using a flow-through cell and a field-calibrated water quality meter. Groundwater purging and sampling logs for each well are presented in Appendix C. After water quality parameters stabilized over three consecutive measurements, groundwater samples were collected and placed directly into pre-labeled, laboratory-supplied, pre-preserved sample containers. The samples were placed in a cooler on ice and were shipped to PACE Laboratories, Inc. and Empirical Laboratories, LLC under chain-of-custody control for analysis. Both laboratories are Virginia Environmental Laboratory Accreditation Program (VELAP)-accredited laboratories. The groundwater samples were analyzed for VOCs using EPA SW-846 Method 624, SVOCs using EPA SW-846 Method 625, and perchlorate using EPA SW-846 Method 6850.

Quality control samples were collected and submitted for analysis as described below:

- Trip Blank. One laboratory-supplied trip blank accompanied each set of groundwater samples sent to the laboratory for analysis (one trip blanks total);
- Field Blank. Field blank samples, prepared in the field with laboratory-supplied deionized water, were collected at a rate of one per every 20 water samples submitted for analysis (one field blank total).
- Rocket Fuel Sample. A sample of the RP-1 rocket fuel was collected and analyzed to compare with COCs detected in the groundwater at the site.

4.2 Water Quality Results

Groundwater quality results from the June 30, 2015, sampling event are summarized in Table 4. Low concentrations of perchlorate and VOCs were detected in the groundwater beneath the site. The VOCs include benzene, toluene, ethylbenzene, and xylenes (BTEX) and styrene (S). These compounds, referred to as cyclic aromatic hydrocarbons, are typically found in petroleum hydrocarbon derivatives such as gasoline or diesel. BTEX VOCs were detected in PZ-1, PZ-2 near the Crater AOC and in PZ-10 and PZ-11 near the parking lot adjacent to Pond 3 and the water tank. Styrene was detected in PZ-1 and PZ-2, only. The concentrations of BTEX and styrene were low, generally below the laboratory quantification limits, except in PZ-2 near the AOC, which had concentrations of styrene benzene and toluene of 2.9, 23.1, and 8.1 micrograms per liter (µg/L), respectively. Only benzene concentrations were above the EPA's MCL. None of the COC concentrations exceeded the DEQ's voluntary remediation program's (VRP) Tier III Commercial Groundwater Screening Level, which are designated as the groundwater

protection standard (GPS) for the site since NASA has indicated a willingness to accept deed restrictions on the property to prevent future residential development. Perchlorate was detected in PZ-3, PZ-5, and PZ-6 with concentrations of 45.2; 1120; and 3.0 µg/L, respectively. EPA does not have a MCL for perchlorate but has initiated regulating it under the Safe Drinking Water Act. EPA has established an Interim Lifetime Drinking Water Health Advisory of 15 µg/L, which is a concentration of a perchlorate in drinking water that is not expected to cause any adverse non-carcinogenic effects for a lifetime of exposure. Perchlorate concentrations are above 15 µg/L in PZ-3 and PZ-5. Two semi-volatile compounds (SVOCs) butylbenzylphthate and chloromethane were detected in PZ-8 at concentrations below their respective method detection limits. These compounds are not considered to be COC related to this AOC. Potential COC's detected in piezometers near the AOC are shown in Figure 10.

Table 4: Summary of Water Quality Results (Detected Parameters Only)

VOCs	GPS	MCL	PZ-1	PZ-2	PZ-3	PZ-5	PZ-6	PZ-8	PZ-10	PZ-11
Perchlorate	NS	NS	-		**45.2**	**1120**	3.01	-	-	-
Styrene	3,896	100	0.63J	2.9	-	-	-	-	-	-
Benzene	1,236	5	-	**23.1**	-	-	-	-	2.4	0.9J
Toluene	8,067	1,000	0.94J	8.1	-	-	-	-	0.29J	-
EthylBenzene	152	700	0.32J	0.66J	-	-	-	-	-	-
Xylenes (total)	2,068	10,000	-	1.88J	-	-	-	-	-	-
SVOCs										
Butylbenzylphthalate	NS	NS	-	-	-	-	-	1.3J	-	-
Chloromethane	109	NS	-	-	-	-	-	0.6J	-	-

Notes
All concentrations are presented in micrograms per liter (µg/L) or parts per billion (ppb)
Bold and shaded values are above the designated MCL for the analyte
GPS = Groundwater Protection Standard based on the DEQ VRP Tier III Commercial Groundwater Screening Level
MCL = EPA Maximum Contaminant Level for drinking water
- = Not Detected
U = below laboratory detection limit
J = Value is estimated because concentration is below laboratory method detection limit.
D = Data reported from dilution.
NS - No Applicable Standard

Figure 10 – Water quality results from the June 30, 2015 sampling event. Only detected COCs are shown. S: styrene; B: benzene; T: toluene; E:ethylbenzene; X: xylenes; P: perchlorate

5.0 CONCLUSIONS AND RECOMMENDATIONS

The VCSFA through its Subconsultant, Golder, has completed a preliminary investigation at Pad-0A at MARS located at NASA's Wallops Flight Facility in Accomack County, Virginia. The investigation helped to characterize groundwater quality and groundwater flow directions in the vicinity of the October 2014 Antares launch failure, which resulted in the release of rocket fuel consisting primarily of RP-1, a highly refined form of kerosene, and ammonium perchlorate. The primary AOC from this incident is a former crater located seaward of the launch pad where approximately 241 tons of soil and 400,000 gallons of groundwater were removed as part of the initial abatement activities for the site. As part of this investigation, 13 piezometers were installed and sampled for VOCs, SVOCs, and perchlorate. In addition, a detailed study of groundwater flow directions and external influences on groundwater flow directions was conducted to determine likely groundwater flow pathways away from the AOC. The conclusions from this preliminary study are:

- The seaward side of Wallops Island is underlain by fine to coarse, shelly sand deposited in a coastal barrier island and narrow beach-dune ridge environment. The area behind the barrier-beach complex is underlain by soft organic mud and sandy mud containing abundant shell material and sand deposited in shallow bays and tidal creeks. The barrier shoreline complex has likely migrated from east to west over finer-grained, lower energy back-barrier marsh and tidal flat deposits. This migration has produced a sequence of approximately 15 to 20 feet of beach sand overlying fine-grained mud and peat deposits that are up to 40 feet thick, locally.
- Groundwater occurs under unconfined conditions with the upper 15 feet of sand and is recharged directly from precipitation. Infiltrating freshwater forms a lens of fresh water that directly contacts the underlying confining unit or that essentially floats on high salinity groundwater (infiltrating seawater). The top of the groundwater surface, or the water table, mimics the local topography of Wallops Island with the highest groundwater elevations occur beneath topographic highs with the water table surface sloping towards topographic lows associated with the Atlantic shoreline and the back-barrier ponds, bay, and tidal creeks. Groundwater flow on Wallops Island is bi-directional with a portion of the groundwater flowing towards and discharging into the Atlantic Ocean and a portion discharging to the back-barrier bay and tidal creeks. The groundwater divide between these two flow regimes is closer to the Atlantic shoreline following the topographic divide, but is landward of the AOC so that the groundwater flow in the vicinity of the AOC is towards the Atlantic Ocean.
- Groundwater levels are influenced by precipitation and tides. After significant rainfall events, groundwater levels across the site rise rapidly in response to infiltrating precipitation and gradually decline over the following week as groundwater drains to nearby discharge sinks.
- Groundwater levels also fluctuate in certain wells in response to predicted tidal fluctuations. The most direct and rapid response is observed in PZ-1 with amplitude fluctuations of 0.05 to 0.15 feet that closely follow the predicted tidal cycles. Tidal fluctuations are also observed in the other piezometers, but are subdued and delayed from predicted tidal cycles. PZ-2, closest to the AOC, does not appear to be affected by tidal influences possibly due to the groundwater storage effects of the nearby, gravel-filled French drain structure

- Synoptic groundwater elevations measured during varying tidal and climatic conditions demonstrate consistent bi-directional groundwater flow beneath the site regardless of external influences on groundwater levels from barometric pressure, precipitation, and tidal influences. Groundwater flow directions within the vicinity of the AOC are consistently towards the Atlantic Ocean. Estimated groundwater flow velocities range from 76 and 390 feet per year.
- Groundwater quality results from the June 30, 2015, sampling event indicate low concentrations of BTEX, styrene, and perchlorate are found in piezometers in the vicinity and downgradient of the AOC. Concentrations of most detected compounds are low, and are less than the laboratory quantification limits. Benzene concentrations were above the EPA MCL of 5 µg/L in one piezometer, PZ-2 immediately downgradient from the AOC. Perchlorate was above the Interim Lifetime Drinking Water Health Advisory of 15 µg/L in two piezometers PZ-3 and PZ-5, further downgradient from the AOC. No compounds were detected of concentrations above the DEQ's VRP Tier III Commercial Groundwater Screening Level, which are designated as the GPS for the site since NASA has indicated a willingness to accept deed restrictions on the property to prevent future residential development.

Based on the investigative results obtained during this investigation, the extent of the groundwater impacts are limited to a relatively small area surrounding and downgradient of the area of concern. Only one parameter, benzene, was found to be above the drinking water standard. Perchlorate was detected in two wells above an interim drinking water standard. No compounds were detected above screening levels for commercial/industrial property. Two additional rounds of groundwater sampling are recommended from select wells to confirm the results. A site-specific risk assessment will then be completed using this data to determine if a No Further Action remedy can be recommended for this site under a Voluntary Remediation Program.

6.0 REFERENCES

Driscoll, F.G., 1986. Ground Water and Wells. 2nd Ed., Johnson Division, St. Paul, MN. 1108 pp., pp. 497, 438-9, 722, 725-26.

Hillis-Carnes Engineering Associates, Inc., 2009, Geotechnical evaluation for the proposed Taurus II Rocket Launch Complex. Prepared for the Mid-Atlantic Regional Spaceport and submitted on February 13, 2009.

Mixon, R.B., 1985, Stratigraphic and Geomorphic Framework of Uppermost Cenozoic Deposits in the Southern Delmarva Peninsula, Virginia and Maryland: V.S. Geological Survey Professional Paper 1067-0, 53 p.

Mixon, R.B., and Powars, D.S., 1985, Middle Pleistocene depositional environments and facies sequences, Accomack barrier complex, southern Delmarva peninsula, Virginia. In AAPG Annual Meeting Eastern Section Field Trip 2 Guidebook.

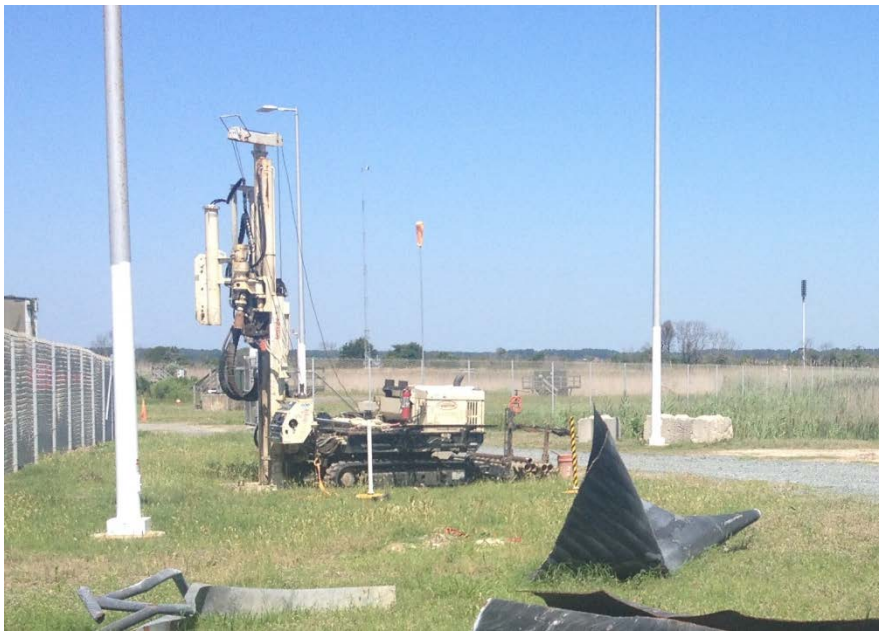
Mixon, R.B., Berquist, C.R., Newell, W.L., Johnson, G.H., Powars, D.S., Schindler, J.S., and Rader, E.K., 1989, Geologic map and generalized cross sections of the Coastal Plain and adjacent parts of the Piedmont, Virginia. U.S. Geological Survey Miscellaneous Investigations Series Map I-2033, 2 maps with text, scale 1:250,000.

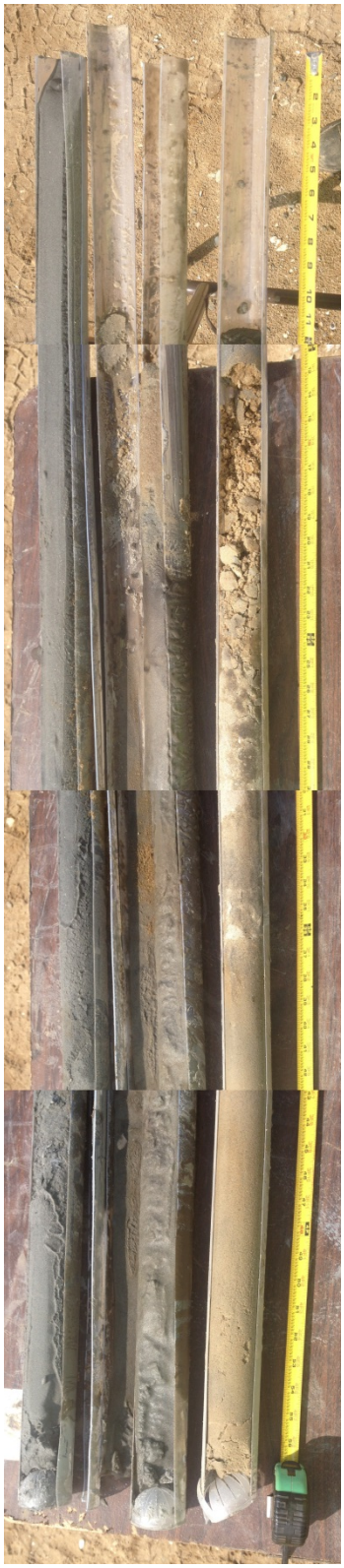
NOAA, 2002. Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1971-2000. Climatology of the United States No 81: Virginia. National Oceanic and Atmospheric Administration, National Climatic Data Center. Asheville, NC.

Richardson, D. L., 1994, Hydrogeology and analysis of the ground-water flow system of the Eastern Shore, Virginia. U.S. Geological Survey Open File Report 91-490, 118 p.

Sanford, W.E., Pope, J.P., and Nelms, D.L., 2009, Simulation of groundwater-level and salinity changes in the Eastern Shore, Virginia: U.S. Geological Survey Scientific Investigations Report 2009–5066, 125 p.

APPENDIX A
PHOTOGRAPHIC DOCUMENTATION OF FIELD INVESTIGATION

Project Title:	**Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**
PHOTO 1 Drilling operations for temporary piezometers around Pad 0A.	
PHOTO 2 Geoprobe 7822DT at PZ-13 location.	

Project Title:	**Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**
PHOTO 3 Soil core from PZ-1. Each core is 5 ft in length. Cores start in upper right at 0 ft bgs and end at 15 ft bgs in the lower left.	

Project Title: **Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**

PHOTO 4

Soil core from PZ-2. Each core is 5 ft in length. Cores start in upper right at 0 ft bgs and end at 15 ft bgs in the lower left.

Project Title: **Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**

PHOTO 5

Soil core from PZ-3. Each core is 5 ft in length. Cores start in upper right at 0 ft bgs and end at 15 ft bgs in the lower left.

Project Title: **Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**

PHOTO 6

Soil core from PZ-4. Each core is 5 ft in length. Cores start in upper right at 0 ft bgs and end at 15 ft bgs in the lower left.

Project Title:	**Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**
PHOTO 7 Soil core from PZ-5. Each core is 5 ft in length. Cores start in upper right at 0 ft bgs and end at 10 ft bgs in the lower left.	

Project Title: **Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**

PHOTO 8

Soil core from PZ-6. Each core is 5 ft in length. Cores start in upper right at 0 ft bgs and end at 15 ft bgs in the lower left.

Project Title: **Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**

PHOTO 9

Soil core from PZ-7. Each core is 5 ft in length. Cores start in upper right at 0 ft bgs and end at 15 ft bgs in the lower left.

Project Title: **Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**

PHOTO 10

Soil core from PZ-8. Each core is 5 ft in length. Cores start in upper right at 0 ft bgs and end at 15 ft bgs in the lower left.

Project Title:	**Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**
PHOTO 11 Soil core from PZ-9. Each core is 5 ft in length. Cores start in upper right at 0 ft bgs and end at 15 ft bgs in the lower left.	

Project Title: **Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**

PHOTO 12

Soil core from PZ-10. Each core is 5 ft in length. Cores start in upper right at 0 ft bgs and end at 15 ft bgs in the lower left.

Project Title: **Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**

PHOTO 13

Soil core from PZ-11. Each core is 5 ft in length. Cores start in upper right at 0 ft bgs and end at 15 ft bgs in the lower left.

Project Title: **Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**

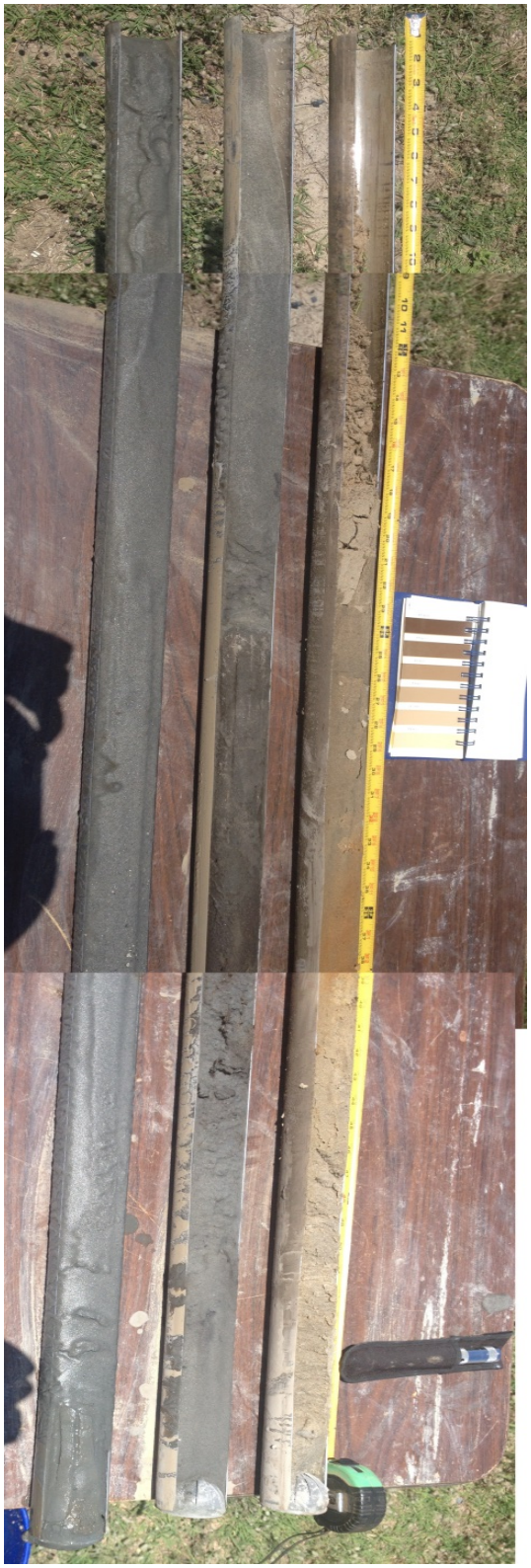


PHOTO 14

Soil core from PZ-12. Each core is 5 ft in length. Cores start in upper right at 0 ft bgs and end at 15 ft bgs in the lower left.

Project Title: **Photographic Documentation of the Site Characterization Investigation at the Mid-Atlantic Spaceport Pad 0A, Wallops Island, Virginia**

PHOTO 15

Soil core from PZ-13. Each core is 5 ft in length. Cores start in upper left at 0 ft bgs and end at 15 ft bgs in the lower right.

APPENDIX B
SOIL BORING AND PIEZOMETER CONSTRUCTION LOGS

RECORD OF BOREHOLE PZ-1

SHEET 1 of 1

PROJECT: VCSFA - MARS
PROJECT NUMBER: 1524461
DRILLED DEPTH: 15.00 ft
DRILL METHOD: Direct Push Continuous Coring

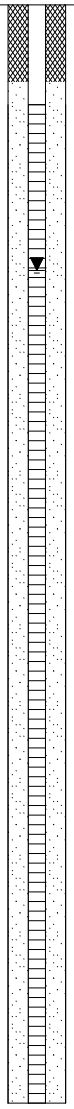
DRILL RIG: Geoprobe 7822DT
DATE STARTED: 6/24/15
DATE COMPLETED: 6/24/15

NORTHING: 3,840,968.66
EASTING: 12,352,815.03
GS ELEVATION: 6.10 ft
TOC ELEVATION: 9.84 ft

DEPTH W.L.: 3.46 ft
ELEVATION W.L.: 6.38 ft
DATE W.L.: 7/21/15
TIME W.L.: 10:06 am

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	REC / ATT
0		0.00 - 6.50 (SP) SAND, fine to medium, angular; pale brown, 10YR 6/3; eolian to supratidal; non-cohesive, moist, loose.	SP			4.00 / 5.00
	5					
5						
	0				-0.40 / 6.50	
		6.50 - 8.50 (SP) SAND, fine to medium, angular; some organics (roots); dark brown, 10YR 3/3; intertidal; non-cohesive, wet, loose.	SP			4.00 / 5.00
					-2.40 / 8.50	
		8.50 - 15.00 (SP) SAND, fine, angular; gray, N 5/0; subtidal; non-cohesive, wet, loose.	SP			5.00 / 5.00
10						
	-5					
15					-8.90	
		Boring completed at 15.00 ft				
	-10					
20						

MONITORING WELL/ PIEZOMETER DIAGRAM and NOTES



WELL CONSTRUCTION DETAILS / COMMENTS

WELL CASING
Interval: -3.7' - 1.3'
Material: PVC
Diameter: 1"
Joint Type: SCREW

WELL SCREEN
Interval: 1.3' - 14.3'
Material: PVC
Diameter: 1"
Slot Size: 0.010"
End Cap: PVC Push-On

FILTER PACK
Interval: 1' - 14.3'
Type: SP#2

FILTER PACK SEAL
Interval: None
Type: None

ANNULUS SEAL
Interval: 0'-1'
Type: 3/8" Bentonite Chips

WELL COMPLETION
Pad: None
Protective Casing: None

DRILLING METHODS
Type: Direct Push Continuous Coring
Notes:

LOG SCALE: 1 in = 2.5 ft
DRILLING COMPANY: John D. Hynes & Associates, Inc.
DRILLER: Mike Hynes

PREPARED: Colin D. Langford
REVIEWED: B. Waters
DATE: 7/1/15

Golder Associates

RECORD OF BOREHOLE PZ-2

SHEET 1 of 1

PROJECT: VCSFA - MARS
PROJECT NUMBER: 1524461
DRILLED DEPTH: 15.00 ft
DRILL METHOD: Direct Push Continuous Coring

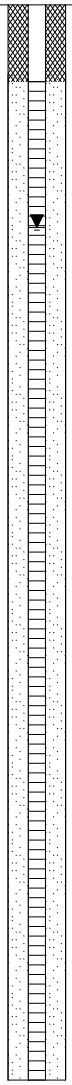
DRILL RIG: Geoprobe 7822DT
DATE STARTED: 6/24/15
DATE COMPLETED: 6/24/15

NORTHING: 3,841,034.67
EASTING: 12,352,824.23
GS ELEVATION: 5.70 ft
TOC ELEVATION: 9.74 ft

DEPTH W.L.: 2.90 ft
ELEVATION W.L.: 6.84 ft
DATE W.L.: 7/21/15
TIME W.L.: 10:04 am

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	REC / ATT
0		0.00 - 3.00 (SP) SAND, fine to medium, angular; pale brown, 10YR 6/3 to buff; eolian to supratidal; non-cohesive, moist, loose.	SP		2.70	3.00 / 5.00
	5	3.00 - 6.00 (FILL) GRAVEL, medium to course, angular; light gray, N 7/0; compacted; non-cohesive, moist, loose.	FILL		3.00	
5	0	6.00 - 13.25 (FILL) SAND, fine to medium, angular; pale brown, 10YR 6/3; disturbed; eolian to supratidal; non-cohesive, moist, loose.	FILL		-0.30 6.00	2.00 / 5.00 5.00 / 5.00
10	-5	13.25 - 15.00 (FILL) SAND, fine to medium, angular; some organics(roots); dark brown, 10YR 3/3; disturbed; intertidal; non-cohesive, wet, loose.	FILL		-7.55 13.25	
15	-10	Boring completed at 15.00 ft			-9.30	
20						

MONITORING WELL/ PIEZOMETER DIAGRAM and NOTES



WELL CONSTRUCTION DETAILS / COMMENTS

WELL CASING
Interval: -4' - 1'
Material: PVC
Diameter: 1"
Joint Type: SCREW

WELL SCREEN
Interval: 1' - 14'
Material: PVC
Diameter: 1"
Slot Size: 0.010"
End Cap: PVC Push-On

FILTER PACK
Interval: 1' - 14'
Type: SP#2

FILTER PACK SEAL
Interval: None
Type: None

ANNULUS SEAL
Interval: 0'-1'
Type: 3/8" Bentonite Chips

WELL COMPLETION
Pad: None
Protective Casing: None

DRILLING METHODS
Type: Direct Push Continuous Coring
Notes:

LOG SCALE: 1 in = 2.5 ft
DRILLING COMPANY: John D. Hynes & Associates, Inc.
DRILLER: Mike Hynes

PREPARED: Colin D. Langford
REVIEWED: B. Waters
DATE: 7/1/15

Golder Associates

RECORD OF BOREHOLE PZ-3

SHEET 1 of 1

PROJECT: VCSFA - MARS
PROJECT NUMBER: 1524461
DRILLED DEPTH: 15.00 ft
DRILL METHOD: Direct Push Continuous Coring

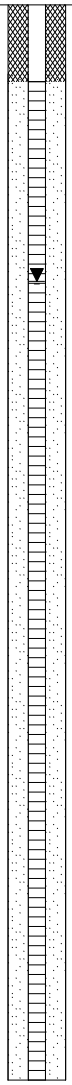
DRILL RIG: Geoprobe 7822DT
DATE STARTED: 6/23/15
DATE COMPLETED: 6/23/15

NORTHING: 3,841,072.53
EASTING: 12,352,907.43
GS ELEVATION: 6.30 ft
TOC ELEVATION: 10.38 ft

DEPTH W.L.: 3.60 ft
ELEVATION W.L.: 6.78 ft
DATE W.L.: 7/21/15
TIME W.L.: 10:00 am

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	REC / ATT
0		0.00 - 2.75 (SP) SAND, fine to medium, angular; pale brown, 10YR 6/3 to buff; eolian to supratidal; non-cohesive, dry, loose.	SP			
	5				3.55	3.50 / 5.00
		2.75 - 3.25 (SHELL HASH) SHELLS, medium to coarse, angular; light yellowish brown, 10YR 6/4 to buff; non-cohesive, moist, loose.			2.75 3.05	
		3.25 - 6.50 (SP) SAND, fine to medium, angular; pale brown, 10YR 6/3 to buff; eolian to supratidal; non-cohesive, moist to wet, loose.	SP		3.25	
5						
	0				-0.20	
		6.50 - 8.00 (SP) SAND, fine to medium, angular; some organics(roots); dark brown, 10YR 3/3; intertidal; non-cohesive, wet, loose.	SP		6.50	4.00 / 5.00
		8.00 - 15.00 (SP) SAND, fine, angular; gray, N 5/0; subtidal; non-cohesive, wet, loose. Thin shell layer at ~9' bgs.	SP		-1.70 8.00	
10						
	-5					5.00 / 5.00
15		Boring completed at 15.00 ft			-8.70	
	-10					
20						

MONITORING WELL/ PIEZOMETER DIAGRAM and NOTES



WELL CONSTRUCTION DETAILS / COMMENTS

WELL CASING
Interval: -4' - 1'
Material: PVC
Diameter: 1"
Joint Type: SCREW

WELL SCREEN
Interval: 1' - 14'
Material: PVC
Diameter: 1"
Slot Size: 0.010"
End Cap: PVC Push-On

FILTER PACK
Interval: 1' - 14'
Type: SP#2

FILTER PACK SEAL
Interval: None
Type: None

ANNULUS SEAL
Interval: 0'-1'
Type: 3/8" Bentonite Chips

WELL COMPLETION
Pad: None
Protective Casing: None

DRILLING METHODS
Type: Direct Push Continuous Coring
Notes:

LOG SCALE: 1 in = 2.5 ft
DRILLING COMPANY: John D. Hynes & Associates, Inc.
DRILLER: Mike Hynes

PREPARED: Colin D. Langford
REVIEWED: B. Waters
DATE: 7/1/15

Golder Associates

RECORD OF BOREHOLE PZ-4

SHEET 1 of 1

PROJECT: VCSFA - MARS
PROJECT NUMBER: 1524461
DRILLED DEPTH: 15.00 ft
DRILL METHOD: Direct Push Continuous Coring

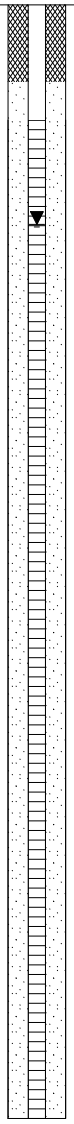
DRILL RIG: Geoprobe 7822DT
DATE STARTED: 6/23/15
DATE COMPLETED: 6/23/15

NORTHING: 3,840,920.93
EASTING: 12,352,808.84
GS ELEVATION: 5.40 ft
TOC ELEVATION: 8.98 ft

DEPTH W.L.: 2.86 ft
ELEVATION W.L.: 6.12 ft
DATE W.L.: 7/21/15
TIME W.L.: 9:58 am

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	REC / ATT
0	5	0.00 - 3.00 (SP) SAND, fine to medium, angular; pale brown, 10YR 6/3 to buff; eolian to supratidal; non-cohesive, dry, loose.	SP		2.40	3.50 5.00
		3.00 - 4.20 (SHELL HASH) SHELLS, medium to coarse, angular; light yellowish brown, 10YR 6/4 to buff; non-cohesive, moist, loose.			3.00 1.20	
5	0	4.20 - 6.50 (SP) SAND, fine to medium, angular; pale brown, 10YR 6/3 to buff; eolian to supratidal; non-cohesive, moist to wet, loose.	SP		4.20 -1.10	
		6.50 - 7.50 (SP) SAND, fine to medium, angular; some organics; dark brown, 10YR 3/3; intertidal; non-cohesive, wet, loose.	SP		6.50 -2.10	4.00
10	-5	7.50 - 14.50 (SP) SAND, fine, angular; gray, N 5/0; subtidal; non-cohesive, wet, loose. Thin shell layer at ~9' bgs.	SP		7.50 -9.10	5.00 5.00
15	-10	14.50 - 15.00 (CH) CLAY, high plasticity; gray, N 5/0; subtidal; cohesive, w > PL, soft. Boring completed at 15.00 ft	CH		14.50 -9.60	
20						

MONITORING WELL/ PIEZOMETER DIAGRAM and NOTES



WELL CONSTRUCTION DETAILS / COMMENTS

WELL CASING
Interval: -3.5' - 1.5'
Material: PVC
Diameter: 1"
Joint Type: SCREW

WELL SCREEN
Interval: 1.5' - 14.5'
Material: PVC
Diameter: 1"
Slot Size: 0.010"
End Cap: PVC Push-On

FILTER PACK
Interval: 1' - 14.5'
Type: SP#2

FILTER PACK SEAL
Interval: None
Type: None

ANNULUS SEAL
Interval: 0'-1'
Type: 3/8" Bentonite Chips

WELL COMPLETION
Pad: None
Protective Casing: None

DRILLING METHODS
Type: Direct Push Continuous Coring
Notes:

LOG SCALE: 1 in = 2.5 ft
DRILLING COMPANY: John D. Hynes & Associates, Inc.
DRILLER: Mike Hynes

PREPARED: Colin D. Langford
REVIEWED: B. Waters
DATE: 7/1/15

Golder Associates

RECORD OF BOREHOLE PZ-5

PROJECT: VCSFA - MARS
PROJECT NUMBER: 1524461
DRILLED DEPTH: 15.00 ft
DRILL METHOD: Direct Push Continuous Coring

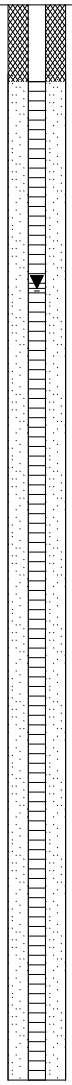
DRILL RIG: Geoprobe 7822DT
DATE STARTED: 6/23/15
DATE COMPLETED: 6/23/15

NORTHING: 3,841,031.77
EASTING: 12,352,861.46
GS ELEVATION: 6.40 ft
TOC ELEVATION: 10.71 ft

DEPTH W.L.: 3.69 ft
ELEVATION W.L.: 7.02 ft
DATE W.L.: 7/21/15
TIME W.L.: 9:55 am

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	REC / ATT
0		0.00 - 6.80 (SP) SAND, fine to medium, angular; pale brown, 10YR 6/3 to buff; eolian to supratidal; non-cohesive, dry, loose.	SP			3.00 / 5.00
	5					
5						
	0				-0.40	
		6.80 - 7.20 (SP) SAND, fine to medium, angular; some organics(roots); dark brown, 10YR 3/3; intertidal; non-cohesive, wet, loose.	SP		6.80 -0.80	
		7.20 - 15.00 (SP) SAND, fine, angular; gray, N 5/0; subtidal; non-cohesive, wet, loose. Thin shell layer at ~9' bgs.			7.20	4.00 / 5.00
10			SP			
	-5					0.00 / 5.00
15		Boring completed at 15.00 ft			-8.60	
	-10					
20						

MONITORING WELL/ PIEZOMETER DIAGRAM and NOTES



WELL CONSTRUCTION DETAILS / COMMENTS

WELL CASING
Interval: -4' - 1'
Material: PVC
Diameter: 1"
Joint Type: SCREW

WELL SCREEN
Interval: 1' - 14'
Material: PVC
Diameter: 1"
Slot Size: 0.010"
End Cap: PVC Push-On

FILTER PACK
Interval: 1' - 14'
Type: SP#2

FILTER PACK SEAL
Interval: None
Type: None

ANNULUS SEAL
Interval: 0'-1'
Type: 3/8" Bentonite Chips

WELL COMPLETION
Pad: None
Protective Casing: None

DRILLING METHODS
Type: Direct Push Continuous Coring
Notes:

LOG SCALE: 1 in = 2.5 ft
DRILLING COMPANY: John D. Hynes & Associates, Inc.
DRILLER: Mike Hynes

PREPARED: Colin D. Langford
REVIEWED: B. Waters
DATE: 7/1/15

Golder Associates

RECORD OF BOREHOLE PZ-6

SHEET 1 of 1

PROJECT: VCSFA - MARS
PROJECT NUMBER: 1524461
DRILLED DEPTH: 20.00 ft
DRILL METHOD: Direct Push Continuous Coring

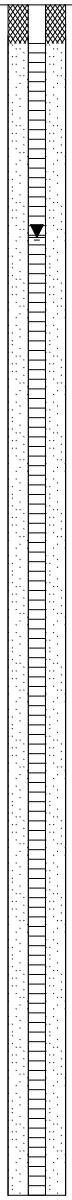
DRILL RIG: Geoprobe 7822DT
DATE STARTED: 6/23/15
DATE COMPLETED: 6/23/15

NORTHING: 3,841,011.64
EASTING: 12,352,892.29
GS ELEVATION: 5.60 ft
TOC ELEVATION: 10.29 ft

DEPTH W.L.: 3.03 ft
ELEVATION W.L.: 7.26 ft
DATE W.L.: 7/21/15
TIME W.L.: 9:53 am

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	REC / ATT
0		0.00 - 6.00 (SP) SAND, fine to medium, angular; pale brown, 10YR 6/3 to buff; eolian to supratidal; non-cohesive, dry, loose.	SP			3.00 / 5.00
	5					
5						
	0				-0.40	
		6.00 - 6.75 (SP) SAND, fine to medium, angular; some organics(roots); dark brown, 10YR 3/3; intertidal; non-cohesive, wet, loose.	SP		6.00 -1.15	
		6.75 - 10.00 (SP) SAND, fine, angular; gray, N 5/0; subtidal; non-cohesive, wet, loose.	SP		6.75 -4.40	4.25 / 5.00
10		10.00 - 20.00 No sample. Saturated running sands, hole collapse and sand heaved upward into sample tubes.			10.00	4.50 / 5.00
	-5					
15						5.00 / 5.00
	-10					
20		Boring completed at 20.00 ft			-14.40	

MONITORING WELL/ PIEZOMETER DIAGRAM and NOTES



WELL CONSTRUCTION DETAILS / COMMENTS

WELL CASING
Interval: -4.5' - 0.5'
Material: PVC
Diameter: 1"
Joint Type: SCREW

WELL SCREEN
Interval: 0.5' - 15.5'
Material: PVC
Diameter: 1"
Slot Size: 0.010"
End Cap: PVC Push-On

FILTER PACK
Interval: 0.5' - 15.5'
Type: SP#2

FILTER PACK SEAL
Interval: None
Type: None

ANNULUS SEAL
Interval: 0'-0.5'
Type: 3/8" Bentonite Chips

WELL COMPLETION
Pad: None
Protective Casing: None

DRILLING METHODS
Type: Direct Push Continuous Coring
Notes:

LOG SCALE: 1 in = 2.5 ft
DRILLING COMPANY: John D. Hynes & Associates, Inc.
DRILLER: Mike Hynes

PREPARED: Colin D. Langford
REVIEWED: B. Waters
DATE: 7/1/15

Golder Associates

RECORD OF BOREHOLE PZ-7

SHEET 1 of 1

PROJECT: VCSFA - MARS
PROJECT NUMBER: 1524461
DRILLED DEPTH: 15.00 ft
DRILL METHOD: Direct Push Continuous Coring

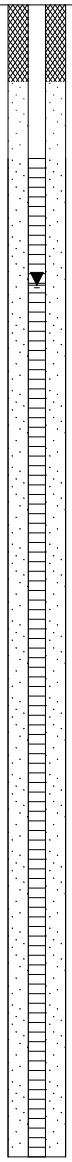
DRILL RIG: Geoprobe 7822DT
DATE STARTED: 6/23/15
DATE COMPLETED: 6/23/15

NORTHING: 3,841,137.10
EASTING: 12,352,859.55
GS ELEVATION: 6.50 ft
TOC ELEVATION: 9.42 ft

DEPTH W.L.: 3.65 ft
ELEVATION W.L.: 5.77 ft
DATE W.L.: 7/21/15
TIME W.L.: 9:52 am

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE – DESCRIPTION	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	REC / ATT
0		0.00 - 5.00 (SP) SAND, fine to medium, angular; pale brown, 10YR 6/3 to buff, some orange tint; eolian to supratidal; non-cohesive, dry to moist, loose. Black heavy mineral sand lense at ~3.5' bgs.	SP		1.50	4.00 / 5.00
5	5	5.00 - 8.20 (SP) SAND, fine to medium, angular; brown, 10YR 5/3; cross-bedded; eolian to supratidal; non-cohesive, wet, loose.	SP		5.00	4.25 / 5.00
	0	8.20 - 8.50 (SP) SAND, fine to medium, angular; some organics(roots); dark brown, 10YR 3/3; anoxic odor; intertidal; non-cohesive, wet, loose.	SP		-1.70 -2.00	
		8.50 - 15.00 (SP) SAND, fine, angular; gray, N 5/0; subtidal; non-cohesive, wet, loose. Some CH CLAY on tip of tooling from ~15' bgs.	SP		8.50	4.00 / 5.00
10	-5					
15	-10	Boring completed at 15.00 ft			-8.50	
20						

MONITORING WELL/ PIEZOMETER DIAGRAM and NOTES



WELL CONSTRUCTION DETAILS / COMMENTS

WELL CASING
Interval: -3' - 2'
Material: PVC
Diameter: 1"
Joint Type: SCREW

WELL SCREEN
Interval: 2' - 15'
Material: PVC
Diameter: 1"
Slot Size: 0.010"
End Cap: PVC Push-On

FILTER PACK
Interval: 1' - 15'
Type: SP#2

FILTER PACK SEAL
Interval: None
Type: None

ANNULUS SEAL
Interval: 0'-1'
Type: 3/8" Bentonite Chips

WELL COMPLETION
Pad: None
Protective Casing: None

DRILLING METHODS
Type: Direct Push Continuous Coring
Notes:

LOG SCALE: 1 in = 2.5 ft
DRILLING COMPANY: John D. Hynes & Associates, Inc.
DRILLER: Mike Hynes

PREPARED: Colin D. Langford
REVIEWED: B. Waters
DATE: 7/1/15

Golder Associates

RECORD OF BOREHOLE PZ-8

PROJECT: VCSFA - MARS
PROJECT NUMBER: 1524461
DRILLED DEPTH: 15.00 ft
DRILL METHOD: Direct Push Continuous Coring

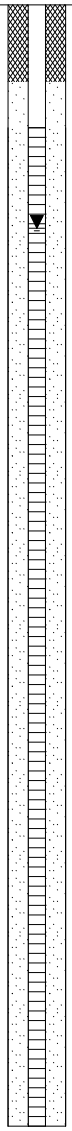
DRILL RIG: Geoprobe 7822DT
DATE STARTED: 6/22/15
DATE COMPLETED: 6/22/15

NORTHING: 3,841,406.83
EASTING: 12,352,901.66
GS ELEVATION: 5.50 ft
TOC ELEVATION: 8.91 ft

DEPTH W.L.: 2.91 ft
ELEVATION W.L.: 6.00 ft
DATE W.L.: 7/21/15
TIME W.L.: 9:48 am

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE – DESCRIPTION	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	REC / ATT
0		0.00 - 3.00 (SP) SAND, fine to medium, angular; very pale brown, 10YR 7/4 to buff; eolian to supratidal; non-cohesive, dry, loose.	SP		2.50	3.00 / 5.00
	5	3.00 - 7.00 (SP) SAND, fine to medium, angular; light gray, 10YR 7/2 to gray N 5/0; eolian to supratidal; non-cohesive, moist to wet, loose.	SP		3.00 -1.50	
5	0	7.00 - 9.00 (SP) SAND, fine to medium, angular; some organics(roots); dark brown, 10YR 3/3 to gray N 5/0; cross-bedded; intertidal; non-cohesive, wet, loose.	SP		7.00 -3.50	4.50 / 5.00
		9.00 - 13.30 (SP) SAND, fine, angular; gray, N 5/0; subtidal; non-cohesive, wet, loose. Thin shell layer at ~9' bgs.	SP		9.00 -7.80	5.00 / 5.00
10	-5	13.30 - 15.00 (CH) CLAY, high plasticity; gray, N 5/0; subtidal; cohesive, w > PL, soft.	CH		13.30 -9.50	
15	-10	Boring completed at 15.00 ft				
20						

MONITORING WELL/ PIEZOMETER DIAGRAM and NOTES



WELL CONSTRUCTION DETAILS / COMMENTS

WELL CASING
Interval: -3.4' - 1.6'
Material: PVC
Diameter: 1"
Joint Type: SCREW

WELL SCREEN
Interval: 1.6' - 14.6'
Material: PVC
Diameter: 1"
Slot Size: 0.010"
End Cap: PVC Push-On

FILTER PACK
Interval: 1' - 14.6'
Type: SP#2

FILTER PACK SEAL
Interval: None
Type: None

ANNULUS SEAL
Interval: 0'-1'
Type: 3/8" Bentonite Chips

WELL COMPLETION
Pad: None
Protective Casing: None

DRILLING METHODS
Type: Direct Push Continuous Coring
Notes:

LOG SCALE: 1 in = 2.5 ft
DRILLING COMPANY: John D. Hynes & Associates, Inc.
DRILLER: Mike Hynes

PREPARED: Colin D. Langford
REVIEWED: B. Waters
DATE: 7/1/15

Golder Associates

RECORD OF BOREHOLE PZ-9

SHEET 1 of 1

PROJECT: VCSFA - MARS
PROJECT NUMBER: 1524461
DRILLED DEPTH: 15.00 ft
DRILL METHOD: Direct Push Continuous Coring

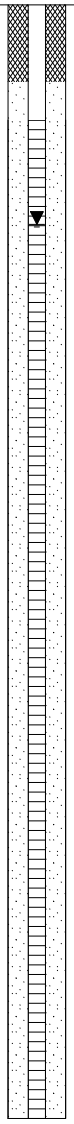
DRILL RIG: Geoprobe 7822DT
DATE STARTED: 6/24/15
DATE COMPLETED: 6/24/15

NORTHING: 3,841,244.22
EASTING: 12,352,686.67
GS ELEVATION: 5.60 ft
TOC ELEVATION: 8.99 ft

DEPTH W.L.: 2.86 ft
ELEVATION W.L.: 6.13 ft
DATE W.L.: 7/21/15
TIME W.L.: 9:45 am

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	REC / ATT
0		0.00 - 5.00 (SP) SAND, fine to medium, angular; pale brown, 10YR 6/3 to buff; eolian to supratidal; non-cohesive, moist, loose.	SP		0.60	2.50 / 5.00
5	5	5.00 - 7.00 (SP) SAND, fine to medium, angular; some organics(roots); dark brown, 10YR 3/3; intertidal; non-cohesive, wet, loose.	SP		5.00 -1.40	
	0	7.00 - 13.00 (SP) SAND, fine, angular; gray, N 5/0; subtidal; non-cohesive, wet, loose.	SP		7.00 -7.40	2.00 / 5.00 5.00 / 5.00
10	-5	13.00 - 15.00 (CH) CLAY, high plasticity; gray, N 5/0; subtidal; cohesive, w > PL, soft.	CH		13.00 -9.40	
15	-10	Boring completed at 15.00 ft				
20						

MONITORING WELL/ PIEZOMETER DIAGRAM and NOTES



WELL CONSTRUCTION DETAILS / COMMENTS

WELL CASING
Interval: -3.5' - 1.5'
Material: PVC
Diameter: 1"
Joint Type: SCREW

WELL SCREEN
Interval: 1.5' - 14.5'
Material: PVC
Diameter: 1"
Slot Size: 0.010"
End Cap: PVC Push-On

FILTER PACK
Interval: 1' - 14.5'
Type: SP#2

FILTER PACK SEAL
Interval: None
Type: None

ANNULUS SEAL
Interval: 0'-1'
Type: 3/8" Bentonite Chips

WELL COMPLETION
Pad: None
Protective Casing: None

DRILLING METHODS
Type: Direct Push Continuous Coring
Notes:

LOG SCALE: 1 in = 2.5 ft
DRILLING COMPANY: John D. Hynes & Associates, Inc.
DRILLER: Mike Hynes

PREPARED: Colin D. Langford
REVIEWED: B. Waters
DATE: 7/1/15

Golder Associates

RECORD OF BOREHOLE PZ-10

SHEET 1 of 1

PROJECT: VCSFA - MARS
PROJECT NUMBER: 1524461
DRILLED DEPTH: 15.00 ft
DRILL METHOD: Direct Push Continuous Coring

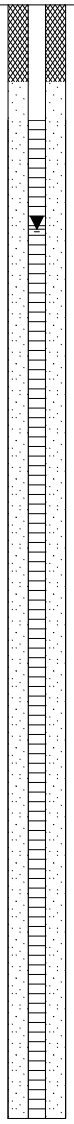
DRILL RIG: Geoprobe 7822DT
DATE STARTED: 6/22/15
DATE COMPLETED: 6/22/15

NORTHING: 3,841,148.13
EASTING: 12,352,614.04
GS ELEVATION: 5.50 ft
TOC ELEVATION: 8.66 ft

DEPTH W.L.: 2.92 ft
ELEVATION W.L.: 5.74 ft
DATE W.L.: 7/21/15
TIME W.L.: 9:41 am

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	REC / ATT
0		0.00 - 2.50 (SP) SAND, fine to medium, angular; trace shell fragments; dark yellowish brown, 10YR 4/4 to buff; eolian to supratidal; non-cohesive, dry, loose.	SP		3.00	4.00 / 5.00
	5	2.50 - 5.00 (SP) SAND, fine to medium, angular; very dark brown, 10YR 2/2; intertidal; non-cohesive, moist, loose.	SP		2.50 0.50	
5	0	5.00 - 9.00 (SP) SAND, fine to medium, angular; some organics(roots); very dark brown, 10YR 2/2; intertidal; non-cohesive, wet, loose.	SP		5.00 -3.50	4.50 / 5.00
10	-5	9.00 - 14.50 (SP) SAND, fine, angular; gray, N 5/0; cross-bedded; subtidal; non-cohesive, wet, loose.	SP		9.00 -9.00	5.00 / 5.00
15	-10	14.50 - 15.00 (CH) CLAY, high plasticity; gray, N 5/0; subtidal; cohesive, w > PL, soft. Boring completed at 15.00 ft	CH		14.50 -9.50	
20						

MONITORING WELL/ PIEZOMETER DIAGRAM and NOTES



WELL CONSTRUCTION DETAILS / COMMENTS

WELL CASING
Interval: -3.5' - 1.5'
Material: PVC
Diameter: 1"
Joint Type: SCREW

WELL SCREEN
Interval: 1.5' - 14.5'
Material: PVC
Diameter: 1"
Slot Size: 0.010"
End Cap: PVC Push-On

FILTER PACK
Interval: 1' - 14.5'
Type: SP#2

FILTER PACK SEAL
Interval: None
Type: None

ANNULUS SEAL
Interval: 0'-1'
Type: 3/8" Bentonite Chips

WELL COMPLETION
Pad: None
Protective Casing: None

DRILLING METHODS
Type: Direct Push Continuous Coring
Notes:

LOG SCALE: 1 in = 2.5 ft
DRILLING COMPANY: John D. Hynes & Associates, Inc.
DRILLER: Mike Hynes

PREPARED: Colin D. Langford
REVIEWED: B. Waters
DATE: 7/1/15

Golder Associates

RECORD OF BOREHOLE PZ-11

PROJECT: VCSFA - MARS
PROJECT NUMBER: 1524461
DRILLED DEPTH: 15.00 ft
DRILL METHOD: Direct Push Continuous Coring

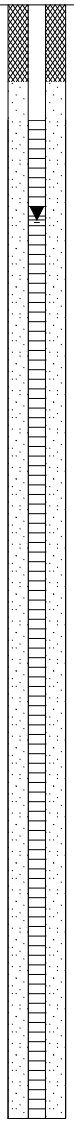
DRILL RIG: Geoprobe 7822DT
DATE STARTED: 6/22/15
DATE COMPLETED: 6/22/15

NORTHING: 3,841,011.99
EASTING: 12,352,611.54
GS ELEVATION: 5.60 ft
TOC ELEVATION: 9.13 ft

DEPTH W.L.: 2.80 ft
ELEVATION W.L.: 6.33 ft
DATE W.L.: 7/21/15
TIME W.L.: 9:39 am

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE – DESCRIPTION	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	REC / ATT
0		0.00 - 1.00 (FILL) GRAVEL, medium to coarse, angular; light gray, N 7/0; compacted; non-cohesive, dry, loose.	FILL		4.60	
	5	1.00 - 3.00 (SP) SAND, fine to medium, angular; very pale brown, 10YR 7/3; eolian to supratidal; non-cohesive, dry, loose.	SP		1.00 2.60	3.50 5.00
		3.00 - 3.75 (SP) SAND, fine to medium, angular; grayish brown, 10YR 5/2; eolian to supratidal; non-cohesive, moist, loose.	SP		3.00 1.85	
		3.75 - 4.50 (SP) SAND, fine to medium, angular; gray, N 5/0; subtidal; non-cohesive, wet, loose.	SP		3.75 1.10	
5	0	4.50 - 6.80 (SP) SAND, fine to medium, angular; grayish brown, 10YR 5/2; eolian to supratidal; non-cohesive, wet, loose.	SP		4.50 -1.20	
		6.80 - 7.40 (SP) SAND, fine to medium, angular; some organics(roots); very dark brown, 10YR 2/2; intertidal; non-cohesive, wet, loose.	SP		6.80 -1.80	4.00 5.00
		7.40 - 14.00 (SP) SAND, fine, angular; gray, N 5/0; cross-bedded; subtidal; non-cohesive, wet, loose.	SP		7.40 -8.40	1.50 5.00
10	-5					
		14.00 - 15.00 (CH) CLAY, high plasticity; gray, N 5/0; subtidal; cohesive, w > PL, soft.	CH		14.00 -9.40	
15		Boring completed at 15.00 ft				
	-10					
20						

MONITORING WELL/ PIEZOMETER DIAGRAM and NOTES



WELL CONSTRUCTION DETAILS / COMMENTS

WELL CASING
Interval: -3.5' - 1.5'
Material: PVC
Diameter: 1"
Joint Type: SCREW

WELL SCREEN
Interval: 1.5' - 14.5'
Material: PVC
Diameter: 1"
Slot Size: 0.010"
End Cap: PVC Push-On

FILTER PACK
Interval: 1' - 14.5'
Type: SP#2

FILTER PACK SEAL
Interval: None
Type: None

ANNULUS SEAL
Interval: 0'-1'
Type: 3/8" Bentonite Chips

WELL COMPLETION
Pad: None
Protective Casing: None

DRILLING METHODS
Type: Direct Push Continuous Coring
Notes:

LOG SCALE: 1 in = 2.5 ft
DRILLING COMPANY: John D. Hynes & Associates, Inc.
DRILLER: Mike Hynes

PREPARED: Colin D. Langford
REVIEWED: B. Waters
DATE: 7/1/15

Golder Associates

RECORD OF BOREHOLE PZ-12

SHEET 1 of 1

PROJECT: VCSFA - MARS
PROJECT NUMBER: 1524461
DRILLED DEPTH: 15.00 ft
DRILL METHOD: Direct Push Continuous Coring

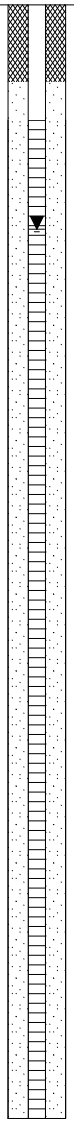
DRILL RIG: Geoprobe 7822DT
DATE STARTED: 6/22/15
DATE COMPLETED: 6/22/15

NORTHING: 3,840,838.90
EASTING: 12,352,524.70
GS ELEVATION: 5.60 ft
TOC ELEVATION: 8.96 ft

DEPTH W.L.: 2.92 ft
ELEVATION W.L.: 6.04 ft
DATE W.L.: 7/21/15
TIME W.L.: 9:37 am

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	REC / ATT
0		0.00 - 5.00 (SP) SAND, fine to medium, angular; light yellowish brown, 10YR 6/4 to orange red; cross-bedded; eolian to supratidal; non-cohesive, dry to moist, loose.	SP		0.60	3.80 / 5.00
5	5	5.00 - 7.00 (SP) SAND, fine, angular; gray, N 5/0; cross-bedded; subtidal; non-cohesive, wet, loose.	SP		5.00 -1.40	
	0	7.00 - 8.50 (SP) SAND, fine to medium, angular; trace organics(roots); very dark brown, 10YR 2/2; intertidal; non-cohesive, wet, loose.	SP		7.00 -2.90	4.50 / 5.00
		8.50 - 14.50 (SP) SAND, fine, angular; gray, N 5/0; cross-bedded; subtidal; non-cohesive, wet, loose. Shell layer at ~13' bgs.	SP		8.50 -8.90	5.00 / 5.00
10	-5					
		14.50 - 15.00 (CH) CLAY, high plasticity; gray, N 5/0; subtidal; cohesive, w > PL, soft.	CH		14.50 -9.40	
15		Boring completed at 15.00 ft				
	-10					
20						

MONITORING WELL/ PIEZOMETER DIAGRAM and NOTES



WELL CONSTRUCTION DETAILS / COMMENTS

WELL CASING
Interval: -3.5' - 1.5'
Material: PVC
Diameter: 1"
Joint Type: SCREW

WELL SCREEN
Interval: 1.5' - 14.5'
Material: PVC
Diameter: 1"
Slot Size: 0.010"
End Cap: PVC Push-On

FILTER PACK
Interval: 1' - 14.5'
Type: SP#2

FILTER PACK SEAL
Interval: None
Type: None

ANNULUS SEAL
Interval: 0'-1'
Type: 3/8" Bentonite Chips

WELL COMPLETION
Pad: None
Protective Casing: None

DRILLING METHODS
Type: Direct Push Continuous Coring
Notes:

LOG SCALE: 1 in = 2.5 ft
DRILLING COMPANY: John D. Hynes & Associates, Inc.
DRILLER: Mike Hynes

PREPARED: Colin D. Langford
REVIEWED: B. Waters
DATE: 7/1/15

Golder Associates

RECORD OF BOREHOLE PZ-13

PROJECT: VCSFA - MARS
PROJECT NUMBER: 1524461
DRILLED DEPTH: 15.00 ft
DRILL METHOD: Direct Push Continuous Coring

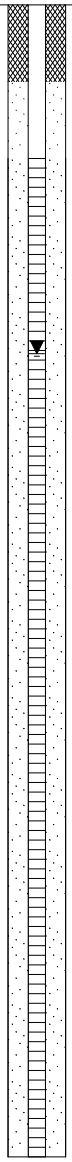
DRILL RIG: Geoprobe 7822DT
DATE STARTED: 6/22/15
DATE COMPLETED: 6/22/15

NORTHING: 3,840,706.29
EASTING: 12,352,546.41
GS ELEVATION: 7.30 ft
TOC ELEVATION: 10.47 ft

DEPTH W.L.: 4.54 ft
ELEVATION W.L.: 5.93 ft
DATE W.L.: 7/21/15
TIME W.L.: 9:34 am

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	REC / ATT
0		0.00 - 3.00 (SP) SAND, fine to medium, angular; light yellowish brown, 10YR 6/4; eolian to supratidal; non-cohesive, dry, loose.	SP			
	5					3.50 5.00
					4.30	
		3.00 - 7.50 (SP) SAND, medium to coarse, angular; very pale brown, 10YR 7/4; eolian to supratidal; non-cohesive, moist to wet, loose.			3.00	
5			SP			
	0				-0.20	4.00
		7.50 - 9.00 (SP) SAND, fine, angular; gray, N 5/0; cross-bedded; subtidal; non-cohesive, wet, loose. Black heavy mineral sand banding at ~8.5' bgs.	SP		7.50	5.00
					-1.70	
		9.00 - 10.00 (SP) SAND, fine to medium, angular; some organics(roots); very dark brown, 10YR 2/2; intertidal; non-cohesive, wet, loose.	SP		9.00	
					-2.70	
10		10.00 - 14.50 (SP) SAND, fine, angular; gray, N 5/0; subtidal; non-cohesive, wet, loose.			10.00	
	-5		SP			5.00 5.00
					-7.20	
		14.50 - 15.00 (CH) CLAY, high plasticity; gray, N 5/0; subtidal; cohesive, w > PL, soft.	CH		14.50 -7.70	
15		Boring completed at 15.00 ft				
	-10					
20						

MONITORING WELL/ PIEZOMETER DIAGRAM and NOTES



WELL CONSTRUCTION DETAILS / COMMENTS

WELL CASING
Interval: -3' - 2'
Material: PVC
Diameter: 1"
Joint Type: SCREW

WELL SCREEN
Interval: 2' - 15'
Material: PVC
Diameter: 1"
Slot Size: 0.010"
End Cap: PVC Push-On

FILTER PACK
Interval: 1' - 15'
Type: SP#2

FILTER PACK SEAL
Interval: None
Type: None

ANNULUS SEAL
Interval: 0'-1'
Type: 3/8" Bentonite Chips

WELL COMPLETION
Pad: None
Protective Casing: None

DRILLING METHODS
Type: Direct Push Continuous Coring
Notes:

LOG SCALE: 1 in = 2.5 ft
DRILLING COMPANY: John D. Hynes & Associates, Inc.
DRILLER: Mike Hynes

PREPARED: Colin D. Langford
REVIEWED: B. Waters
DATE: 7/1/15

Golder Associates

APPENDIX C
MICROPURGE FIELD SAMPLING LOGS AND WATER QUALITY ANALYTICAL LABORATORY REPORTS

Golder Associates

Date: 6/30/15

WELL GAUGING LOG

Project Name: MARS Sampling - Morning

Project No./Task No.: 1524116000

Sampler(s): L. Hamelman, C. Giordano

Equipment: WL Indicator

Well ID	Personnel (initials)	Time	DTW (feet)	DTB (feet)	Well Condition Summary				
					Protective Casing	Well Casing	Label	Lock	Pad Condition
PZ-12	LH	1112	6.18	–	OK N/A Damaged	OK Damaged	OK Inadequate	Yes No	OK N/A Damaged
PZ-11	LH	1120	6.23	–	OK N/A Damaged	OK Damaged	OK Inadequate	Yes No	OK N/A Damaged
PZ-10	LH	1128	6.02	–	OK N/A Damaged	OK Damaged	OK Inadequate	Yes No	OK N/A Damaged
PZ-9	LH	1133	6.19	–	OK N/A Damaged	OK Damaged	OK Inadequate	Yes No	OK N/A Damaged
PZ-8	LH	1140	6.22	–	OK N/A Damaged	OK Damaged	OK Inadequate	Yes No	OK N/A Damaged
PZ-7	LH	1145	6.49	–	OK N/A Damaged	OK Damaged	OK Inadequate	Yes No	OK N/A Damaged
PZ-6	LH	1154	7.57	–	OK N/A Damaged	OK Damaged	OK Inadequate	Yes No	OK N/A Damaged
PZ-5	LH	1200	7.90	–	OK N/A Damaged	OK Damaged	OK Inadequate	Yes No	OK N/A Damaged
PZ-4	LH	1203	6.29	–	OK N/A Damaged	OK Damaged	OK Inadequate	Yes No	OK N/A Damaged
PZ-3	LH	1205	7.57	–	OK N/A Damaged	OK Damaged	OK Inadequate	Yes No	OK N/A Damaged
PZ-2	LH	1207	6.87	–	OK N/A Damaged	OK Damaged	OK Inadequate	Yes No	OK N/A Damaged
PZ-1	LH	1211	7.07	–	OK N/A Damaged	OK Damaged	OK Inadequate	Yes No	OK N/A Damaged
PZ-13	CCG	1130	6.76	–	OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
					OK Damaged	OK Damaged	OK Inadequate	Yes No	OK Damaged
					OK Damaged	OK Damaged	OK Inadequate	Yes No	OK Damaged
					OK Damaged	OK Damaged	OK Inadequate	Yes No	OK Damaged

Observations/Notes: PZ-3 missing cap. Placed Nitrile glove over casing

Signature: [signature]

Date: 6/30/15

Page 1 of 1

Golder Associates

Date: 6/30/15

WELL GAUGING LOG

Project Name: MARS Sampling - Afternoon

Project No./Task No.: 1524116.000

Sampler(s): L Hawkman

Equipment: WL Indicator

Well ID	Personnel (initials)	Time	DTW (feet)	DTB (feet)	Well Condition Summary				
					Protective Casing	Well Casing	Label	Lock	Pad Condition
PZ-13	LH	1745	7.69		OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
PZ-12	LH	1747	6.21		OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
PZ-11	LH	1749	6.27		OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
PZ-10	LH	1751	6.06		OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
PZ-09	LH	1752	6.26		OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
PZ-8	LH	1757	6.25		OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
PZ-7	LH	1759	6.50		OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
PZ-6	LH	1800	7.60		OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
PZ-5	LH	1803	7.92		OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
PZ-4	LH	1806	6.33		OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
PZ-2	LH	1807	6.88		OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
PZ-1	LH	1808	7.11		OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
PZ-3	LH	1810	7.59		OK NA Damaged	OK Damaged	OK Inadequate	Yes No	OK NA Damaged
					OK Damaged	OK Damaged	OK Inadequate	Yes No	OK Damaged
					OK Damaged	OK Damaged	OK Inadequate	Yes No	OK Damaged
					OK Damaged	OK Damaged	OK Inadequate	Yes No	OK Damaged

Observations/Notes: PZ-3 missing cap. placed Nitrile glove over casing.

Signature: [signature]

Date: 07/01/2015

Page 1 of 1

MICROPURGE SAMPLING LOG

Golder Associates

Date: ~~6~~ LH 7/1/15

Weather: Partly Cloudy, 70's Windy

Project Name: MARS

Project No./Task No.: 1524116.000

Event: Preliminary Screening Invest.

Sampler(s): L. Heuelman

Well ID: PZ-1

Field Calibration Completed: ~~7~~ LH 0858

Well Diameter: 1 inches

Initial Depth to Water: 7.13 feet

Depth to Bottom: 17.10 (soft) feet

Water Column Thickness: 9.97 feet

Equipment Used:
- [x] WL Indicator
- [x] YSI ~~556~~ ProDSS 15F100443
- [ ] In Situ 9500 ___
- [ ] Turbidity Meter
- [ ] Horiba U-22
- [ ] MP-10 Controller Box
- [ ] Air Tank
- [ ] Compressor
- [ ] MP-15 Controller Box
- [ ] Dedicated Bladder Pump
- [ ] Non-dedicated BP
- [x] Peristaltic Pump

Time (5 minute int.)	pH (S.U.)	Sp. Cond. (uS/cm)°C	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (°C)	ORP (mV)	DTW (feet)	Flow Rate (mL/min)
Stabilization	+/- 0.1	+/- 3%	if >10, +/- 10%	+/- 10%	+/- 1°C	+/- 10 mV	<0.3 feet	<500
1028	7.53	766	86.0	1.87	22.0	-2.8	7.18	300
1033	7.47	775	37.1	1.09	20.8	-11.8	7.18	300
1038	7.48	773	14.4	0.87	20.6	-16.6	7.19	300
1043	7.48	774	7.5	0.75	20.5	-22.1	7.19	300
1045	SAMPLED							~~300~~ LH
1101	7.53	780	2.6	0.88	20.7	-18.4	7.19	300

Purge Cycle (End): – @ – psi

Flow Rate (ml/min End): 300

Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): –

Total Purge Volume (Gallons): ~1.5

Purge Water Management: Containment Drums On Site

Purge Observations (color, odor, turbidity, sheen): Clear Grab Sample

Sample Time: 1045

Field Filtered (0.45um): [ ] Yes [x] No

Sample Parameters/Analyte(s):
- [ ] VSWMR Table 3.1 Column A VOCs
- [ ] VSWMR Table 3.1 Column A Metals
- [ ] VSWMR Table 3.1 Column B
- [x] Other VOCs (624), SVOCs (625), perchlorate

Other Observations / Equipment Operation Problems: ~ 2 ft. from sandy road w/ traffic

Signed Sampler: [signature]

Date: 7/1/15

Signed QA/QC: [signature]

Date: 07/01/2015

Golder Associates

MICROPURGE SAMPLING LOG

Date: 07/01/2015
Weather: 80s, sun

Project Name: Mars
Project No./Task No.: 1524416.000
Event: Preliminary Screening Investigation
Sampler(s): C. Giordano
Well ID: PZ-2
Field Calibration Completed: 0850
Well Diameter: 1 inches
Initial Depth to Water: 6.93 feet
Depth to Bottom: 16.79 hard feet
Water Column Thickness: 9.86 feet

Equipment Used:
- [x] WL Indicator
- [x] YSI ~~556~~ CCS DSS
- [ ] In Situ 9500 ___
- [ ] Turbidity Meter
- [ ] Horiba U-22
- [ ] MP-10 Controller Box
- [ ] Air Tank
- [ ] Compressor
- [ ] MP-15 Controller Box
- [ ] Dedicated Bladder Pump
- [ ] Non-dedicated BP
- [x] peristaltic pump

Time (5 minute int.)	pH (S.U.)	Sp. Cond. (uS/cm)°C	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (°C)	ORP (mV)	DTW (feet)	Flow Rate (mL/min)
Stabilization	+/- 0.1	+/- 3%	if >10, +/- 10%	+/- 10%	+/- 1°C	+/- 10 mV	<0.3 feet	<500
1023	7.05	685	177.1	1.92	23.4	-1.1	6.94	250
1028	7.09	713	70.4	1.32	23.3	-15.7	6.95	200
1033	7.12	723	22.8	1.11	23.3	-21.9	6.95	200
1038	7.12	724	17.9	1.00	23.3	-26.2	6.96	200
1043	7.12	723	16.4	0.90	23.3	-29.0	6.96	200
1045	Sampled							
1059	7.18	727	21.6	1.08	23.9	-35.6	6.95	200

Purge Cycle (End): — @ — psi
Flow Rate (ml/min End): 200
Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): ~0.15
Total Purge Volume (Gallons): CCS ~1.25
Purge Water Management: containment drum
Purge Observations (color, odor, turbidity, sheen): clear grab sample

Sample Time: 1045
Field Filtered (0.45um): [ ] Yes [x] No

Sample Parameters/Analyte(s):
- [ ] VSWMR Table 3.1 Column A VOCs
- [ ] VSWMR Table 3.1 Column A Metals
- [ ] VSWMR Table 3.1 Column B
- [x] Other VOCs (624), SVOCs (625), perchlorate

Other Observations / Equipment Operation Problems: –

Signed Sampler: [signature]
Date: 07/01/2015
Page 1 of 1

Signed QA/QC: [signature]
Date: 7/1/15

Golder Associates

MICROPURGE SAMPLING LOG

Date: 06/30/2015

Weather: 80s sun, breeze

Project Name: Mars

Project No./Task No.: 1524461.000

Event: Preliminary Screening Investigation

Sampler(s): a.Giordano

Well ID: PZ-3

Field Calibration Completed: 1045

Well Diameter: 1 inches

Initial Depth to Water: 7.58 feet

Depth to Bottom: 16.67 (GPA) feet

Water Column Thickness: 9.09 feet

Equipment Used:
- [x] WL Indicator
- [x] YSI ~~556~~ 556 DSS
- [ ] In Situ 9500 ___
- [ ] Turbidity Meter
- [ ] Horiba U-22
- [ ] MP-10 Controller Box
- [ ] Air Tank
- [ ] Compressor
- [ ] MP-15 Controller Box
- [ ] Dedicated Bladder Pump
- [ ] Non-dedicated BP
- [x] peristaltic pump

Time (5 minute int.)	pH (S.U.)	Sp. Cond. (uS/cm)°C	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (°C)	ORP (mV)	DTW (feet)	Flow Rate (mL/min)
Stabilization	+/- 0.1	+/- 3%	if >10, +/- 10%	+/- 10%	+/- 1°C	+/- 10 mV	<0.3 feet	<500
1727	7.65	569	11.2	2.33	22.5	-16.4	7.65	225
1732	7.60	577	7.9	1.33	21.1	-40.9	7.65	225
1737	7.55	577	8.2	1.27	21.0	-54.7	7.65	225
1742	7.54	579	8.5	1.07	20.8	-60.7	7.65	225
1743	sampled	—	—	—	—	—	—	—
1800	7.58	578	24.1	1.22	21.7	-64.2	7.66	225

Purge Cycle (End): — @ — psi

Flow Rate (ml/min End): 225

Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): ~0.1

Total Purge Volume (Gallons): ~1 gallon

Purge Water Management: containment drum

Purge Observations (color, odor, turbidity, sheen): clear grab sample

Sample Time: 1743

Field Filtered (0.45um): [ ] Yes [x] No

Sample Parameters/Analyte(s):
- [ ] VSWMR Table 3.1 Column A VOCs
- [ ] VSWMR Table 3.1 Column A Metals
- [ ] VSWMR Table 3.1 Column B
- [x] Other VOCs (624), SVOCs (625), perchlorate.

Other Observations / Equipment Operation Problems: —

Signed Sampler: [signature] Date: 06/30/2015

Page 1 of 1

Signed QA/QC: [signature] Date: 6/30/15

Golder Associates

MICROPURGE SAMPLING LOG

Date: 6/30/15
Weather: Sunny, 80's

Project Name: MARS
Project No./Task No.: 1524116.000
Event: Preliminary Screening Investigation
Sampler(s): L Hamelman
Well ID: PZ-4
Field Calibration Completed: 1045
Well Diameter: 1 inches
Initial Depth to Water: 6.32 feet
Depth to Bottom: 16.70 (Soft) feet
Water Column Thickness: 10.38 feet

Equipment Used:
- [x] WL Indicator
- [x] YSI ~~556~~ Pro DSS
- [ ] In Situ 9500 15F100443
- [ ] Turbidity Meter
- [ ] Horiba U-22
- [ ] MP-10 Controller Box
- [ ] Air Tank
- [ ] Compressor
- [ ] MP-15 Controller Box
- [ ] Dedicated Bladder Pump
- [ ] Non-dedicated BP
- [x] Peristaltic Pump

Time (5 minute int.)	pH (S.U.)	Sp. Cond. (uS/cm)°C	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (°C)	ORP (mV)	DTW (feet)	Flow Rate (mL/min)
Stabilization	+/- 0.1	+/- 3%	if >10, +/- 10%	+/- 10%	+/- 1°C	+/- 10 mV	<0.3 feet	<500
1641	7.37	936	33.2	1.53	21.5	-55.4	6.36	200
1646	7.31	944	68.2	1.02	20.8	-62.1	6.35	200
1651	7.33	953	48.9	0.40	20.8	~~-7~~ -71.4	6.35	200
1656	7.35	940	37.5	0.36	20.8	-74.8	6.35	200
1701	7.35	928	30.9	0.33	20.7	-77.2	6.35	200
1706	7.36	928	18.4	0.31	20.7	-78.1	6.36	200
1708	SAMPLED							
1725	7.40	930	9.4	0.69	21.5	-70.0	6.36	200

Purge Cycle (End): — @ — psi
Flow Rate (ml/min End): 200
Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): —
Total Purge Volume (Gallons): ~~1.17~~ ~1.75
Purge Water Management: Containment Drums On Site
Purge Observations (color, odor, turbidity, sheen): Clear Grab Sample

Sample Time: 1708
Field Filtered (0.45um): [ ] Yes [x] No

Sample Parameters/Analyte(s):
- [ ] VSWMR Table 3.1 Column A VOCs
- [ ] VSWMR Table 3.1 Column A Metals
- [ ] VSWMR Table 3.1 Column B
- [x] Other VOCs (624), SVOCs (625), perchlorate

Other Observations / Equipment Operation Problems: —

Signed Sampler: [signature] Date: 7/1/15
Signed QA/QC: [signature] Date: 07/01/2015

Page 1 of 1

Golder Associates

MICROPURGE SAMPLING LOG

Date: 06/30/2015

Weather: 80s, breezy, sun

Project Name: Mars

Project No./Task No.: 1524461.000

Event: Preliminary Screening Investigation

Sampler(s): C. Giordano

Well ID: PZ-5

Field Calibration Completed: 1045

Well Diameter: 1 inches

Initial Depth to Water: 7.90 feet

Depth to Bottom: 16.84 hard feet

Water Column Thickness: 8.94 feet

Equipment Used:
- [x] WL Indicator
- [x] YSI 556 DSS
- [ ] In Situ 9500 ___
- [ ] Turbidity Meter
- [ ] Horiba U-22
- [ ] MP-10 Controller Box
- [ ] Air Tank
- [ ] Compressor
- [ ] MP-15 Controller Box
- [ ] Dedicated Bladder Pump
- [ ] Non-dedicated BP
- [x] peristaltic pump

Time (5 minute int.) Stabilization	pH (S.U.) +/- 0.1	Sp. Cond. (uS/cm)°C +/- 3%	Turbidity (NTU) if >10, +/- 10%	Dissolved Oxygen (mg/L) +/- 10%	Temp. (°C) +/- 1°C	ORP (mV) +/- 10 mV	DTW (feet) <0.3 feet	Flow Rate (mL/min) <500
1633	7.73	689	5.2	2.28	23.4	-27.7	7.97	200
1638	7.46	909	2.6	1.56	22.5	-26.8	7.99	200
1643	7.42	952	1.6	1.33	22.1	-31.6	8.00	200
1648	7.41	940	1.6	1.23	21.9	-36.1	8.00	200
1653	7.40	943	2.0	1.13	21.9	-34.6	8.00	200
1654	sampled	—	—	—	—	—	—	—
1712	7.44	951	1.8	1.29	22.3	-41.5	8.00	200

Purge Cycle (End): — @ — psi

Flow Rate (ml/min End): 200

Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): ~0.10

Total Purge Volume (Gallons): ~1.25

Purge Water Management: containment drum

Purge Observations (color, odor, turbidity, sheen): clear grab sample

Sample Time: 1654

Field Filtered (0.45um): [ ] Yes [x] No

Sample Parameters/Analyte(s):
- [ ] VSWMR Table 3.1 Column A VOCs
- [ ] VSWMR Table 3.1 Column A Metals
- [ ] VSWMR Table 3.1 Column B
- [x] Other VOCs (624), SVOCs (625), perchlorate

Other Observations / Equipment Operation Problems: —

Signed Sampler: [signature]

Date: 06/30/2015

Signed QA/QC: [signature]

Date: 6/30/15

Golder Associates

MICROPURGE SAMPLING LOG

Date: 06/30/2015
Weather: 80s, sun

Project Name: Mars
Project No./Task No.: 1524461.000
Event: Preliminary Screening Investigation
Sampler(s): C. Giordano
Well ID: PZ-6
Field Calibration Completed: 1045 06/30/2015
Well Diameter: 1 inches
Initial Depth to Water: 7.59 feet
Depth to Bottom: 16.84 hard feet
Water Column Thickness: 9.25 feet

Equipment Used:
- [x] WL Indicator
- [x] YSI ~~556~~ CCS DSS
- [ ] In Situ 9500 ___
- [ ] Turbidity Meter
- [ ] Horiba U-22
- [ ] MP-10 Controller Box
- [ ] Air Tank
- [ ] Compressor
- [ ] MP-15 Controller Box
- [ ] Dedicated Bladder Pump
- [ ] Non-dedicated BP
- [x] peristaltic pump

Time (5 minute int.)	pH (S.U.)	Sp. Cond. (uS/cm)°C	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (°C)	ORP (mV)	DTW (feet)	Flow Rate (mL/min)
Stabilization	+/- 0.1	+/- 3%	if >10, +/- 10%	+/- 10%	+/- 1°C	+/- 10 mV	<0.3 feet	<500
1531	7.63	877	134.1	0.81	22.9	-74.7	7.64	200
1536	7.60	876	71.0	0.53	21.9	-92.1	7.64	200
1541	7.59	875	41.2	0.42	21.4	-100.1	7.64	200
1546	7.59	875	20.8	0.36	21.5	-104.1	7.65	200
1547	sampled		—	—	—	—	—	—
1606	7.60	868	5.0	0.84	21.6	-105.1	7.64	200

Purge Cycle (End): — @ — psi
Flow Rate (ml/min End): 200
Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): ~0.15
Total Purge Volume (Gallons): ~1.25
Purge Water Management: containment drum
Purge Observations (color, odor, turbidity, sheen): clear grab sample

Sample Time: 1547
Field Filtered (0.45um): [ ] Yes [x] No

Sample Parameters/Analyte(s):
- [ ] VSWMR Table 3.1 Column A VOCs
- [ ] VSWMR Table 3.1 Column A Metals
- [ ] VSWMR Table 3.1 Column B
- [x] Other VOCs (624), SVOCs (625), perchlorate

Other Observations / Equipment Operation Problems: —

Signed Sampler: [signature] Date: 06/30/2015
Signed QA/QC: [signature] Date: 6/30/15

Golder Associates

MICROPURGE SAMPLING LOG

Date: 6/30/15
Weather: Sunny, 80's

Project Name: MARS - Wallops Island
Project No./Task No.: 1524116.000
Event: Preliminary Screening Investigation
Sampler(s): L. Hamelman
Well ID: PZ-7
Field Calibration Completed: ~~1030~~ 1045
Well Diameter: 1 inches
Initial Depth to Water: ~~6.22~~ 6.50 feet
Depth to Bottom: 17.07 feet
Water Column Thickness: 10.57 feet

Equipment Used:
- [x] WL Indicator
- [x] YSI ~~556~~ ProDSS 15F100443
- [ ] In Situ 9500 ___
- [ ] Turbidity Meter
- [ ] Horiba U-22
- [ ] MP-10 Controller Box
- [ ] Air Tank
- [ ] Compressor
- [ ] MP-15 Controller Box
- [ ] Dedicated Bladder Pump
- [ ] Non-dedicated BP
- [x] Peristaltic Pump

Time (5 minute int.)	pH (S.U.)	Sp. Cond. (uS/cm)°C	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (°C)	ORP (mV)	DTW (feet)	Flow Rate (mL/min)
Stabilization	+/- 0.1	+/- 3%	if >10, +/- 10%	+/- 10%	+/- 1°C	+/- 10 mV	<0.3 feet	<500
1525	7.42	374.0	64.8	1.73	20.4	-89.9	6.52	200
1530	7.33	416.6	99.6	1.55	20.2	-108.7	6.52	200
1535	7.35	475.3	59.5	0.85	19.9	-132.3	6.52	200
1540	7.34	498.0	35.0	0.75	19.9	-139.4	6.52	200
1545	7.35	509	22.2	0.67	19.8	-146.9	6.53	200
1550	7.35	516	18.7	0.58	19.8	-154.1	6.53	200
1555	7.35	~~4~~ 523	16.8	0.54	20.0	-159.7	6.53	200
1557	SAMPLED							
1615	7.35	548	15.5	0.81	20.1	-159.4	6.54	200

Purge Cycle (End): – @ – psi
Flow Rate (ml/min End): 200
Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): –
Total Purge Volume (Gallons): ~2.0
Purge Water Management: Containment Drum On site
Purge Observations (color, odor, turbidity, sheen): Clear Grab Sample

Sample Time: 1557
Field Filtered (0.45um): [ ] Yes [x] No

Sample Parameters/Analyte(s):
- [ ] VSWMR Table 3.1 Column A VOCs
- [ ] VSWMR Table 3.1 Column A Metals
- [ ] VSWMR Table 3.1 Column B
- [x] Other VOCs (624), SVOCs (625), perchlorate

Other Observations / Equipment Operation Problems: –

Signed Sampler: [signature] Date: 7/1/15
Page 1 of 1
Signed QA/QC: [signature] Date: 07/01/2015

Golder Associates

MICROPURGE SAMPLING LOG

Date: 07/01/2015
Weather: sun 70s

Project Name: Mars
Project No./Task No.: 1524461.000
Event: Preliminary Screening Investigation
Sampler(s): C. Giordano
Well ID: PZ-8
Field Calibration Completed: 0850
Well Diameter: 1 inches
Initial Depth to Water: 6.29 feet
Depth to Bottom: 16.40 hard feet
Water Column Thickness: 10.11 feet

Equipment Used:
- [x] WL Indicator
- [x] YSI ~~556~~ CCA DSS
- [ ] In Situ 9500 ___
- [ ] Turbidity Meter
- [ ] Horiba U-22
- [ ] MP-10 Controller Box
- [ ] Air Tank
- [ ] Compressor
- [ ] MP-15 Controller Box
- [ ] Dedicated Bladder Pump
- [ ] Non-dedicated BP
- [x] peristaltic pump

Time (5 minute int.)	pH (S.U.)	Sp. Cond. (uS/cm)°C	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (°C)	ORP (mV)	DTW (feet)	Flow Rate (mL/min)
Stabilization	+/- 0.1	+/- 3%	if >10, +/- 10%	+/- 10%	+/- 1°C	+/- 10 mV	<0.3 feet	<500
0916	6.83	358.6	79.9	2.00	23.8	-68.4	6.32	200
0921	6.82	355.6	36.6	1.51	23.3	-65.3	6.35	200
0926	6.84	353.7	24.6	1.12	23.1	-64.9	6.35	200
0931	6.84	354.6	18.6	0.99	23.0	-70.7	6.35	200
0932	sampled	—	—	—	—	—	—	—
0954	6.86	359.3	11.2	1.39	23.2	-79.2	6.36	200

Purge Cycle (End): — @ — psi
Flow Rate (ml/min End): 200
Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): ~0.10
Total Purge Volume (Gallons): ~ 1.25
Purge Water Management: containment drum
Purge Observations (color, odor, turbidity, sheen): clear grab sample

Sample Time: 0932
Field Filtered (0.45um): [ ] Yes [x] No

Sample Parameters/Analyte(s):
- [ ] VSWMR Table 3.1 Column A VOCs
- [ ] VSWMR Table 3.1 Column A Metals
- [ ] VSWMR Table 3.1 Column B
- [x] Other VOCs (624), SVOCs (625), perchlorate

Other Observations / Equipment Operation Problems: —

Signed Sampler: [signature] Date: 07/01/2015
Signed QA/QC: [signature] Date: 7/1/15

Golder Associates

MICROPURGE SAMPLING LOG

Date: 7/1/15

Weather: Partly Cloudy, 70's

Project Name: MARS

Project No./Task No.: 1524116.000

Event: Preliminary Screening Investigation

Sampler(s): L Hamelman

Well ID: PZ-9

Field Calibration Completed: 0850

Well Diameter: 1 inches

Initial Depth to Water: 6.31 feet

Depth to Bottom: 17.23 (soft) feet

Water Column Thickness: 10.92 feet

Equipment Used:
- [x] WL Indicator
- [x] YSI ~~556~~ ProDSS
- [ ] In Situ 9500 ___
- [ ] Turbidity Meter
- [ ] Horiba U-22
- [ ] MP-10 Controller Box
- [ ] Air Tank
- [ ] Compressor
- [ ] MP-15 Controller Box
- [ ] Dedicated Bladder Pump
- [ ] Non-dedicated BP
- [x] Peristaltic Pump

Time (5 minute int.)	pH (S.U.)	Sp. Cond. (uS/cm)°C	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (°C)	ORP (mV)	DTW (feet)	Flow Rate (mL/min)
Stabilization	+/- 0.1	+/- 3%	if >10, +/- 10%	+/- 10%	+/- 1°C	+/- 10 mV	<0.3 feet	<500
0920	6.42	615	11.1	1.72	22.4	-49.1	6.48	300
0925	6.42	614	4.0	1.34	22.3	-49.6	6.46	300
0930	6.42	614	5.7	1.04	22.1	-50.4	6.48	300
0935	6.42	615	3.3	0.84	22.1	-51.3	6.49	300
0937	SAMPLED							
0953	6.46	638	11.0	0.63	22.2	-47.8	6.47	300

Purge Cycle (End): — @ — psi

Flow Rate (ml/min End): 300

Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): —

Total Purge Volume (Gallons): ~1.5

Purge Water Management: Containment Drum on site

Purge Observations (color, odor, turbidity, sheen): Clear Grab Sample

Sample Time: 0937

Field Filtered (0.45um): [ ] Yes [x] No

Sample Parameters/Analyte(s):
- [ ] VSWMR Table 3.1 Column A VOCs
- [ ] VSWMR Table 3.1 Column A Metals
- [ ] VSWMR Table 3.1 Column B
- [x] Other VOCs (624), SVOCs (625), perchlorate

Other Observations / Equipment Operation Problems: —

Signed Sampler: [signature] Date: 7/1/15

Page 1 of

Signed QA/QC: [signature] Date: 07/01/2015

Golder Associates

MICROPURGE SAMPLING LOG

Date: 6/30/15
Weather: Sunny, 80's

Project Name: MARS - Wallops Island
Project No./Task No.: 1524116.000
Event: Preliminary Screening Investigation
Sampler(s): L. Heuchman
Well ID: PZ-10
Field Calibration Completed: 1045
Well Diameter: 1 inches
Initial Depth to Water: 6.04 feet
Depth to Bottom: 15.96 feet
Water Column Thickness: 9.92 feet

Equipment Used:
- [x] WL Indicator
- [ ] Turbidity Meter
- [ ] Air Tank
- [ ] Dedicated Bladder Pump
- [x] YSI ~~556~~ Pro DSS SN: 15A100143
- [ ] Horiba U-22
- [ ] Compressor
- [ ] Non-dedicated BP
- [ ] In Situ 9500 ___
- [ ] MP-10 Controller Box
- [ ] MP-15 Controller Box
- [x] Peristaltic Pump

Time (5 minute int.)	pH (S.U.)	Sp. Cond. (uS/cm)°C	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (°C)	ORP (mV)	DTW (feet)	Flow Rate (mL/min)
Stabilization	+/- 0.1	+/- 3%	if >10, +/- 10%	+/- 10%	+/- 1°C	+/- 10 mV	<0.3 feet	<500
1352	6.97	1143	94.0	1.52	21.1	-145.0	6.10	200
1357	6.94	1053	72.5	1.12	20.7	-152.0	6.10	200
1402	6.90	999	57.0	1.09	20.7	-153.9	6.10	200
1407	6.93	1011	60.6	0.70	20.4	-165.2	6.10	200
1412	6.95	1015	30.7	0.59	20.5	-176.5	6.10	200
1417	6.95	1024	27.5	0.52	20.5	-186.6	6.10	200
1422	6.94	1020	16.1	1.25	20.4	-179.0	6.10	200
1424	SAMPLED							
1442	7.00	1036	5.0	1.09	21.6	-164.0	6.12	200

Purge Cycle (End): - @ - psi
Flow Rate (ml/min End): 200
Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): -
Total Purge Volume (Gallons): 21.75
Purge Water Management: Containment Drums on site
Purge Observations (color, odor, turbidity, sheen): Clear Grab Sample

Sample Time: 1424
Field Filtered (0.45um): [ ] Yes [x] No
Sample Parameters/Analyte(s):
- [ ] VSWMR Table 3.1 Column A VOCs
- [ ] VSWMR Table 3.1 Column A Metals
- [ ] VSWMR Table 3.1 Column B
- [x] Other VOCs (624), SVOCs (625), perchlorate

Other Observations / Equipment Operation Problems: -

Signed Sampler: [signature] Date: 7/1/15
Page 1 of 1
Signed QA/QC: [signature] Date: 07/01/2015

Golder Associates

MICROPURGE SAMPLING LOG

Date: 06/30/2015
Weather: 80s, breezy, sun

Project Name: Mars
Project No./Task No.: 1524461.000
Event: Preliminary Screening Investigation
Sampler(s): C. Giordano
Well ID: PZ-11
Field Calibration Completed: 1045
Well Diameter: 1 inches
Initial Depth to Water: 6.24 feet
Depth to Bottom: 16.99 soft feet
Water Column Thickness: 10.75 feet

Equipment Used:
- [ ] WL Indicator
- [ ] Turbidity Meter
- [ ] Air Tank
- [ ] Dedicated Bladder Pump
- [ ] YSI 556
- [ ] Horiba U-22
- [ ] Compressor
- [ ] Non-dedicated BP
- [ ] In Situ 9500 ___
- [ ] MP-10 Controller Box
- [ ] MP-15 Controller Box
- [x] peristaltic pump

Time (5 minute int.)	pH (S.U.)	Sp. Cond. (uS/cm)°C	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (°C)	ORP (mV)	DTW (feet)	Flow Rate (mL/min)
Stabilization	+/- 0.1	+/- 3%	if >10, +/- 10%	+/- 10%	+/- 1°C	+/- 10 mV	<0.3 feet	<500
1335	7.67	347.8	95.4	1.65	23.1	-128.9	6.38	250
1340	7.64	353.2	139.8	1.81	22.5	-133.1	6.36	200
1345	7.69	358.5	58.4	1.77	21.4	-134.0	6.36	200
1350	7.76	360.7	28.6	1.38	21.4	-145.5	6.36	200
1355	7.83	365.2	20.1	1.15	21.3	-153.8	6.36	200
1400	7.90	372.5	25.8	0.93	21.2	-165.0	6.36	200
1405	7.95	374.9	15.2	0.76	21.2	-169.7	6.36	200
1410	7.98	375.0	12.8	0.69	21.1	-173.9	6.36	200
1411	Sampled	—	—	—	—	—	—	—
1430	8.00	380.2	14.6	0.70	21.4	-141.5	6.37	200

Purge Cycle (End): — @ — psi
Flow Rate (ml/min End): 200
Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): ~0.10
Total Purge Volume (Gallons): ~ 2 gallons
Purge Water Management: containment drum
Purge Observations (color, odor, turbidity, sheen): clear grab sample

Sample Time: 1411
Field Filtered (0.45um): [ ] Yes [x] No

Sample Parameters/Analyte(s):
- [ ] VSWMR Table 3.1 Column A VOCs
- [ ] VSWMR Table 3.1 Column A Metals
- [ ] VSWMR Table 3.1 Column B
- [x] Other VOCs (624), SVOCs (625), perchlorate

Other Observations / Equipment Operation Problems: —

Signed Sampler: [signature] Date: 06/30/2015
Signed QA/QC: [signature] Date: 6/30/15

Golder Associates

MICROPURGE SAMPLING LOG

Date: 06/30/2015
Weather: 80s, sun, breezy

Project Name: Mars
Project No./Task No.: 1524461.000
Event: Preliminary Screening Investigation
Sampler(s): C. Giordano
Well ID: PZ-12
Field Calibration Completed: 1045
Well Diameter: 1 inches
Initial Depth to Water: 6.19 feet
Depth to Bottom: 16.63 (soft) feet
Water Column Thickness: 10.44 feet

Equipment Used:
- [x] WL Indicator
- [ ] YSI ~~556~~ DSS SN 15C104268
- [ ] In Situ 9500 ___
- [ ] Turbidity Meter
- [ ] Horiba U-22
- [ ] MP-10 Controller Box
- [ ] Air Tank
- [ ] Compressor
- [ ] MP-15 Controller Box
- [ ] Dedicated Bladder Pump
- [ ] Non-dedicated BP
- [x] peristaltic pump

Time (5 minute int.)	pH (S.U.)	Sp. Cond. (uS/cm)°C	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (°C)	ORP (mV)	DTW (feet)	Flow Rate (mL/min)
Stabilization	+/- 0.1	+/- 3%	if >10, +/- 10%	+/- 10%	+/- 1°C	+/- 10 mV	<0.3 feet	<500
1232	7.03	588	165.5	2.43	20.8	-26.9	6.23	250
1237	6.91	569	176.2	1.43	20.9	-21.7	6.24	225
1242	6.78	566	46.0	0.54	21.0	-30.1	6.24	200
1247	6.76	564	19.9	0.44	21.2	-35.4	6.24	200
1252	6.77	564	12.4	0.39	21.1	-37.5	6.24	200
1255	sampled	--	--	--	--	--	--	--
1311	6.83	576	3.6	0.93	22.2	-43.8	6.22	200

Purge Cycle (End): — @ — psi
Flow Rate (ml/min End): 200
Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): ~0.1 gallon
Total Purge Volume (Gallons): ~1.25
Purge Water Management: containment drum
Purge Observations (color, odor, turbidity, sheen): Clear Grab Sample

Sample Time: 1255
Field Filtered (0.45um): [ ] Yes [x] No
Sample Parameters/Analyte(s):
- [ ] VSWMR Table 3.1 Column A VOCs
- [ ] VSWMR Table 3.1 Column A Metals
- [ ] VSWMR Table 3.1 Column B
- [x] Other VOCs (624), SVOCs (625), perchlorate

Other Observations / Equipment Operation Problems: –

Signed Sampler: [signature] Date: 06/30/2015
Signed QA/QC: [signature] Date: 6/30/15

Golder Associates

MICROPURGE SAMPLING LOG

Date: 06/30/2015
Weather: 70s, slight breeze, sun

Project Name: Mars
Project No./Task No.: 1524461.000
Event: Preliminary Screening Investigation
Sampler(s): C. Giordano
Well ID: PZ-13
Field Calibration Completed: 06/30/2015 @ 1045
Well Diameter: 1 inches
Initial Depth to Water: ~~6.18~~ 7.67 feet
Depth to Bottom: 17.00 soft feet
Water Column Thickness: 9.33 feet

Equipment Used:
- [x] WL Indicator
- [x] YSI 556 DSS SN 15C104268
- [ ] In Situ 9500 ___
- [ ] Turbidity Meter
- [ ] Horiba U-22
- [ ] MP-10 Controller Box
- [ ] Air Tank
- [ ] Compressor
- [ ] MP-15 Controller Box
- [ ] Dedicated Bladder Pump
- [ ] Non-dedicated BP
- [x] peristaltic pump

Time (5 minute int.)	pH (S.U.)	Sp. Cond. (uS/cm)°C	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (°C)	ORP (mV)	DTW (feet)	Flow Rate (mL/min)
Stabilization	+/- 0.1	+/- 3%	if >10, +/- 10%	+/- 10%	+/- 1°C	+/- 10 mV	<0.3 feet	<500
1131	6.80	385.0	7.9	2.83	21.5	28.0	7.71	200
1136	6.79	400.1	4.8	1.71	20.9	9.0	7.71	200
1141	6.77	400.4	5.0	0.97	20.6	5.7	7.72	200
1146	6.77	400.5	4.9	0.83	20.6	8.2	7.72	200
1147	Sampled	- - -	- -	- -	- -	- -	- -	- -
1207	6.82	406.6	6.7	1.70	21.4	-8.9	7.72	200

Purge Cycle (End): — @ — psi
Flow Rate (ml/min End): 200 mL/min
Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): ~0.1
Total Purge Volume (Gallons): ~0.75 gallons
Purge Water Management: containment drum
Purge Observations (color, odor, turbidity, sheen): clear grab sample, some white elongated solids present

Sample Time: 1147
Field Filtered (0.45um): [ ] Yes [x] No

Sample Parameters/Analyte(s):
- [ ] VSWMR Table 3.1 Column A VOCs
- [ ] VSWMR Table 3.1 Column A Metals
- [ ] VSWMR Table 3.1 Column B
- [x] Other VOCs (624), SVOCs (625), perchlorate

Other Observations / Equipment Operation Problems: -

Signed Sampler: [signature] Date: 06/30/2015
Signed QA/QC: [signature] Date: 6/30/15

Golder Associates

MICROPURGE SAMPLING LOG

Date: 07/01/2015

Weather: 80s, sun

Project Name: Mars

Project No./Task No.: 1524461.000

Event: Preliminary Screening Investigation

Sampler(s): C. Giordano

Well ID: Field Blank

Field Calibration Completed: –

Well Diameter: – inches

Initial Depth to Water: – feet

Depth to Bottom: – feet

Water Column Thickness: – feet

Equipment Used:
- ☐ WL Indicator
- ☐ Turbidity Meter
- ☐ Air Tank
- ☐ Dedicated Bladder Pump
- ☐ YSI 556
- ☐ Horiba U-22
- ☐ Compressor
- ☐ Non-dedicated BP
- ☐ In Situ 9500 ___
- ☐ MP-10 Controller Box
- ☐ MP-15 Controller Box
- ☐ _____

Time (5 minute int.)	pH (S.U.)	Sp. Cond. (uS/cm)°C	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temp. (°C)	ORP (mV)	DTW (feet)	Flow Rate (mL/min)
Stabilization	+/- 0.1	+/- 3%	if >10, +/- 10%	+/- 10%	+/- 1°C	+/- 10 mV	<0.3 feet	<500

Purge Cycle (End): – @ – psi

Flow Rate (ml/min End): –

Purge volume (gallons) prior to stabilization monitoring (3/8" I.D. Tube: Vol=Depth to Pump x 0.006 gal/ft): –

Total Purge Volume (Gallons): –

Purge Water Management: –

Purge Observations (color, odor, turbidity, sheen): clear grab sample using lab-provided DI H_2O Taken @ PZ-8

Sample Time: 0922

Field Filtered (0.45um): ☐ Yes ☑ No

Sample Parameters/Analyte(s):
- ☐ VSWMR Table 3.1 Column A VOCs
- ☐ VSWMR Table 3.1 Column A Metals
- ☐ VSWMR Table 3.1 Column B
- ☑ Other VOCs (624), SVOCs (625), perchlorate

Other Observations / Equipment Operation Problems: –

Signed Sampler: [signature]

Date: 07/01/2015

Page 1 of 1

Signed QA/QC: [signature]

Date: 7/1/15

Pace Analytical®
www.pacelabs.com

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page: 1 of 2

1941315

Section A Required Client Information:

Company:	Golder Associates
Address:	2108 W Laburnum Ave Ste 300 Richmond VA 23227
Email To:	brent_waters@golder.com
Phone: 804 358 7900	Fax: 804 358 2900
Requested Due Date/TAT:	Standard

Section B Required Project Information:

Report To:	Brent Waters
Copy To:	Peter Nasl
Purchase Order No.:	1524461.000
Project Name:	VA Space Authority
Project Number:	1524461.000

Section C Invoice Information:

Attention:	
Company Name:	
Address:	
Pace Quote Reference:	
Pace Project Manager:	
Pace Profile #:	

REGULATORY AGENCY

☐ NPDES ☐ GROUND WATER ☐ DRINKING WATER
☐ UST ☐ RCRA ☐ OTHER _____

Site Location STATE: VA

Section D Required Client Information

SAMPLE ID (A-Z, 0-9 / ,-) Sample IDs MUST BE UNIQUE

Matrix Codes (MATRIX / CODE): Drinking Water DW; Water WT; Waste Water WW; Product P; Soil/Solid SL; Oil OL; Wipe WP; Air AR; Tissue TS; Other OT

Requested Analysis Filtered (Y/N)

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED Composite Start DATE	COLLECTED Composite Start TIME	COLLECTED Composite End/Grab DATE	COLLECTED Composite End/Grab TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Preservatives: Unpreserved	H_2SO_4	HNO_3	HCl	NaOH	$Na_2S_2O_3$	Methanol	Other	Analysis Test (Y/N): VOCs 624	SVOCs 625	Hexane	Residual Chlorine (Y/N)	Pace Project No./ Lab I.D.
1	PZ-1	WT	G			7/1/15	1045		12									✓	✓	✓		* Please hold all additional sample bottles until further notice. *
2	PZ-2	WT	G			7/1/15	1045		12									✓	✓	✓		
3	PZ-3	WT	G			6/30/15	1743		12									✓	✓	✓		
4	PZ-4	WT	G			6/30/15	1708		12									✓	✓	✓		
5	PZ-5	WT	G			6/30/15	1654		12									✓	✓	✓		
6	PZ-6	WT	G			6/30/15	1547		12									✓	✓	✓		
7	PZ-7	WT	G			6/30/15	1557		12									✓	✓	✓		
8	PZ-8	WT	G			7/1/15	0932		12									✓	✓	✓		
9	PZ-9	WT	G			7/1/15	0937		12									✓	✓	✓		
10	PZ-10	WT	G			6/30/15	1479		12									✓	✓	✓		
11	PZ-11	WT	G			6/30/15	1411		12									✓	✓	✓		
12	PZ-12	WT	G			6/30/15	1255		12									✓	✓	✓		

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	SAMPLE CONDITIONS
Level III Data package	[signature]	7/1/15	1640	[signature]	7-1-15	1641	

3

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: C. Giordano / L. Hamelman

SIGNATURE of SAMPLER: [signature] DATE Signed (MM/DD/YY): 07/01/2015

Temp in °C | Received on Ice (Y/N) | Custody Sealed Cooler (Y/N) | Samples Intact (Y/N)

*Important Note: By signing this form you are accepting Pace's NET 30 day payment terms and agreeing to late charges of 1.5% per month for any invoices not paid within 30 days.

F-ALL-Q-020rev.07, 15-May-2007

Pace Analytical®
www.pacelabs.com

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

1940957

Section A Required Client Information:

Company:	Kuller Associates
Address:	3108 W. Jefferson Ave
	Ste 200 Richmond VA 23227
Email To:	brent.waters@kuller.com
Phone: 804-358-7900	Fax: 804-358-7400
Requested Due Date/TAT:	Standard

Section B Required Project Information:

Report To:	Brent Waters
Copy To:	Peter Nash
Purchase Order No.:	1524461.000
Project Name:	VA Space Authority
Project Number:	1524461.000

Section C Invoice Information:

Attention:	
Company Name:	
Address:	
Pace Quote Reference:	
Pace Project Manager:	
Pace Profile #:	

REGULATORY AGENCY

☐ NPDES ☐ GROUND WATER ☐ DRINKING WATER
☐ UST ☐ RCRA ☐ OTHER _____

Site Location STATE: VA

Section D Required Client Information

SAMPLE ID (A-Z, 0-9 / ,-) Sample IDs MUST BE UNIQUE

Matrix Codes (MATRIX / CODE): Drinking Water DW; Water WT; Waste Water WW; Product P; Soil/Solid SL; Oil OL; Wipe WP; Air AR; Tissue TS; Other OT

Requested Analysis Filtered (Y/N)

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED Composite Start DATE	COLLECTED Composite Start TIME	COLLECTED Composite End/GRAB DATE	COLLECTED Composite End/GRAB TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Preservatives: Unpreserved	H_2SO_4	HNO_3	HCl	NaOH	$Na_2S_2O_3$	Methanol	Other	Analysis Test (Y/N): VOCs 624	SVOCs 625	Metals	Residual Chlorine (Y/N)	Pace Project No./ Lab I.D.
1	P2-13	WT	G			6/30/15	1147		12									/	/	/		* Please hold all additional sample bottles until further notice *
2	Field Blank	WT	G			7/1/15	0922		12									/	/	/		
3	Trip Blank	-	-			—	—		2									/	/	/		
4																						
5																						
6																						
7																						
8																						
9																						
10																						
11																						
12																						

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	SAMPLE CONDITIONS
Level II data package	[signature]	7/1/15	1640	[signature]	7-1-15	1640	

3

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: C. Giordano / L. Hamelmann

SIGNATURE of SAMPLER: [signature]

DATE Signed (MM/DD/YY): 07/01/2015

Temp in °C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)

*Important Note: By signing this form you are accepting Pace's NET 30 day payment terms and agreeing to late charges of 1.5% per month for any invoices not paid within 30 days.

Pace Analytical®
www.pacelabs.com

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page: 1 of 1

1940956

Section A
Required Client Information:

Company:	Golder Associates
Address:	2108 W Laburnum Ave. Ste. 200 Richmond VA 23227
Email To:	brent_waters@golder.com
Phone:	804 358 7906
Fax:	804 358 2706
Requested Due Date/TAT:	Standard

Section B
Required Project Information:

Report To:	Brent Waters
Copy To:	Peter Nasl
Purchase Order No.:	1524461.000
Project Name:	VA Space Authority
Project Number:	1524461.000

Section C
Invoice Information:

Attention:	Brent Waters
Company Name:	
Address:	
Pace Quote Reference:	
Pace Project Manager:	
Pace Profile #:	

REGULATORY AGENCY

☐ NPDES ☐ GROUND WATER ☐ DRINKING WATER
☐ UST ☐ RCRA ☐ OTHER _____

Site Location
STATE: VA

Section D
Required Client Information

SAMPLE ID
(A-Z, 0-9 / ,-)
Sample IDs MUST BE UNIQUE

Matrix Codes
MATRIX / CODE

Drinking Water	DW
Water	WT
Waste Water	WW
Product	P
Soil/Solid	SL
Oil	OL
Wipe	WP
Air	AR
Tissue	TS
Other	OT

Requested Analysis Filtered (Y/N)

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED COMPOSITE START DATE	COLLECTED COMPOSITE START TIME	COLLECTED COMPOSITE END/GRAB DATE	COLLECTED COMPOSITE END/GRAB TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Unpreserved	H_2SO_4	HNO_3	HCl	NaOH	$Na_2S_2O_3$	Methanol	Other	Analysis Test (Y/N)	VOCs 624	SVOCs 625	Residual Chlorine (Y/N)	Pace Project No./ Lab I.D.
1	RT-1	SL	G			7/1/15	1140		2									X	X			
2	~~[illegible]~~	~~SL~~	~~G~~			~~7/1/15~~	~~1140~~															
3																						
4																						
5																						
6																						
7																						
8																						
9																						
10																						
11																						
12																						

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	SAMPLE CONDITIONS
Level II data package	[signature]	7/1/15	1640	[signature]	7-1-15	1640	

3

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: Doug Martin

SIGNATURE of SAMPLER: X [signature]

DATE Signed (MM/DD/YY): 07/01/2015

Temp in °C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)

*Important Note: By signing this form you are accepting Pace's NET 30 day payment terms and agreeing to late charges of 1.5% per month for any invoices not paid within 30 days.

EMPIRICAL LABORATORIES, LLC - CHAIN OF CUSTODY RECORD

SHIP TO: 621 Mainstream Drive, Suite 270 ♦ Nashville, TN 37228 ♦ 877-345-1113 ♦ (fax) 866-417-0548

26782

Send Results to:	Send Invoice to:
Name Brent Waters	Name Brent waters
Company Golder Associates	Company
Address 2108 W. Laburnum Ave Ste 200	Address
City Richmond VA. 23227	City
State, Zip VA 23227	State, Zip
Phone 804 358 7900	Phone
Fax 804 358 2900	Fax
E-mail brent_waters@golder.com	E-mail
Project No./Name: 1524461.000 Mars	**Sampler's (Signature):**

Analysis Requirements: Preclude

Lab Use Only:

VOA Headspace	Y	N	NA
Field Filtered	Y	N	NA
Correct Containers	Y	N	NA
Discrepancies	Y	N	NA
Cust. Seals Intact	Y	N	NA
Containers Intact	Y	N	NA

Airbill #:

CAR #:

Lab Use Only Lab #	Date/Time Sampled	Sample Description	Sample Matrix	Preclude	Comments	No. of Bottles	Lab Use Only Containers/Pres
	7/1/15 1045	PZ-1	GW	✓		1	
	7/1/15 1045	PZ-2	GW	✓		1	
	6/30/15 1743	PZ-3	GW	✓		1	
	6/30/15 1908	PZ-4	GW	✓		1	
	6/30/15 1654	PZ-5	GW	✓		1	
	6/30/15 1547	PZ-6	GW	✓		1	
	6/30/15 1557	PZ-7	GW	✓		1	
	07/01/15 0932	PZ-8	GW	✓		1	
	7/1/15 0937	PZ-9	GW	✓		1	
	6/30/15 1424	PZ-10	GW	✓		1	
	6/30/15 1411	PZ-11	GW	✓		1	
	6/30/15 1255	PZ-12	GW	✓		1	

Sample Kit Prep'd by: (Signature)	Date/Time	Received By: (Signature)
Relinquished by: (Signature)	Date/Time 7/1/15 1700	Received By: (Signature)
Relinquished by: (Signature)	Date/Time	Received By: (Signature)
Received for Laboratory by: (Signature)	Date/Time	*Temperature*

REMARKS:

Fedex: 6377 6275 3652

Details:

Page 1 of 2

Cooler No. 1 of 1

Date Shipped 7/1/15

Shipped By Golder

Turnaround standard

Distribution: Original and yellow copies accompany sample shipment to laboratory; Pink retained by samplers.

EMPIRICAL LABORATORIES, LLC - CHAIN OF CUSTODY RECORD

SHIP TO: 621 Mainstream Drive, Suite 270 ♦ Nashville, TN 37228 ♦ 877-345-1113 ♦ (fax) 866-417-0548

26788

Send Results to:	Send Invoice to:
Name Brent Waters	Name Brent Waters
Company Golder Associates	Company
Address 2108 W. Laburnum Ave. Ste 2	Address
City Richmond	City
State, Zip VA 23227	State, Zip
Phone 804 358 7900	Phone
Fax 804 358 2900	Fax
E-mail brent_waters@golder.com	E-mail
Project No./Name: 1524461,000 Mars	**Sampler's (Signature):**

Analysis Requirements: perchlorate

Lab Use Only:

VOA Headspace	Y	N	NA
Field Filtered	Y	N	NA
Correct Containers	Y	N	NA
Discrepancies	Y	N	NA
Cust. Seals Intact	Y	N	NA
Containers Intact	Y	N	NA

Airbill #:

CAR #:

Lab Use Only Lab #	Date/Time Sampled	Sample Description	Sample Matrix	Comments	No. of Bottles	Lab Use Only Containers/Pres
	6/30/15 1147	PZ-13	GW			

Sample Kit Prep'd by: (Signature)	Date/Time	Received By: (Signature)
Relinquished by: (Signature)	Date/Time 7/1/15 1700	Received By: (Signature)
Relinquished by: (Signature)	Date/Time	Received By: (Signature)
Received for Laboratory by: (Signature)	Date/Time	*Temperature*

REMARKS:

Details:

Page 2 of 2

Cooler No. 1 of 1

Date Shipped 7/1/15

Shipped By Golder

Turnaround standard

Distribution: Original and yellow copies accompany sample shipment to laboratory; Pink retained by samplers.

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

Africa	+ 27 11 254 4800
Asia	+ 852 2562 3658
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Inc.
2108 W. Laburnum Avenue, Suite 200
Richmond, VA 23227 USA
Tel: (804) 358-7900
Fax: (804) 358-2900

Golder, Golder Associates and the GA globe design are trademarks of Golder Associates Corporation